Research Baselines for Central Karakorum National Park Management Plan

CENTRAL KARAKURAM NATIONAL PARK

CKNP

Pakistan

Italy

Gilgit - Baltistan

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The document will be property of the Central Karakorum National Park Directorate.

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RESEARCH BASELINES FOR CKNP MANAGEMENT PLAN

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INTRODUCTION

The Central Karakorum National Park, better identifiable as the Park of K2, is situated in the Northern area of Pakistan by bordering with China and India.

The definition of the CKNP Management Plan started from a paramount concept: the design of a management plan not strictly "closed" which has given the possibility of further improvements, revisions and updates. Each design phase has been defined by specific documents and each plan revision has been based on the feedbacks received through a participative approach, which saw directly involved the local communities, the institutional and governmental bodies and the stakeholders.

The documents which characterized the different phases of the aforementioned process are given below:

- *CKNP Integrated Management Plan, Information Requirements and Strategies – Version 0.0*, December 2009;
- *Updating phase of CKNP Management Plan – Version 0.1*, June 2012;
- *Integrated Park Management Plan for CKNP – Version 1.1*, March 2013;
- *Management Plan for CKNP – Integration and Operational Plan – Version 1.1*, April 2014

We believe necessary to underline as the document *Integration and Operational Plan of the CKNP Management Plan,* shows:

i. the new Park Boundaries and internal zoning system, as well as the proposed new rules defined upon a process of evaluation and consultation with the local communities, government and stakeholders, by complementing the previous version of the Management Plan;

ii. the Operational Plan which contains the actions deemed of high priority for the CKNP management, functional to ensure the proper structuring of the various aspects related to the CKNP Directorate management, as well as the achievement of the sustainable use of natural resources both internal and external (but that could have effects inside the Park).

During 2014, moreover, many Ev-K2-CNR and KIU research programs, aimed at find strategies for Park management, concluded their field activities, while for some others, the end is foreseen for June 2015. Therefore, in the document Research Baselines for CKNP Management Plan, both the Part I of the *Integrated Park Management Plan for CKNP – Version 1.1* of March 2013, describing the research preliminary results, as well as the final results achieved in the last months have been included.

The title of the volume *Management Plan for CKNP – Integration and Operational Plan – Version 1.1*, April 2014 has been thus modified by finally becoming **Management Plan for CKNP**. This shall be considered as the overall framework through which the CKNP Directorate should build the next phases of the Park implementation and the basic tool for the conservation of present ecosystems and a sustainable use of natural resources by local communities.

Research Baselines for Central Karakorum National Park Management Plan

Research Baselines
PRELIMINARY RESULTS

1. OVERVIEW

1.1 Localization and access

The Central Karakorum National Park (CKNP), officially gazetted as national park in 1993, is the largest protected area of Pakistan, covering over 10,000 km^2 in the Central Karakorum mountain range. It falls into four administrative districts of Gilgit-Baltistan Region.

CKNP encompasses the world's largest glaciers, outside the Polar Regions. It is characterized by extremes of altitudes that range from 2,000 m a.s.l. to over 8,000 m a.s.l., including K2, the second highest peak in the world (IUCN, 2008).

The Gilgit Baltistan Region covers about 72,500 km^2 in the north of Pakistan and it borders with China, Afghanistan and India. Its position represents one section of the Asian high-mountain system of Hindukush-Karakorum-West Himalaya (HKKH).

For centuries, the Gilgit Baltistan was one of the most remote and inaccessible region of the sub-continent but, since 1965, roads to the southern lowlands of Pakistan connected the GB on a year-round basis.

Then, the realization of the Karakorum Highway (completed in 1978) opened up the Gilgit Baltistan to a series of unprecedented changes (social, economic, cultural and environmental). The Karakorum Highway (KKH), linking Pakistan and China, crosses through the GB for about 840 km and provides them with a vital link to the rest of Pakistan. The road has also spawned a network of "jeepable" roads throughout the Region.

The region now has hundreds of kilometres of roads, over 360 bridges and two substantial airports (Government of Pakistan and IUCN, 2003; ICIMOD and The Macaulay Institute, 2005).

1.2 Local Climate

The Central Karakorum National Park's area is part of the "transitional zone" between the arid Central Asia and the semi-humid subtropics of the South Asia.

Local climate is characterized by greater precipitation in winter and spring and by the effects of arid continental climate in summer with sudden onsets of cold weather in early autumn. As a general rule, a decreasing humidity and an increasing significance of continental climate elements can be observed from south to north.

The amount of precipitation increases with altitude, an essential precondition for the expanded glaciation of mountain peaks. At high altitudes generally, it occurs to have more snowfalls than rainfalls (WWF-Pakistan, 2008). Down the valleys, aridity prevails with an average annual precipitation of less than 300 mm (Clemens and Nusser, 1997). Average rainfall in the valleys is 100-300 mm most of which occurs during winter and early spring.

1.3 Ecological zoning

The great altitudinal range and the climatic conditions (considering, in particular, low precipitation and the effects of westerly humid winds) have carved out distinctive ecological zones (Rao and Marwat, 2003), which have been identified on the basis of researches on vegetation (Champion et al., 1965) and on the rich faunal component associated to each zone (Beg, 1975; Roberts, 1991, 1992, 1997, 2005).

The major ecological zones represented in CKNP are reported and described in the following section.

1.3.1 Alpine Dry Steppe (Artemisia-Steppe)

The heterogenous moraine and gravel base of the valley floor and lower slopes are covered by sparse grass and bush lands and represent the lowest vegetation zone. According to the predominant scrub-species it is also referred to as Artemisia-Steppe. The Artemisia-Steppe expands from 2,600 m a.s.l. to 3,000 m a.s.l.. These steppes offer rangeland grazing that is especially useful to sheep and goats in spring. Moreover the main settlements are situated within the Alpine Dry Steppe (Flury, 2012) represented both in medium and lower elevations on dry slopes, not covered with sub-alpine scrub. The steppe is sparsely vegetated with *Juniperus* spp., *Artemisia* spp., etc.

1.3.2 Sub-alpine Scrub Zone

Riverbanks covered by scrubs and tree patches are located in the Sub-Alpine Scrub zone. They are distributed in narrow belts along streams, often bordering with small ravines on upper slopes. The Sub-Alpine Scrub zone is important for both livestock and mountain ungulate species like markhor, Himalayan ibex, and Ladakh urial, and it is also considered to be an important summer grazing ground for these species. The vegetation of this zone is represented by small deciduous species like *Betula utilis*, *Berberis* spp., *Lonicera korolkovi*, and evergreens like *Cotoneaster* spp., *Juniperus communis*, *Juniperus squamata*, *Rhododendron hypenanthemum*, and poa grass with many Primula, Ranunculaceae and Anemone species.

1.3.3 Alpine Meadows and Alpine Scrub Zone

Alpine Scrub Zone and Alpine Meadows host a semi-humid steppe with 'open' to 'semi-closed' forest in the lower-lying areas of this ecoregion (Intermediate pastures). Alpine Meadows are situated largely above the treeline and include extended grasslands (high pastures). These areas are accessible only during the peak summer season The vegetation zone that follows in the Alpine Meadows and Alpine Scrub Zone, is characterized by semi-humid forests, for e.g., juniper, pine, fir, birch, and willow. This vegetation zone is rarely found in the Shimshal valley, whereas the slopes of the more humid Haramosh valley are widely covered by forests. The alpine pasture zone lies above the timberline that fluctuates from 3,500 m a.s.l. to 4,200 m a.s.l.. These are lush green areas mostly confined to plain grounds, gentle slopes and large depressions, lying between high valleys and permanent snowfields. These areas are rich in plant biomass due to high moisture regimes, therefore represent the most productive food habitats for wildlife and livestock. Traditional rights of communities in these pastures are usually well defined, and they establish seasonal summer pastures in these areas. In spring these meadows offer a breathtaking view because of the high diversity of colorful wild flowers. Many species of grasses of the genus *Poa* and sedges (*Carex*), Artemisia and clover are found in these meadows. Other plant species include *Draba trinervia*, *Polygonum affine*, *Saxifraga sibirica*, and *Euphorbia kanaorica*. These provide ideal habitats for many important mammalian species like Marcopolo sheep, bharal, brown bear and golden marmot, etc.

1.3.4 Permanent Snowfields and Cold Deserts (Sub-Nival and Nival Zones)

In the high alpine and sub-nival zone at altitudes of about 4,200 m a.s.l. - 5,100 m a.s.l., patchy and sparse alpine vegetation forms final grassy seats that are accessible only in July and August. However, these offer good summer grazing in the large expanse grasslands on the floors and slopes of the wide glacier, which carved upper valleys. The grassy vegetation, with a large number of species, shows an exposure dependant differentiation with more or less open forb-rich steppes on sun-exposed slopes, while closed sedge mats are confined to shady areas.

The nival zone, essentially important for the water supply to the valleys, limits the vegetation. The landscape is characterized by the vast glaciers, boulders and sheer cliffs. Famous glaciers like Hispar, Biafo, Panama, Baltoro lie in this zone. The vegetation is largely xerophytic and sparse. Major species include *Salix denticulate*, *Juniperus communis*, *Mertensia tibetica*, and Potentilla desertorum. Snow leopard (*Uncia uncia*), Himalayan ibex (*Capra ibex sibirica*) and brown bear (*Ursus arctos*) are the main mammalian species found on the fringe of this zone.

1.3.5 Land Cover

The land cover map of the area (see Section 6.4 and) indicates that a major part (66.5%) is covered by snow and glaciers. Bare rocks and bare soils also represent a substantial part (15.4%) of CKNP, whereas vegetation base classes represents about more than 14.7% of the area. Vegetation classes considered for the area are the followings:

- Scattered vegetation;
- Sparse vegetation;
- Pasture and/or Meadows < 3,750 m a.s.l.;
- Pasture and/or Meadows > 3,750 m a.s.l.;
- Open forest;
- Closed forest;
- Cultivated areas.

1.3.6 Vegetation pattern

The distribution of natural vegetation is closely linked to climatic and topographic conditions, and is also increasingly affected by human interferences such as grazing and woodcutting. The decreasing diversity in natural vegetation towards the north, it is due to increasing aridity; thus, the expansion of forests declines northwards, so that people in the Hopar and Hispar valleys suffer from a lack of firewood. In the upper parts of Bagrot and Haramosh valleys, located further south, a greater amount of forests can be found, ensuring better wood supply. A major cause of this, it is the significant difference in precipitation, humidity, and the varying periods of snow coverage. The vegetation of lower sub alpine areas is influenced by arid to semi-arid conditions, whereas plants of the alpine and sub-nival level are influenced by humidity. Consequently, each valley in CKNP provides agricultural lands and pastures at several distinct altitudinal levels.

Most of the cultivated area and major settlements are along the beds of the major rivers (Indus and Shigar). The most common crops of the area include Wheat, Maize and Potato while Apricot and Pomegranate are the most common fruit trees of the orchards. Populus plantation is very common within the cultivated areas and also as separated plantation for domestic timber use. Eastern and western extremes of CKNP, depict distinct variations with respect to land cover classes. On the eastern side there were very few coniferous forest patches. The *Artemisia* spp. shrub was dominating at lower elevations, and Juniper spp. scrub at higher elevations. Whereas western side of CKNP have fairly large patches of Coniferous forest, and *Artemisia* spp. is relatively less common. This difference in vegetation patterns could be attributed to their respective climate differences, because the western areas receive higher precipitation due to summer rain fall.

2. ECOLOGICAL SYSTEMS AND COMPONENTS

2.1 Geology and landform

2.1.1 Geology and landform

A first draft of a geological map for the CKNP area (Exhibit 1) was realized in digital format (see Section 6.7 for details) and is here proposed. Though it does not represent a final output, since a lot of references need still to be studied and included into the definitive map (see Section 6.7), it provides a complete overview of the main geological formations, locations and characteristics.

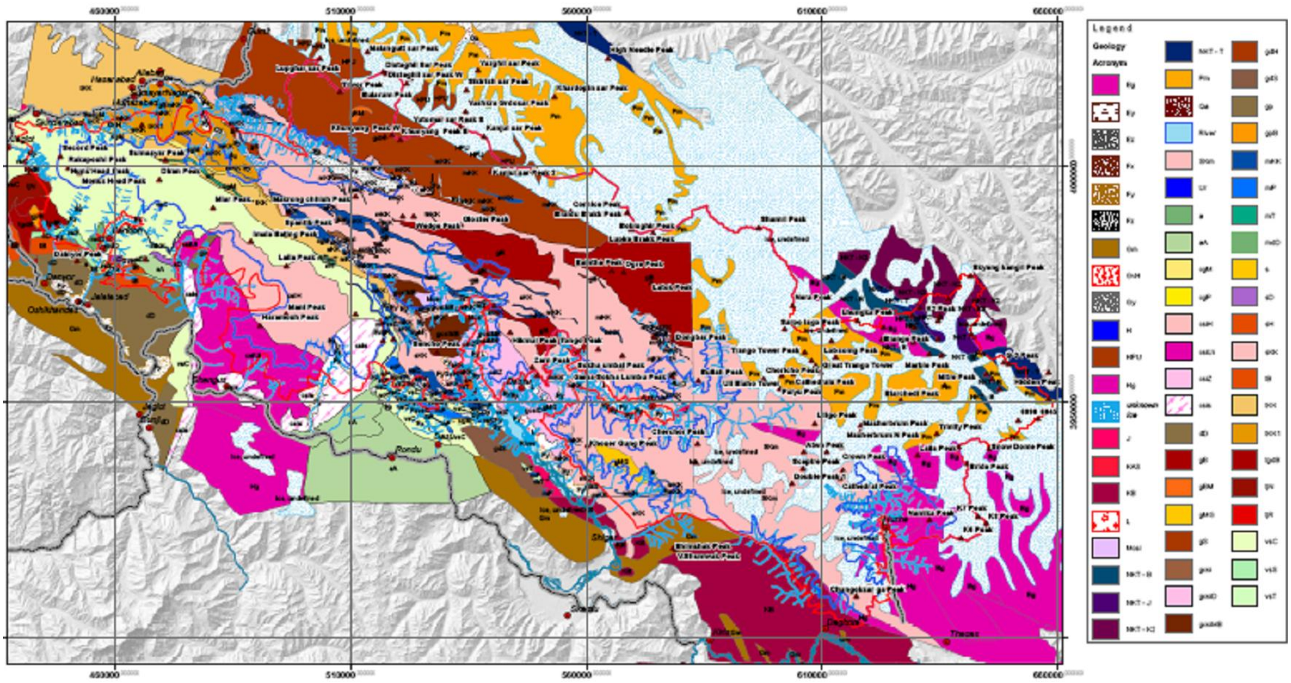


Exhibit 1. Geological map of the Central Karakorum National Park

The area covered by the presented map is located on the right bank (north) of the Indus River, along the watershed of two of its major tributaries: the Hunza river on the west-side and the Shigar river on the est-side. It covers some of the main glaciers present in the Karakorum such as the Biafo, Hispar and Chogo Lungma that form some of the most mountainous and rugged regions of the planet.

As Le Fort says, the area comprised in the map groups the 3 major units of the Himalayan collision zone: the Karakorum mountain range, the Khoistan-Ladakh arc and the Nanga-Parbat-Haramosh massif, NW protruding end of the Himalayan mountain range (Tahirkheli, 1996).

The Karakorum mountain range

The Karakorum mountain range is built on Peri-Godwanian continental crust rifted away from Gondwana during Late Paleozoic and accreted to the southern Eurasian margin during the Upper Mesozoic (Gaetani et al., 1990). It is bounded to the South by the Shyok suture or Main Karakorum Trust (Tahirkheli et al., 1979); whereas to the north, the limit lies along the Tas Kupruk zone of Kafarskyi and Abdullah (1976) and its eastword prolongation, associated with alkaline femic volcanic (Gaetani et al., 1996; Zanchi et al., 1997) that may represent the Paleo-Tethyan suture separating Karakorum from HinduKush-Pamir.

Following Gansser (1964) the Karakorum unit is usually subdivided into three main parallel sub-units, from north to south:

1) the northern sedimentary belt, made up of a pile of thrust sheets (Zanchi and Gaetani, 1994);
2) the Karakorum batholith, or central plutonic belt, it covers about 30% of the range;
3) the southern metamorphic belt, as the northern sub-unit, is also predominantly made up of sedimentary series, but the metamorphism accompanying the polyphased deformation usually reaches the amphibolites grade facies (Rolland, 2001b).

The Kohistan-Ladakh Unit

The Kohistan-Ladakh Unit, formed by the two large areas stretching on both sides on the Nanga Parbat-Haramosh massif, is attributed to a large section of an oceanic island arc, since the pioneer work of Tahirkheli (1979) and Tahirkheli et al. (1979). The island arc is usually considered to result from the north dipping subduction of the Tethys oceanic floor during the northwards drift of the Indo-Pak continental plate. Khan T. et al. (1994) and Treloar et al. (1996) have identified back-arc formations in the northern part of the Kohistan. Rolland et al. (2000, 2001) have shown that this back-arc basin extended eastward in Ladakh, with geochemical signatures suggesting the eastward progressive implication of the Asian continental margin. The back-arc zone forms a greater part of the reworked and sliced terrains of the Shyok suture. The Kohistan-Ladakh Unit may provide the most complete exposed section of an arc crust, from its upper mantle base to its subaerial volcanic. A revised lithostratigraphy of the volcanic and sedimentary formations of the Kohistan arc have been propounded by Treloar et al. (1996) and help them to pinpoint the four major phases of magmatism, linked to extension phases that they date as Middle and Late Cretaceous, Eocene and Oligo-Miocene. The two first phases have been deformed and the plutonics orthogneissifide. Up till now, the equivalence between Ladakh and Kohistan was broadly assumed and based on large scale correlation.

The Himalayan Unit

The Himalayan Unit is represented by the north-south promontory of the Nanga Parbat–Haramosh massif. Culminating at 8,125 m, it consists of a wide variety of high grade gneisses in which Madin (1986) has distinguished a large western anticlinorial area of orthogneisses, the Iskeere gneisses, covered by a thick succession of meta-volcanic and meta-sedimentary para-gneisses, called the Shengus gneisses. Ages obtained by Chamberlain et al. (1991), Zeitler et al. (1989, 1993), Schneider et al. (1999a, 1999c) and also Treloar et al. (2000) show the complexity of the evolution of the zone in which an old Precambrian magmatism and metamorphism have been largely obliterated by the Himalayan thermal evolution probably starting before 40 Ma, culminating around 20Ma, but continuing up to recent Neogene.

2.1.2 Risk assessment

The Central Karakorum National Park (CKNP) region has to be preserved in order to maintain its ecosystem, cultural values and the scenic beauty of the landscape for the benefit of the present and future generations. Earthquakes, landslides, snow avalanches and flash floods are the most common types of geological hazards on these mountains, where small portions of territory are suitable for life. Therefore, considering the premises, people are forced to live in dangerous zones.

In this environment, through the multidisciplinary SEED project, a new approach permits the characterization of the study area from different points of view. The better knowledge of the territory focusing on the theme of landslides is one of the important goals and tools for a future sustainable territorial planning. In fact, the project has the general aim to promote the sustainable development of the local communities of the Gilgit-Baltistan Region. In this context, an inventory of landslide bodies and a map of landslide or rock fall-prone areas (Guzzetti et al., 2012) are useful to identify the zones where human settlements must be avoided and therefore it provides the stakeholders with an important updatable tool for territorial planning, as required by the management plan for the national park, where zoning system for conservation of the ecosystem, and promotion of tourism is recommended.

To reach the defined goal, it was decided to analyze the area through Digital Elevation Models (DEMs) derived from ASTER images (pixel: 30m X 30m), which can be considered powerful tools for visual and mathematical analysis of the topographic surface at a regional scale (Gullà et al., 2008; Kamp, 2003, Tarolli et al., 2012). These documents, used in a barren territory, visited mainly by mountain climbers and porters, are valuable in order to identify landforms and deposits, modeled by surface processes. The landslide susceptibility study (Fell et al., 2008; Van Wasten et al., 2008) was analyzed with the application of the Analytical Hierarchy Process (AHP) (Ayalev et al., 2004; Bajracharya et al., 2008; Komac, 2006; Moradi et al., 2012; Othman et al., 2012; Phukon et al, 2012) based on the indexing on data layers as slope angle, slope aspect, slope curvature, geo-lithology, distance to tectonic structures and vegetation (Ruff et al., 2008) seen that these intrinsic variables determine the susceptibility of landslides (Dahal et al., 2007).

The method was tested in the Bagrot valley, located in the extreme north west of the park and then applied to the rest of the park area. Through the analysis of the DEM, different slope morphologies were pointed out and the main landslides were identified (areas subjected to rock falls, single rock falls and debris flows) (Varnes, 1984).

Landslide-prone areas identification: methodological approach

The present research tries to produce a slope instability susceptibility map, taking advantage of GIS and remote sensing tools (Gardner et al., 2004; Guzzetti et al., 2012). A multidisciplinary approach was applied to determine the meaning of event-controlling parameters in triggering the landslides (Kamp et al., 2008, Ruff et al., 2012). The evaluated parameters (Dahal et al., 2008) included geology, tectonic structures as trusts and faults, plan curvatures, slope angles, aspect and the drainage net. According to Kamp (2008), there are three steps that need to be taken into account in order to study, with a good accuracy, an area affected by landslides.

The first step involves the implementation of a landslide inventory map, providing the location and outlines of landslides (Spiker and Gori, 2000; Chacon et al., 2006). The second step consists in the production of a landslide susceptibility map, which includes the spatial distribution of event-controlling parameters, that means that the intrinsic parameters have to be defined and prepared for the GIS analysis. This will allow landslide-prone areas to be defined, independently from temporal controls, and they will indicate where landslides may occur in the future (Chacon et al., 2006). The third step is the production of a landslide hazard map.

For the present research, started in 2011, the first step, for the test area, was accomplished through field surveys, the second one was realized through the GIS analysis of the geological and DEM data, while the third step is still in progress.

The inventory of landslides and their distribution were mapped only in some test areas, using the available topographic maps (1:25,000 scale topo-sheet) and the satellite multispectral ASTER images. At first, the geological and lithological conditions were analyzed, than the main geomorphologic parameters (slope angle, aspect and plan curvatures) were extracted from the ASTER images.

The obtained parameters were later combined using the Analytical Hierarchy Process (AHP) method and plotted as output in the landslide-prone area raster map (Ayalew et al., 2004; Intarawichian et al., 2010; Komac, 2005; Moradi et al., 2012; Phukon et al., 2012). These preliminary results were validated on field while identifying the landslides in the studied area. As for all these types of analyses, the quality of the results mainly depends on the DEM resolution (Kamp et al., 2003; Sarkar et al., 2004; Tarolli et al., 2012).

Going into details: a landslide susceptibility map was obtained combining the different factors in accordance with their relative influence to landslide occurrence. The AHP is the methodology that allowes to assign a rate not only to the parameters but also to the classes in which each parameter is subdivided (Saaty, 2000). For the present research the pair-wise comparison matrix presented in Table 1 was used. The considered parameters were arranged in hierarchical order of priorities in rows and columns to generate a pair-wise comparison matrix. At the same time, also the classes in which each parameter has been subdivided were arranged with the same technique using the 9 point defined in Table 1. This method can be defined a Weighted Linear Combination (WLC) where secondary – level weights are opinion-based scores (Ayalew et al., 2004).

Table 1 Slope, 2. Plan curvature, 3. Geology, 4. Distance from drainage, 5.Distance from lineaments, 6.Aspect, 7. Geometric mean, 8. Factor weight.

Parameters	1	2	3	4	5	6	7	8
(1) Slope	1	5	2	6	7	3	3.2864	0.4186
(2) Plan curvature	0.2	1	3	5	7	1	1.6610	0.2116
(3) Geology	0.5	0.33	1	3	5	3	1.3967	0.1779
(4) Distance from drainage	0.16	0.14	0.33	1	2	4	0.6241	0.0795
(5) Distance from lineaments	0.14	0.14	0.2	0.5	1	4	0.4457	0.0567
(6) Aspect	0.33	1	0.33	0.25	0.25	1	0.4353	0.0554

Weights of each parameter were calculated dividing the geometric mean of each row of the matrix by the total of geometric mean in a column of a matrix. Weights were later normalized.

Ranks and rates were later linearly combined (WLC) obtaining the Landslide Potential Index (LPI) according to the formula:

$$LPI = \sum (Ri \times Wij) \qquad [1]$$

where i = 1 – 9, Ri is the rank for parameter i and Wij is the weight for class j of i factor.

The map obtained as a result of the overlapping weighted raster datasets, represents the distribution of the LPI index values that were than classified into 6 potential landslide susceptibility classes obtaining a landslide susceptibility map (Exhibit 4) (Davis, 1986; Sarkar et al., 2004).

The complete list of numerical grades adopted for the present research is summarized in the Tables from 2 to 5.

Table 2 Pair-wise comparison table (Saaty, 2000).

Intensity of importance for each considered parameter	Importance definition	Explanatory notes
1	Equal importance	Both parameters contribute equally to the objective
3	Moderate importance	One parameter is considered, based on experience, slightly favoured over another
5	Essential or strong importance	One parameter is strongly favoured over the other
7	Very strong or demonstrated importance	A parameter is very strongly favoured over another
9	Extreme importance	The evidence is favouring a parameter over another
2,4,6,8	Intermediate values between the categories	If and when is needed a compromise

Table 3 Weights assigned to the slope angle and slope aspect parameters.

Slope angle [°]	Factor weight	Slope aspect	Factor weight
0°-10°	0.1	N	0.2
11°-20°	0.4	NE	0.4
21°-30°	0.8	E	0.6
31°-40°	1	SE	0.8
41°-50°	0.6	S	1
51°-60°	0.2	SW	0.8
61°-70°	0.1	W	0.6
>70°	0.1	NW	0.4

Table 4 Weights assigned to the distance from lineament, distance from drainage net and plan curvature parameters.

Distance from lineament (m)	Factor weight	Distance from drainage net (m)	Factor weight	Plan curvature	Factor weight
0-50	0.7	0-50	0.7	Hollows	0.8
50-100	0.2	50-100	0.2	Noses	0.1
>100	0.1	>100	0.1	Planar regions	0.3

Table 5 Weights assigned to geological formations and quaternary deposits parameters.

Geological description	Acronym	Factor weight
Active scree and elluvium	Ez	0.9
Highest terrasse	Fx	0.9
Quaternary deposit	Fy	0.8
Lowest terrasse	Fz	0.8
Hummocky moraine	GvH	0.6
Askor amphibolite	aA	0.2
Iskere gneiss (predominantly orthogneiss)	csiUi	0.2
Stak gneiss (predominantly paragneiss)	csis	0.1
Dainyor and Thowar heterogeneous diorite	dD	0.3
marble	mKK	0.4
amphibolite	mdD	0.4
Sulfide and sulphur mineralization	s	0.2
Dobani - Dasu ultramafics	sD	0.1
Bilchar tonalite to granodiorite - Skoyo tonalite	tB	0.1
N-Barti tonalite to granodiorite	tgdB	0.2
Chalt formation and Turmik greenstone group	vsC	0.5
Sinakkar volcano-sediment	vsS	0.7

Digital Elevation Model and its derivatives

The research used as topographical base the maps derived from the high-spatial-resolution multispectral images known as ASTER images. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra spacecraft collects in-track stereo using nadir- and aft looking near infrared cameras. Since 2000, these stereo pairs have been used to produce single-scene (60 x 60 km) digital elevation models having vertical (root-mean-squared-error) accuracies generally between 10 m and 25 m. On June 29, 2009, NASA and the Ministry of Economy, Trade and Industry (METI) of Japan released a Global Digital Elevation Model (GDEM) to users worldwide at no charge as a contribution to the Global Earth Observing System of Systems (GEOSS). NASA and METI have released a second version of the ASTER GDEM (GDEM2) in mid-October, 2011. The GDEM2 has the same gridding and tile structure as GDEM1, but benefits from the inclusion of 260,000 additional scenes to improve coverage, a smaller correlation kernel (5x5 versus 9x9 for GDEM1) yielding higher spatial resolution, and improved water masking. While the ASTER GDEM 2 benefits from substantial improvements over GDEM 1, users are nonetheless advised that the products still may contain anomalies and artifacts that will reduce its usability for certain applications, because they can introduce large elevation errors on local scales. The GDEM2 used in this research was acquired by downloading from http://reverb.echo.nasa.gov/reverb with the bounding box of the Gilgit Baltistan limit. With reference to the limitation expressed above, a comparison between the GDEM1 and GDEM2 datasets on CKNP has been done. The main problem in GDEM1 was the lack of data on some of the peaks probably due to the high reflectance of snow and ice. This mistake in GDEM2 has been corrected.

The resulted DEM presents some artifacts visible as a regular grid, that can produce in the derived maps irregular data. The minimization of this noise was resolved with the application of a neighborhood operation that computes an output raster where the value for each output cell is a function of the values of all the input cells that are in a specified neighborhood around that location. A kernel of 5x5 was chosen and the mean was calculated for the output pixel.

Geomorphometric analysis: slope, aspect and curvature parameters

From ASTER DEM it has been possible to calculate four different geomorphic parameters as slope angle, aspect and plan curvature that are a first step to describe the geomorphologic landforms and processes (Chang et al., 1991; Ohlmacher, 2007).

The slope angle value, calculated through 3D Analyst tool, was divided into 8 classes (Ruff et al., 2008), from 0° to more than 75°. It is known that highest susceptibility consists in slope angles between 20° and 40° (Ruff et al., 2008). Rock falls is instead the main type of mass movement at higher angles. Eight classes are characterizing the aspect value, which can be used as an indicator for valley asymmetries. Southward orientations imply a high susceptibility for soil slides. As defined by Ruff, a high susceptibility weight was given to the southward orientated slopes and medium to low weights were assigned symmetrically to the other directions.

The curvature of the surfaces can be used to describe the physical characteristics of a drainage basin in order to better understand the geomorphic development of landslide terrains (Olmacher, 2007). According to Ohlmacher (2007) plan curvature is the second derivative of elevation with regard to aspect, it is the curvature of topography from a map view (following contour lines) (Moreno et al., 2004), that is the curvature of the hillside on a horizontal plane. According to the morphology, three different types of curvature can be recognized on one hillside: hollows, noses and planar regions, these last ones are defined as straight contours. The plan curvature noses and hollows can be quite easily identified due to their very complex and divergent profiles. Mesoscale objects such as wide debris flow fans can be identified with the plan curvature map.

Landslide distribution map in the test site area: the Bagrot valley area

Landslides were identified using DEM hillshade data set and the curvature map derived from DEM. Due to the lack of vegetation, a high reflectance is present and the identification of the phenomena is easier. All of the mapped landslides were later cross-checked in the field.

In this area most of the landslides are represented by rock falls, debris falls and debris flows (Exhibit 2). Neither rotational nor translational slides were identified during the field survey. The rock falls are widely distributed in the all valley, along both sides, where it is possible to identify coalescing debris fans (Exhibit 2). Steep cliffs are heavily subjected to physical weathering having as consequence a decrease of the geotechnical characteristics and an accelerated weakening of the rocks creating daily rock falls. Areas subjected to rock falls have a maximum length of 6.4 km with a high difference of 2000m in some places. One of the smallest phenomena has a scree extension of about 1 km. All the Bagrot valley area is interested by active rock falls, only some small portions of the surveyed territory can be considered as not subjected to these phenomena. Also most part of the debris flows are active. In this region, villages are built on the debris flow stabilized fans with a gentle slope and a wide cultivable area. The active channel of the debris flow usually remains on a side of the cultivated fan. The smaller debris phenomena can instead be considered active. They are locations of avalanches and debris flows during the different seasons.

Debris falls are usual phenomena in these areas, where terraces are heavily interested by them. Terraces heights can reach 100 m, and the toe erosion is their main triggering cause. The most part of surveyed landslides can be considered active according to the WP/WLI Multilingual Landslide Glossary (1993).

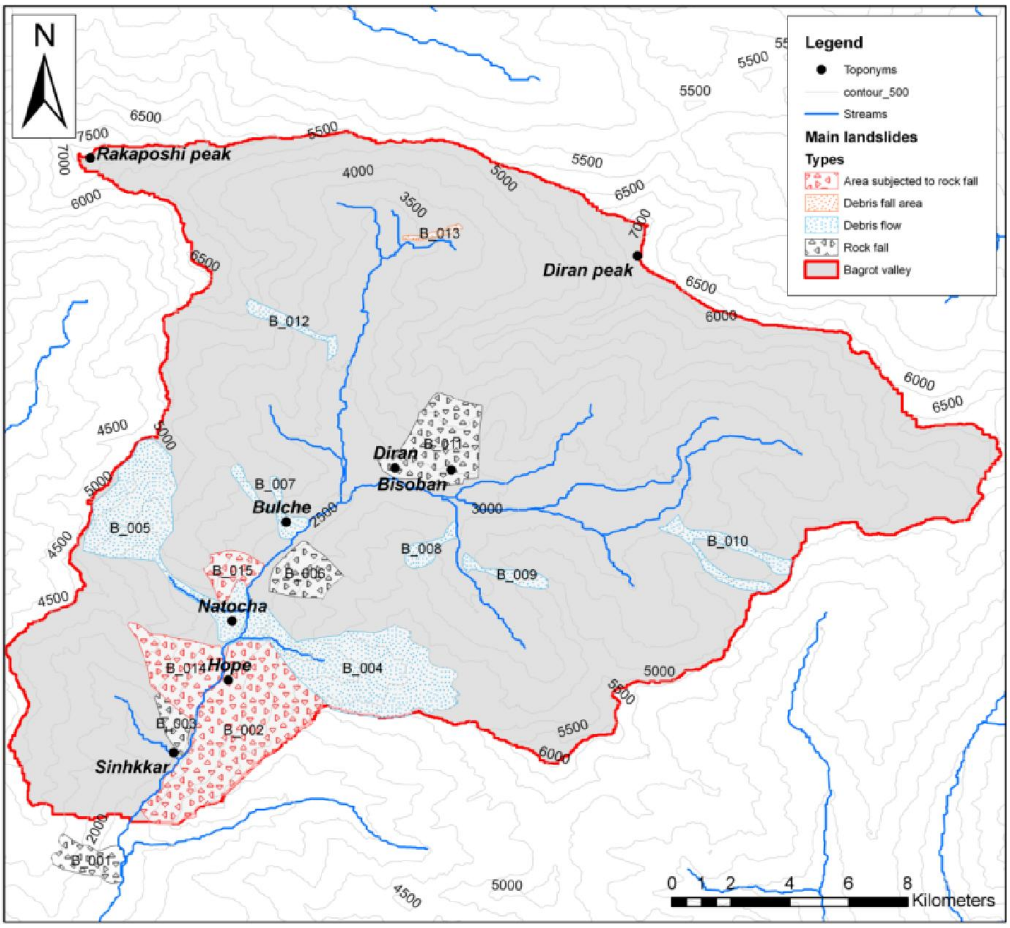


Exhibit 2. Main landslides identified in the Bagrot valley area; landslide outline has been realized following the I.F.F.I. proposed methodology.

Results and discussion

Knowing that a simple pair-wise comparison in which only two parameters can be considered at a time means simplifying the weighting process and making it more opinion-based dependent, the method guarantees a widespread knowledge of the wild territories also with few parameters that are the ones available for the whole CKNP territory.

During the field work in the Bagrot valley area, mainly rock falls and debris flows were identified, this predominance has been highlighted also by the parameter analysis through the GIS tools. The scale of the available geological map (1:150.000) and the cell size (30m) did not permit to obtain a detailed map, but guarantee a wide geomorphological analysis.

The influence of the fault/lineament parameter was considered and simulated creating buffer zones around the fault lines (0-50 m, 50-100 m and more than 100 m). These distances were decided according to the field survey evidences examined, showing that fault are not equally distributed. Same subdivision was assigned also to the distance to stream parameter. Landslides may occur on the sides of the slopes affected by streams. In the study area, the proximity to streams represents an important parameter, considering the erosion capacity of the flowing waters in such a barren territory, especially during monsoon season.

The importance of the aspect parameter was based on the landslide distribution. According to Dhakal, south- and east-facing slopes were considered to be more susceptible to landslides (Dhakal et al., 2000).

The land use parameter, during this first screening analysis, was not considered. Barren slopes are widespread and the vegetation is mainly confined to the valley bottoms, were the slope angles are more gentle (<15°). Hence, in a first approximation, the parameter was considered to have the same influence/value all over the investigated area. For future analyses, to obtain more reliable results, land use and land cover parameters need to be taken into account.

In order to obtain the landslide susceptibility map, as previously defined, parameters were weighted and a WLC was obtained producing a continuous scale of numerical values (LI). These values were later divided into six susceptibility classes using the standard deviation (Ayalev et al., 2004). These categories are described in Table 6 for the Bagrot Valley and in Table 7 for the CKNP area and correspond to six relative scales of landslide susceptibility for the Bagrot valley area (Exhibit 3) and in Exhibit 4 for the CKNP area.

Table 6 Susceptibility classes for the Bagrot valley area.

Classes	N. of cells	%	Susceptibility description
1	647	0.13	Extremely low
2	46760	9.71	Very low
3	107003	22.22	Low
4	160054	33.25	Medium
5	133666	27.76	High
6	33246	6.91	Very high

For the Bagrot valley area, medium (33.25%) and high (27.76%) are the most populated categories corresponding to areas were the slope gradient is elevated and the plan curvature is hollows. This demonstrates the importance of weight of these 2 parameters. Also geology and distance to structural lineaments played an important role, weaker rocks are more prone to fall. As expected instead, flat areas, as the ones covered by glaciers, resulted to be more stable.

For the CKNP area the values are the following:

Table 7 Susceptibility classes for the CKNP area.

Classes	N. of cells	%	Susceptibility description
1	892450	31.74	Extremely low
2	135936	4.83	Very low
3	236260	8.40	Low
4	510812	18.17	Medium
5	727526	25.88	High
6	308012	10.95	Very high

In the CKNP area, extremely (31,74%), medium (18,17%) and high (25,88%) are the most populated categories corresponding to areas covered by the glaciers (mainly flat areas) or were the slope gradient is elevated and the plan curvature is hollows. This demonstrates the importance of weight of these 2 parameters in the susceptibility computing. Also geology and distance to structural lineaments played an important role, weaker rocks are more prone to fall. As highlighted in the focused draft version Exhibit 4, in the geological map were identified the alluvial terraces which banks are eroded by the rivers and the debris fan or other loose deposits, susceptibility values become higher. Flat areas, as the ones covered by glaciers, resulted to be more stable and occupy a wide part of the territory of the park.

Therefore, as highlighted in Exhibit 4 there are some areas in which the susceptibility is very high, these areas are mainly represented by high elevations as the Diran peak area, the Hispar glacier area and the areas between Biafo-Hispar, Baltoro and Panmah glaciers.

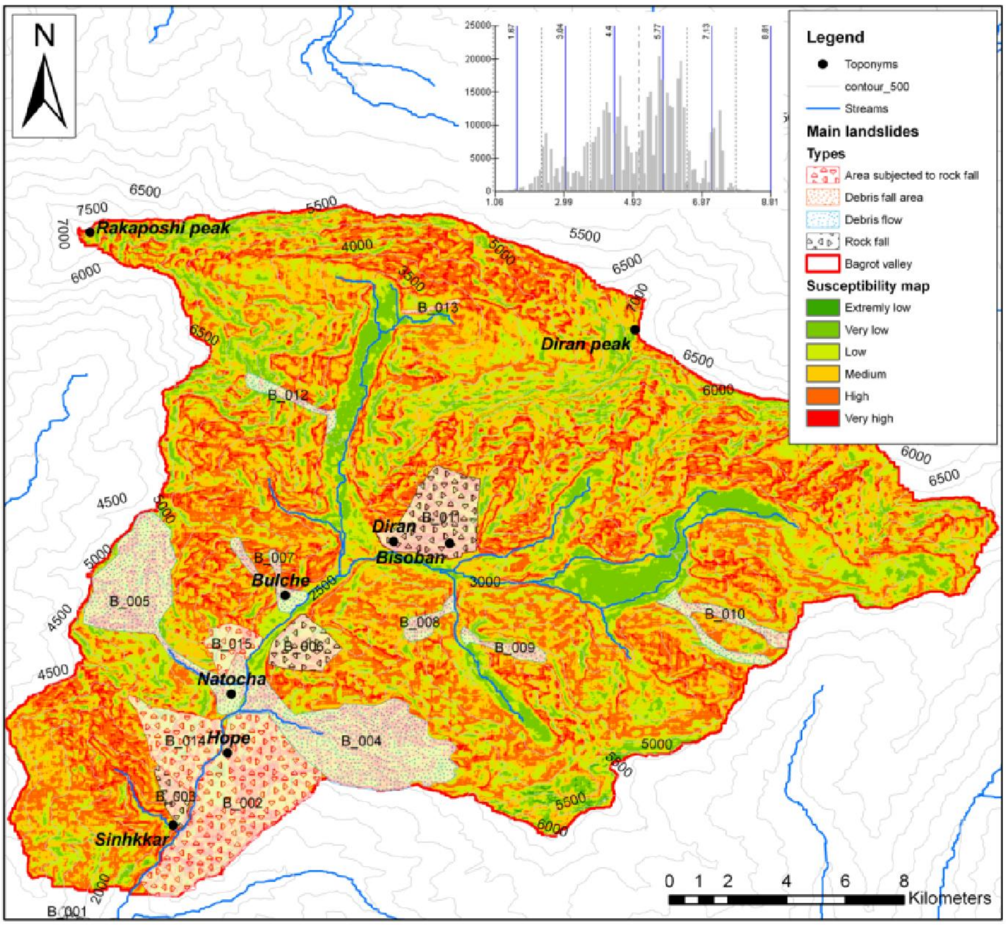


Exhibit 3 Landslide susceptibility map obtained for the Bagrot valley area. Susceptibility has been classified into 6 classes by the standard deviation method.

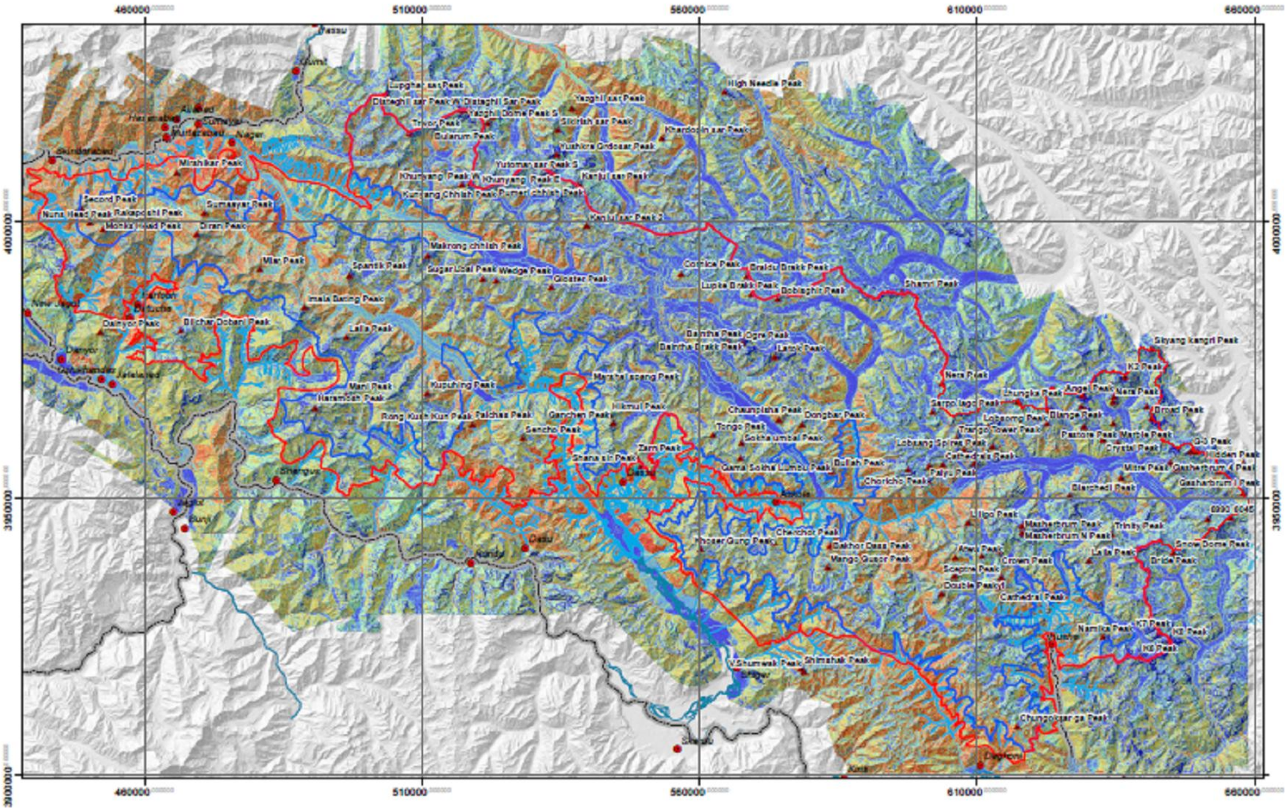


Exhibit 4 Preliminary Landslide susceptibility map for the CKNP area.

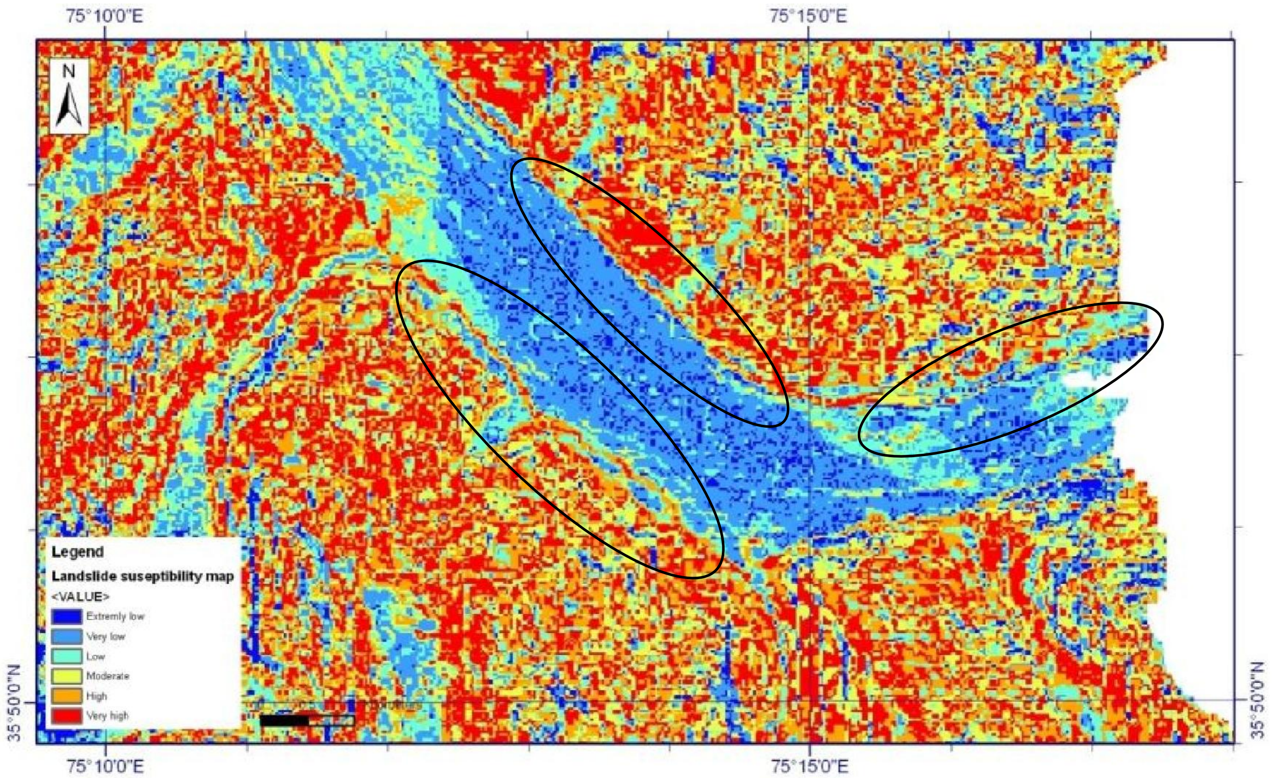


Exhibit 5 Preliminary draft version of the susceptibility map computed for the Chogo Lungma area. Inside the black ellipse, terraces are present and highlighted by the computation as moderate to high risk areas. Glacier area has instead a susceptibility from low to extremely low, as it has to be.

Final remarks

The simple methodology presented, allowes to define the areas having an intrinsic susceptibility to landslides. The methodology belongs to the generation of maps obtained through the weighted overlay of different data layers.

In this study 6 event-controlling parameters named geology, aspect, slope, distance from drainage, distance from lineaments and plan curvature were considered. Their interaction with the analytical hierarchy process and the Weighed Linear Combination permitted to obtain a landslide susceptibility map for the CKNP. The result of the entire analysis was the division of the investigated area into 6 classes of susceptibility: extremely low (31,74%), very low (4,83%), low (8,40%), medium (18,17%), high (25,88%) and very high (10,95%).

The quality of these results heavily depends on the quality of the input data, but the methodological approach is so simple that it can be easily upgraded on demand and it provides a relatively quick analysis. So it can be considered a useful tool to identify slope sectors liable to landsliding.

The research has obvious limits due to the actual scale of the available geological map (1:150.000 and 1:650.000 for the eastern area), the resolution of the ASTER DEM (30m X 30m), the lack of some fundamental information, such as the land use or top soil cover. However, it is just the beginning of a multi-disciplinary study in which different themes are going to converge during the following years.

The susceptibility assessment research is focused on the identification of the most vulnerable areas of the CKNP core zone and in its buffer zones, concerning the landslide topic in order to build a knowledge base system also in a wild territory like the one of the CKNP. The results of the research can provide the basic data for a future strategic territorial development planning inside the park and for its buffer zones, considering the increasing tourism that has to remain sustainable for the territory. Against this, focused studies on the planned new tracks, evaluating safer courses and safe resting places or eventually proposing ad hoc mitigation measure, could facilitate the tourism in barren territories. Indeed, the research focuses on the identification of the safer areas from a landslide point of view. For the National Authorities, this can represent the basic usable knowledge, upon which decisions, concerning the safety of the people in case of natural disasters, should be undertaken. It can be viewed as a preliminary disaster management tool, considering the scale at which it operates.

Last point is that the study has been conducted mainly within the park area, however one of the main problems of the Gilgit Baltistan Region is the roads connecting villages, towns and also the park. The road from Skardu to Askole is heavily affected by huge landslides as rock falls, slides and debris flows destroying the road especially in case of rainy weather or due to the heavy bank erosion. A detailed study and planned works need to be guaranteed in order to promote a bright and safe image for the territory..

2.2 Glacier and water

2.2.1 Cryosphere

The term cryosphere is used to indicate ice, snow and permafrost occurrence in the Planet. Cryosphere is a not negligible resource in the Karakorum range and in the CKNP, due to its large surface coverage, the wide variety of cold phenomena and processes here occurring and its role in supplying freshwater available to natural systems and human uses. On mountain areas, cryosphere is mainly represented by glaciers, snow coverage and permafrost. These elements are all present in the Karakorum but they have been subjected to systematic studies only in recent times (with respect to other cold areas of the Planet) and with different deepening levels. Glaciers are surely the most studied and best known elements of the Karakorum cryosphere and their large coverage explains the fact that Karakorum together with Himalaya and Hindu Kush areas are considered the “Third ice Pole” of the Earth after Antarctica and Greenland.

Data source

Information from bibliography

Glaciers in the Karakorum are also well known due to peculiar features such as the abundant supraglacial debris coverage which make several glaciers actual debris covered glaciers (sensu Benn and Evans, 2010) and the occurrence of unusual phenomena like surges (i.e.: fast and abrupt increases of glacier surface velocity, see Paterson, 1994; Benn and Evans, 2010). Moreover several glaciers in the CKNP are famous being the normal routes and paths to reach and climb the main peaks such as K2 (8,611 m a.s.l.). Then Karakorum glaciers have been visited and observed during the many climbing expeditions performed since the end of the XIX century and devoted to make attempts of ascending the Karakorum peaks.

Since the last twenty years Karakorum glaciers have been experiencing a strong interest from scientists and researchers due to an unusual ongoing phenomenon: the so called “Karakorum anomaly” (Hewitt, 2005). In fact, some researches report that there has been expansion and thickening of the larger glaciers mainly in the central Karakorum since the 1990s, accompanied by an exceptional number of glacier rapid advances (i.e.: surge-type phenomena, see among the others Diolaiuti et al., 2003; Belo’ et al., 2008); moreover many stagnant situations are also reported (Hewitt, 2005). This may result from the high elevation combined with a possible increase in orographic precipitation leading to accelerated accumulation.

This kind of behaviour of some glaciers in the highest parts of central Karakorum can be defined as an “anomaly”. After decades of decline, some glaciers advanced and thickened in the late 1990s (Hewitt, 2005).

In spite of the many scientific topics supporting the need for studying and analysing Karakorum glaciers, systematic studies devoted to evaluate the whole glacier resource and to describe its features have started only recently. The first inventory devoted to describe the whole Karakorum glaciation was performed by ICIMOD (2005) by processing and analysing remote sensing data (mainly Landsat imagines with automatic techniques).

Field data

This first fundamental effort to quantify the actual glaciation was improved by the Ev-K2-CNR research staff in the framework of the SEED project by analysing CKNP glaciers to describe with further details glacier size, surface coverage and features and to update such information for evaluating glacier changes over the whole park area in a time frame of a decade thus contributing to discussing and understanding the “glacier anomaly”. Moreover also field campaigns and measurements were performed by Ev-K2-CNR staff on some selected glaciers in the park to improve and check findings from remote sensing investigations and to lay the bases for a permanent monitoring network of the glacier resource.

Considering the crucial role of glaciers in the Central Karakorum National Park as water suppliers, the opportunity for tourist exploitation and their importance in witnessing climate change effects is fundamental to adopt a strategy for evaluating, managing and promoting glacier resource. Here is reported in details the most recent researches performed in the Park area by Ev-K2-CNR staff and developed according to the most recent international work protocols. These data permit to describe and quantify the glacier resource and are essential for the hydrological analysis.

Description and main findings

The CKNP Glacier inventory

Among the possible methods to analyze the ongoing evolution of glaciers, collection and analysis of glacier inventories (e.g. glacier area) can be used to investigate mountain glaciers in a changing climate (Paul et al., 2004), and potential scenarios on a regional scale (Zemp et al., 2006). Glacier geometry changes are staple variables for early detection of enhanced greenhouse effects on climate (Kuhn, 1984, Hoelzle et al., 2003). Glacier inventories allow comparison of long-term behaviour of different mountain ranges upon extended areas, thus integrating high resolution (ground) measurements that can be carried out on a few selected glaciers, but may not be fully representative of climate signal within a whole mountain range (Hoelzle et al., 2007). Glacier inventories should be carried out at intervals compatible with the characteristic dynamic response times of mountain glaciers (a few decades or less in the case of small glaciers), and the currently observed glacier down-wasting calls for frequent updates of inventories (Paul et al., 2007).

Moreover complete detailed glacier parameters such as glacier area, length, elevation, hypsography and ice volume in particular are needed for those glacierized regions that are currently missing from global mass-balance records or have only preliminary data in the WGI (World Glacier Inventory), such as the Arctic, Himalaya, Karakorum and Patagonia (Braithwaite, 2002; Dyurgerov and Meier, 2005; WGMS, 1989; 2007). Moreover, coupled models for assessing the impact of climate change on glacier evolution (e.g. Gregory and Oerlemans, 1998; Raper et al., 2000; Raper and Braithwaite, 2006) require detailed glacier parameters, in particular glacier area and hypsography. To compile the CKNP Glacier Inventory the Ev-K2-CNR researchers in the framework of the SEED project followed the recommendations by Paul et al. (2010); Landsat imagines 2001 were analysed to permit comparisons with the data base from ICIMOD (2005) as well. Furthermore, to update the CKNP Glacier Inventory, the Landsat 2010 imagines were processed and analysed thus assessing glacier changes in this time frame. The CKNP glacier data from SEED project are available in a GIS project to be managed, used and update by personnel from Park. Moreover also maps are available as the ones attached to the Management Plan.

From Landsat images (2001) 711 glaciers have been identified. Their total area is 4606,706 (±5%) km^2. This amount accounts for the 38% of the total surface of the Central Karakorum National Park, that in the preliminary delineation of Park's boundaries within SEED project was 12,162 km^2). Moreover, this glacierized area represents 31% of the glacial surface of the entire Pakistani Karakorum (by comparison with data from ICIMOD, 2005). Thus, the present study could represent a solid basis for future considerations on the state of glaciers in the whole Pakistan. Glacier size ranges from 0,025 to 604,237 km^2, with an average size of 6,478 km^2. The 9 largest glaciers are covering more than half of the glacierized surface but they represent only 1,27% of the total glacier number. The smallest glaciers (433 ice bodies <1 km^2) represent about 61% of the whole glacier number but they cover only 3,6% of the CKNP glacierized surface (see Tab. 8).

Table 8 Size distribution of glaciers in the CKNP. Data are referred to 2001 glacier coverage (SEED data). The largest glaciers cover the majority of the glacierized surface instead a small coverage is due to a great number of small glaciers.

	Glacier number	**Glacier area (km^2)**	**% with respect to total glacier area**	**% with respect to total glacier number**
total glaciers in CKNP	**711**	**4606,706**	100,0	100,00
glaciers< 1km^2	433	**167,2842**	3,6	60,90
glaciers>1km^2	278	**4439,421**	96,4	39,10
glaciers>10km^2	51	**3781,679**	82,1	7,17

	Glacier number	Glacier area (km^2)	% with respect to total glacier area	% with respect to total glacier number
glaciers>50km^2	17	**3010,587**	65,4	2,39
glaciers>100km^2	9	**2467,761**	53,6	1,27

Fifty-three glaciers in 2001 featured an area minor than 0,1 km^2 thus suggesting to be classified as "glacierets", nevertheless they all together covered a surface area of 2,17 km^2. These ice bodies were inserted in the CKNP Glacier Inventory and labeled them and "uncertain ice bodies" to follow in the inventory updates their evolution.

As regards glacier minimum elevation (which also represents the glacier terminus altitude), this resulted between 4,500 and 5,000 m a.s.l. for the 37% of the analysed glacier, on the other hand about 47% of the total glacier area is covered by glaciers featuring a minimum elevation between 3,000 and 3,500 m a.s.l. (see Tab. 9). This reflects the fact that larger glaciers tend to reach lower elevations, while smaller glaciers have higher termini. These patterns were observed in other glacier areas, namely the Alaska Brooks Range (Manley, 2010), the Swiss glaciers (Kaab et al., 2002), the Cordillera Blanca (Racoviteanu et al., 2008), and the Aosta Valley glaciers in the Italian Alps (Diolaiuti et al., 2012).

Table 9 Glacier minimum altitude distribution. Data are referred to 2001 glacier coverage. In yellow in the table are labeled the maximum glacier percentage with respect to glacier area and to glacier number respectively

Glacier minimum altitude	Glacier number	Cumulative coverage (km^2)	% with respect to area	% with respect to number
2000-2500	3	105.770	2.30	0.42
2500-3000	12	633.715	13.77	1.69
3000-3500	24	2152.567	46.78	3.38
3500-4000	80	945.191	20.54	11.25
4000-4500	234	449.619	9.77	32.91
4500-5000	266	259.535	5.64	37.41
5000-5500	75	35.774	0.78	10.55
>5500	17	19.243	0.42	2.39
total	**711**	**4601,414**	**100,00**	**100,00**

Then glaciers have been sorted according to the size classes introduced by Bolch et al. (2011), who studied Garhwal Himalaya's glaciers in India. The applied size classes are the following: <0.5 km^2, 0.51-1.0 km^2, 1.01-2.0 km^2, 2.01-5.0 km^2, 5.01-10.0 km^2, 10.01-20.0 km^2, 20.01-50.0 km^2, >50.01 km^2 (Tab. 10).

Table 10 Glaciers sorted according to the size classes introduced by Bolch et al. (2011), data are referred to 2001 glacier coverage.

2001 size CLASSES	Mean minimum altitude from SRTM DEM 2000 (m)	2001 Cumulative Area [km^2]	2001 Glacier number	Area % (2001_Areas/Total Area)	Number % (2001_glacier number/Total glacier number)
<0.5	4726.45	66.40	291	1.44	40.93
0.51-1.00	4552.49	99.45	142	2.16	19.97
1.01-2.00	4387.74	170.47	117	3.70	16.46
2.01-5.00	4272.34	237.87	74	5.16	10.41
5.01-10.00	3868.25	246.27	36	5.35	5.06
10.01-20.00	3857.22	247.98	18	5.38	2.53
20.01-50.00	3517.81	525.50	16	11.41	2.25
>50.01	3192.35	3012.10	17	65.39	2.39
Total	**4459.37**	**4606.04**	**711**	**100**	**100**

In Exhibit 6 is reported the hypsographic curve of CKNP glaciers (i.e.: glacierized area in glacier area size class, by 100 m elevation intervals) as derived from 2001 glacier polygons (SEED data) and the SRTM DEM (year 2000). Glaciers range in elevation from 2,250 to 7,900 m a.s.l.. The graph shows the position of the early 1990s' Equilibrium Line Altitude as well (ELA; Bhutiyani, 1999). The elevation of the total maximum glacierized area (5,100 m a.s.l.) is just below the 1990s' ELA, and it might be close to coincident in 2000 if the ELA descending trend of the period 1976-1995 reported in Fujita and Nuimura, 2011 would be still ongoing.

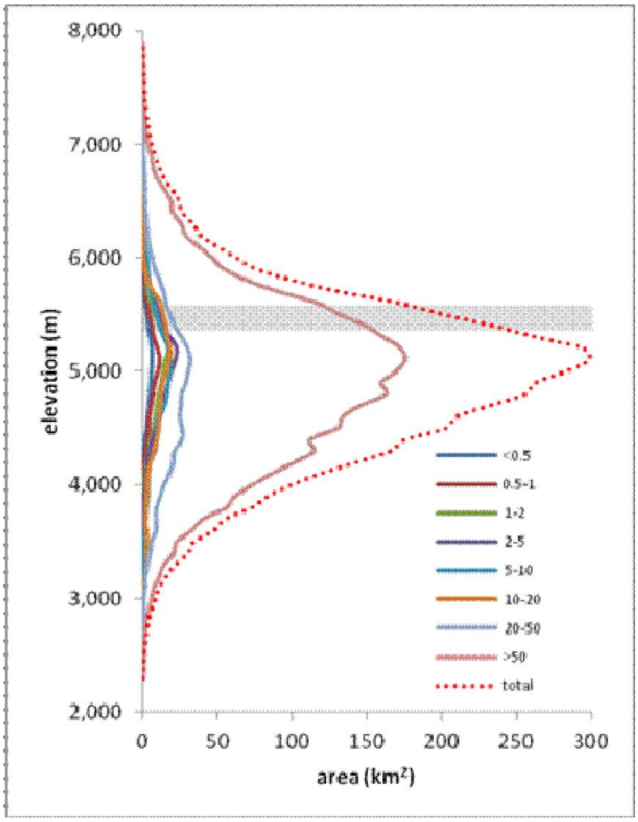


Exhibit 6 Hypsography of glacier area distribution per area class by 100m elevation intervals. Data are referred to 2001 glacier coverage. Gray zone shows the 1990s' equilibrium line altitude (ELA) reported by Bhutiyani, 1999.

Exhibit 7 displays minimum and maximum elevation values versus glacier size for individual glaciers, and mean values for discrete values for different size classes (2001 data from SEED project). While the black lines show the trend of minimum (maximum) elevation to decrease (increase) with glacier size (i.e. elevation range grows with growing class-size), the scatter plot reveals that glaciers bigger than 1 km^2 can be found at both very high and very low altitudes, revealing favorable environmental condition regardless glacier area size. More precisely small glaciers possess smaller altitudinal range (i.e. maximum minus minimum elevation); in contrast, larger glaciers display a wide altitudinal range, with ELA well below maximum elevation. Most glaciers of interest originate above 7000 m and have wide elevation range, while the total minimum elevation is 2250 m, much lower than in the Greater Himalaya of India and Nepal (Hewitt, 2005).

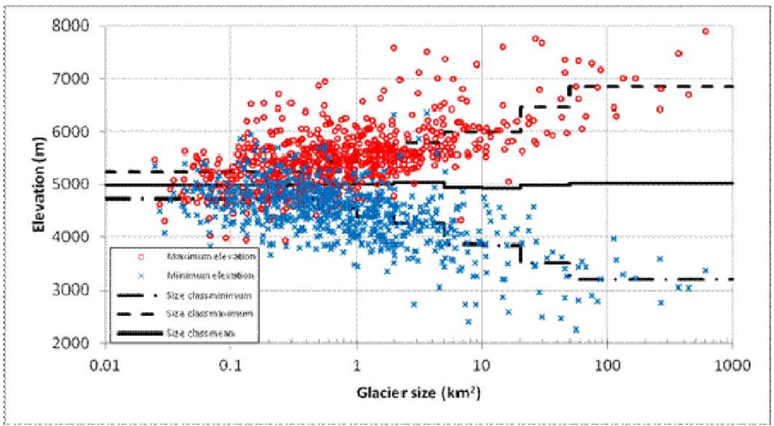


Exhibit 7 Minimum and maximum elevation versus area size (2001 glacier data). Mean values for discrete size classes are also given.

By analyzing 2010 Landsat imagines, 707 glaciers were found and their size distribution is shown in Tab. 11. Examining column 2 in table 11 shows that some glaciers have shifted from one size classes to another one. To avoid inconsistencies, table 12 was obtained by crediting the contribution of each glacier according to the class it belonged to in 2001. We considered the 707 glaciers surveyed both in 2001 and in 2010.

Table 11 Glaciers sorted according to the size classes introduced by *Bolch et al. (2011)*, data are referred to 2010 glacier coverage.

2010 size CLASSES	2010 Cumulative Area [km2]	2010 glacier number	% 2010_Areas/Total Area	% 2010_glacier number/Total glacier number
<0.5	66.13	290	1.43	41.02
0.51-1.00	99.63	142	2.16	20.08
1.01-2.00	170.66	117	3.70	16.55
2.01-5.00	232.12	72	5.03	10.18
5.01-10.00	246.64	36	5.35	5.09
10.01-20.00	238.15	17	5.16	2.40
20.01-50.00	525.68	16	11.39	2.26
>50.01	3034.28	17	65.77	2.40
Total	**4613.29**	**707**	**100.00**	**100.00**

Table 12 Glacier changes in the period 2001-2010. Only glaciers present in both the database are considered. Positive values mean glacier gains, negative values mean glacier losses.

Size classes	Glacier number	2001 glacier coverage (km2)	2010 glacier coverage (km2)	2001-2010 glacier changes (km2)	2001-2010 glacier changes (%)
<0.5	290	66.232	66.133	-0.099	-0.372
0.51-1.00	142	98.954	99.127	0.173	0.651
1.01-2.00	117	170.465	170.664	0.199	0.749
2.01-5.00	72	230.477	232.116	1.638	6.161
5.01-10.00	36	246.271	246.636	0.365	1.372
10.01-20.00	17	236.205	238.154	1.950	7.331
20.01-50.00	16	525.497	525.678	0.180	0.678
>50.01	17	3012.098	3034.283	22.185	83.43
Total	**707**	**4586.200**	**4612.791**	**26.591**	**100**

From our data, total glacier surface seems to be slightly increased in 2010, gaining 26.6 km^2 (±10%) km^2 with regards to 2001. Although the total area increment is not remarkable (+0.6% of the 2001 area coverage) and this value is in the range of the data accuracy, it suggests quite stable conditions for Karakorum glaciers. This is in agreement with the phenomenon known as “Karakorum anomaly” (Hewitt, 2005), a regional glacier behavior contrasting with the general glacier shrinkage which has been occurring in all the other glacierized zones of the Planet. Moreover, other neighboring Asian glacierized areas are undergoing a general glacier decline (IPCC, 2007), thus making the Karakorum the Asian exception.

From our data it results that in the CKNP area glaciers experienced, over the last decade, quite stable conditions or small gains (up to an area increase of 22.185 km^2 for glaciers wider than 50 km^2) and only the smallest glaciers (<0.5 km^2) had an area loss of 0.099 km^2. The largest part of the area change was due to variations experienced by the largest glaciers.

These results are in agreement with other recent studies dealing with glacier mass balance, as the one by Gardelle et al. (2012).

In the time window 2001-2010 a total of 92 glaciers have changed. In some cases they advanced so much to become part of bigger glaciers they ended up to touch. By the way, one emblematic and studied example is represented by Panmah's tributaries (three of them in particular), which have experienced sudden surges from 2001 and 2005 (Hewitt, 2007), now becoming part of the Panmah glacier. Sometimes this implies a surface area increase (Exhibit 8a), sometimes there is an advance without area increment (Exhibit 8b).

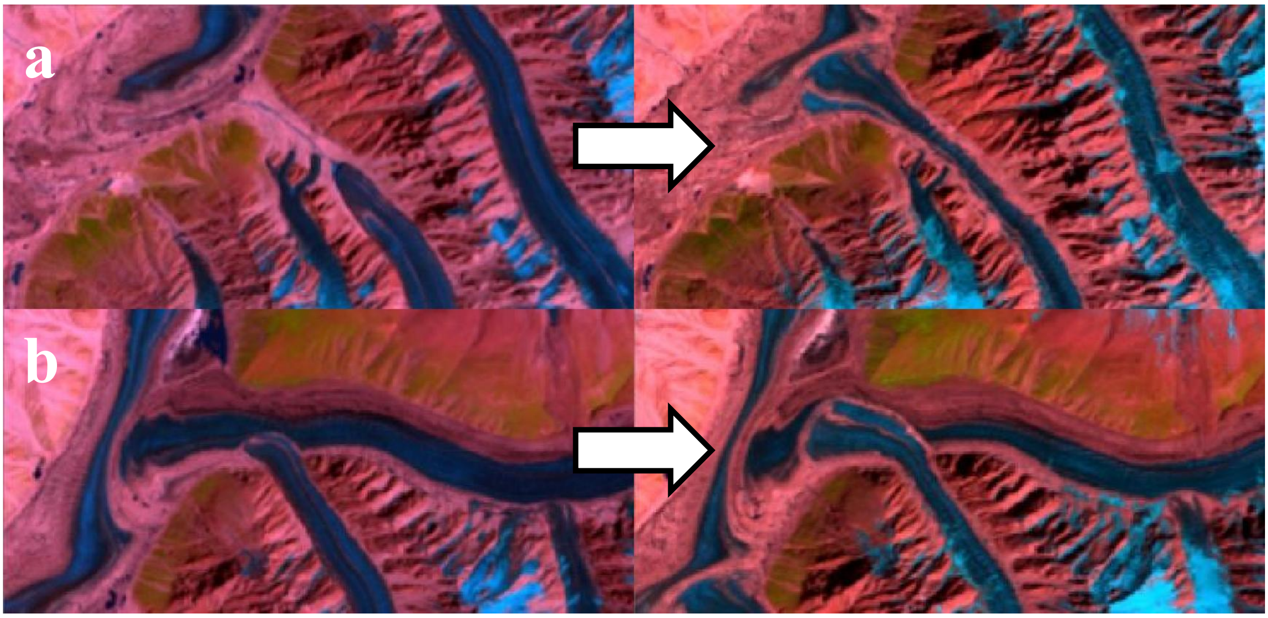


Exhibit 8 a, b Comparison of Panmah's tributaries position in 2001 (left) and 2010 (right) (the analysed imagines are Landsat from NASA).

Glacier are very active over their termini in this area (Copland et al., 2009). In fact, many have gone downwards since 2001 (Exhibit 9). The number of detected advances is 40, resulting in a downshift of the total minimum elevation in 2010. Minimum elevation change is significant for glaciers with surface between 10 to 50 km^2, which have gone up to 60m down in 2010 with respect to 2001. Maximum elevation remains the same between the two studied years, as image inspection revealed.

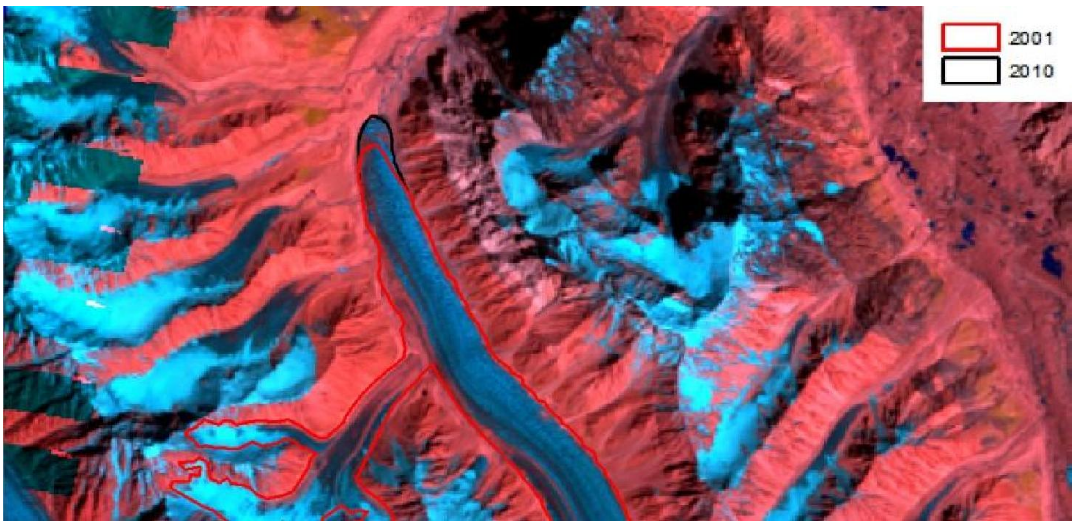


Exhibit 9 Display advance of a glacier near Braldu glacier from 2001-2010 (the base layer is the 2010 Landsat imagine, from NASA).

The small variability in mean elevation per area size (Exhibit 10) suggests there is a common elevation range where glaciers of different sizes find favorable environmental conditions. However, once observing the large scatter of individual glacier mean elevations, something seems controlling glacier favorable individual elevation, most likely local topographic characteristics (e.g. glacier aspect).

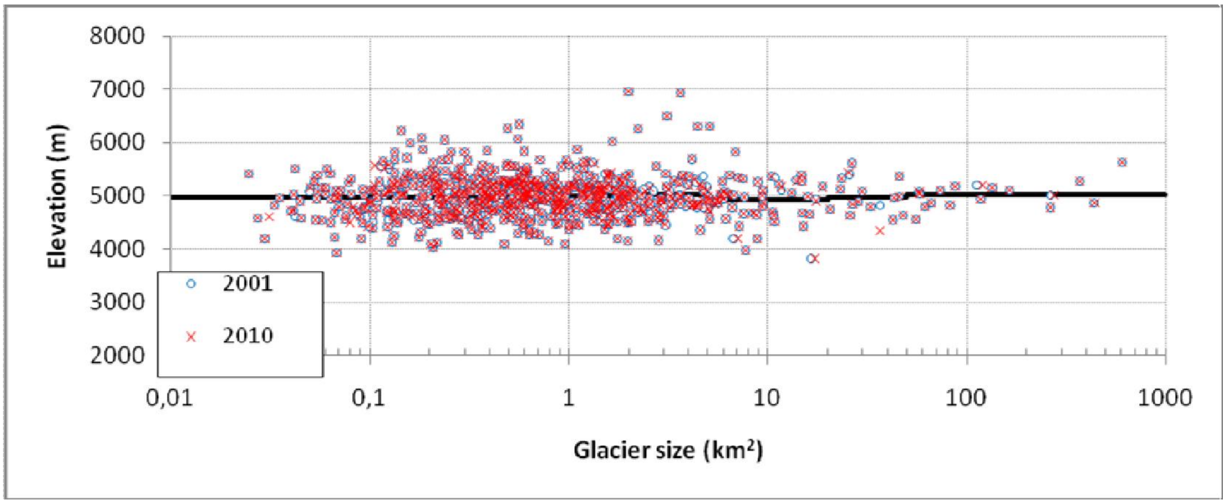


Exhibit 10 2001 and 2010 mean glacier elevation per area size. Solid line represents mean values for each size classes.

2.2.2 Mountain hydrology

CKNP is a water rich area. Seasonal melting of snow and ice from the Karakorum provides plenty of water for drinking and irrigation, and for storage in reservoirs downstream for the population of Pakistan. The mountain range of the Karakorum contains a large amount of glacier ice, delivering water for agriculture, drinking purposes and power production.

Data source

Information from bibliography

There are estimates indicating that more than 50% of the water flowing in the Indus river, Pakistan, which originates from the Karakorum, is due to snow and glacier melt (Immerzeel et al., 2010). The hydrological regimes of Karakorum rivers and potential impact of climate change therein have been hitherto assessed in a number of contribution in the available scientific literature (Aizen et al., 2002; Hannah et al, 2005; Kaser et al., 2010).

The Karakorum stores a very relevant amount of water in its extensive glacier cover at higher altitudes (about 16,300 km^2), but the lower reaches are very dry. Especially in the Central and Northern Karakorum, the lower elevations receive only occasional rainfall during summer and winter (Winiger et al., 2005). The state of the glaciers also plays an important role in future planning: shrinking glaciers may initially provide more melt water, but later their amount may reduce; on the other hand, growing glaciers store precipitation, reduce summer runoff, and can also generate local hazards. These differences could be caused by increases in precipitation since the 1960s (Archer and Fowler, 2004) and a simultaneous trend towards higher winter temperatures and lower summer temperatures (Fowler and Archer, 2005).

Therefore, it is tremendously important that water resources and their dynamics within the CKNP are being continuously monitored, by starting as soon as possible. Building a clear picture of the surface water availability, and temporal dynamics in the area are necessary for developing accurate water management strategies.

Field data and main findings

We report hereafter two examples of design and installation of hydrometric stations, aimed at continuously monitoring stream flows, within Karakorum (and one into CKNP), that can be considered paradigmatic for the CKNP.

A first station has been installed in April 2011 at Shigar bridge (Exhibit 11). This point was historically measured by WAPDA agency until 1998, while ever since then no measurements were carried out. We therefore decided to install such a station to start new flow series in this area. This station will be used jointly with the old available data for the assessment on long term water resources in the area.

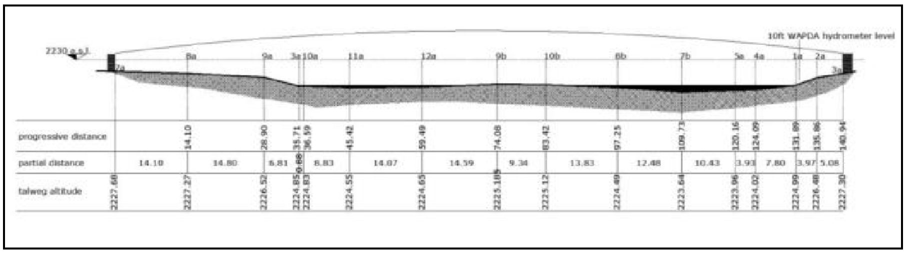
The Shigar river (ca. 7000 km^2, closed as Shigar, 2,230 m a.s.l.), albeit not included within the park boundaries, it can be considered as paradigmatic of water resources in the CKNP area, displaying a dry climate, with low flows during Fall and Winter, and floods mostly from Spring and Summer, this is mainly caused by snow and ice melting within the highest Karakorum, and less due to to monsoonal rainfall.


a)

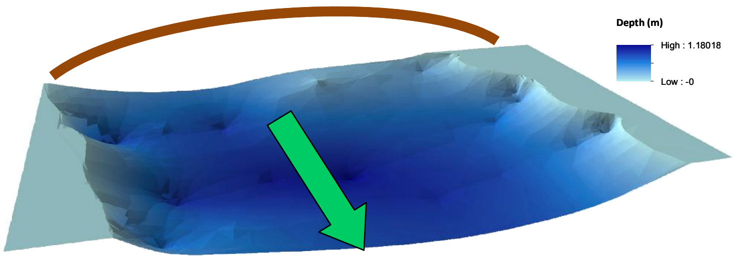

b)

Exhibit 11 Gaugins stations installed. a) Shigar. b) Paiju

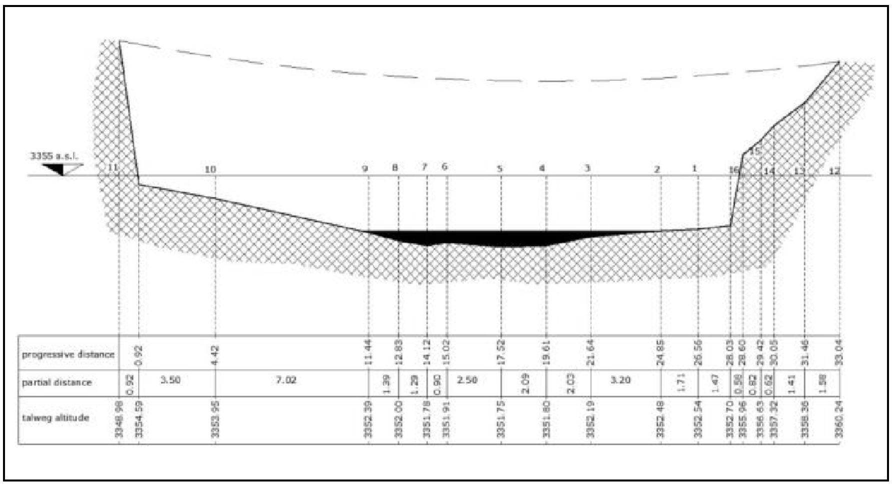
In Exhibit 12, the cross section of the two stations is reported. A second station was cast in Paiju (1,331 km^2, 3,355 ma.s.l.), along the Baltoro glacier, in May 2012. This station was installed to measure explicitly water discharge coming from ice melt upon the major Baltoro glacier. This area is within the CKNP and represents a tremendously paradigmatic area within the park, which is covered for the most part with seasonal snow and permanent ice.



a)



b)

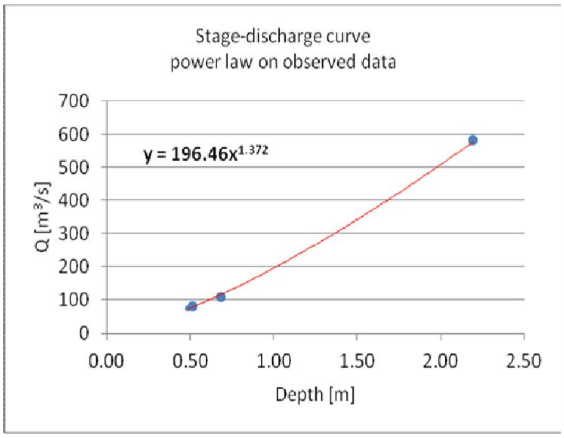


c)

Exhibit 12 River sections at surveyed points. a) Shigar 2-D. b) Shigar 3D. c) Paiju 2d.

The stage discharges curves, converting hydrometric level into discharge, are given in Exhibit 13.

In Exhibit 14 we report the estimated discharge at Shigar bridge using the available data during the operating periods.



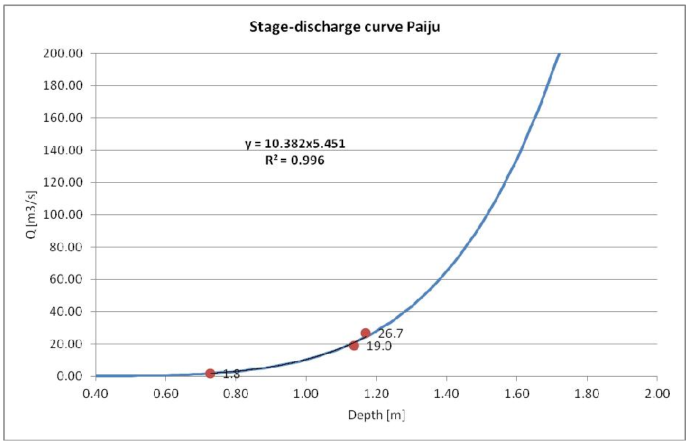
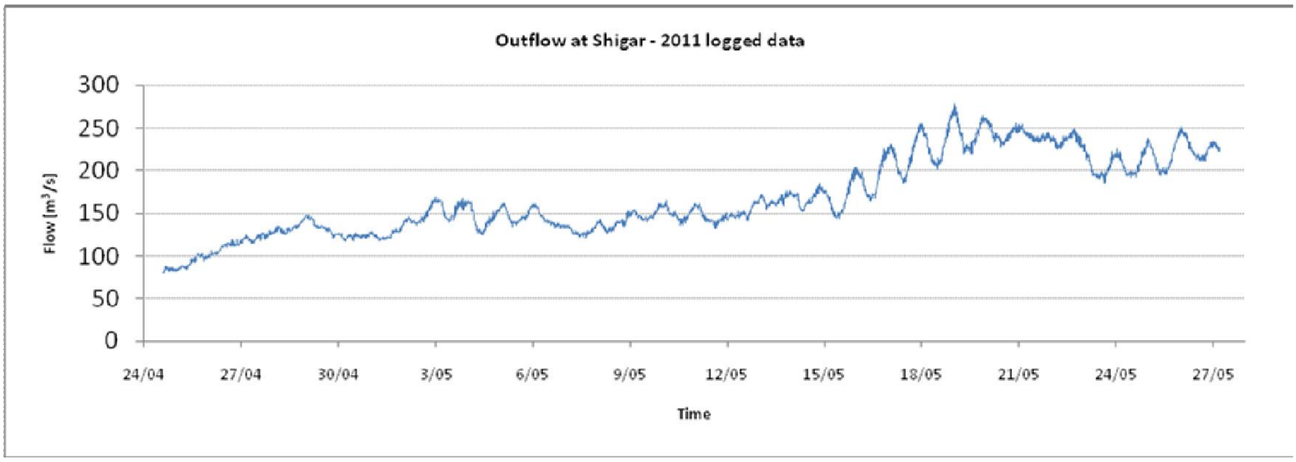
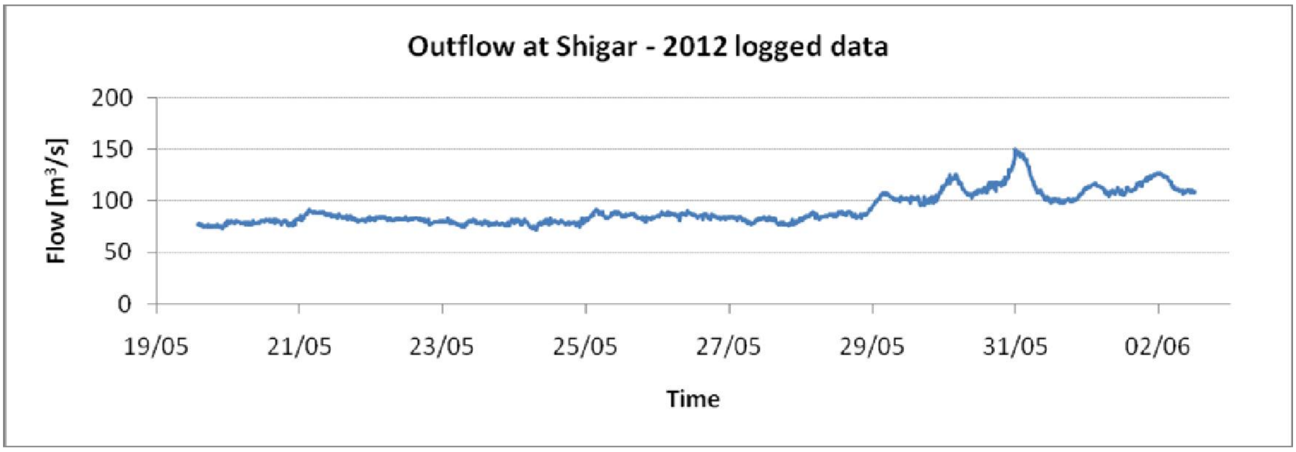


Exhibit 13 Stage discharge curves (power law type). a) Shigar. b) Paiju



a)



b)

Exhibit 14 Estimated discharge at Shigar bridge using the available data during the operating periods. a) 2011. b) 2012

Hydrological modeling is tremendously important to understand water resources dynamics within the CKNP park. Notice that hydrological models can provide estimates of discharges not only at the monitored sites (normally used for calibration), but also at unmonitored sites upstream and downstream of the available gauging sites. This allows a tremendous gain of knowledge concerning the spatial distribution and temporal dynamics of stream flows. As an example of hydrological modeling approach, we report here the case study of the Shigar river, including the Braldo valley, the Biafo-Ispar, Baltoro, and several other glacier groups (Exhibit 15).

We set up a minimal hydrological model (Bocchiola et al., 2011), tuned against a short series of observed ground climatic data from a number of stations, in situ measured ice ablation, and remotely sensed snow covered areas. The highest altitude here is reached by K2 mountain (8,611 m a.s.l.) and the lower is at Shigar bridge at 2,204 m a.s.l., the average altitude is 4,613 m a.s.l. and around the 35% of the area is above 5000 m a.s.l.. According to the Köppen-Geiger climate classification (Peel et al., 2007) this area falls in the BWK region, that displays dry climate with little precipitation and a wide daily temperature range. The HKH area displays considerable vertical gradients. The Nanga Parbat massif forms a barrier to the Northward movement of monsoon storms, which little intrudes in Karakorum. In the HKH range there is extensive coverage of glaciers. In the Shigar basin, the main ice body is the Baltoro, greater than 700 km^2 in area. Thus, the hydrological regime is slightly influenced by monsoon, while the major contribution results from snowmelt and glacier melt.

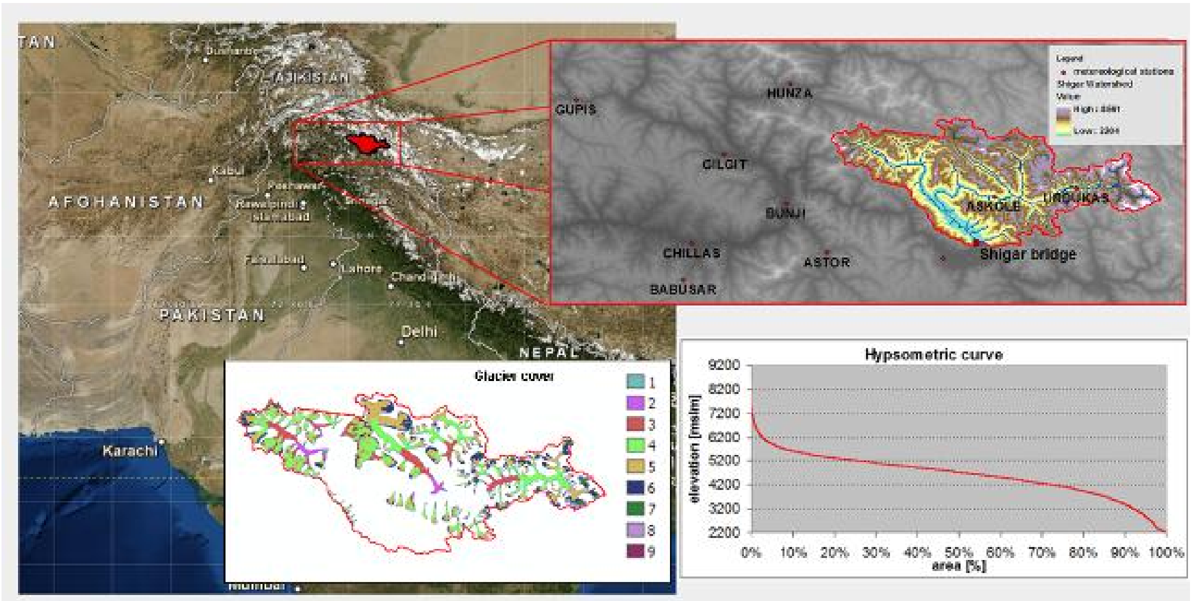


Exhibit 15 The study area: Shigar river basincloesd at Shigar. Red dots are the weather stations. Glaciers' cover reported in the 10 chosen altitude belts (no glacier cover in belt 10).

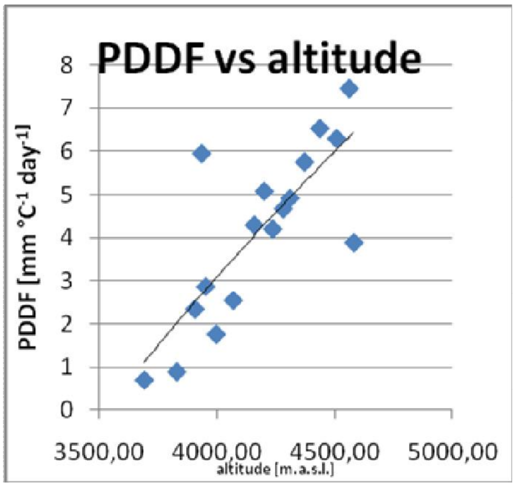
In the Shigar river catchment, the available data came from two meteorological stations, owned by Ev-K2-CNR committee: Askole (3,015 m a.s.l.), and Urdukas (3,926 m a.s.l.). For these stations, daily values of rainfall and mean air temperature for the period from 2005 until 2011 are available, but with significant missing data periods, especially for the precipitation. These gaps are concentrated particularly in Winter, as precipitation occurs in snow form, which is not measured by these stations. Outside the Shigar basin, weather data are available, namely the monthly values of precipitation and temperature during 1980-2009, for 8 stations belonging to Pakistan meteorological department, PMD, all positioned below 2,500 m a.s.l.. Monthly mean discharge averaged over the period from 1985 until 1997 are available. During this period there was an hydrometric station property of the water power development agency of Pakistan WAPDA at the Shigar bridge (2,204 m a.s.l.), that is our control section (e.g. Archer, 2003).

Here we used snow covered area SCA as derived from MODIS® images. Nowadays, SCA estimation from satellite data is widely adopted for water storage assessment in mountain areas, distributed modeling of snow cover and melting and hydrological and glaciological implications therein (e.g. Swamy and Brivio, 1996;

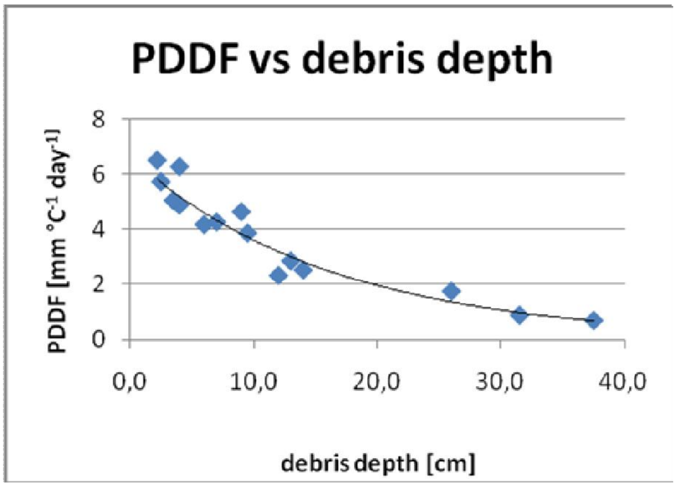
Simpson et al., 1998; Cagnati et al., 2004; Hauser et al., 2005; Parajka and Blöschl, 2008; Georgievsky, 2009; Immerzeel et al., 2009).

Here we used 40 images of SCA from MODIS during 2006-2008, taken from the product MODIS/Terra Maximum-Snow Cover 8-Day, L3 Global, at a 500 m resolution (MOD10A2, e.g. Hall et al., 2002). This contains Maximum SCA (yes/no) over an 8-day composing period. As no snow cover data were available within the catchment, as reported, we could not attempt either spatial estimation of snow cover (as e.g. in Bocchiola, 2010; Bocchiola and Groppelli, 2010), or investigation of snowfall properties in the area (e.g. Bocchiola and Rosso, 2007).

Shigar watershed includes glaciers spread over a considerable area, several of which displaying debris cover. Mihalcea et al. (2006) and Mayer et al. (2006) evaluate ice melt factors for both ice covered and ice free glacier based upon field ablation data from the Baltoro glacier, and Mayer et al. (2010) evaluated melt factors for Bagrot valley, and Hinarche glacier. Mihalcea et al. (2008) provided evaluation of debris cover thickness again upon Baltoro. We classified ice covered area using visible images, and compared our estimates glaciers' inventory from ICIMOD (Campbell, 2004) within the Shigar catchment. We obtained an ice covered area of ca. 2774 km^2 vs 2240 km^2 as from ICIMOD.



a)



b)

Exhibit 16 Melt factors PDDF from ablation stake data. a) vs altitude. b) vs debris thickness

To evaluate the ice melting factor we use ablation data collected in summer 2011 and 2012 during a joint expedition by UNIMI and POLIMI (Exhibit 16). From these campaigns, the ablation for 15 ablation stakes along the Baltoro glacier at different altitude and debris coverage depth are available. From this data it is possible to estimate a multiple regression between PDDF (positive degree day factor), debris depth and altitude. From this relation, it is possible to calculate the PDDF value for each belt. As a rough average value on the area, we found a melt factor for ice DDi = 5.3 with a maximum value of 7.7 according to the Mayer et al. (2010) analysis.

Snow melt was tackled using degree day approach and melt factor. We used our hydrological model to simulate snow cover at different altitudes for different values of melt factors, during years 2005-2008, when weather data from Ev-K2-CNR stations were available, and also MODIS SCA data could be retrieved. We then compared the estimated snow cover depth, or snow water equivalent SWE (including no snow) against SCA given by MODIS images for 2006-2008. Year 2005 was not considered, because no information about snowfall during the antecedent Fall was available to be used as boundary conditions. We then estimated a best value for the snow melt factor, as the one providing the best correspondence in term of SCA variation, and snow depletion period.

We used a semi-distributed altitude belts based model able to reproduce deposition of snow and ablation of both ice and snow, evapotranspiration, recharge of groundwater reservoir, discharge formation and routing to the control section (Groppelli et al., 2011b; Bocchiola et al., 2011). This simple model needs a few input data, i.e. a DEM, daily values of precipitation and temperature, information about soil use, vertical gradient of temperature and precipitation and some other parameters.

The hydrological model uses a daily series of precipitation and temperature from one representative station, here Askole, and the estimated vertical gradients to project those variables at each altitude belt. Topography is here represented by a DTM model, with 500 m spatial resolution, derived from ASTER (2006) mission, used to define altitude belts and local weather variables against altitude.

In Exhibit 17 we report modeled monthly mean values during 2005-2008 (plus confidence limits, 95%), compared against the observed counterparts (during 1985-1997, Archer, 2003). Confidence limits of the monthly mean, as calculated by the model, indicate some criticalities of the model. While discharges are quite well represented during the peak months, some inaccuracy in estimation is observed during the raising limb of the monthly hydrograph (slight overestimation in May and June). Also, low base flows during Spring are slightly underestimated by the model.

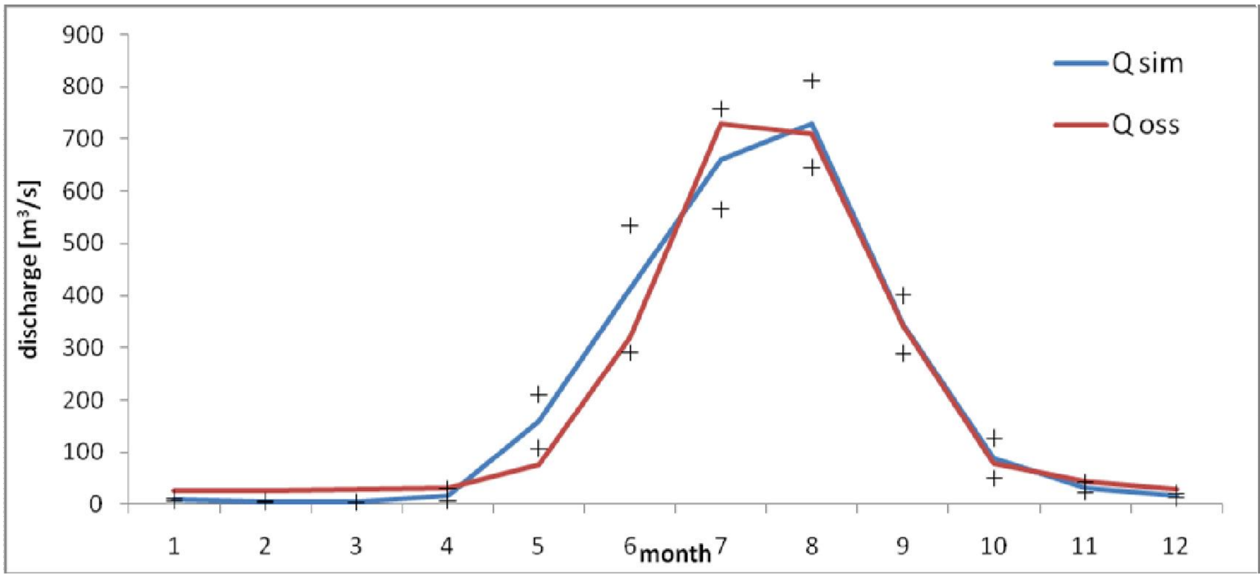


Exhibit 17 Shigar at Shigar bridge. Modeled (2005-2008) and observed mean monthly discharge (1985-1997), with 95% confidence interval.

The monthly discharges, as shown in Exhibit 17 clearly depicts the unimodal (i.e. with one peak) flow regime within the Shigar river, and park area, with increasing flow during May and June, as due to snow melt, and peaking floods during July and August, as due to ice melt until about 5000 m a.s.l..

The approach to hydrological modeling, we proposed here, seems simple enough to show that portability to catchments nearby should be reasonably practicable, covering the whole CKNP area.

2.2.3 Water quality

Data source

Information from bibliography

Despite water quality being acknowledged as one of the major issues related to water resource management, reliable data and information are generally very scanty and limited in relation to water quality for drinking purpose (e.g. faecal contamination). In addition, very few data are available for the high altitude part of the GB included in the CKNP area (Lodhi, 2003; Shahid and Joyia, 2003; Khalil and Shah, 2007). In addition, these data are apparently contradictory since they are generally based on one sampling expedition in a limited area, however the conclusions are extended to the whole area. For example Lodhi (2003) concluded that most of the water spring examined are suitable for human consumption, while Shahid and Joyia (2003) and Khalil and Shah (2007) reported that water from the Gilgit Baltistan are highly contaminated.

Field data

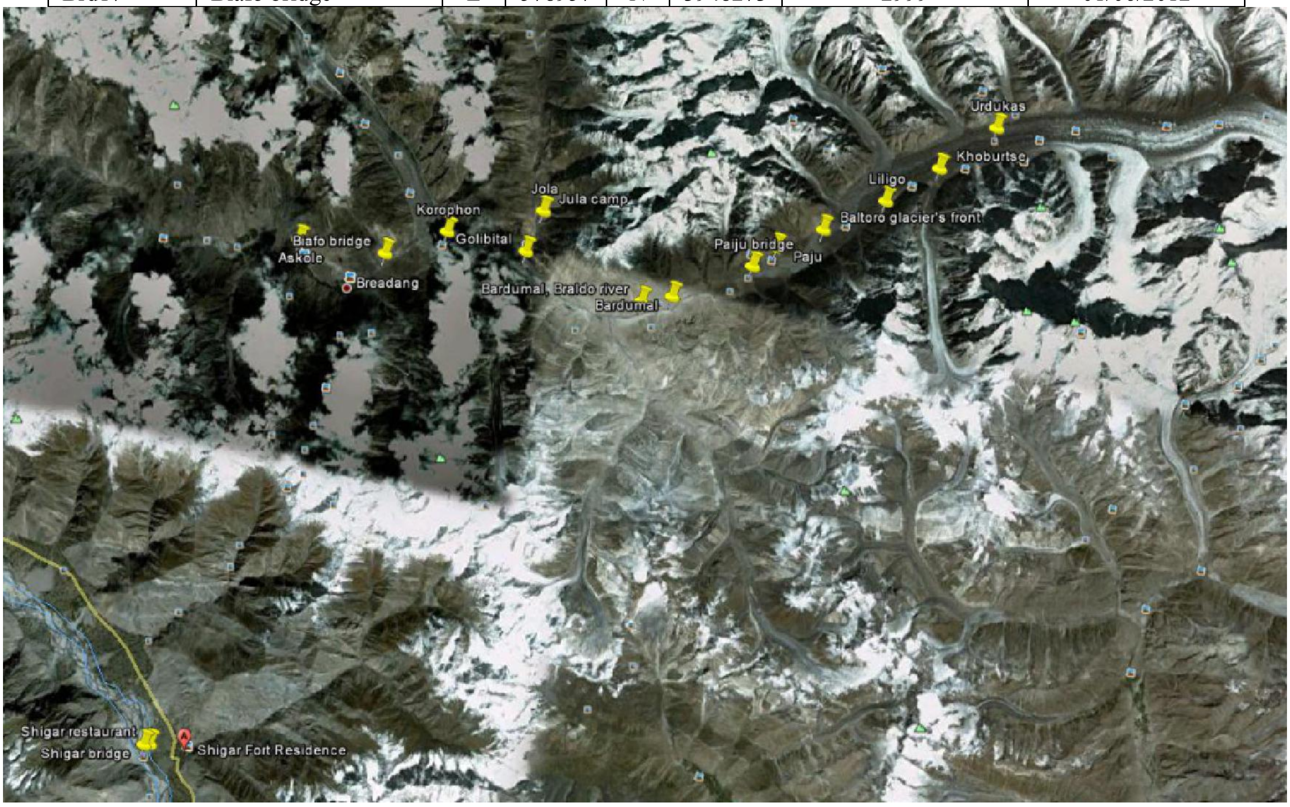
Within SEED project it was established to pursue an evaluation of two Valleys as test case to evaluate the condition of the water quality. The Valley (Basha and Braldu) have been selected because they have different anthropogenic impacts. Braldu is strongly affected by tourism, while Basha is mainly used by local communities.

The survey was performed in 2011 and in 2012 on about 17 sites in each valley, as shown in table 13 here below:

Table 13 List of the sampling site in the Braldu (A) and Basha (B) Valleys

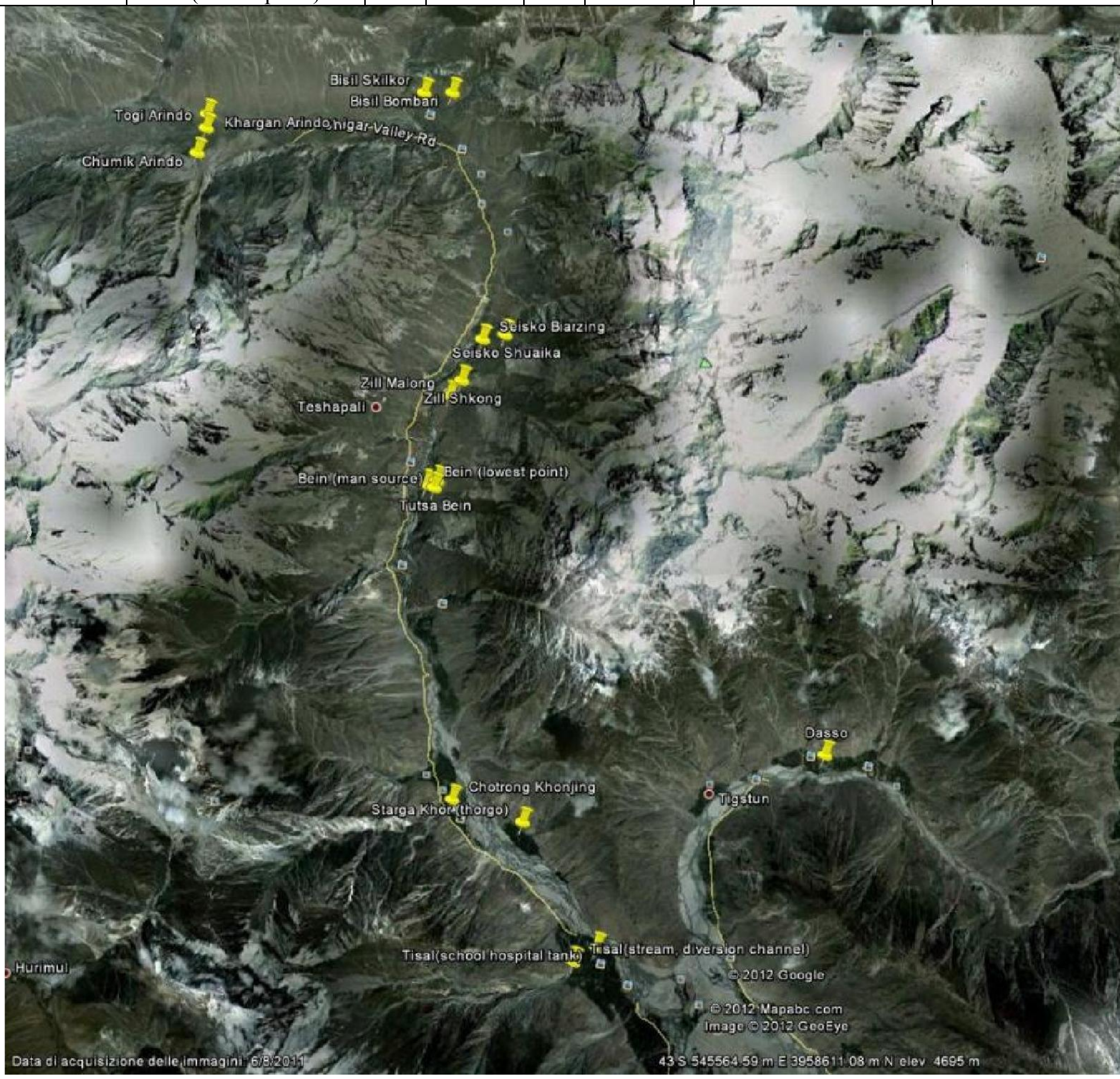
A)

SITE code	SITE	GPS coordinates UTM-WGS84 (Zone 43N)				Elevation (m asl)	Date
Brd01	Korophon	E	582724	N	3949958	3073	01/06/2102
Brd03	Paiju	E	601855	N	3948750	3425	31/05/2012
Brd04	Baltoro glacier's front	E	604460	N	3949784	3413	30/05/2012
Brd05	Paiju bridge	E	600529	N	3947737	3351	31/05/2012
Brd07	Askole	E	573948	N	3949010	3061	02/06/2012
Brd08	Shigar bridge	E	564812	N	3919985	2234	02/06/2012
Brd10	Urdukas	E	616118	N	3954396	4050	28/05/2012
Brd11	Jula bridge	E	587993	N	3951704	3124	01/06/2012
Brd13	Jula camp	E	588185	N	3950681	3169	01/06/2012
Brd14	Shigar restaurant	E	565160	N	3920084	2208	02/06/2012
Brd15	Dasso	E	546796	N	3952590	3065	02/06/2012
Brd09	Khoburtse	E	611566	N	3953189	3848	29/05/2012
Brd16	Liligo	E	608042	N	3951377	3720	29/05/2012
Brd17	Biafo bridge	E	578957	N	3948273	2999	01/06/2012



B)

SITE code	SITE	GPS coordinates UTM-WGS84 (Zone 43N)				Elevation (m asl)	Date
Bsh01	Chumik Arindo	E	530015	N	3968332	2874	09/06/2012
Bsh02	Togi Arindo	E	530194	N	3969027	2793	09/06/2012
Bsh03	Khargan Arindo	E	530220	N	3969391	2757	09/06/2012
Bsh04	Bisil Bombari	E	536744	N	3969997	2835	10/06/2012
Bsh05	Bisil Skilkor	E	535972	N	3970013	2720	10/06/2012
Bsh06	Zill Shkong	E	537033	N	3962438	2680	10/06/2012
Bsh07	Zill Malong	E	536692	N	3962035	2618	10/06/2012
Bsh08	Seisko Shuaika	E	538204	N	3963637	2794	10/06/2012
Bsh09	Seisko Biarzing	E	537561	N	3963539	2662	10/06/2012
Bsh10	Chotrong Khonjing	E	536812	N	3951322	2463	11/06/2012
Bsh11	Tisal	E	540102	N	3947051	2530	10/06/2012
Bsh12	Tisal	E	540709	N	3947413	2412	10/06/2012
Bsh13	Starga Khor/thorgo	E	538705	N	3950735	2580	11/06/2012
Bsh14	Tutsa Bein	E	536296	N	3959605	2650	10/06/2012
Bsh15	Bein (main source)	E	536376	N	3959788	2645	10/06/2012
Bsh16	Bein (lowest point)	E	536088	N	3959687	2570	10/06/2012



The analysis have been performed in Italy at CNR-Institute for Ecosystem Studies, Verbania and at ARPA Piemonte, Dipartimento VCO. The chemical variables were performed with the methodologies in use at the laboratory (http://www.idrolab.ise.cnr.it): pH, conductivity, and alkalinity by potentiometric methods, major anions (sulphate, nitrate and chloride) and cations (calcium, magnesium, sodium and potassium) by ion chromatography, and total reactive phosphorus, ammonium, reactive silica and total nitrogen by spectrophotometry. The results of the analysis were subjected to analytical quality control based on a comparison between the total concentrations of cations and anions and a comparison between measured and calculated conductivity on the basis of the concentrations of major ions. The chemical and biological variable and the method used are listed here below:

List of the chemical parameters to be analyzed in natural and drinking water for the SEED project

Variables	Unit	Range	Methods
pH		3-10	Pot.
Conductivity	µS /cm	0.5-800	Cond.
Turbidity	FTU	1-400	Spec.
Nitrate	mg N /L	0.01-6	Spec.
Ammonium	µg N /L	5-1500	Spec.
Nitrite	µg N /L	1-100	Spec.
Phosphate	µg P /L	3-400	Spec.
Total phosphorus	µg P /L	3-400	Spec.
Total nitrogen	mg N /L	0.1-6	Spec.
Silicate	mg Si /L	0.02-10	Spec.

As to microbiological tests, the following tests will be performed with membrane-filtration and liquid broth tests (presence-absence and most-probable-number, MPN):.

Coliform bacteria
Escherichia coli
Total bacteria at 22°C
Salmonella spp.
Fecal coliform

In tables listed below are summarized the results obtained from the field work performed in 2011 (Table 13) and 2012 (Tables 14, 15; 16; 17, 18, 19) in the Braldu and Basha Valley.

Table 14 Braldu valley: results of the chemical composition of the water samples collected in 2011

Site code	Site	Sampling date	Analysis date	Bottle	Temp. °C	Turbidity FTU	pH	c20°C µS cm^{-1}	T.Alc. meq l^{-1}	Cl mg l^{-1}	SO_4 mg l^{-1}	N-NO_3 µg l^{-1}	N-NH_4 µg l^{-1}	Ca mg l^{-1}	Mg mg l^{-1}	Na mg l^{-1}	K mg l^{-1}	RP µg l^{-1}	TP µg l^{-1}	TN mg l^{-1}	Si mg l^{-1}	F mg l^{-1}	TOC mg l^{-1}
Brd01	Korophon	14/04/2011	06/06/2011	5	1,8		7,89	289	2,379	0,9	45,1	105	4	40,4	10,2	6,9	4,1	2	6	0,12	3,04	0,60	0,3
Brd01	Korophon	01/08/2011	16/09/2011	6	4,0	sediment	7,75	84	0,764	0,1	6,7	0	1	13,9	1,3	0,2	2,4	2	2	0,01	0,59	0,07	0,3
Brd03	Paiju	15/04/2011	06/06/2011	1	2,5		8,07	285	2,506	1,3	34,7	0	1	43,1	7,1	11,4	1,8	3	6	0,07	7,81	1,80	1,9
Brd03	Paiju	30/07/2011	16/09/2011	3	12 ?		8,22	201	1,691	0,5	25,1	0	2	31,6	4,5	6,6	0,8	1	1	0,03	6,74	1,06	0,5
Brd02	Bardumal	14/04/2011	06/06/2011	4	7,0		7,73	208	1,854	0,6	24,0	0	2	28,2	6,5	7,5	3,9	4	4	0,01	2,78	0,60	0,4
Brd04	Baltoro	17/04/2011	06/06/2011	2	0,0		7,21	79	0,413	0,2	16,4	40	4	9,5	1,5	2,2	1,9	6	8	0,05	1,85	0,20	0,3
Brd05	Paiju bridge	18/04/2011	06/06/2011	3	2,0		7,56	148	1,157	0,5	20,9	0	2	18,5	4,6	4,8	3,6	3	5	0,03	2,25	0,50	0,5
Brd06	Golibital	19/04/2011	06/06/2011	8	6,0		7,94	308	2,465	0,9	50,2	0	2	41,8	12,6	6,8	4,3	2	2	0,04	3,08	0,60	0,6
Brd07	Askole	20/04/2011	06/06/2011	10	6,0		8,12	555	2,050	0,5	211	238	1	69,0	28,0	4,3	16,3	3	3	0,24	5,43	0,30	0,3
Brd08	Shigar bridge 22/4	22/04/2011	06/06/2011	6	11,5		7,84	358	2,446	1,1	78,3	0	7	48,9	12,8	7,0	7,6	16	17	0,03	3,74	0,50	0,4
Brd08	Shigar bridge 2/8	02/08/2011	16/09/2011	8	1,0	sediment	7,08	182	1,628	0,2	19,6	0	3	31,7	3,4	1,3	4,0	2	2	0,04	1,85	0,16	0,4
Brd07	Askole	01/08/2011	16/09/2011	7	4,0		7,86	591	2,471	1,0	217	24	3	69,6	32,8	4,8	18,0	1	1	0,13	5,89	0,31	0,7
Brd09	Khoburtse	29/07/2011	16/09/2011	2	4,0		6,84	54	0,216	0,1	13,1	231	2	7,2	1,1	0,2	0,6	0	0	0,26	0,54	0,11	0,6
Brd10	Urdukas	27/07/2011	16/09/2011	1	3,0		6,73	16	0,143	0,05	0,5	165	2	2,7	0,4	0,1	0,2	3	3	0,18	0,26	0,06	0,4
Brd11	Jola	31/07/2011	16/09/2011	5	8,0	sediment	7,22	134	0,763	0,1	30,3	115	3	19,8	3,6	0,3	3,0	1	1	0,14	0,94	0,04	0,5
Brd12	Bardumal, Braldo river	31/07/2011	16/09/2011	4	2,0	sediment	8,27	128	1,198	0,2	10,7	0	1	20,7	2,7	1,4	3,2	2	3	0,03	1,81	0,26	0,5

Table 15 Braldu valley: results of the heavy metals in the water samples collected in 2012.

Site code	Site	Sampling date	Analysis date	Bottle	Al µg l-1	As µg l-1	B µg l-1	Ba µg l-1	Cd µg l-1	Co µg l-1	Cr µg l-1	Cu µg l-1	Fe µg l-1	Li µg l-1	Mn µg l-1	Ni µg l-1	Pb µg l-1	Pt µg l-1	Se µg l-1	Sr µg l-1	Tl µg l-1	V µg l-1	Zn µg l-1
Brd01	Korophon	01/06/2012	19/06/2012	1	115	<LOD	2,7	6,4	<LOD	<LOD	0,2	0,7	34,4	6,3	2,8	0,5	<LOD	<LOD	<LOD	29	<LOD	4,4	3,0
Brd03	Paiju	31/05/2012	19/06/2012	3	11	<LOD	6,2	19,0	<LOD	0,3	<LOD	<LOD	6,4	16,3	0,8	1,0	<LOD	<LOD	<LOD	472	<LOD	23,7	7,2
Brd05	Paiju bridge	31/05/2012	19/06/2012	3a	172	<LOD	5,3	5,9	<LOD	0,2	0,2	<LOD	11,5	10,3	0,6	0,4	<LOD	<LOD	<LOD	100	<LOD	9,1	3,2
Brd04	Baltoro	30/05/2012	19/06/2012	4	21	5,8	17,6	6,6	<LOD	0,2	0,2	<LOD	21,1	17,4	0,6	0,8	<LOD	<LOD	<LOD	74	<LOD	15,1	3,1
Brd07	Askole	02/06/2012	19/06/2012	7	11	<LOD	7,2	8,3	<LOD	0,4	0,4	1,0	8,6	39,2	0,3	0,7	<LOD	<LOD	<LOD	350	<LOD	117,2	3,2
Brd08	Shigar bridge	02/06/2012	19/06/2012	8	77	<LOD	32,4	14,3	<LOD	0,3	<LOD	0,7	18,2	16,0	0,5	0,6	<LOD	<LOD	<LOD	132	<LOD	26,1	1,2
Brd14	Shigar restaurant	02/06/2012	19/06/2012	8A	28	<LOD	19,1	16,1	<LOD	0,3	0,4	1,4	10,5	6,6	0,2	0,5	<LOD	<LOD	<LOD	174	<LOD	33,8	7,4
Brd10	Urdukas	28/05/2012	19/06/2012	10	68	<LOD	5,3	7,3	<LOD	0,3	0,2	3,4	61,8	4,8	1,1	1,6	<LOD	<LOD	<LOD	39	<LOD	11,1	4,9
Brd13	Jula camp	01/06/2012	19/06/2012	11	122	<LOD	15,0	6,6	<LOD	0,2	<LOD	0,8	17,8	10,8	2,0	0,3	<LOD	<LOD	<LOD	68	<LOD	9,0	2,7
Brd11	Jula bridge	01/06/2012	19/06/2012	11A	20	<LOD	5,8	14,7	<LOD	0,3	0,3	2,5	11,8	5,1	0,2	2,3	<LOD	<LOD	<LOD	85	<LOD	19,3	1,9
Brd15	Dasso	02/06/2012	19/06/2012	13	23	<LOD	4,3	4,3	<LOD	0,2	<LOD	1,0	6,3	6,3	0,3	0,8	<LOD	<LOD	<LOD	61	<LOD	6,4	1,7
Brd09	Khoburtse	29/05/2012	19/06/2012	14	18	<LOD	2,6	3,3	<LOD	0,2	<LOD	1,9	6,9	2,6	0,2	1,3	<LOD	<LOD	<LOD	27	<LOD	4,7	1,4
Brd16	Liligo	29/05/2012	19/06/2012	15	28	<LOD	2,9	7,4	<LOD	0,2	<LOD	1,0	13,2	3,5	0,5	0,5	<LOD	<LOD	<LOD	56	<LOD	9,6	1,3
Brd17	Biafo bridge	01/06/2012	19/06/2012	16	181	<LOD	4,0	7,3	<LOD	0,2	0,2	<LOD	17,1	8,1	0,5	0,4	<LOD	<LOD	<LOD	53	<LOD	9,1	0,9

Table 16 Braldu valley: results of the determination of pathogens and index organism in water samples collected in 2012.

Site code	Site	Sampling date	Analysis date	Bottle	Total Coliforms x100ml	Faecal Coliforms x100ml	Faecal streptococci x100ml	Salmonella spp. 1 L	Salmonella spp. 5 L
Brd01	Korophon	01/06/2012	20/06/2012	1	13	<1	<1	ass	n.d.
Brd03	Paiju	31/05/2012	20/06/2012	3	71	<1	110	ass	n.d.
Brd05	Paiju bridge	31/05/2012	20/06/2012	3a					
Brd04	Baltoro	30/05/2012	20/06/2012	4					
Brd07	Askole	02/06/2012	20/06/2012	7	25	<1	<1	ass	n.d.
Brd08	Shigar bridge	02/06/2012	20/06/2012	8					
Brd14	Shigar restaurant	02/06/2012	20/06/2012	8A	29	4,0	4	ass	n.d.
Brd10	Urdukas	28/05/2012	20/06/2012	10	290	<1	340	ass	n.d.
Brd13	Jula camp	01/06/2012	20/06/2012	11					
Brd11	Jula bridge	01/06/2012	20/06/2012	11A	17	<1	31	ass	n.d.
Brd15	Dasso	02/06/2012	20/06/2012	13	37	1,0	34	ass	n.d.
Brd09	Khoburtse	29/05/2012	20/06/2012	14	850	<1	330	ass	n.d.
Brd16	Liligo	29/05/2012	20/06/2012	15	28	<1	8	ass	n.d.
Brd17	Biafo bridge	01/06/2012	20/06/2012	16					

Table 17 Basha valley results of the chemical composition of the water samples collected in 2012.

Site code	Site	Sampling date	Analysis date	Bottle	Temp. °C	Turbidity FTU	pH	c20°C µS cm-1	T.Alc. meq l-1	Cl mg l-1	SO_4 mg l-1	N-NO_3 µg l-1	N-NH_4 µg l-1	Ca mg l-1	Mg mg l-1	Na mg l-1	K mg l-1	RP µg l-1	TP µg l-1	TN mg l-1	Si mg l-1	F mg l-1	TOC mg l-1
Bsh01	Chumik Arindo	09/06/2012	18/06/2012	12		0,2	7,97	133	1,126	0,1	16,2	35	1	18,5	4,9	2,2	2,7	2	2	0,05	3,4	0,1	0,4
Bsh02	Togi Arindo	09/06/2012	18/06/2012	23		0,2	8,04	133	1,132	0,1	16,2	50	1	18,6	4,9	2,2	2,7	1	2	0,06	3,4	0,1	0,4
Bsh03	Khargan Arindo	09/06/2012	18/06/2012	9		0,1	7,97	133	1,124	0,1	16,2	45	1	18,6	4,9	2,2	2,7	2	2	0,07	3,4	0,1	0,4
Bsh04	Bisil Bombari	10/06/2012	18/06/2012	15		6,5	7,98	137	1,057	0,2	19,7	331	2	20,7	4,2	0,6	4,0	1	10	0,47	1,5	0,0	0,5
Bsh05	Bisil Skilkor	10/06/2012	18/06/2012	11		2	7,97	135	1,035	0,2	19,3	336	2	20,5	4,1	0,6	3,9	2	5	0,41	1,5	0,0	0,4
Bsh06	Zill Shkong	10/06/2012	18/06/2012	14		107,2	8,00	174	1,052	0,2	37,2	342	2	26,6	5,2	1,3	3,3	15	22	0,63	1,9	0,3	1,6
Bsh07	Zill Malong	10/06/2012	18/06/2012	13		76,1	8,00	178	1,081	0,2	38,2	357	2	27,1	5,4	1,4	3,3	10	16	0,57	1,9	0,3	0,9
Bsh08	Seisko Shuaika	10/06/2012	18/06/2012	24		1	7,95	335	1,789	0,7	87,5	1405	1	53,0	9,6	2,0	10,5	14	23	1,64	3,4	0,2	1,0
Bsh09	Seisko Biarzing	10/06/2012	18/06/2012	21		0,7	8,06	338	1,800	0,7	88	1400	1	55,7	9,2	2,0	10,5	13	21	1,66	3,4	0,2	1,0
Bsh10	Chotrong Khonjing	11/06/2012	18/06/2012	10		2,2	8,17	153	1,314	0,2	16,8	535	3	23,1	6,2	0,4	1,4	4	5	0,64	0,8	0,1	0,3

Table 18 Basha valley: results of the heavy metals in the water samples collected in 2012.

Site code	Site	Sampling date	Analysis date	Bottle	Al µg l-1	As µg l-1	B µg l-1	Ba µg l-1	Cd µg l-1	Co µg l-1	Cr µg l-1	Cu µg l-1	Fe µg l-1	Li µg l-1	Mn µg l-1	Ni µg l-1	Pb µg l-1	Pt µg l-1	Se µg l-1	Sr µg l-1	Tl µg l-1	V µg l-1	Zn µg l-1
Bsh01	Chumik Arindo	09/06/2012	18/06/2012	12	<LOD	<LOD	<LOD	4,6	<LOD	0,2	<LOD	<LOD	<LOD	4,9	<LOD	<LOD	<LOD	<LOD	<LOD	42	<LOD	12,3	2,0
Bsh02	Togi Arindo	09/06/2012	18/06/2012	23	<LOD	<LOD	<LOD	4,6	<LOD	0,2	<LOD	<LOD	<LOD	4,9	<LOD	<LOD	<LOD	<LOD	<LOD	41	<LOD	12,3	1,0
Bsh03	Khargan Arindo	09/06/2012	18/06/2012	9	8,2	<LOD	<LOD	4,4	<LOD	0,2	<LOD	<LOD	<LOD	4,9	<LOD	<LOD	<LOD	<LOD	<LOD	40	<LOD	11,7	1,7
Bsh04	Bisil Bombari	10/06/2012	18/06/2012	15	8,3	<LOD	<LOD	20,7	<LOD	0,2	<LOD	<LOD	1,0	4,6	<LOD	<LOD	<LOD	<LOD	<LOD	52	<LOD	10,1	2,0
Bsh05	Bisil Skilkor	10/06/2012	18/06/2012	11	10,2	<LOD	<LOD	18,4	<LOD	0,2	<LOD	<LOD	<LOD	4,6	<LOD	<LOD	<LOD	<LOD	<LOD	51	<LOD	10,3	0,8
Bsh06	Zill Shkong	10/06/2012	18/06/2012	14	18,4	<LOD	<LOD	5,3	<LOD	0,2	<LOD	<LOD	5,2	8,9	1,0	<LOD	<LOD	<LOD	<LOD	69	<LOD	12,7	0,9
Bsh07	Zill Malong	10/06/2012	18/06/2012	13	20,5	<LOD	<LOD	5,6	<LOD	0,2	<LOD	<LOD	5,9	9,1	<LOD	<LOD	<LOD	<LOD	<LOD	71	<LOD	13,1	1,7
Bsh08	Seisko Shuaika	10/06/2012	18/06/2012	24	4,7	<LOD	<LOD	14,8	<LOD	0,3	0,2	0,8	<LOD	9,8	<LOD	<LOD	<LOD	<LOD	<LOD	79	<LOD	21,9	11,4
Bsh09	Seisko Biarzing	10/06/2012	18/06/2012	21	<LOD	<LOD	<LOD	15,6	<LOD	0,3	0,2	0,8	<LOD	10,4	<LOD	<LOD	<LOD	<LOD	<LOD	82	<LOD	22,9	117
Bsh10	Chotrong Khonjing	11/06/2012	18/06/2012	10	5,7	<LOD	<LOD	9,0	<LOD	0,2	<LOD	<LOD	<LOD	2,0	1,3	<LOD	<LOD	<LOD	<LOD	141	<LOD	16,2	8,9

Table 19 Basha valley: results of the determination of pathogens and index organism in water samples collected in 2012.

Site code	Site	Sampling date	Analysis date	Bottle	Total Coliforms x100ml	Faecal Coliforms x100ml	Faecal streptococci x100ml	Salmonella spp. 1 L	Salmonella spp. 5 L
Bsh01	Chumik Arindo	09/06/2012	19/06/2012	12	48	< 1	7,00	ass	n.d.
Bsh02	Togi Arindo	09/06/2012	19/06/2012	23	90	< 1	< 1	ass	n.d.
Bsh03	Khargan Arindo	09/06/2012	19/06/2012	9	120	6,0	3,00	ass	n.d.
Bsh04	Bisil Bombari	10/06/2012	19/06/2012	15	85	< 1	< 1	ass	n.d.
Bsh05	Bisil Skilkor	10/06/2012	19/06/2012	11	80	< 1	4,00	ass	n.d.
Bsh06	Zill Shkong	10/06/2012	19/06/2012	14	112	< 1	13,00	ass	n.d.
Bsh07	Zill Malong	10/06/2012	19/06/2012	13	200	2	38,00	ass	n.d.
Bsh08	Seisko Shuaika	10/06/2012	19/06/2012	24	300	< 1	14,00	ass	n.d.
Bsh09	Seisko Biarzing	10/06/2012	19/06/2012	21	120	2	10,00	ass	n.d.
Bsh10	Chotrong Khonjing	11/06/2012	19/06/2012	10	38	6,0	4,00	ass	n.d.

Description and main findings

Based on the above analysis of samples these are the major conclusions:

I. Comparison of sites in relation to the data collected in April, during periods of low speed, should ensure a better comparison between stations. A wide range of chemical characteristics can be viewed by the data and expressed as the content of major ions. The station Askole is different from the other points, because characterized by a content of ions higher, compared to the contents of calcium, magnesium and sulfate;

II. Taking into account the different forms of nitrogen measured during two campaigns, low values were observed typically in remote areas. There are exceptions such as the station Askole (in April) and the two sampling sites (Khoburtse, Urdukas). It will therefore be important to monitor these sites to see if the values are kept under observation, are in reality occasional events or phenomena related to localized situations;

III. Once that the different forms of nitrogen were plotted as a percentage of contribution of total nitrogen, one can easily see that the organic nitrogen is the predominant, except in some cases (Askole and Korophon, but only in the first sampling) where the 'nitrogen prevails. In the latter cases, the measured concentrations of nitrate are similar to those normally found in high-altitude alpine lakes, subject to atmospheric input of nitrogen (Rogora et al., 2008);

IV. In conclusion, the comparison between the data collected in April and those collected in July and August 2011, which have been made available from three different sites, showed a decrease in the concentration of solutes in the second period. This is due to a dilution effect as the higher water supply.

For the purposes of the use of these waters for irrigation or drinking, the results obtained confirm its good quality both from the chemical point of view that microbiological; values of nutrient concentrations are low and do not appear to be present phenomena of fecal contamination or presence of pathogens such as Salmonella. The only limitation for human use, in some cases, is due to the presence of a high content of suspended solids, due to poor protection of springs and that could be addressed by implementing filtering systems (for example beds of filtration sand).

Finally, the data collected in 2012 have shown in some cases to increase concentrations of some ions, in addition to higher values of E. coli, thus confirming the need for a strengthening of monitoring, both in terms of number of stations that frequency.

Clearly the samples are limited in time a and a more contiguous surveillance protocol is needed in order to have a better understanding of the few values that were relatively high. Especially for the microbiological assessment it is strongly recommended the activation of the a local laboratory to assure that the analysis are completed in a shorter time interval from the sample collection.

For this reason within the SEED project and in collaboration with KIU a Water analytical lab was established and specific training was given to local staff.

2.3 Vegetation

Data source

All the data on average forest biomass, increment and species composition are results of research conducted by University of Padova and Ev-K2-CNR. Forest types have been shaped on (Ahmed et al., 2006; Akbar et al., 2010; Akbar et al., 2011; Champion et al., 1965; Du, 1998; Eberhardt et al., 2007) classifications with additional revision following the field mission of 2011 and 2012 in Haramosh, Khaltaro, Jaglot Gor, Minapin Nagar and Hispar (Gilgit district) and Basho, Braldo, Tormik, Astak, Hushey (Skardu district) valleys.

General setting

The vegetation of Central Karakorum National Park grows only in a small percentage of the park area (14.7%). This is a consequence of different abiotic factors which constraints plants growth: the high average elevation which reduces temperature and the length of the growing season, the rough relief and large glacial masses which restrict the area suitable for plants establishment, the continental climate and rain-shadow caused by the mountain massifs and their impact on precipitation distribution along altitudinal gradient. In particular, temperature is a limiting factor at higher elevations (above 4500 m[1]) while insufficient water availability during the growing season is impeding plants growth at lower altitudes (below 2000 m, where natural vegetation is mainly found around water bodies as streams or lakes). Additionally, natural floristic composition has been affected by the millennium-old human presence that impacted and modified the vegetation components both directly (i.e. clearings of forest for pastureland and cultivated areas) and indirectly (i.e. prolonged grazing by livestock). Nevertheless, different vegetation types grow in the CKNP and they are of major importance both for ecological reasons (e.g. as habitat for wildlife, biodiversity conservation, etc) and for the sustainment of local communities (e.g. for the provision of grazing ground, firewood, timber, etc). Additionally environmental services like protection from soil erosion, regulation of water quantity and quality, nutrient recycling are being provided.

[1] All the altitude limits for vegetation used in the document are indicative only, valid for most of CKNP area. They should NOT be consider as a fixed boundary but might varies, considerably, according to valleys microclimate, aspects and terrain morphology.

The plant communities present in Central Karakorum National Park are of particularly interest since the park location in the transition zone between sub-tropical humid condition to the south and continental dry climate of northern areas. Indeed, inside the CKNP borders, this transition is evident moving from southwest towards northeast. CKNP can therefore ideally be divided into two main ecological zones: a southwest part, around Gilgit district, which is relatively warmer and partially influenced by the summer monsoon and the northeast part, felling mostly in Skardu district which is characterized by a more continental climate (Treydte et al., 2006). This climate patterns have a major influence on vegetation characteristics and distribution: it is of particularly interest to deeply evaluate the effect of climate transition on the CKNP forest resources, especially for their importance in the livelihoods of local communities. Overall, the South-Western sector is characterized by a forest composition and structure which is richer both in area, biomass and species. Most of the largest forest of CKNP are located in the Southern lateral valleys of the main Gilgit river valley (with few exceptions on the southern border of CKNP along Indus river). Good examples of those rich forest ecosystems can be found in Haramosh, Khaltaro, Bagrote, Jaglot Gor and Astak valleys among others. On the contrary, in the North-Eastern valleys, mainly plant adapted to cold and xeric environment can be found. Forest cover is more fragmented and sparse with lower densities, stand biomass and increments. Forests areas here are therefore more scattered.

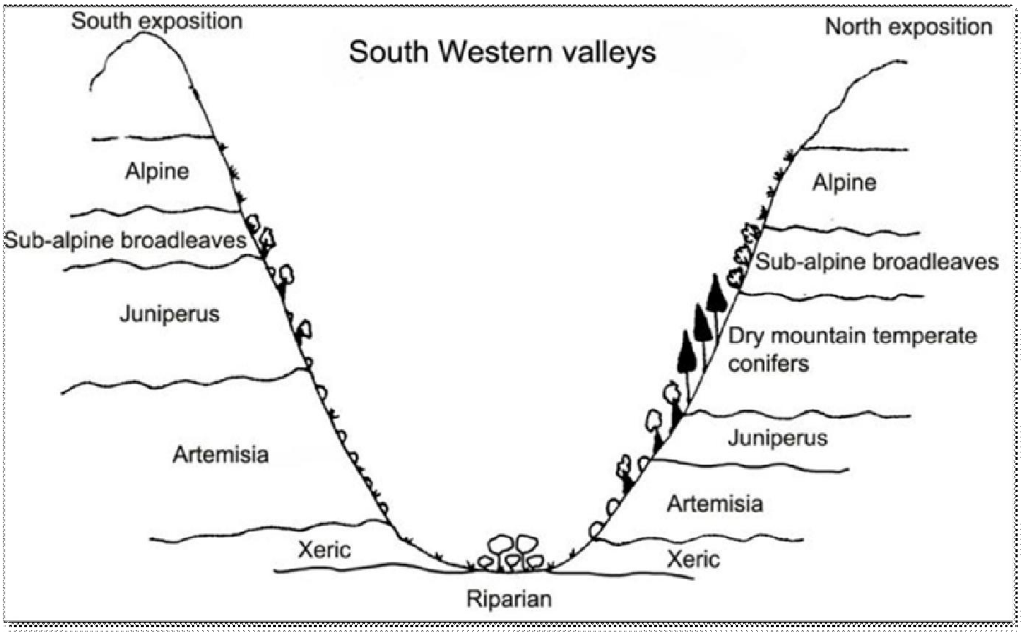


Exhibit 18 Vegetation distribution in SW valleys (modified from Miehe and Miehe, 1998).

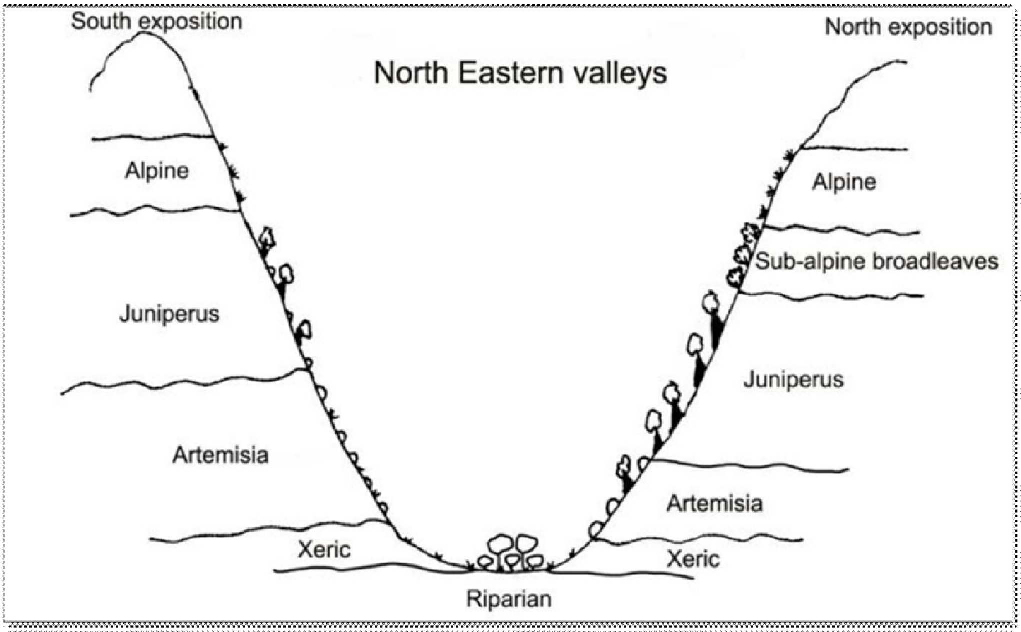


Exhibit 19 Vegetation distribution in NE valleys (modified from Miehe and Miehe, 1998).

Description and main findings

Vegetation types

Vegetation types, which partially follow the classification proposed by Champion et al. (1965), have been formulated according to the species composition and, therefore, as a consequence of the most prominent ecological processes shaping their geographic distribution. Overall, inside the CKNP limits 4 forests and 3 shrub-lands types can be recognized.

Climate (especially temperature and water availability) is the main driver which influence species distribution in the park area (Miehe and Miehe, 1998). At valley level, instead, aspect and morphology leads to a series of common distribution patterns although with differences from valley to valley (Exhibits 18 and 19).

To describe CKNP vegetation we will follow an ideal transect, starting from the valley bottom and gradually increasing altitude until we will reach the snowline.

In close proximity to river/streams, in all CKNP valleys, a plant community adapted to this seasonally humid but disturbed environment, characterized by frequent floods, draughts, and landslides is common: riparian vegetation. Broadleaved species as willows (*Salix* spp.), poplars (*Populus* spp.), sea-buckthorns (*Hippophae rhamnoides ssp. Turkestanica*) and Tamarisk (*Tamarix ramosissima*) are the prominent species. Unlike the other vegetation belts, the distribution of this community is not altitude driven (it can be found from 1800 m a.s.l. up to 3000 m a.s.l.) but its limited by air and soil moisture derived from water bodies. For this reason it can be described as an “azonal” vegetation which usually has a linear shape, few tens of meters large. The closeness to villages and fields have an effect on riparian vegetation, which is often managed by local communities. Poplar is mainly managed for timber production, while sea-buckthorns and willows for firewood. Fruit trees are also diffuse.

Where the river moisture effect ends, as the humidity derived by the presence of stream decreases exponentially with distance, the dry environment is hampering the growth to most plants. Only the most drought resistant species with particular physiological adaptation to couple with this harsh environment, like *Capparis himalayensis*, *Ephedra* spp and *Cardus* spp can develop, but their cover is sparse and fragmented. Xeric vegetation is frequent in all valleys, starting from 1600 m a.s.l. At lower elevation those communities develop mainly in shaded, north-exposed areas, while at higher elevation they are mainly confined in the most dry and sunny locations (2000/2200 m a.s.l.).

Moving at higher elevations (above 2,200 m a.s.l.), precipitation and water availability gradually increase, allowing the development of a steppe-like community of perennial shrubs adapted to xeric environment. Among the most representative species, Artemisia (*Artemisia brevifolia*, *Artemisia wellby*, *Artemisia fragrans*) are common all over the CKNP boundaries and characterize this vegetation belt (Artemisia shrub-land). Other species include *Agrostis* spp, *Astragalus* spp. Few tree species, adapted to grow in xeric locations as Junipers can be found in protected location. Artemisia shrub-land is often grazed during autumn and winter months by livestock. In the coldest and driest valleys of CKNP (like Braldu) the stems and roots of those bushes are collected and used as firewood (Flury, 2012). Additionally, Artemisia shrub-land can be the result of a persistent and long-lasting degradation of more fertile vegetation belt (as Juniperus shrub-land/forest).

As altitude increase, from approximately 2600 m a.s.l., stands of Junipers (*Juniperus* spp.) are frequent (Juniperus shrub/forest). The ecological plasticity of those species is remarkable: often isolated trees are found in inaccessible locations on very steep mountain sides where just a small pocket of soil might be available. The stands biomass and increment is correlated to water availability: at higher altitude, or where water availability is more abundant, Juniperus become denser and taller (>5 m in height). In those areas, Juniperus can be classified as forests according to FAO definition (UN-ECE and FAO, 2000). At lower elevation or in the drier sites instead, sparse individuals are growing in between Artemisia shrubs (Juniperus shrub-land). Three species of Juniperus have been recorded by far in the CKNP (*Juniperus excelsa ssp polycarpos*, *Juniperus semiglobosa* and *Juniperus pseudosabina*). Other shrub species are usually available: *Berberis* spp., *Caragana gerardiana*, *Rosa webbiana* among others. Juniperus trees are the preferred species for firewood thanks to their dry and fragrant wood. Consequently a long lasting harvesting resulted in degradation of stands located in proximity to villages and a reduction of their spatial diffusion. Nevertheless, inside CKNP borders, Juniperus are still very common and diffuse in most of the valleys: generally, in northern exposed location, they can be found at lower elevation, compared to the drier and warmer southern exposed sides. However, while in the North-Eastern sector of the park they are the only forest biomes to be found up to the sub-alpine broadleaved forests, in the more humid sides of the South-Western part, from around 3000 m a.s.l., this community is substituted by the mountain dry temperate forests. Here Junipers stands above 3000 m a.s.l. are confined in steep and dry southern exposed mountain sides.

The above mentioned differences in climate between SW and NE sector of CKNP, affect heavily the diffusion of species inside the CKNP. This is particularly evident for the typical mountain dry temperate forest vegetation belt of the Western Himalayan/Karakorum range (IUCN, 2007), characterized by tall conifer trees as *Pinus wallichiana* and *Picea smithiana* mixed or in purity. This community, living in areas characterized by a strong relief, high precipitation (for CKNP standard) mostly felling during the winter months and a strong continental climate, is naturally scarce, occurring mainly at an altitude between 2800 and 3800 m a.s.l. The most forest rich areas are generally located on the shaded Northern and Eastern slopes (due to higher water availability) or on the frontal and lateral glacier moraine (deeper soils). In general, trees growth is strongly favoured in areas where snow accumulation and melting can guarantee a sufficient water availability during the growing season. Those conditions are mainly met in the South-Western valleys. Few stands of those species are present in the valleys north of the Rakaposhi-Diran-Spantik ridge and east of the Shigar valley: Pinus wallichiana has been recorded in Shaghar Logma, Doko and Besil valleys (in Basha) and Baumaharel (Shigar). Moreover, *Picea smithiana* mixed with *Pinus wallichiana* is still present in some lateral valleys of Nagar like Nilt, Minapin and Sumayar among others. Traditionally, mountain dry temperate forest have been managed for the production of timber. Initially, this activity was limited to fulfil local households needs but, following roads constructions in the Indus-Gilgit river lateral valleys[2], timber has been and occasionally is felled for the market in Gilgit or Skardu. Illegal harvesting, lack of proper management guidelines and lack of regeneration is often threatening those forests, which today appear often degraded (low stand densities, lack of small diameters).

The last forest belt, diffuse in the entire CKNP, to be found before the alpine meadows and shrub-land is sub-alpine broadleaved forests. This is composed mainly by stand of *Betula utilis* and *Salix* spp., located at high elevation (above 3500 m a.s.l.) where snow accumulation and avalanche guarantee water availability

[2] Most of the lateral valleys of Indus and Gilgit river where reached by roads at the end of the 1980s – beginning of the 1990s.

throughout the short growing season (June-September). As a direct consequence most of the stands are located on shaded north or northeast exposed mountain side. The largest birch forests are found in the more humid southwest valleys. Traditionally, birch trees are used by the shepherds: the outer white portion of the stem is peeled to obtain "paper" mainly used to pack the local butter. This vegetation are often in a good conservation status since timber or firewood is rarely harvested.

Above 3800-4000 m a.s.l., the short growing season and the low temperatures do not allow the growth of trees. Here herbs and few shrubs are abundant, identifying the Alpine meadows and shrubs-land belt. Thanks to the relatively high summer rainfall, alpine meadows have a good fertility and are a key-asset for the sustainment of local communities which relies heavily on this belt for the grazing of livestock (during summer) (Miehe and Miehe, 1998). Through the centuries, alpine meadows lower altitudinal limit have often been increased in size by local communities through clearings of sub-alpine broadleaved forest, mountain dry temperate forest and Juniperus shrub-land/forest. *Poa* and *Carex* genus are the most common plant members (Mari et al., 2009), but many other species are present such as *Kobresia* spp, *Bistorta* spp, *Polygonum* spp.

These areas provide ideal habitats for many important mammalian species like Marcopolo sheep, Blue sheep, ibex and marmots (Mari et al., 2009).

Table 20 Summary of CKNP Vegetation types

Vegetation type	Altitude (m a.s.l.)	Description
Riparian vegetation	Azonal distribution	next to mountain streams and rivers, along a wide altitudinal gradient (azonal). Species as Willow (*Salix* spp.), Poplars (*Populus* spp.) and Sea-Buckthorns (*Hippophae* spp.) are common, often cultivated for the production of timber and firewood.
Xeric vegetation	< 2200 m	on extremely dry sites. Presence of xeric tolerant species, as *Capparis*, *Ephedra* and *Carduus*, protected by rocks or in favourable niche. Grazed by livestock in winter months.
Artemisia shrub land	< 2600 m	Occasionally presence of scattered Junipers. Can be the result of a long lasting and heavy degradation of former forests. This vegetation is common all-over the CKNP. Important grazing ground in the autumn-winter months.
Juniperus shrubs/forest	SW CKNP: < 3000 m (3800 m*) NE CKNP: 2800 – 3800 m	stands of Juniperus are distributed all over CKNP. In the South-West valleys, the stands are located mainly at low elevation (at altitude below 3000 m) or on the dry, southern exposed mountain sides (up to treeline, 3800 m*). Moving North-East their abundance increase and Juniperus stands are located an altitude between 3000 and 3800 m. Usually stand density is low and stand dynamic is slow (scatter regeneration). The Juniperus forests are the main source of firewood for local communities inside the CKNP.
Mountain dry temperate coniferous forest	3000 – 3800 m	stands of Himalayan Blue Pine (*Pinus wallichiana*, Kail) and Morinda spruce (*Picea smithiana*, Kutwal) with marginal presence of *Juniperus* spp are frequent in the south-western valleys of the CKNP. Those forests are located on moist and fertile sites, at an average altitude between 3000 and 3800 m usually on North/North-East exposed mountain sides. In the recent past most of them have been heavily managed for timber production. The livestock grazing which reduce trees regeneration and the lack of proper management guidelines makes temperate mixed forest types often degraded.
Sub-alpine broadleaved forest	3300 – 3800 m	stand composed by birch (*Betula utilis*) and/or willow (*Salix* sp.) are scattered at high altitude mainly on northern exposed valley sides. Relying heavily on snow accumulation and avalanche for water availability, those species are usually composing the upper tree-line. Harvesting of firewood is low, mainly used for "paper" production.
Alpine meadows and shrubs	> 3900	The alpine pasture zone lies above the timberline that fluctuates from 3,800 m a.s.l. to 4,000 m a.s.l.. At this altitude the temperature does not allow the growth of trees, however, alpine pastures shows good levels of growth and fertility(Miehe and Miehe, 1998). *Poa* and *Carex* genus are the most common plant members (Ev-K2-CNR, 2009). These area provide ideal habitats for many important mammalian species.

Table 21 Broad distribution of Vegetation types according to the two "ecological zones" of CKNP. Based on field observations.

Vegetation types	SW valleys	NE valleys
Riparian	Frequent	Present
Xeric vegetation	Present	Present
Artemisia shrub land	Frequent	Frequent
Juniperus shrub/forest	Frequent	Frequent
Mountain dry temperate coniferous	Present	Absent
Sub-alpine broadleaved	Frequent	Present
Alpine meadows and shrubs	Frequent	Frequent

CKNP Forest classification

For management purposes and due to the limitations imposed by satellite image classification, forests inside the CKNP have been classified into 3 broad categories according to forest biomass. Those are enough general to encompass a wide variety of similar forests and enough different between each other to simplify their recognition in the field. The classes are: sparse trees, open forest and closed forest. Two parameters have been used to classified the forests: vegetation cover and average height of the tallest trees. The vegetation cover is the ratio between the projection of the trees/shrubs canopy on the soil and the soil surface, in percent, while for average height of tallest trees trees we intend the mean heights of the 4-5 tallest trees of the area.

Sparse trees vegetation

It's a class with a reduced tree cover (<10%) which therefore cannot be classified as a forest according to FAO standards. The tree individuals are sparse and small (<5 m), often Junipers or heavily degraded mountain dry temperate coniferous forests. The stand biomass is low as the average forest increment.

Open Forest

It's the first classification of forest. Can be the result of the degradation of a closed forest or a forest growing on poor soil. The vegetation cover is between 10 and 50% and the mean height of tallest trees is between 5 and 15 m. In this category are included the forest which might be managed in the future and in which reforestation is suggested. The species composition can be various, from degraded spruce (*Picea smithiana*) and Pine (*Pinus wallichiana*) to dense Juniperus woodland.

Closed Forest

It's the category which includes the most productive forests. The vegetation cover is above 50% and the mean height of tallest trees it's above 15 m. The sustainable forest management will be applied mostly to this category. Usually this class is composed by dense forests of spruce (*Picea smithiana*), pine (*Pinus wallichiana*) and/or birch (*Betula utilis*). This category have the highest biomass and increment.
For each class of vegetation the average biomass and increment have been calculated (Anfodillo et al., 2009).

	Increment Mg $ha^{-1}yr^{-1}$	Biomass (Mg ha^{-1})
Sparse trees	0.910	29.37
Open forest	1.528	50.93
Closed forest	2.714	104.39

Table 22 Vegetation cover for the different CKNP valleys.

			Vegetation area (km^2)		
Valley name	**Valley ID**	**Valley Area**	**Closed forest**	**Open forest**	**Sparse vegetation**
Hispar	1	1305	1.047	18.31	108.89
% on valley area			0.1	1.4	8.3
Biafo	2	828.45	0.171	9.93	34.26

			Vegetation area (km²)		
Valley name	**Valley ID**	**Valley Area**	**Closed forest**	**Open forest**	**Sparse vegetation**
% on valley area			0.0	1.2	4.1
Dumordo	3	847.14	0.053	10.45	51.8
% on valley area			0.0	1.2	6.1
Baltoro	4	1709.63	0.008	3.486	44.65
% on valley area			0.0	0.2	2.6
Hushey	5	1039.22	2.33	30.37	151.95
% on valley area			0.2	2.9	14.6
Menapin	6	373.85	28.76	22.86	71.18
% on valley area			7.7	6.1	19.0
Shigar	7	388.88	1.55	22.16	78.55
% on valley area			0.4	5.7	20.2
Thalley La	8	395.24	3.85	32.63	84.75
% on valley area			1.0	8.3	21.4
Haramosh	9	486.23	74.82	40.06	72.22
% on valley area			15.4	8.2	14.9
Braldu	10	1068.29	18.85	68.86	268.194
% on valley area			1.8	6.4	25.1
Basha	11	1668	58.34	98.04	242.49
% on valley area			3.5	5.9	14.5
Stak	12	269.53	16.27	20.03	34.65
% on valley area			6.0	7.4	12.9
Hopar	13	425.89	9.49	17.17	53.16
% on valley area			2.2	4.0	12.5
Danyore	14	116.07	10.36	9.78	23.86
% on valley area			8.9	8.4	20.6
Jaglot	15	101.65	6.75	7.1	25.71
% on valley area			6.6	7.0	25.3
Bagrote	16	432.42	47.23	33.07	77.27
% on valley area			10.9	7.6	17.9
Shengus	17	133.83	6.32	11.94	23.71
% on valley area			4.7	8.9	17.7
Tormik	18	221	26.79	21.96	35.33
% on valley area			12.1	9.9	16.0
Kharku	19	49.86	0	1.627	9.54
% on valley area			0.0	3.3	19.1
No_name	20	154.32	0	0.33	3.27
% on valley area			0.0	0.2	2.1

2.4 Fauna

2.4.1 Mammals

Due to the scarce previous available information on wildlife distribution it was decided to focus the field researches for the Management Plan on large mammals both because they are umbrella species better than any other taxon, but also for the interest to develop trophy hunting programs, able to support the income of the local communities (Mari et al., 2009).

An umbrella species is defined as a species with large area requirements for which its protection offers protection to other species which share the same habitat (Groom et al., 2006). Therefore these species are often selected to make conservation related decisions, helping to select the locations of potential reserves, to find the minimum size of these conservation areas and to determine the composition, structure and processes of ecosystems.

The term was first used by Wilcox (1984) who defined an umbrella species as one whose minimum area requirements are comprehensive of those of the rest of the community for which protection is sought, through the establishment and management of a protected area. The umbrella species concept has been demonstrated as an effective tool in the conservation of habitat (Launer and Murphy, 1994) and it is considered valuable to decision makers.

De Vrie (1995) proposed the use of habitat requirements of large herbivores as umbrella species to design large-scale nature reserves and to preserve both, plants and other animals. In particular, the large ranges of mountain-dwelling ungulates are often a consequence of seasonal migrations as a response to seasonally fluctuating food resources. In areas where winters are severe, food availability is decreasing and energetic costs for locomotion and thermoregulation are the highest. Therefore, in mountains, as well as in all populations living in a strongly seasonal climate, seasonal movements (to and from summer/winter areas) may develop as a function of changes in the environment.

At the same time, a significant biodiversity-related consideration associated to mountain ungulate conservation is the importance of maintaining sufficient numbers of prey species to support viable populations of large predators, such as the snow leopard, the wolf and the lynx. Each of these predator species has endangered or threatened populations within the Indo-Himalayan region. Large protected areas are important for the conservation of these predators and the ability to co-ordinate conservation efforts in creating large reserves across mountainous borders is highly desiderable.

Viable populations of large mammals require vast areas of land (herbivores: 10.000 ha as a minimum threshold, De Vrie, 1995; carnivores: at least 100.000 ha as a minimum threshold, Belowsky, 1987) and all of them can be considered as an umbrella species group for the preservation of plants and others animals. In particular, the requirements of large carnivores should be considered in the final step of a management plan.

Data source

Information from bibliography

The CKNP is a refuge area not only for threatened species (e.g. Schaller, 1977), i.e. markhor, musk deer, Ladakh urial, Marco Polo sheep (stable presence to be confirmed in CKNP) and snow leopard, but also for not threatened but important “flag” species, i.e. blue sheep, Himalayan ibex, Himalayan lynx and grey wolf.

The status of those large mammals in the Central Karakorum National Park is almost unknown: the rugged and steep high mountains, the size of glaciers and the poor road network have made it difficult to carry out reliable counts of wildlife, in very few areas.

Some bibliographic information indicates that numbers of snow leopard and especially of markhor are very low and close to their biological threshold (Shackleton, 1997). Over-hunting, habitat loss and isolation of small populations have probably been the main reasons for this depletion (Shackleton, 1997). Although a "focal approach" and systematic surveys were proposed as a key action in the IUCN Action Plan for Caprinae (Shackleton, 1997) and in the 1999 draft Management Plan (McDonough, 1999), very limited sound information was available on the distribution and numbers of local wildlife, before SEED started (e.g. Virk et al., 2003, Roberts, 2005). Furthermore, all the information were limited to the border areas of the Park, where human activities are greater and access is easier.

As to Caprinae, Pakistan is one of the most important countries in the world for their conservation (Shackleton, 1997), because most of the taxa present in the country are threatened. The I.U.C.N. Caprinae Action Plan (Shackleton, 1997) emphasises how (A) the current distribution pattern of wildlife in Pakistan is to some extent a consequence of persecution by humans and (B) their status is often the consequence of overhunting, poaching, habitat degradation, resulting in population fragmentation and isolation.

As to ungulates species accounts:

- Northern Pakistan represents the westernmost part range of *blue sheep*; Roberts (2005) mentioned its occurrence in the CKNP area (around Shigar and Baltoro glacier). The western distribution of bharal touches the eastern end of the Karakorum (Schaller 1977). Limited range and low numbers make it vulnerable to poaching and habitat loss.
- In terms of relative numbers, the *Asiatic ibex* is probably the most abundant Caprinae species in north-western India and Pakistan, occupying all the major ranges (Schaller, 1977). Competition for food with livestock is a growing threat to Asiatic ibex in Pakistan. As to the CKNP area, there are small populations of ibex in northern Chitral, Dir, northern Swat and in Gilgit around Ishkoman, Yasin, Nagar and Hunza, as well as Astore and in Baltisan throughout the Karakorum (Roberts, 2005). Burrard (2008) reports that "there are [*were*] ibex in plenty" in the Shigar valley, in the first few decades of the last century.
- The occurrence of *markhor* in the area of CKNP has been reported several times (Schaller and Kahn, 1975; Hess, 1986), but always at small numbers. Markhor have a limited geographical distribution, their range being squeezed between those of ibex and wild goat. Schaller (1977) reports the presence of the Astor markhor in the Gilgit area; thinly scattered populations have been recorded in Chitral and Gilgit, with the best populations surviving in protected parks or hunting preserves (Roberts, 2005).
- The *Ladakh urial*, like the markhor, advanced into the mountains of northern Pakistan and India mainly by penetrating the major river valleys such as the Kunar, Indus, Gilgit and Shyok (Schaller, 1977). As to the CKNP area, some reduced populations still occur along the Shigar and Braldo rivers and possibly along the Indus (Schaller, 1977). Roberts (2005) reports the urial surviving in small numbers in the higher hill ranges of Balochistan, with very few surviving anywhere in Chitral or around the main valley of Gilgit.
- *Blue sheep* occur in the higher, steeper, watershed tributaries of the Shimshall valley (Roberts, 2005).
- The *musk deer* survive in small numbers in Chitral, Gilgit and Baltisan, especially on Deosai plateau, and are more numerous in the Neelum valley of Azad Kashmir and the higher valleys of Indus Kohistan (Roberts, 2005).
- Ibex and livestock are the main food of *wolves* in northern Pakistan, where they occur over most of the Himalayan uplands, avoiding only dense forests and steep gorges (Schaller, 1977).

Referring to the large carnivore species :

- as to carnivores, the *brown bear* was once abundant in the Himalaya, but the species is become rare nowadays in the far northern valleys of Chitral, Dir, Swat and Gilgit and the best known population survives in the Deosai Plateau of Baltisan (Roberts, 2005), with several tens of individuals. As to the CKNP area, brown bears are reported in low densities from Shigar, Baraldu and Baltoro Glacier, as well as from Nagir, Chaprote and Bar Nullah (Nawaz, 2007). Brown bears in the Baltoro valley subsisted mostly on grass and various roots (Schaller, 1977).

- the *snow leopard* has a patchy and restricted distribution from across the Himalaya and Karakorum. In particular, in Pakistan, it still occurs from Northern Chitral, through Indus Kohistan, northern parts of Gilgit and Karakorum (Roberts, 2005).
- the *lynx* has been recorded in northern Chitral from the Turikho, Baroghil and Kharumbar valleys and the Shandur Plateau (Roberts, 2005). In Gilgit it occurs from the northern reaches of Yasin, Nagar and Hunza valleys (Roberts, 2005). Although rare in Pakistan, it is still hunted for its valuable fur whenever encountered (Roberts, 2005).

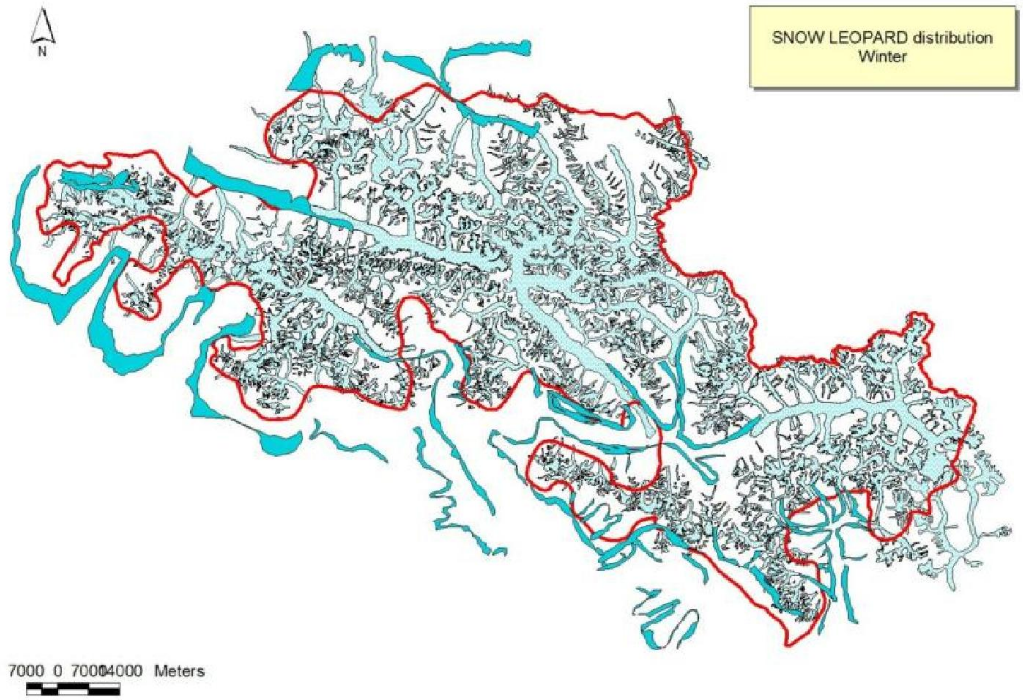
Field data

The following earlier information, collected in the framework of SEED project, provided for the Management Plan will deserve some local cross-check, as their credibility should be improved. The field work was set up by SEED research staff that has conduct research in some areas (Hushey, Nar Ghoro, Askoli); define protocols, training personal and took part of seasonal counts made in cooperation with CKNP game watchers, WWF and GB Wildlife Dept. staff; supervised the survey on distribution and numbers of different species made in cooperation with Snow Leopard Trust (Dr. Ali Naway and collaborators).

Description and main findings

The following Exhibits[3] show the preliminary data on distribution of mammals in CKNP; question marks show areas where data require especial cross-checking.

[3] The Park's boundaries shown in these exhbits are those considered in the notification of May 1996.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Winter
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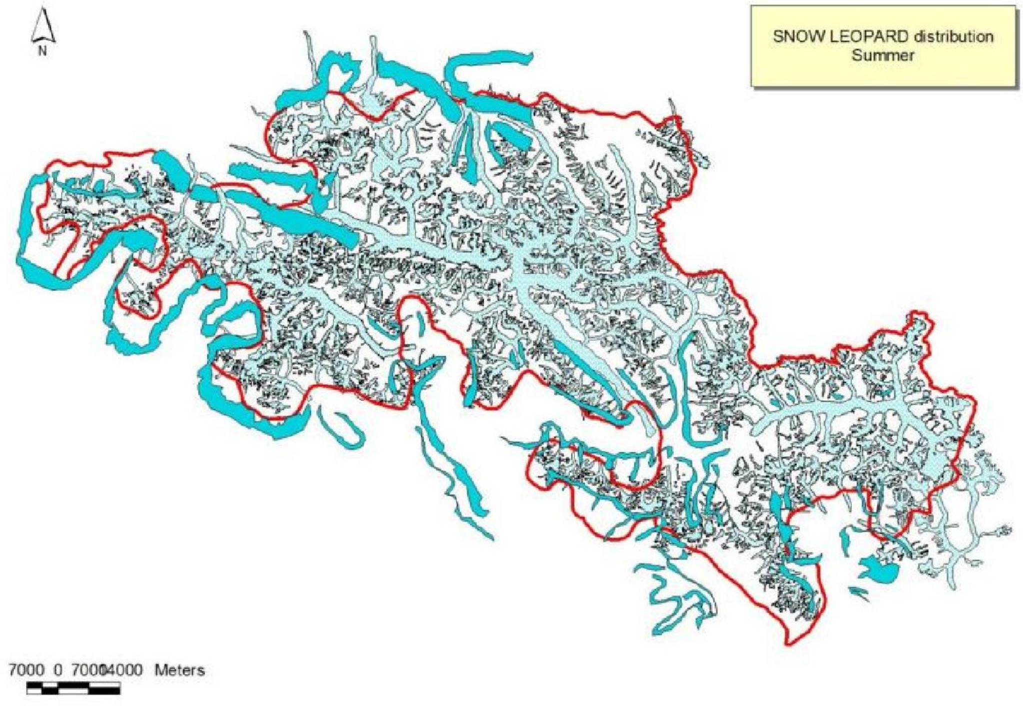
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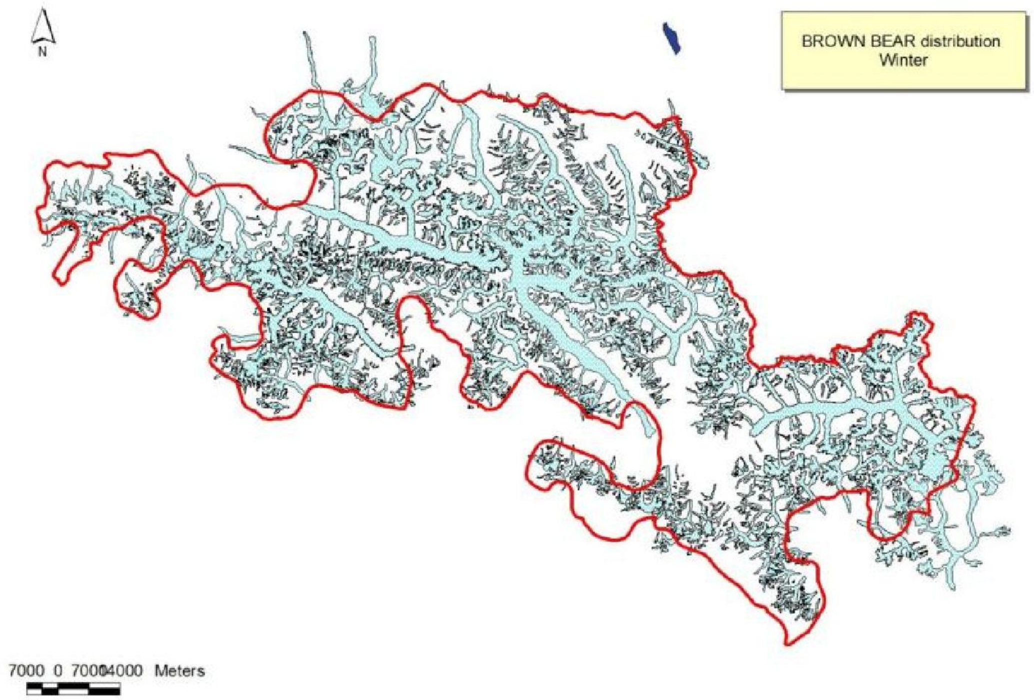
SNOW LEOPARD distribution
Summer
7000 0 70004000 Meters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BROWN BEAR distribution
Winter
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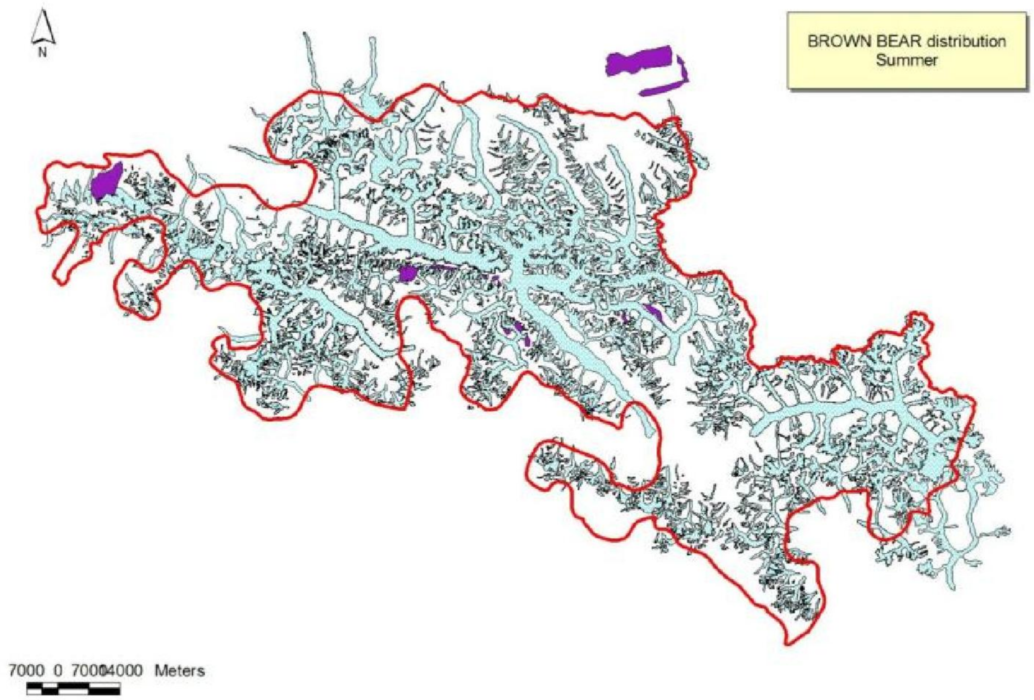
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Summer
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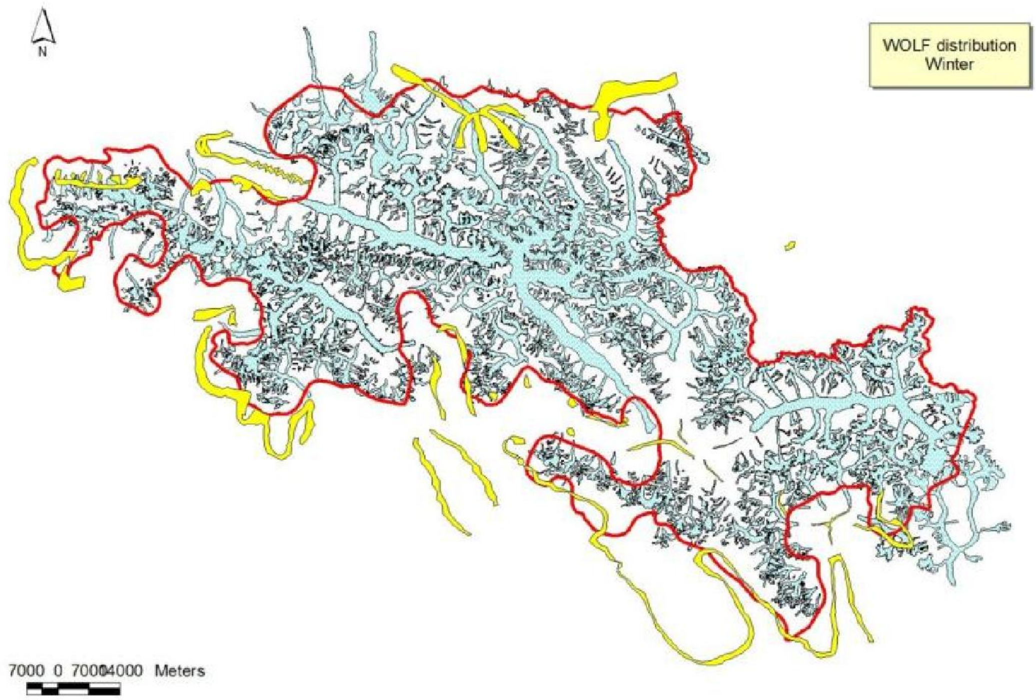
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Winter
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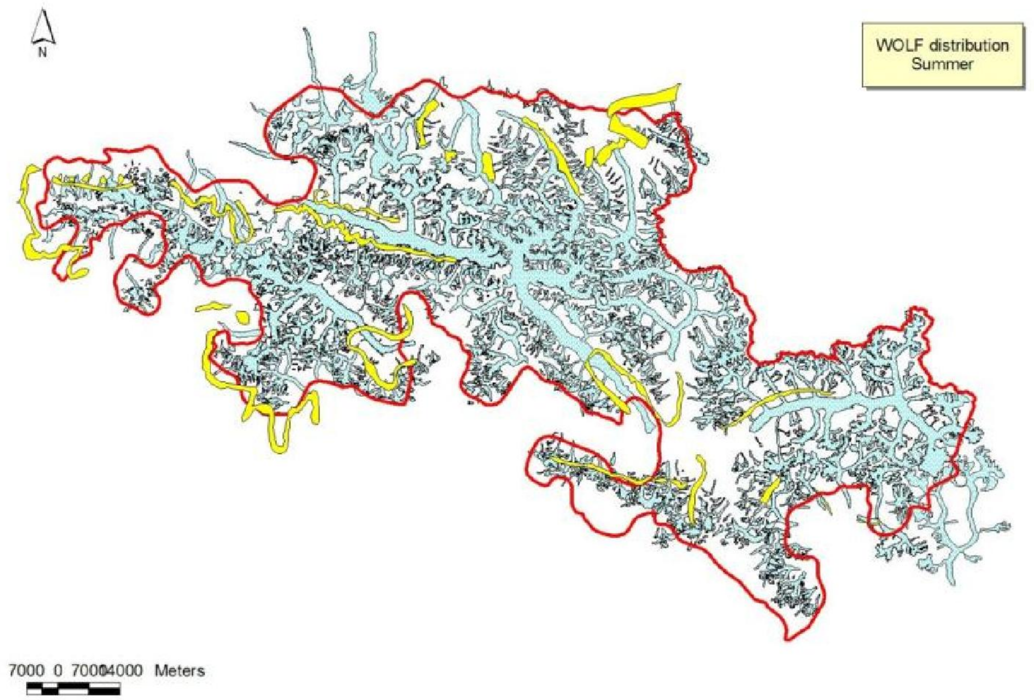
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Summer
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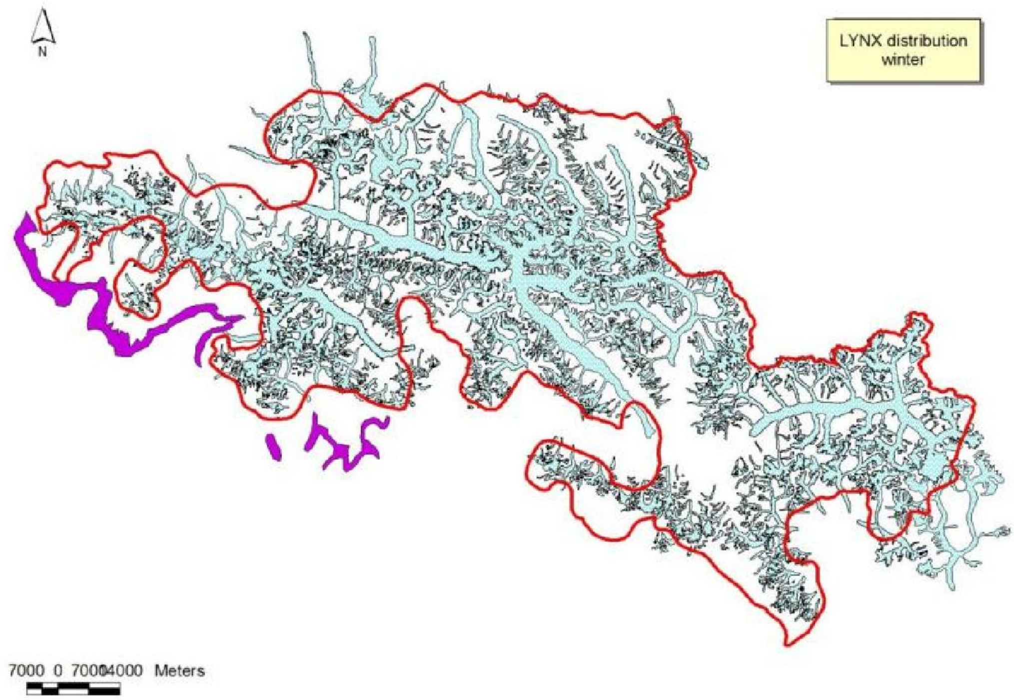
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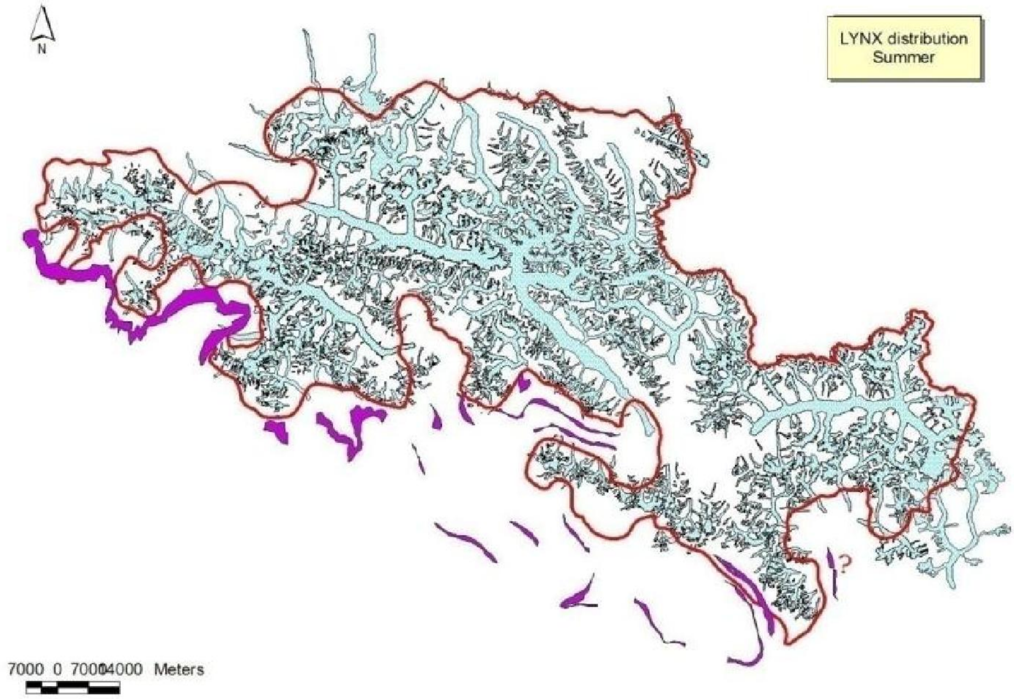
LYNX distribution
winter
7000 0 7000 14000 Meters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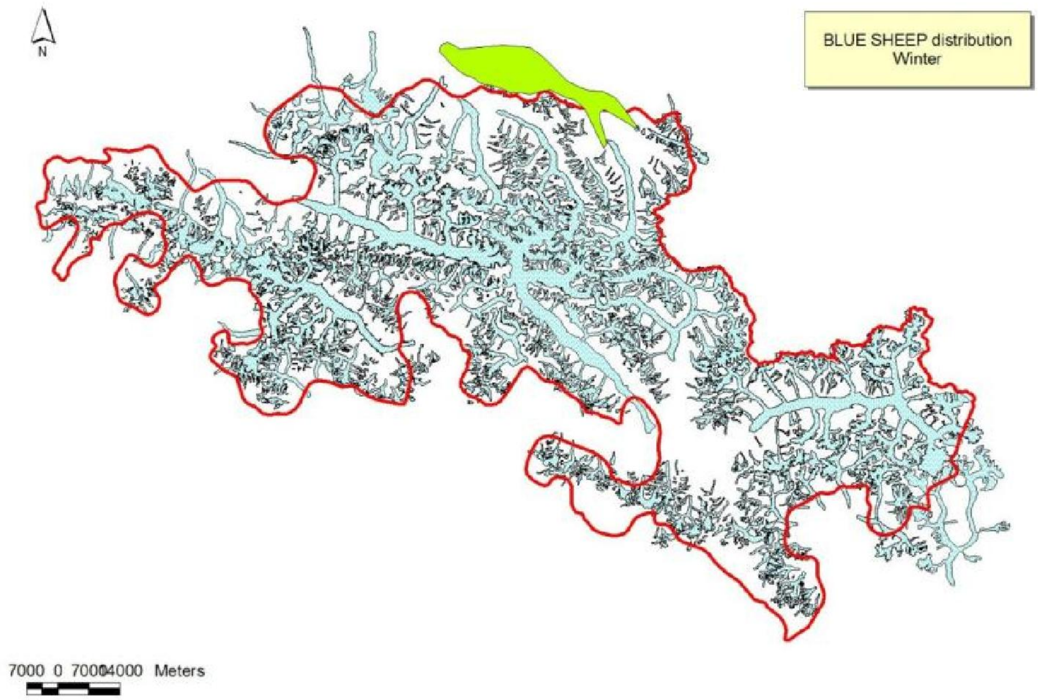
Summer
7000 0 7000 14000 Meters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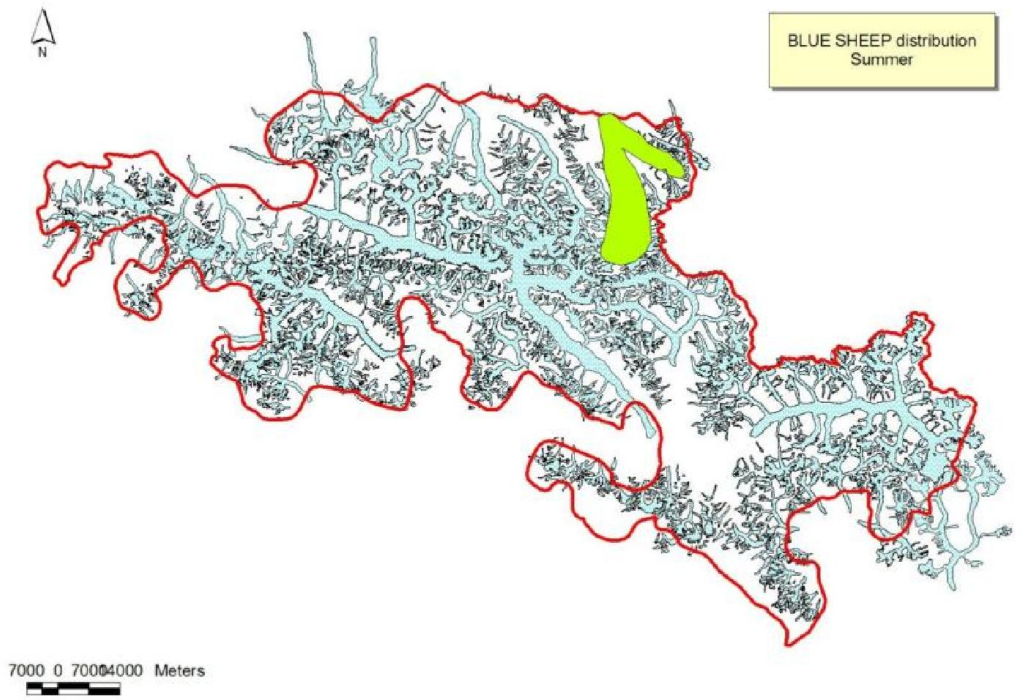
BLUE SHEEP distribution
Winter
7000 0 7000 14000 Meters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Summer
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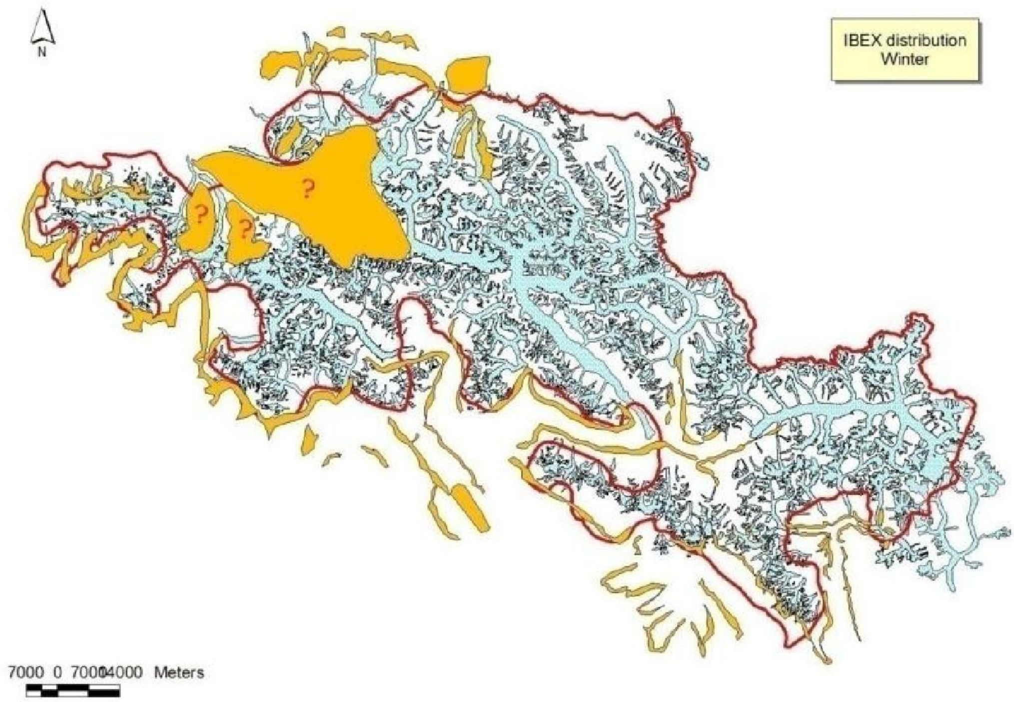
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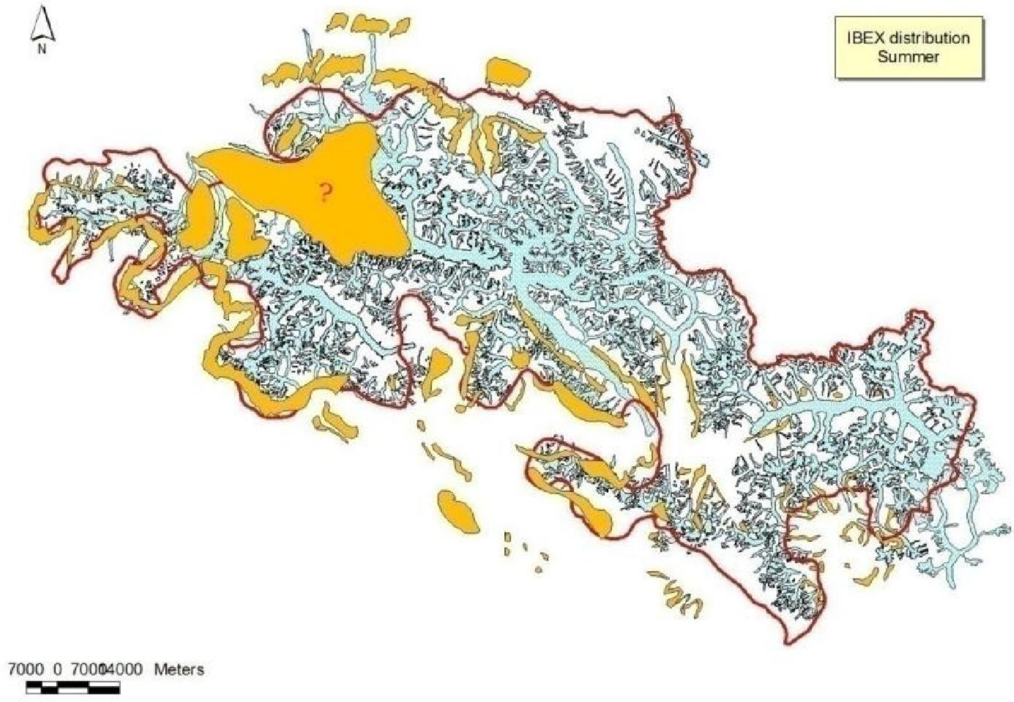
IBEX distribution
Winter
?
?
?
7000 0 70004000 Meters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Summer
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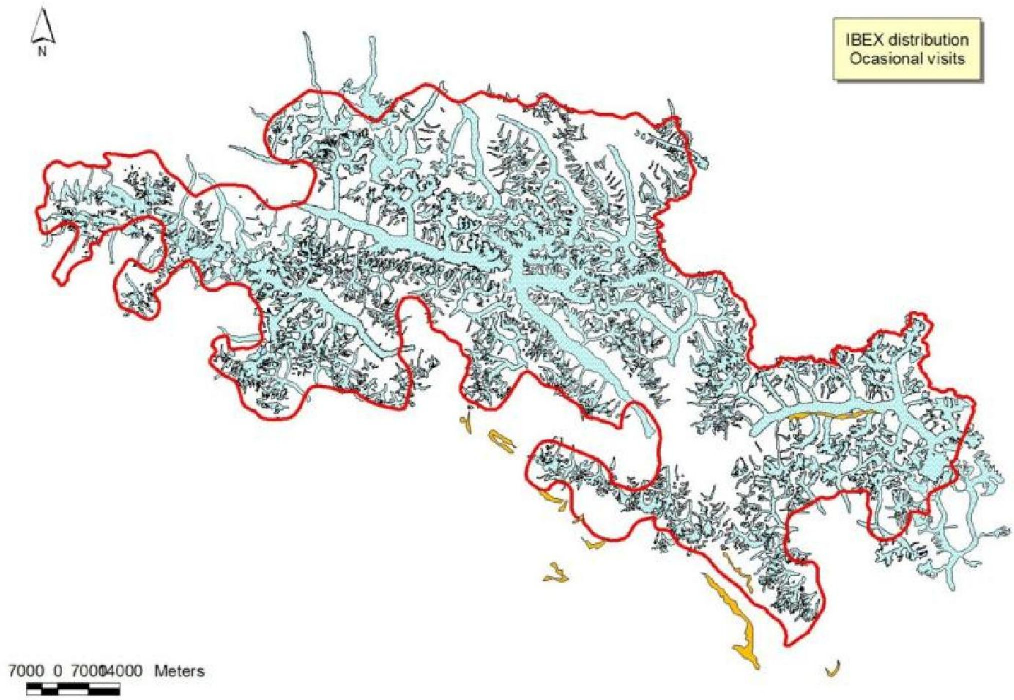
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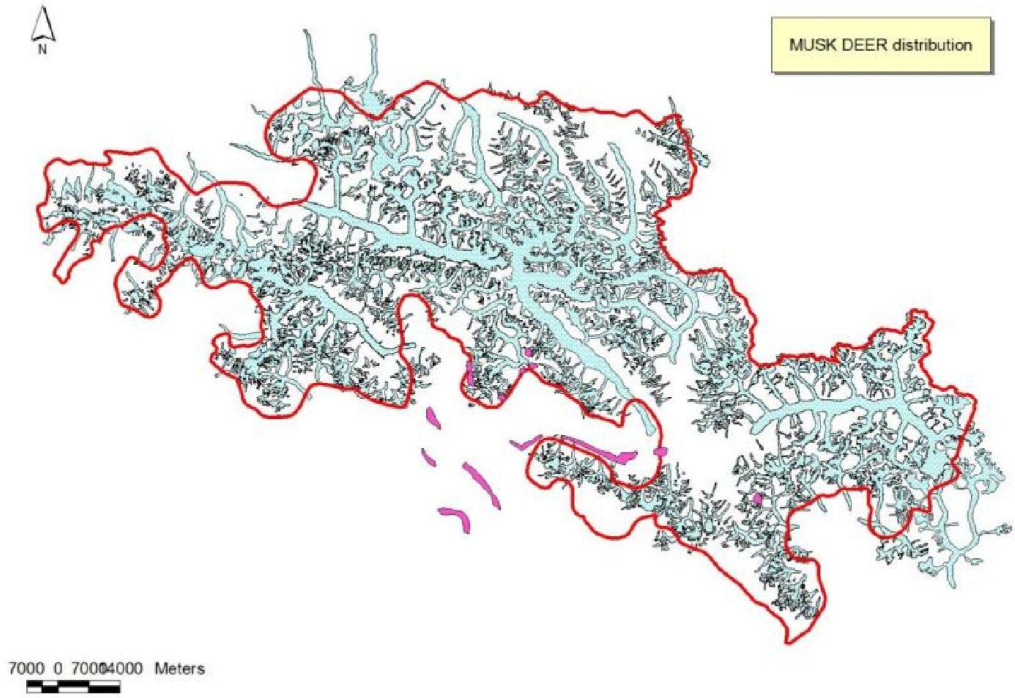
IBEX distribution
Ocasional visits
7000 0 70004000 Meters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MUSK DEER distribution
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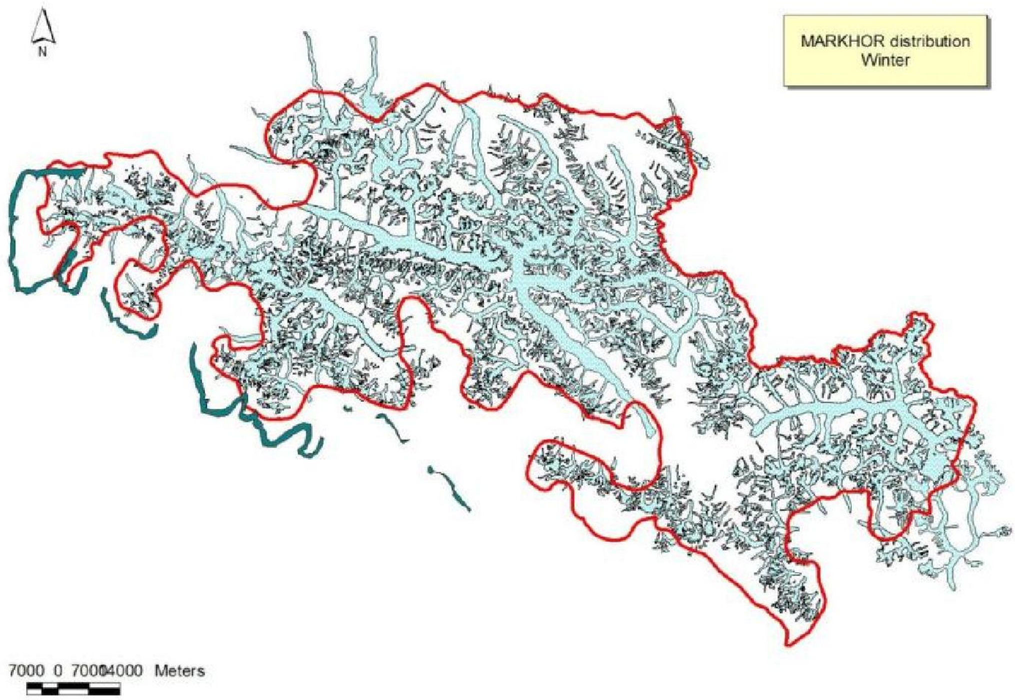
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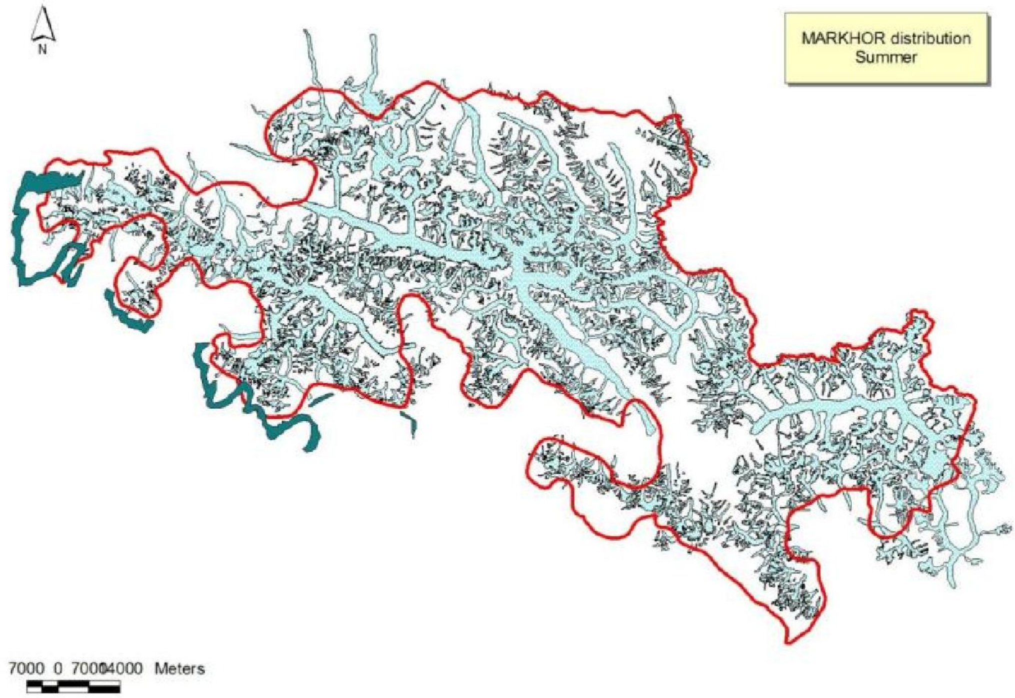
MARKHOR distribution
Winter
7000 0 7000 14000 Meters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MARKHOR distribution
Summer
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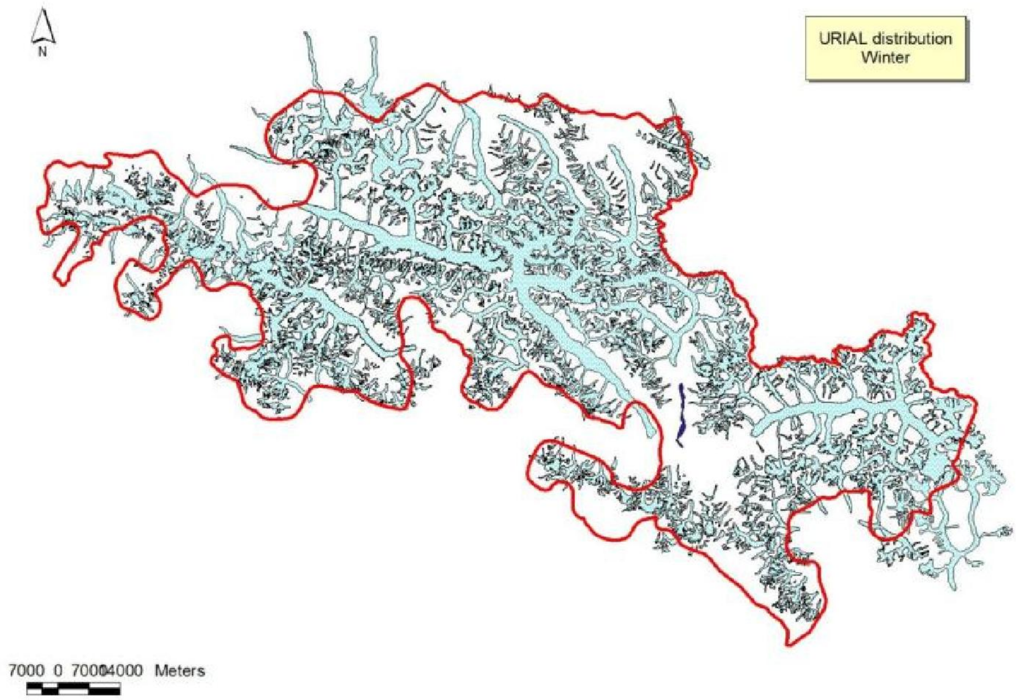
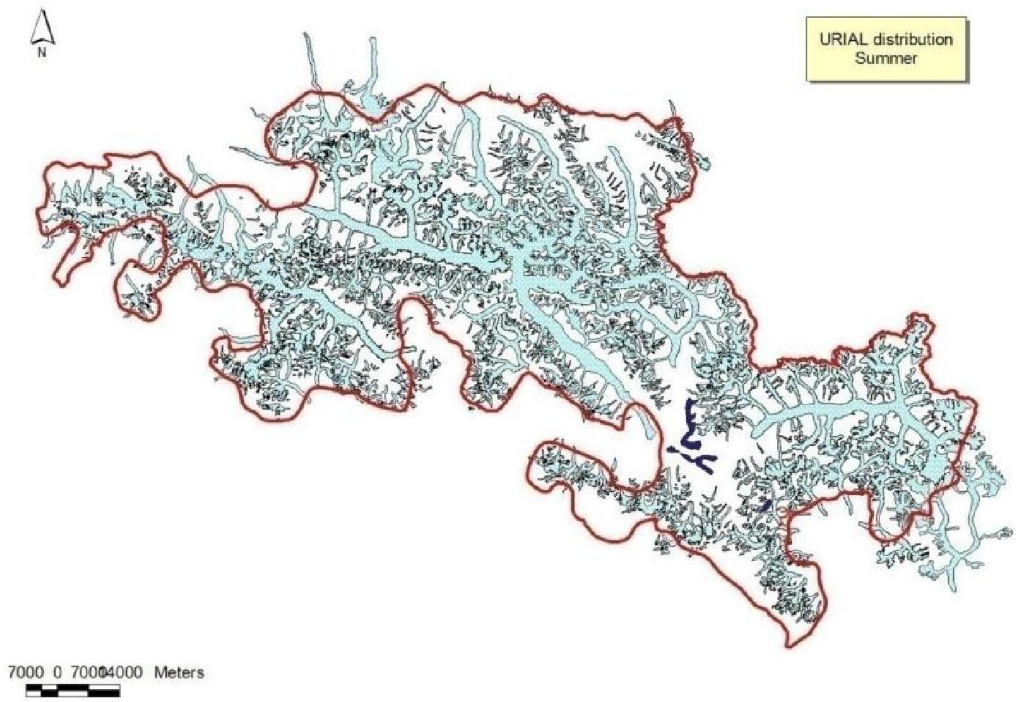




Using the actual available data through a conservative approach mainly for carnivores, by limiting the local population size estimate to its minimum number, a minimum numbers of large mammals in CKNP was reported in the following table:

Table 23 Minimum number of large mammals in CKNP area. (* Conservative approach; ** Data have been cross-checked and, in some cases amended, by comparisons with data recorded by Park rangers and/or own data; ? Data require especial cross-checking).

Catchment	Brown bear	Snow leopard	Lynx	Wolf	Markhor	Ladak urial	Marco Polo sheep	Blue sheep	Asiatic ibex	Musk deer
Jaglot/Minapin	1 *	2 *	1-2 *	1 *	5-25	0	0	0	100-150	0
Bagrote	?	5 *	5 *	2 *	<50	?	0	0	100	?
Haramosh	0	5 *	5 *	5 *	>10	0	0	0	100	?
Astak-Tormik	0	3 *	2 *	2 *	8-12	0	0	0	10-50	1-10
Hoper	1	≥ 2 *	0	≥ 2 *	0	0	0	0	1000 ?	0
Hisper	0	≥ 2 *	0	0	0	0	0	0	1500 ?	0
Hushey	0	2 *	2 *	2 *	0	0	0	0	150 **	0
Thalley	1 *	1 *	3 *	2 *	0	0	0	0	6-150	0
Braldu	1 *	2 *	2 *	2 *	0	30	0	0	10-300	2-6
Basha	≤ 6	1 *	2 *	2 *	0	0	0	0	10-150	2-6
Shigar	0	1 *	2 *	2 *	0	6 ?	0	0	10-150	2-5
Nar	0	3 *	2 *	2 *	0	0	0	0	100 **	0

Preliminary "hot spots" areas for conservation have been outlined below. Not only the number of Mammalian species present has been used to select these areas, but also the threat category (IUCN) of species and other managerial issues.

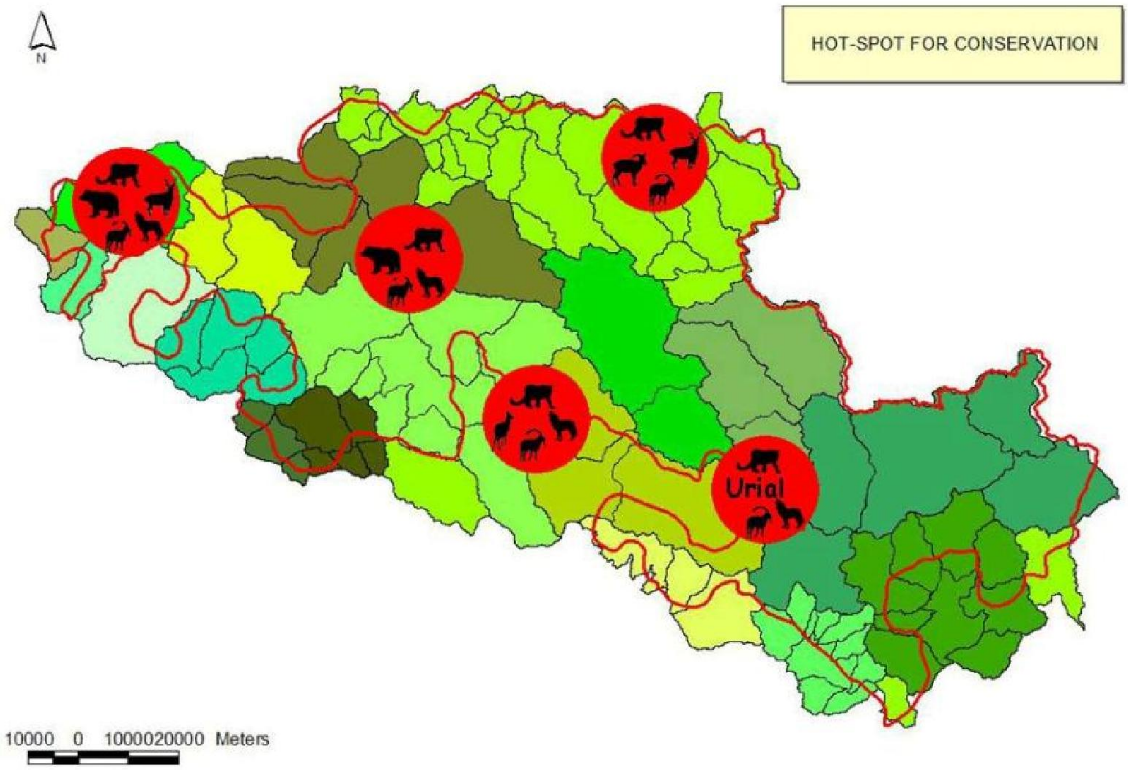


Exhibit 20 Hot spot area for conservation in CKNP.

2.4.2 Birds

The GB Region of Pakistan has one of the most diverse avifauna of the mountain regions of the world, but unfortunately little information is available on the distribution, status and ecology of many of the bird species. The most comprehensive account available on the avifauna of Pakistan comes from Roberts (1991 and 1992). Around 90 species of birds are known to occur in the CKNP in 13 families. Their occurrence status varies from resident to breeder to migratory. Common snow cock, Chukar, rock pigeon, snow pigeon, oriental turtle dove, booted eagle, and common kestrel are among the common resident birds of the area. Common hoopoe, common cuckoo, common swift and Eurasian nightjar represent summer breeding birds of the area. Hen harrier, Eurasian skylark, Spanish sparrow, Himalayan accentor, Eurasian goldfinch, and pine bunting are winter visitors to the area.

Rare birds of the CKNP include snow partridge, Himalayan Monal, golden eagle, alpine accentor, mountain finch, and Hume's Wheatear. The key threats to avifauna are habitat destruction, degradation, change in land use, use of pesticides and hunting.

2.4.3 Reptiles and Amphibians

Pakistan hosts a highly diverse and unique herpetofauna, due to the huge environmental and altitudinal gradients, and to the complex zoogeography of the region. This richness is particularly high for reptiles (about 200 species); furthermore, about 30% of the species are endemic (Khan, 2006, 2008). Despite the Gilgit Baltistan hosting a unique herpetofauna, the knowledge of Amphibians and of Reptiles of the GB, and of the Central Karakorum, largely incomplete (Borkin, 1999; Sindaco and Jeremčenko, 2008). Only a few areas and species have been deeply investigated, and strong uncertainties persist on the distribution and taxonomy of many amphibians and reptiles (Borkin, 1999; Sindaco and Jeremčenko, 2008). The Gilgit Baltistan represents an exceptional environment for both geographical and biogeographical reasons. This area is at the boundary between the Paleartic and the Oriental zoogeographical Realms (Duellman, 1999; Sindaco and Jeremčenko, 2008), and it is the junction point of the three world's greatest mountain ranges: Himalaya; Karakorum and Hindukush. Despite these unique features, the biodiversity of this area remains poorly studied. The Ev-K2-CNR team (Ficetola and Schioppa, 2009) carried out a study on herpetofauna and surveyed seven major areas out CKNP: Gilgit; Bagrot Valley; Skardu; Shigar Valley; Shyok Valley; Hushey Valley; Deosai Plateau.

From the data collected a environmental suitability map for amphibians was developed, and high score rank area are distributed outside the CKNP near waterbodies. Further investigations on herpetofauna are needed, also to individuate relevant areas for these threatened groups.

2.4.4 Fresh water fishes

The CKNP is endowed with a wealth of fresh water resources from river, stream to alpine lakes. Published literature specific to the CKNP is scarce, however information available on fish resources of high mountains in the GB is summarized here. The fish fauna is relatively poor due to high turbidity, low water temperature, high water speed, low benthic productivity, and long stretches of narrow gorges of rivers.

The fish species are predominantly Palearctic having elements of Central Asian Highlands with some mix of Oriental Region. Recent studies report about 17 species of native fish and three of exotic fishes, belonging to five families. Out of these 17 native species, four are endemic to the GB; while several others have restricted range confined to one or two localities. For example, species *Triplophysa stoliczkai*, *Ptychobarbus conirostis*, and *Schizopygopsis stoliczkai* are only found in eastern water-heads up to Kachura, close to Skardu Town (Dr. M. Rafiq, Pakistan Museum of Natural History, Pers. Comm.).

2.5 Climate

2.5.1 Climate

Unique interactions among the atmosphere, cryosphere, and hydrosphere systems and influences from multiple climatic regimes, make the Hindu-Kush Karakorum Himalaya (HKKH) region extremely complex and prevent from treating it as a single region. The HKK in the west and the Himalaya in the east differ primarily in circulation patterns and, by consequence, in sources and types of precipitation and in glacier behaviour and dynamics. The eastern Himalaya is dominated by the southwest Indian monsoon: precipitation occurs during summer months (typically from June to September), owing to the moisture advected northwards from the Indian Ocean (e.g., Li and Yanali, 1996; Wu and Zhang, 1998; Krishnamurti and Kishtawal, 2000). In the HKK, which encompasses the CKNP, precipitation occurs also during winter and spring (December to April), carried on mid-latitude "western weather patterns", i.e., westerly winds bringing moisture from the Mediterranean and Caspian Sea (Singh et al., 1995; Archer, 2001; Archer and Fowler, 2004; Treydte et al., 2006; Syed et al., 2006). Actually, it is well known that the monsoon circulation exerts a limited effect on the overall summer precipitation in the upper Indus basin and in the Karakorum region (e.g., Wake, 1989), since the mountains limit the intrusion of the monsoon whose influence weakens north-westerly. The most significant precipitation input is in fact associated with the wintertime western weather patterns; winter precipitation associated to these disturbances represents the main nourishment for the Karakorum glacier systems and as such a fundamental reserve of water for Pakistan in the dry season.

The dynamics of the cryosphere system in this region deserves particular attention. Based on extensive field experience over several decades in the central Karakorum, Hewitt (1989, 2005) noted that in the late 1990s there was widespread evidence of mass glacier gain in high-level glaciers (typically above 5,000 m), and reported exceptional numbers of glacier surges. For that, he introduced the concept of "Karakorum anomaly" (Hewitt, 2005), to emphasize the difference between the observed slight mass gain and stability of some central Karakorum glaciers and the general shrinking of eastern Himalayan glaciers (in line with the global glacier behaviour associated with global warming). The observed stability and slight mass gain for some glaciers in the central Karakorum was suggested to be linked to the increase in winter precipitation, as observed at several high-altitude (but not higher than 3500 m a.s.l.) stations managed by the Pakistan Meteorological Department (PMD), the Water and Power Development Authority (WAPDA), and from the Climate Research Unit (CRU) (Archer and Fowler, 2004). Fowler and Archer (2006) also investigated the temperature trends in the upper Indus basin for the period 1961-2000 using data from some meteorological stations managed by the PMD. They found that, while winter mean and maximum temperatures showed statistically significant increases, in line with the global temperature rise, mean and minimum summer temperatures, key factors for glacial melt, showed a consistent cooling. Hussain et al. (2005) showed temperature falls also at higher altitudes in both monsoon and pre-monsoon season. Therefore, the combined effect of summer temperature reduction and positive trend in winter precipitation was suggested to explain the observed reduced ablation and slight expansion of Karakorum glaciers. However, factors other than temperature and precipitation may have a role in driving the glacier dynamics in these regions. The prevalence of debris-covered ice, in particular, has been seen to explain unusual climatic responses in the Karakorum (Kick, 1989; Shroder and Bishop, 2010). In the Baltoro glacier, one of the longest glaciers in northern Pakistan running through part of the Karakorum, for instance, the presence and the thickness of a debris layer on the glacier surface has been suggested to have an important role in reducing ice ablation (Mihalcea et al., 2006; Mihalcea et al., 2008; Mayer et al., 2006).

2.5.2 Meteorological observations (field data)

The time series of the meteorological parameters (air temperature, relative humidity, short wave radiation, air pressure, wind speed and direction and precipitation) measured by two Automatic Weather Stations (AWS) installed at the Askole and Urdukas (Baltoro glacier) have been analyzed for years 2004 - 2009. The experimental set-up at these stations is reported in Table 24. The meteorological measurements and data validation are carried out following WMO guidelines (Zahumenský, 2004;. WMO, 2008).

Particular attention has been focused on temperature and precipitation measurements. Precipitation is the most critical parameter measured in the regions - such as the Karakorum area - characterized by highly heterogeneous orography. Compared to the other variables collected at the Askole and Urdukas AWS, there are significant data gaps in the precipitation time series, all concentrated during winter and early spring, when the collection efficiency lowers considerably owing to the difficulty in measuring precipitation in solid form, mostly caused by the strong interference of wind with the automatic measurement devices (e.g., Winiger et al., 2005) in mountain environments. Wind speed is considered the most important environmental factor contributing to the systematic underestimation of snow in high altitude regions, and the measurement errors for solid precipitation can range from 20% to 50% due to undercatch in windy conditions (Rasmussen et al., 2011). The lack of winter/early spring precipitation data does not allow to clearly distinguish a rainfall seasonality in the target region.

The interannual and long-term variability of precipitation cannot be captured as well, since the records are not long enough to perform this kind of studies or trend analyses. The same considerations apply to the other variables measured at the two sites.

Table 24 Experimental set-up of the Askole and Urdukas AWSs

Parameter	Instrument
Air pressure at 2m	CX115P Lsi-Lastem
Air temperature at 2 m	DMA570 Lsi-Lastem
Dew point at 2 m	Derived
Relative humidity at 2m	DMA570 Lsi-Lastem
Specific humidity at 2m	derived
Wind speed at 5 m	DNA022 Lsi-Lastem
Wind direction at 5 m	DNA022 Lsi-Lastem
U wind component at 5 m	Derived
V wind component at 5 m	Derived
Precipitation at 1.5 m	DQA035 Lsi-Lastem
Incoming shortwave radiation at 2 m	CM3 Kipp&Zonen

Exhibits 21 and 22 show, as an example, the time series of temperature and precipitation, respectively, measured at the Askole (red) and Urdukas (blue) AWS in the Baltoro from 2004 to 2008 (Urdukas) and from 2005 to 2009 (Askole) .

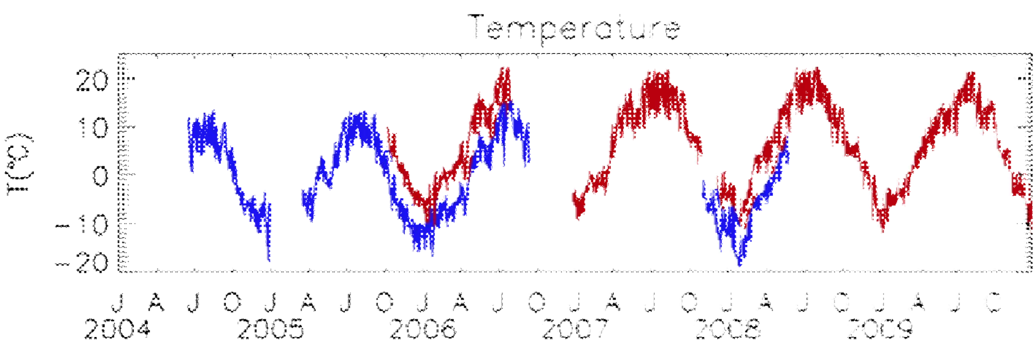


Exhibit 21 Time series of daily mean two-metres temperature at Askole (red) and Urdukas (blue), from 2004 to 2009

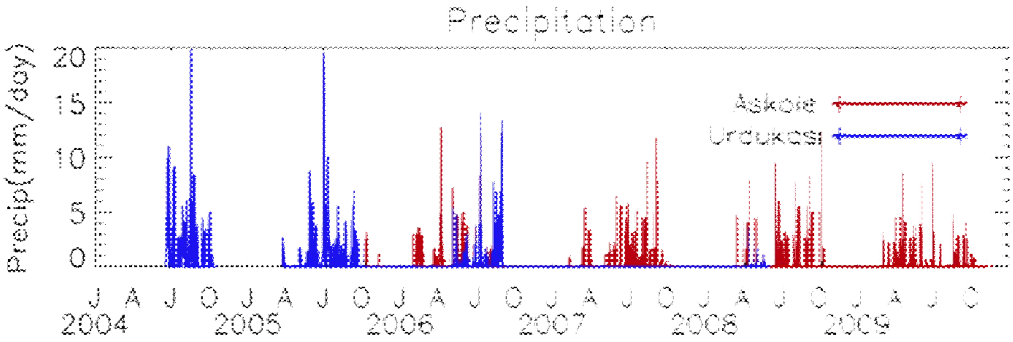


Exhibit 22 Time series of daily-cumulated precipitation at Askole (red) and Urdukas (blue) from 2004 to 2009.

Surface air temperatures at the two stations (Exhibit 21) exhibit strong spatial variability, dependent primarily on elevation, with clear seasonal cycle. The maximum and minimum temperature values recorded at the Askole AWS are 22.3 °C (July 30, 2008) and -12.1 °C (January 6, 2009); while those recorded at the Urdukas AWS are 15.7 °C (July 31, 2006) and -18.9 °C (January 31, 2008). At both sites, the annual cycle of temperature is characterized by maximum values in July-August and minimum values in December-January, reflecting the expected central Asian high-altitude annual range.

The linear correlation between the daily temperature time series of recorded observations at Askole and Urdukas gives a correlation coefficient of 0.95, indicating the spatially-coherent behaviour of this variable, independently on the local conditions found at the two sites and on their separation in distance (the two stations are located 45 km each other).

As already stressed, the time series of daily precipitation at Askole and Urdukas shown in Exhibit 22 indicate that rainfall data at the two stations are strongly discontinuous, and almost completely missing during winter and early spring months, with very few exceptions for measurements performed at the Askole AWS in early spring. Maximum daily rainfall values at Askole are found in spring (April 4, 2006) with 12.8 mm/day, while at Urdukas in summer (August 18, 2004) with 19.8 mm/day. Nevertheless, Exhibit 22 corroborates the persistence of semiarid conditions in the region surrounding the two AWS, with higher values at the Urdukas than the Askole AWS (though a direct comparison between the two records is hampered by the lack of sufficiently long overlapping time periods).

2.5.3 Atmospheric composition

In the recent past, field experiments, in situ observations, and satellite monitoring have pointed to the existence of so-called "atmospheric brown clouds" (ABCs), wide polluted tropospheric layers characterized by anthropogenic aerosol optical depth (AOD) greater than 0.3 and by absorbing AOD greater than 0.03 (Ramanathan and Ramana et al., 2007, Ramanathan et al., 2007). ABCs typically consist of particles (referred to as primary aerosols) and pollutant gases. The brownish color of these "clouds" is due to the absorption and scattering of solar radiation by anthropogenic black carbon (BC), fly ash, soil dust particles, and nitrogen dioxide gas. ABCs' implications for regional and global climate were rapidly recognized; they represent a global climate issue (Ramanathan and Carmichael, 2008).

Over South Asia, the Atmospheric Brown Cloud (ABC) phenomenon (Ramanathan et al., 2007) has important regional climate impacts, with strong perturbations of the regional radiative balance both at the surface and within the atmosphere, and with strong impacts on the hydrological cycle and monsoonal regimes. As reported in the framework of the UNEP-ABC project, the South Asian ABC lead reductions of crop production and increases in the melting of the Hindu-Kush-Himalayan-Tibetan glaciers, with severe consequences for the freshwater supply over Southern and Eastern Asia. As recently pointed out by UNEP (2011), aerosols (especially black carbon) and ozone represents two important contributors both in terms of climate change and impacts on agriculture and population health.

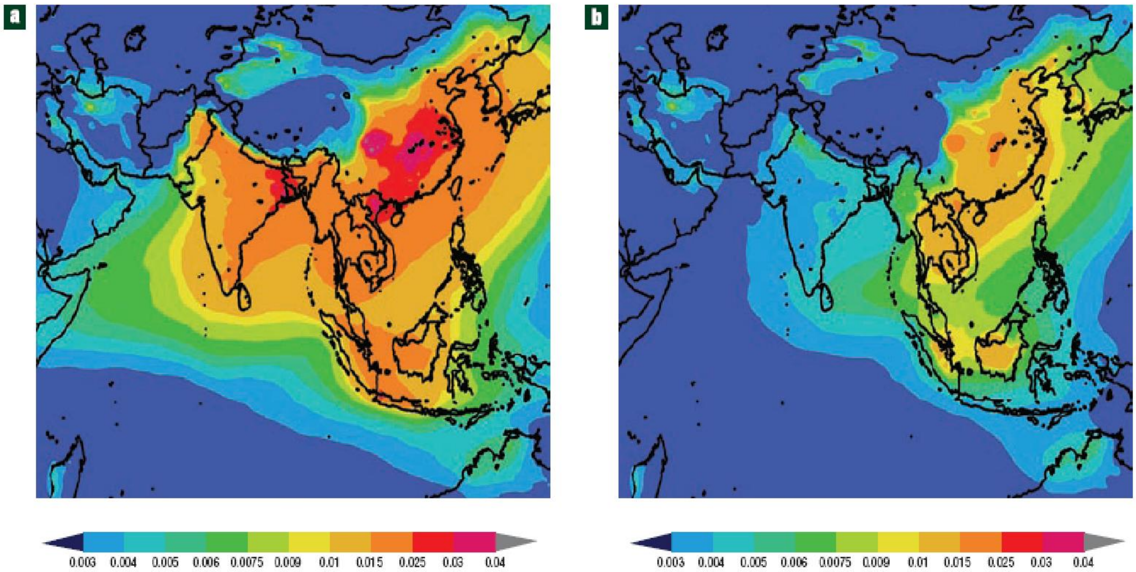


Exhibit 23 The effect of biofuel cooking on Asian BC loading: on the right is shown contributions related to "biofuel cooking fossil fuel and biomass burning", while on the left "fossil fuel and biomass burning" only (Ramanathan and Carmichael, 2008).

At this stage no systematic information about aerosol and ozone average levels and variability existed for the GB and the CKNP. Also for correctly evaluating the impact of these pollutants to ecosystems, agriculture and local population, the implementation of new experimental monitoring activities is recommended within different international initiatives (eg. UNEP-ABC, GAW-WMO). Also to fill this gap of information, the realization of a new Climate Observatory in the Gilgit Baltistan, in the framework of Atmospheric Brown Clouds UNEP and SHARE Ev-K2-CNR projects, was planned for the GB where the CKNP is located. This activity, is conducted in close collaboration with Pakistan Government and local Research Institutions, and represents a fundamental step for a better understanding of the background atmospheric conditions in the Karakorum and global change impacts. With the purpose of coping, remote sensing measurements by MODIS satellite have been analysed and experimental campaigns have been executed in the CKNP. The results from these data-sets will be considered in the following.

MODIS AOD

To obtain a preliminary assessment of the role of mineral dust in affecting atmospheric properties and composition over North Pakistan, we analyse the daily Aerosol Optical Depth at 550 nm (AOD550) provided by the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument onboard EOS Terra (10.30 am, equatorial crossing) and Aqua (1:30 pm, equatorial crossing) satellites. Here we use AOD from MODIS Collection 5, Level 3 data. Collection 5 is an improvement generated with upgraded algorithms after extensive validation of Collection 4 at different land and ocean sites around the globe (see Aloysius et al., 2009 and references therein). As recently indicated by Levy et al. (2010), the AOD provided by MODIS Collection 5 is characterised by an expected error of ±(0.05+0.15*AOD). However, we stress that high albedo areas such as "bright" deserts, snow/ice covered regions and complex terrains (like mountains) are associated with larger uncertainties in MODIS retrievals. Moreover, Levy et al. (2010) concluded that with light aerosol loading (AOD < 0.15), MODIS overestimates AOD over Central Asia (by 0.02 or more) and it underestimates AOD over Indian semi-arid zones.

On the Pakistan region, the spatial AOD field is characterized by a strong North-West to South-East gradient in all seasons. As an example, in Exhibit 24 we show the seasonal AOD fields over Pakistan for 2007. The same spatial gradient can be observed in MODIS data in the whole period 2003 – 2008 (not shown). Two "hot-spot" areas can be identified over Pakistan, respectively over south-eastern (around 25°N; 68°E) and over central-eastern Pakistan (around 32°N, 72°E). These hot-spots strictly follow the topography contour of the Iranian plateau to the west and Karakorum-Hiamalayan arc to the North, indicating that East Pakistan is a basin where aerosol efficiently accumulate. The former area is indicated by a previous work (Alam et al., 2010) as a dust "hot-spot", as it is located within the Cholistan/Thar desert. On the other hand, particulate pollution coming from Karachi (24°51′N, 67°00′E) cannot be completely excluded to contribute to that hot-spot.

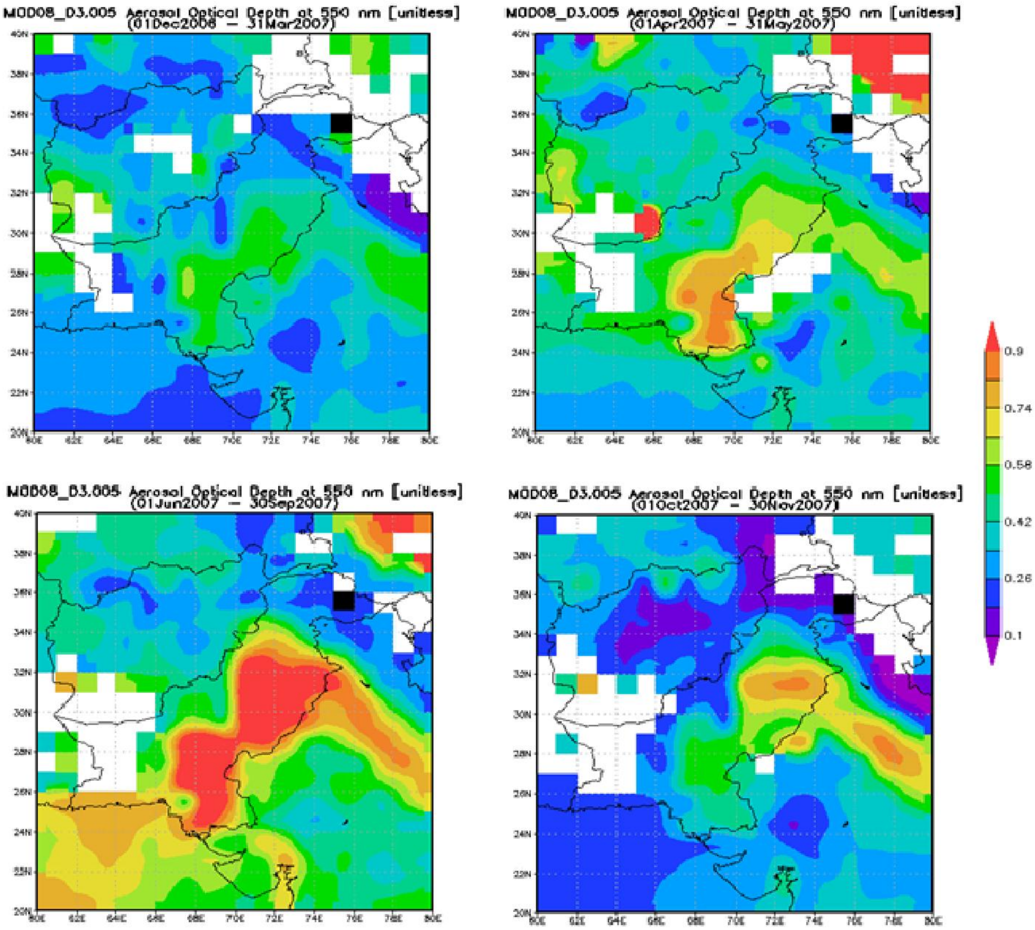


Exhibit 24 Seasonal averaged MODIS (Terra, Collection 5) AOD550 over Pakistan for 2007. The black box denote the areas where the Ev-K2-CNR AWS (Askole and Urdukas) are located.

The latter "hot-spot" is particularly evident during summer and autumn. Pollution from the densely populated city of Lahore (31°32′N, 74°20′E) could also contribute to the high AOD observed in this area. However, as shown by HYSPLIT back-trajectories (Section 3.7.1), southerly air-masses from Cholistan/Thar desert pilling up along Karakorum-Himalayas, can possibly transport high amounts of mineral dust to this region.

As indicated by these MODIS observations, the Gilgit Baltistan where the CKNP is located, are significantly different from the rest of Pakistan. In particular, significantly lower average seasonal AOD550 values and yearly AOD variations are observed in the Karakorum-Baltoro area than in central and south-eastern Pakistan. In part, this is due to the terrain elevation, which leads to a thinner atmospheric column over the Karakorum-Baltoro regions, as well as to the remoteness of the region, leading to more "clean air" conditions. To investigate aerosol loading variations in this northern high-mountain region, we retrieved daily MODIS (Aqua) AOD550 for the box area [34°N ≤ Lat ≤ 35°N; 74°E ≤ Lon ≤ 75°E] reported in black in Exhibit 24. For this region, during the period 2003 – 2008 (493 observations, equivalent to 23% of analysed days), we observed an average AOD550 of 0.27 ± 0.13 (± 1-sigma). To infer a description of the multi-year variability of AOD550 over the Karakorum-Baltoro area, we aggregated daily values by calculating monthly mean values (Exhibit 25): this permitted to obtain a data-base of AOD values for the investigated region.

Presumably owing to the snow cover and high cloud occurrence, only a few valid MODIS measurements are available during winter months, not allowing for a proper AOD550 evaluation over the region. At variance with lowland locations in Pakistan (Alam et al., 2010), the seasonal AOD550 variations are characterised by a maximum in late winter/spring and a minimum in late summer-autumn, further stressing the specific features of this mountain region and a partial decoupling from the lowest troposphere. By averaging over the entire period, the highest AOD550 were detected in April (0.41 ± 0.13) and the lowest in October (0.18 ± 0.09).

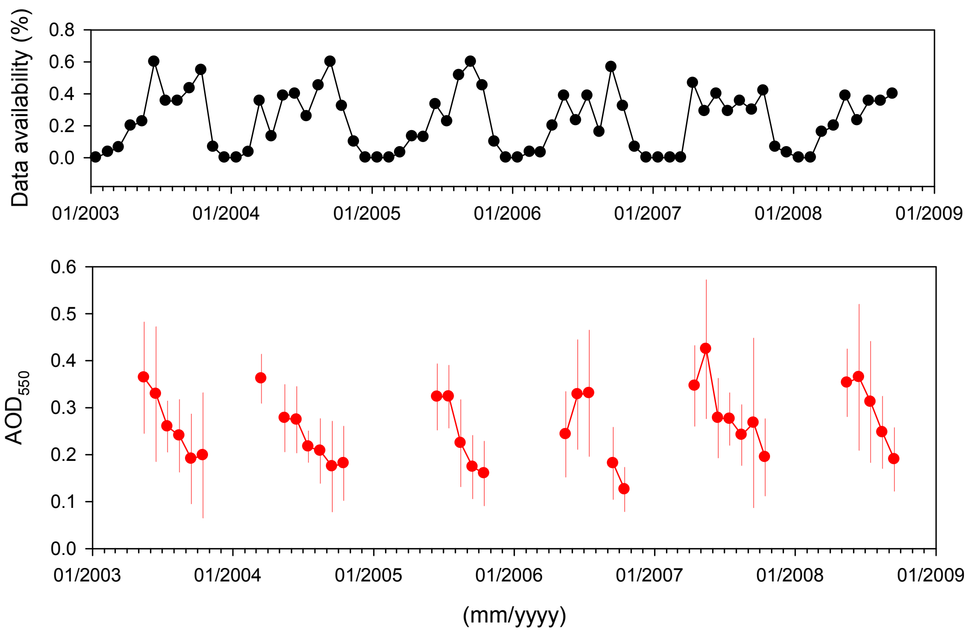


Exhibit 25 MODIS (Aqua) AOD550 monthly averages over the Karakorum-Baltoro box (lower plate, in red). Vertical lines denote standard deviations. The upper plate shows the fraction of available observations for each day. Only months with at least 7 daily values are considered.

Summer 2011 measurement campaign (field data)

A forty-days intensive field campaign was carried out in August 2011 at Urdukas located along the Baltoro Glacier in the CKNP. Measurements of (i) meteorological parameters, such as temperature, pressure, relative humidity, wind speed and direction by the AWS and (ii) aerosol concentrations were performed by using a meteorological station (Lastem LSI) and Aeroqual AQM60 system able to determine aerosol mass values

(PM10, i.e. mass of particulate atmospheric aerosol with diameter lesser than 10 µm) throughout an optical particle counter (OPC). PM10 consists of tiny solid and liquid particles that come from a myriad of sources, both natural and human-caused. Worldwide, PM10 is considered a powerful indicator of air quality and several National legislation adopts standards for this parameter.

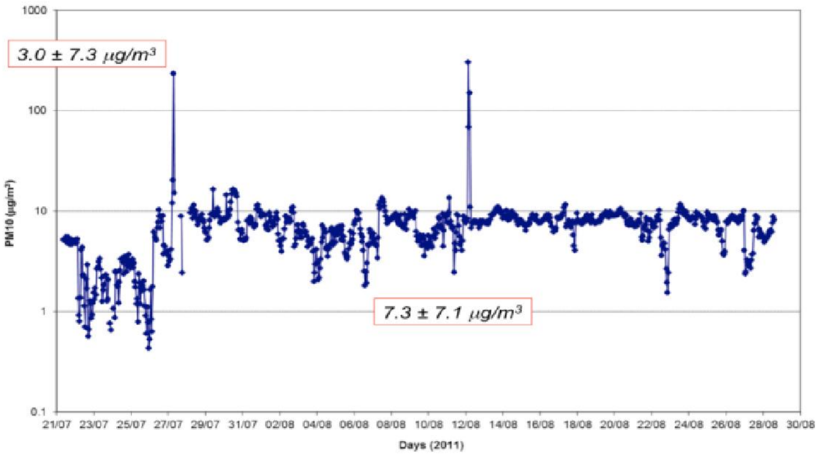


Exhibit 26 PM10 concentrations (blue dots) collected at Urdukas during the summer of 2011 (July 21th - August 30th). Red boxes report mean and standard deviation of PM10 concentrations associated to two different periods, 21–27 July upper box) and 28 July–30 August 2011 (lower box).

Hourly PM10 values observed at Urdukas from July 21th to August 30th have been reported in Exhibit 26. Average and standard deviation are 7.7 µg/m^3 and 7.1 µg/m^3 respectively. Such PM10 levels are rather low with respect of those observed during typical summer time conditions at other sampling sites located in the central and southern Asia, such as Biskhek, Karakol (Shafer et al. 2010) and Manora (Ram et al. 2011), but higher than those collected concurrently at the higher site of NCO-P (Nepal) where the average was 1.1 µg/m^3 and the standard deviation 1.6 µg/m^3.

A qualitative analysis of time series suggests us that two different regime of aerosol variability could have affect the sampling site during the measurements field campaign: the first (21-27 July) was characterized by low particles load (about 3 µg/m^3) and the second (28 July-30 August) was characterised by an increase of a factor 2.4 of the mean PM10 concentrations. It should be noted that, in both cases, no daily cycle of aerosol concentration was observed at Urdukas.

With the aim of investigating the possible role of large-scale atmospheric circulation to the observed PM10 behaviour, air-mass back-trajectories ensembles have been calculated by the HYSPLIT model (provided by NOAA). From this analysis, we preliminary assessed that during the first measurement period (21-27 July, when lower PM10 have been observed) the Baltoro region was affected by a “regional” circulation, while from the following days (when higher PM10 characterised the measurement site) the air masses flow definitely changes, with more “long-range” fingerprints (as shown in Exhibit 27).

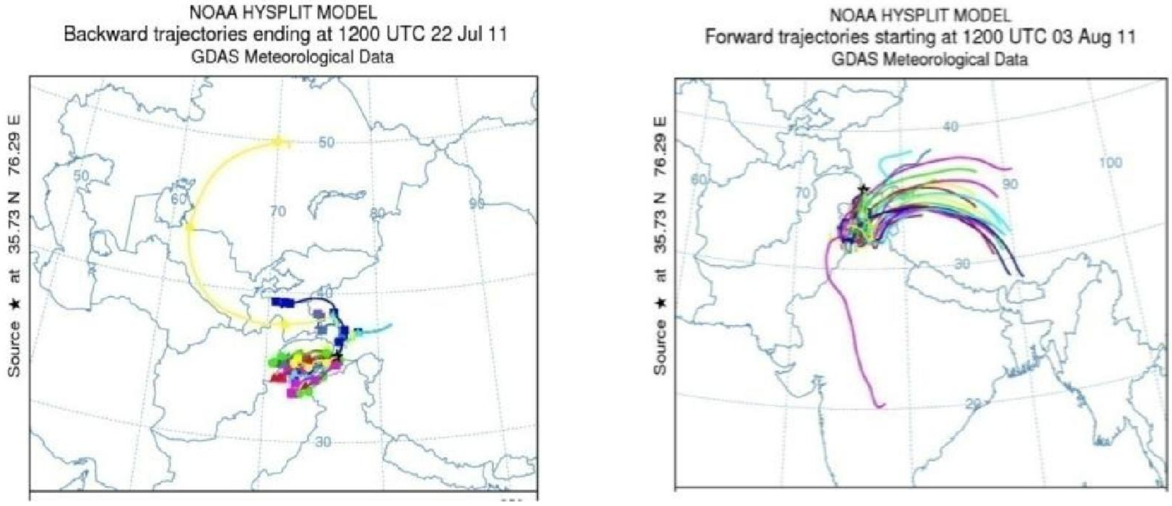


Exhibit 27 HYSPLIT back trajectories ending at 12:00 UTC of July 22-th (August 3-th) on the left (right) panel.

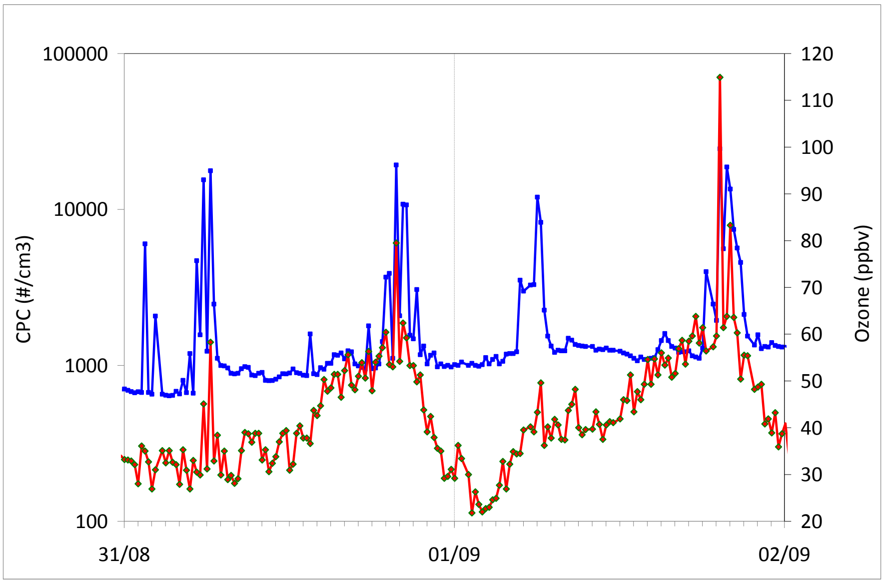
Besides investigation on possible pollution transports and local circulation affecting the air composition along Baltoro region, this field campaign represents a useful possibility to provide preliminary indications about the possible role played by mineral dust transport in affecting aerosol properties over CKNP. In particular, during the measurement field campaign a "special event" with PM10 hourly value up to 300 µg/m^3 was detected on August 12th and possibly associated with direct inputs of mineral dust from near desert regions (Taklimaklan). Even if possible contributions related with air-mass transport from along the south Karakorum-Himalayas foothills and urban areas (Islamabad, Rawalpindi, Lahore…) cannot be completely ruled out.

Summer-autumn 2012 measurement campaign (field data)

On summer 2012, a further experimental campaign is conducted in the CKNP. A NANO-SHARE transportable system, developed in the framework of the SHARE project, has been deployed at Askole on 20th August 2012. It is currently carrying out measurements concerning: ozone, carbon dioxide, total particle number and meteorological parameters.

Once validated and analyzed, these data will provide the first characterization of average levels and variability of these atmospheric compounds in the CKNP area. As an example, in Exhibit 28 two "typical" days for ozone, total particle concentration, CO_2 and wind direction are reported. From these very preliminary data it is possible to discern the influence of mountain-valley breeze circulation on gas concentrations as well as possible impact of local residential emissions on total particle concentrations (systematic peaks with 15-minute values above 104 cm^{-3} are observed at the morning and evening hours, possibly related with cooking activities). These aerosol particles are characterized by small diameter size < 3µm in aerodynamic diameters, which allow them to deeply penetrate into respiratory system (Jacobson, 2007; Cohen et al., 2005). Small aerosols (solid and liquid droplets suspended in a gas) like black carbon are the third-leading contributor to the burden of disease in South Asia and the fifth-leading cause of mortality in Asia as a whole (Ezzati et al., 2006). These peak events in the total particle counts can represent indirect proxy for the evaluation of the daily time spent burning biomass by the population living at Urdukas.

From these preliminary data is also possible to point out some short- lasting episodes (e.g. 2012, 1st September) characterized by very high ozone levels approaching the information threshold values (180 µg/m^3) of the European air quality standards and probably indicating efficient conditions for photochemical O_3 production.



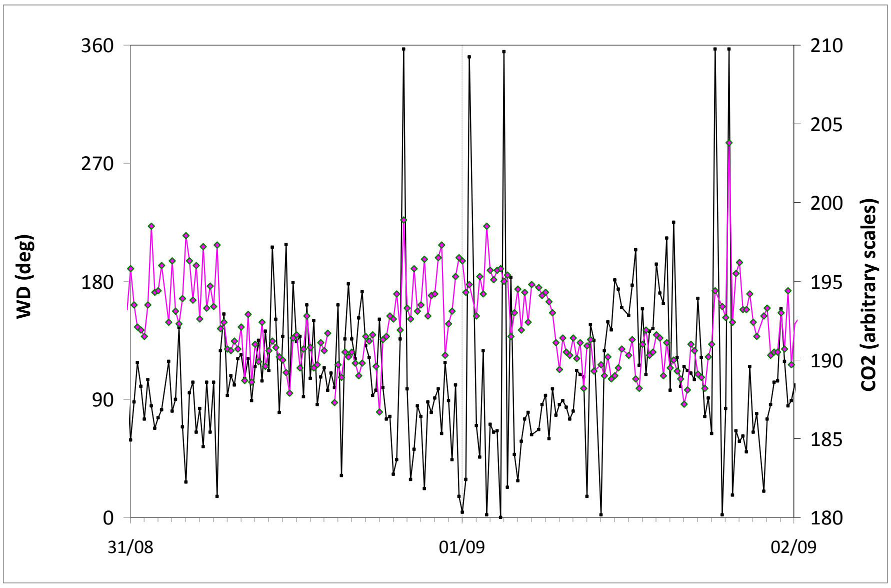


Exhibit 28 Total particle concentration (CPC, blue), surface ozone(red), carbon dioxide (pink) and wind direction (black) recorded on 2012, 31st August and 1st September at Askole.

2.5.4 Analysis of precipitation regimes, seasonality and trends

A wide study has been carried out with the aim of obtaining a picture, the most reliable as possible, of the rainfall amounts and distribution in the mountainous regions of northern Pakistan (Palazzi E., von Hardenberg J, Provenzale, A: Precipitation in the Hindu-Kush Karakorum Himalaya: observations and future scenarios, under revision for J. Geophys. Res., 2012, hereinafter Palazzi, 2012). Due to the lack of continuous precipitation measurements at the collecting points at Askole and Urdukas in the Baltoro, we rely on various sources of rainfall data/estimates having different temporal length and resolution and different spatial coverage and resolution. These data have been used to describe the climatological features of precipitation in the HKK region encompassing the CKNP area. Precipitation climatology and trends in the HKK have been compared to those found for the eastern Himalayan region, which is mostly affected by the summer monsoon circulation and, for that, it is characterized by different sources and types of precipitation. The data sets employed in this study are briefly described in what follows and their main features are summarized in Table 25:

- The Tropical Rainfall Measurement Mission (TRMM) data set, from 1998 to 2010, available through the NASA Mirador interface (http://mirador.gsfc.nasa.gov). We have used the 3B42 product, supplying 3-hour average rainfall rate estimates with 0.25°x0.25° spatial resolution.

- The Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) data set, a daily precipitation dataset obtained from a rain gauge observation network for the "Monsoon Asia (MA)" domain (60°E-150°E longitude, 15°S-55°N latitude), with a 0.25°x0.25° spatial resolution from 1951 to 2007.
- The Global Precipitation Climatology Project (GPCP) data set, providing monthly mean precipitation data on a 2.5°× 2.5° latitude-longitude grid, obtained from a combination of precipitation estimates from low-orbit satellite microwave data, geosynchronous-orbit satellite infrared data, and surface raingauge observations, from 1979 to 2010.
- The Global Precipitation Climatology Centre (GPCC) data set, the in-situ component of the GPCP data set.
- The Climate Research Unit (CRU) data set, consisting of global 0.5° latitude-longitude grids monthly time series of, among other variables, precipitation over land areas (excluding Antarctica), from 1901 to 2009.
- The ERA-Interim total precipitation data set, with a spatial resolution of 0.75° latitude-longitude for the time period from 1979 to 2010.

Table 25 Precipitation data sets employed and their main features.

Data set	Spatial domain	Time domain	Data kind and product	Spatial resolution	Temporal resolution
APHRODITE	Land (60°E-150°E, 15°S-55°N)	1951-2007	Gridded rain gauge (APHRO_V1003R1)	0.25° lat-lon	Daily
GPCC	Land (global)	1901-2009	Gridded rain gauge (V5)	0.5° lat-lon	Monthly
CRU	Land (global)	1901-2009	Gridded rain gauge (CRU TS 3.0)	0.5° lat-lon	Monthly
TRMM	Land and sea (50°S to 50°N latitude)	1998-2010	Merging of different satellite instruments data (3B42)	0.25° lat-lon	3-hourly
GPCP	Land and sea (1.25°E-358.75°E, 88.75°S-88.75°N)	1979-2010	Satellite estimates and rain gauge (V2.2)	2.5° lat-lon	Monthly
ERA-Interim	Global	1979-2010	Reanalyses	0.75° lat-lon	Daily

An analysis of the consistency among the different data sets considered in this study has been carried out (Palazzi, 2012). The highest correlation coefficients are found, as expected, for the pairs GPCC and GPCP, the GPCC data set being the in-situ component of the merged satellite-rain gauge GPCP archive; high correlation coefficients are also found for the pairs GPCC- Aphrodite and GPCP-Aphrodite.

The spatial distribution of summer precipitation (as defined by the period June-July-August-September or JJAS) and of winter precipitation (December-January-February-March-April or DJFMA) obtained from the six data sets considered in this study is shown in Exhibit 29. Each plot shows the multiannual mean seasonal mean precipitation, focusing on the period 1998-2007 for which data from all six archives are available. All data sets coherently reproduce the key features of summer and winter mean precipitation over the target area, though many differences among the data sets are clearly visible, which can arise from their different temporal and spatial sampling and resolution and the specificity of the various products. It is worth pointing out that this region has very complex topography, and the orientation and elevation of the mountain ranges play an important role in determining precipitation. At the higher elevations, much of the precipitation falls as snow, but precipitation in solid form is neglected in both satellite measurements and the data sets consisting of gridded data from rain gauge networks. It should also be noted that in areas with sparse station coverage, such as those we are looking at in this study, the Aphrodite, CRU, and GPCC data sets interpolate grid point values from the nearest few available stations. This certainly represents a significant element of uncertainty.

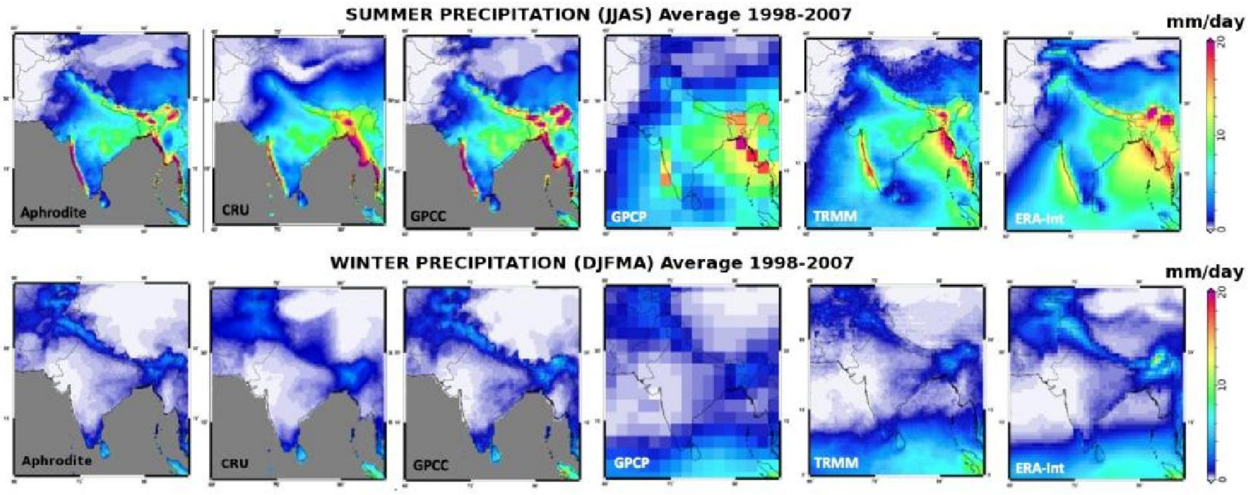


Exhibit 29 Multiannual mean (1998-2007) seasonal mean (summer=JJAS in the upper panels, winter=DJFMA in the lower panels) precipitation over the Indian subcontinent for, from left to right, APHRODITE, CRU, GPCC, GPCP, TRMM and ERA-Interim data sets.

Exhibit 30 shows the time series of precipitation over a box encompassing the HKK (32°N-37°N latitude and 71°E- 78°E longitude) for winter (left) and summer (right) and for the six datasets Aphrodite, GPCC, GPCP, TRMM, CRU, and ERA-Interim. The Exhibit also includes the time series of total precipitation (liquid and solid precipitation) obtained from the state-of-the-art global climate model EC-Earth (http://ecearth.knmi.nl). EC-Earth is a global model developed by a consortium of European research institutions and researchers, based on state-of-the-art models for the atmosphere (IFS from the ECMWF atmospheric model), the ocean (NEMO), sea ice (LIM2) and the biosphere (HTESSEL). At the ISAC institute, recently entered in the consortium, a long historical run (1850-2005) and 3 different scenario runs for the period 2006-2100 (Moss et al., 2010) have been simulated (http://www.to.isac.cnr.it/ecearth/).

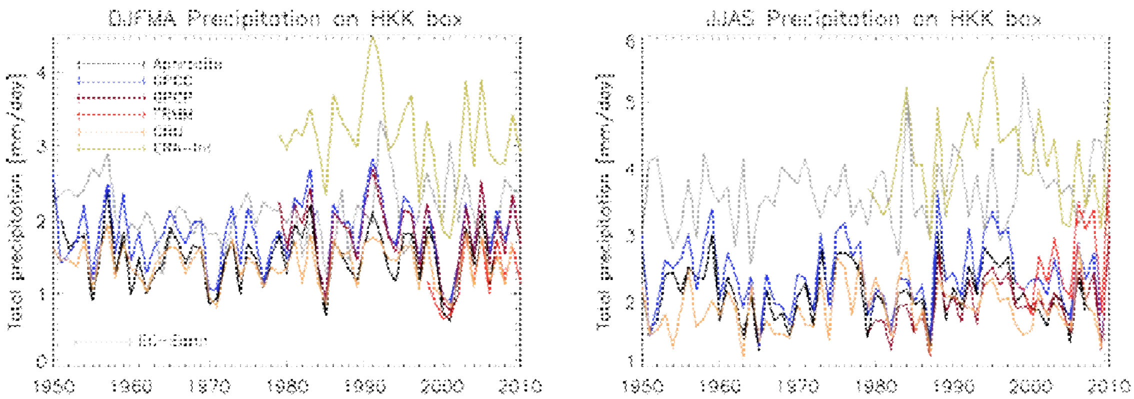


Exhibit 30 Time series of precipitation over the HKK during winter (left) and summer (right) for the APHRODITE, GPCC, GPCP, TRMM, CRU, ERA-Interim and EC-Earth model datasets.

The precipitation time series shown in Exhibit 30 from the various datasets in the time period 1950-2010 reproduce, in spite of the biases between the datasets, the interannual precipitation variability in a coherent way. None of the datasets shows statistically significant trends in the HKK during winter. During summer, GPCP provides a statistically significant increasing trend of 0.017 mm/day/year and so does the EC-Earth model (0.007 mm/day/year). The datasets considered here do not confirm the view of an increasing winter precipitation trend in the Karakorum (Archer and Fowler, 2004), sometimes indicated as one of the possible causes of the snow cover increase and slight glacier advance in this area.

It is quite clear from Exhibit 30 that the HKK region receives comparable amounts of precipitation during winter and summer, due to the influence of a winter and early spring source of precipitation (December to April) carried on western weather patterns originating in the Mediterranean or the Atlantic (e.g., Rao, 1981), at variance with situation encountered in the Himalaya, where the summer monsoon rainfall dominates the seasonality of precipitation. Exhibit 31 shows the mean precipitation annual cycle over the box encompassing the HKK (where the CKNP is located, solid lines) and over another box which includes the greater Himalayan region (dashed lines) for the five observational data sets considered in this study (we do not show here the ERA-Interim reanalyses and data from the global model EC-Earth). The mean annual cycle is obtained by averaging the monthly precipitation over the period 1998-2007, which is common to all data sets considered. The Exhibit highlights that there are two principal sources of precipitation in the whole HKKH range. The dominant source in terms of total amounts of precipitation delivered is probably the monsoon, bringing storm systems from the south. These systems are restricted in time from late July through September and deliver heavy precipitation to the Greater Himalaya. In the HKK region a further source of precipitation is depression coming from the West and it occurs during winter/early spring, representing the major moisture source during these seasons (until about April) in the HKKH. These westerly circulations provide the dominant nourishment for the glacier systems of the Karakorum. Incursions of the monsoon bring occasionally rain over the HKK region but, even during summer months, not all precipitation is thought of as deriving from the monsoon source (Wake, 1987).

The APHRODITE, GPCC, CRU, TRMM and GPCP data sets give a quite consistent picture of the annual cycle of precipitation, with a two-modal (one-modal) distribution in the HKK (Greater Himalaya). A very compact distribution can be seen in the Greater Himalayan box, with a summer peak in July for all data sets, which is slightly lower for APHRODITE and TRMM than for GPCC and GPCP and has intermediate values CRU. In the HKK box, there is somewhat more scatter among the various data sets than in the Greater Himalayan region, though the seasonality of precipitation is coherently reproduced by all of them. The peak of precipitation in July is accompanied by a wintertime peak in February and a comparatively slightly lower peak in April.

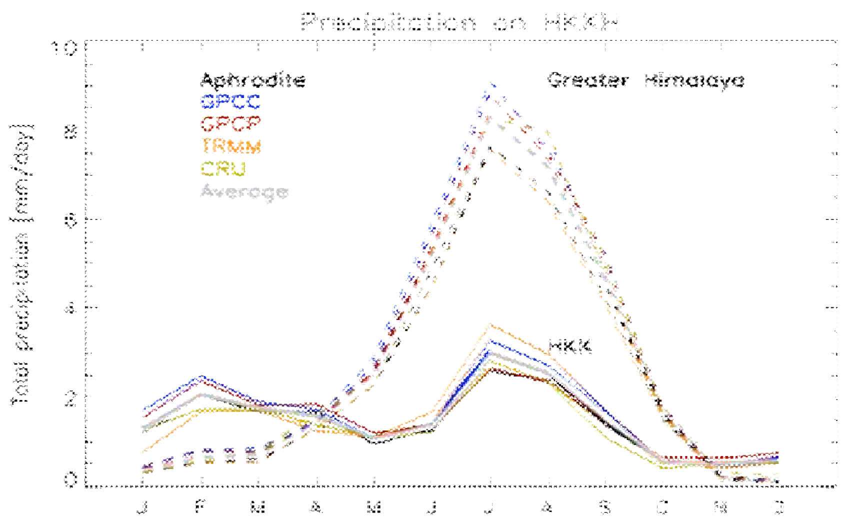


Exhibit 31 Multiannual mean (1998-2007) annual cycle of precipitation over the HKK box (solid lines) and the Greater Himalayan box (dashed lines) for the APHRODITE, GPCC, GPCP, TRMM and CRU data sets. The average of all data sets is shown in grey

3. CKNP NATURAL NETWORK

3.1 The bio-regional approach

In the past there was the general opinion that in order to preserve the biodiversity of a specific area it could be sufficient to delineate specific conservative rules. The available data suggest that for very large Protected Areas, as Yellowstone in USA or CKNP in Pakistan, such rules are not enough to support long-term populations conservation (Noss, 1991a). Actually conservation biologists agree on the necessity of a more wide vision in the management of the environment and Protected Areas. It is surely important to link together the different Protected Areas, but considering a long term prospective, also the same regions have to be interconnected to assure the possibility of dispersion and migration on long range for the different species as answer to the impact of the climate change. This bio-region approach (McNeely, 1992) could also involve different countries, and it has been developed to avoid the habitat loss and territorial fragmentation, one of the most threats for the biodiversity (Wilcove et al.,1986; Noss, 1991b), through the creation and conservation of biological corridors: natural areas (natural or agricultural ecosystems) able to connect the different Protected Areas maintaining the necessary flow of individuals and genes between the populations (i.e. Odum, 1971; Soulé, 1987; Noss, 1993). In recent years the attention to the Transboundary Protected Areas (also known as Peace Parks or Transfrontier Conservation Areas) is spreading at global level and the participation of the local cominities and related benefits are considered essential in achieving the result of this process. Relevant worldwide examples are the Paseo Pantera project, linking North and Central America, and the Y2Y (Yellowstone to Yukon) initiative.

As example (Exhibit 32), this last project is finalized to the constitution of an eco-region of about 1,3 million km^2, 3,200 km long and from 500 to 800 km wide, that encompasses two Canadian Provinces (Alberta and British Columbia), two territories (Yukon and Western Territories), and five US states (Montana, Idaho, Wyoming, Oregon and Washington). The 10% of this area is formed by protected areas with different status.

Exhibit 32 Map of territories included in the *Yellowstone to Yukon Region* project (from Y2Y website).

Regarding the CKNP it is important to underline that the Khujerab NP, CKNP and the Deosai plateau would form together a contiguous conservation area, often referred to as a "bio-region", covering about 50 per cent of the central Karakorum ecosystem. Some projects are moving in a transboundary approach, and this is one of the priority for the CKNP, taking also into consideration the potential impact of climate change.

3.2 The CKNP

Around CKNP area there has been a long discussion about the possibility of linking together the adjoining Khunjerab and Karakorum National Parks with the Deosai plateau in order to form a contiguous area able to preserve about the 50% of the whole central Karakorum ecosystem (Exhibit 33).

This would be able to better assure the necessary long term conservation of this area, also considering the potential impacts of climate change.

For this reason a relevant effort to create specific corridors to maintain ecological and environmental connection has to be supported by all the different boards and institutions; thus a specific study on this topic has to be promoted.

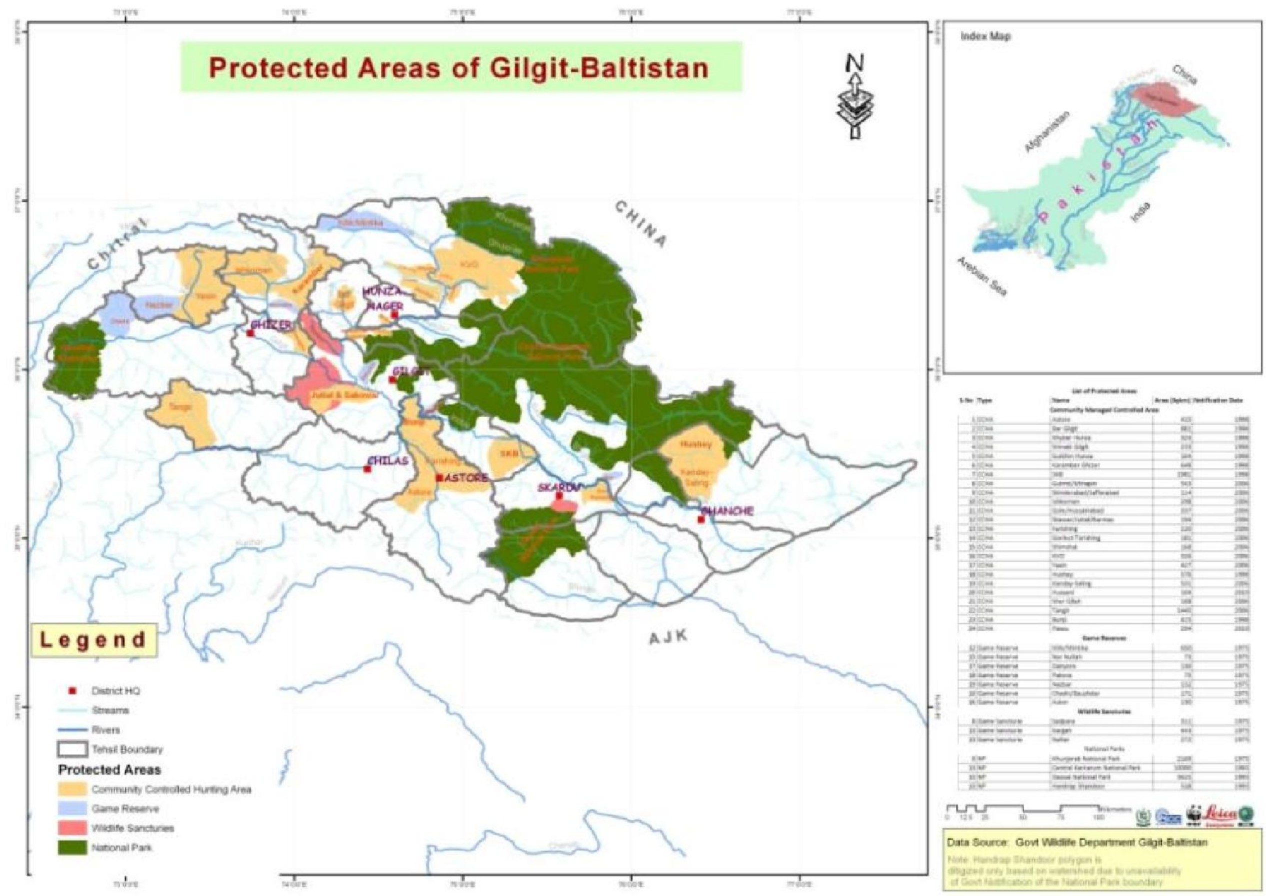


Exhibit 33 CKNP natural network (Source: WWF-Pakistan).

4. SOCIOECONOMIC CONDITION AND NATURAL RESOURCES USE

While the Pakistan legislation (GoP Notification Concerning CKNP, May 1996; see Part II - Park Management Guidelines) reports that *"The Park boundary is along well defined geographical features and excludes all villages, settlements and pasture lands as shown in the enclosed map and these are listed in Annex-A of this notification",* in order to develop the CKNP Management Plan and its related Zoning System it has been paramount to consider the human presence. Actually:

1. one of the National Park`s goals is to preserve and promote, in a sustainable way, local cultural heritage which is widely distributed in the valley adjoined CKNP;
2. the CKNP management process is based on a "participatory development and implementation" strategy. Considering the large extent of the park and the high socio-economic and ecological diversity in the surrounding areas, the resources of the park management office are limited and will have to rely to a large extent on communities living around CKNP for successful park management. For these reasons, the park management office aims at committing community-based organizations to collaboration for management of the park (Mari et al, 2009);
3. however, different activities (e.g. wood collection, grazing, tourism) are conducted inside the Park border. The natural resources of CKNP are subjected to a pressure due to traditional rights of the local inhabitants and tourism practices (Panzeri and Khan, 2009). Also other activities not directly related with resource use could affect the Park integrity;
4. the local communities have some expectances for the Park as a relevant tool to improve their living standards and socio economic conditions.

In the following paragraphs an overview of the main aspects related to the human presence in CKNP and adjoining valleys (livelihoods and socioeconomic conditions) is provided, considering both the potential impact derived from the Park (natural resource use) and the communities expectations.

4.1 Livelihood and socioeconomic conditions

The peripheral zone of CKNP comprises of 230 settlements and is home to almost 115,000 people, living in about 13,000 households and relying on the park resources for their livelihood (WWF-Pakistan, 2008; IUCN, 2008; Hagler-Bailly, 2010; SDPI, 2012).

Two fundamental surveys on livelihoods and socioeconomic conditions of the areas connected to CKNP has been carried out by CESVI and AKRSP in 2008 and Bastian Flury in 2012 in the framework, respectively, of the HKKH Partnership Project (Panzeri and Khan, 2009) and the SEED Project (Flury, 2012).

Some general concepts and information derived from these two studies could be spread out in all the adjacent valleys of the CKNP, but the available data, where reported, are referred to the areas where the surveys were carried out.

The survey carried out by CESVI and AKRSP focused on eight Union Councils (UCs) in Bagrote, Shimshal, Thaley and Shigar valleys, including 29 "revenue-villages" and it was conducted at the household level (Table 26).

The selected Union Councils are situated in narrow mountain valleys of the Karakorum mountain range in Gilgit and Baltistan regions of Northern Pakistan. General terrain of these valleys comprises mountain slopes with run-down streams dividing the valleys in two parts with villages and hamlets settled throughout the valleys on either side of the streams and rivers.

Table 26 Overview of the research area (Panzeri and Khan, 2009; HKKH Partnership Project).

DISTRICT	VALLEY	UCs	REVENUE (numbers)	VILLAGES
GILGIT	BAGROTE	**BAGROTE**	8	
	SHIMSHAL	**GOJAL-I**	8	
GANCHE	THALEY	**THALEY**	Not indicated	
		BALGHAR/DAGHONI	Not indicated	
		KARKHU	Not indicated	
SKARDU	SHIGAR	**ALCHORI**	7	
		CHURKA	2	
		GULABPUR	4	

The survey carried out by Flury (2012) focused on three Union Councils of Braldo and Basha valleys, including 27 municipalities (Table 27).

Braldo and Basha valleys extend north-east and north-west, respectively, from the western end of Shigar valley. The Braldo River, which is formed by the convergence of the Biafo, Dumordo, and Baltoro rivers and numerous smaller streams descending from side valleys, flows south-westwards and discharges into Shigar River. The highest two settlements of Braldo valley are situated at a distance of approximately 100 km from Skardu, the district capital. Braldo valley is connected through a jeep trail to the main road extending through Shigar valley to Skardu. The road is plied by expeditions and trekking parties aiming for Baltoro and K-2. Basha valley extends west, north-west from Shigar valley. The Basha Union Council is also only accessible by jeep. Although access to some important trekking destination is through Basha Union Council, the frequency of groups passing through Basha valley is much lower compared to Braldo valley.

Table 27 Overview of the research area (Flury, 2012; SEED Project).

DISTRICT	VALLEY	UCs	MUNICIPALITIES
SKARDU	BRALDO	**DASSU**	9
		BRALDO	10
	BASHA	**BASHA**	8

Livelihood

The mainstay of livelihoods in the research area, as in the other parts of Gilgit Baltistan (Government of Pakistan and IUCN, 2003), is combined mountain agriculture: it is the complex integration of animal husbandry, agricultural and horticultural productive and reproductive activities across vertical landscapes with different productive potentials in temporal sequence within a yearly cycle (Ehlers and Kreutzmann, 2000; Kreutzmann, 2004; Flury, 2012).

The combined mountain agricultural system is based on two pillars:

1. Cultivation. It is conditional to irrigation and threatened by frequent and omnipresent natural disasters. Decreasing arable landholdings per household and land defragmentation are prevalent processes, while the farm resources - landholding, livestock and trees - constitute the most important household assets.
2. Animal husbandry. It requires main lines of integration between animal husbandry and cultivation, which are i) the requirement to protect cultivation in and around the permanent settlements from livestock grazing during the cropping season, which is achieved by spatially separating livestock from fields through summer grazing of livestock in higher pastures and ii) the production of farmyard manure for cultivation and of crop derivatives to feed the livestock during the winter season. The key factor limiting the size of livestock is fodder availability during the winter season.

Combined mountain agriculture continues to provide the mainstay of livelihood subsistence for households.

However, for many, the revenue from marketing of agricultural produce outweighs the cash required to close the household's staple food deficit and to purchase essential foodstuffs or pay back debt accumulated with shopkeepers, neighbours, or relatives during lean periods or fatalities. Livestock and livestock produce – predominantly butter - constitute important reserves, which can be converted readily into cash as need arises, as are, to a lesser extent, trees and land, but non-farm livelihood income activities are the most important means to meet the household's cash requirements.

Although a large section of the population still engage in these occupations, the socio-economic situation has altered rapidly in the recent past. In particular the mining sector is gaining importance as livelihood activities in some area (e.g., in Dassu UC) and the tourism sector is recently developing, in with regard to allocation of opportunities (Flury, 2012).

So, over the last decade, the livelihood pattern has diversified due to enhanced communication with the rest of the country and strengthening of market economy in the region (IUCN, 2008). Hence, many people are now engaged in commercial or business endeavours (e.g. tourism, banking, construction, carpentry) and public sectors (government service – e.g. armed forces, police department).

Socio-economic conditions

Main findings of the considered surveys are reported below:

Basic facilities

Generally, all the Union Councils have access to basic facilities as roads, electricity, telephone (except in Basha, Braldo and Dassu UCs), primary education, and health services. However, some of the remoter villages and hamlets within these Union Councils are still deprived of these basic necessities, moreover the health ones. The non-availability of basic health and education services takes a toll particularly on women who suffer the most due to the local culture and traditions that restrict their mobility hampering access to these services at farther distances.

Population, Labour force, Incomes and Poverty

i) According to the estimates based on the sample data collected during the survey (Panzeri and Khan, 2009), all of the eight UCs in Bagrote, Shigar, Thaley and Shimshal valleys have a combined population of 66,261 inhabitants that include over 36,450 male and more than 29,800 females dwelling in 8,369 households.

The occupational trends among the households of the eight Union Councils foresees three main categories: farmers (21%), students (38%), and housewives (18%, exclusively women, who, often, practice farming as their secondary occupation). This implies that the communities in these UCs are traditional agro-pastoralists that practice mixed subsistence farming. It is also encouraging to remark the largest proportion of population consists of students (both male, 44%, and female, 32%). However, due to lack of higher education facilities in villages, there is a tendency for female students to drop out of school after basic levels.

Apart from the highly unfavourable demographic, cultural, and social settings, all the Union Councils are rich with natural resources, particularly land, water, forests, and related resources. To reap the maximum benefits from the available natural resources, the communities are equipped with a healthy force of skilled and unskilled labourers. For all the Union Councils, this situation has ensured respectable levels of per capita incomes, which are mostly derived from natural resource management. The Per Capita Income in study area ranged PKR 27,354-105,947 (in Nominal Terms). The income consists of two major components: farm and non-farm incomes. The main contributors in farm incomes are crops, vegetables, livestock and farm-forestry resources; whereas, non-farm contributors are business, skilled and unskilled labourers, employment in public and private sector organizations. In the research area has been identify a 4:1 relationship between farm and non-farm incomes.

On one hand, this is a good sign that people are self-reliant in livelihoods totally dependent on locally available farm resources. However, on the other hand, this situation also raises alarms that people place high pressure on the natural forest and wildlife resources causing degradation of local forests and wildlife and posing a threat to the biodiversity balance and environment.

The total income analysis also allowed to identify the poverty incidence and the inequality of incomes distribution. The poverty incidence, determined from Per Capita Income and expressed as percent of poor households, represents the 4% in the study area (the poverty incidence is highest in Bagrote and Gojal UCs - Gilgit District -, respectively 18% and 11%). But, in general, over the last few years, the poverty rate has declined sharply in these areas.

The CESVI's survey explored also the inequality of income distribution, obtaining the following results: the three UCs of Ganche District have a well-balanced distribution of incomes between the poor and rich income classes. The incomes in the three UCs of Skardu District are concentrated on the well off community classes, whereas the two UCs of Gilgit District show middle to upper class concentration of incomes.

As is the case with the entire population, the poor households also derive more income from farm sources as compared to the non-farm sources. However, in the case of the Bagrote and Thaley UCs, the situation is the other way round where the share of non-farm income is higher than the farm incomes for the poor households.

ii) The socioeconomic survey carried out in Basha and Braldo valleys (Flury, 2012) considers 1,924 households (estimated number).

The percentage of households with income from regular employment varies between 2% and a little over 10% (3-8 residents). Regular employees are teachers, workers employed with Northern Areas Public Works Department (NAPWD), for regular maintenance of public infrastructure, such as roads, hydropower stations or the power grid, police and army officers, health sector employees, or guards for various facilities. Only two villages/municipalities have a significantly higher rate of regular employment with 15-16 people in Askoli and 19 in Bain. The higher rate in Askoli is presumably due to regular employment opportunities with NGOs and tour operators.

Permanent labour migration is not very common. The percentage of families that migrated permanently to major cities in Pakistan, the gulf-states or the middle east varies between 2% and 9% across all villages/municipalities of the research areas. However, some villages show higher shares, with over 10% and even 20% of families in permanent migration. Temporary labour migration (seasonal absence from the resident village) is more frequent. Although the variation is also higher, commonly between 15% and 30% of households have at least one member migrating temporarily in search for labour. The municipalities of Biano and Chaqpo/Tosho, hosting some of the poorest community in Dassu Union Council feature with 80% and 90% some of the highest rates of temporary labour migration of Dassu and Braldo Union Council. A specific practice of many households in some villages/municipalities of upper Basha Union Council is regular migration of some of their male members to Gilgit and Hunza during the winter season in search for agricultural wage labour. The share of young people living abroad or in regional towns for studying is substantial.

The sources of non-agricultural labour opportunities are public, NGO-initiated, community, or private infrastructure projects, while the latter two recruit all or a share of labour through ress4 and rokh5, respectively, which are unpaid labour arrangements. Few households in Basha Union Council seasonally wash gold from the main river.

Health, education, infrastructure, NGO-initiated projects, and communal natural resources are considered common goods and as such concerned for by village councils. However, combined

[4] *ress* is a customary mechanism of rotational duty assignment among the households entitled to benefits on a common pool resource within a system of collective action and is different from *rokh*.

[5] *rokh* is a reciprocal and bi-lateral labour-sharing mechanism, which is universally applied in the research area.

mountain agriculture as subsistence livelihood activity is paramount and ubiquitous

Non-farm income opportunities are generally irregular, unreliable, and access to such opportunities is unequally distributed among the households, geographically, as well as socially. The intensity of labour required to sustain a livelihood is highly skewed towards the summer season when labour-intensive cultivation and livestock-related activities culminate, and also most non-farm income opportunities are available.

The high peak labour demand and unreliability of non-farm income entail the need for livelihood diversification and thus a trend to larger households. On the other hand, local people consider education as only viable means to escape the vulnerability inherent to these livelihoods fostering the family ideal of smaller households, able to invest in quality education of few children. This contradiction leads to a concentration of larger households in the midrange of the poverty-wealth continuum. While joint households exhibit the qualities of larger households regarding managing insecurity and to diversity, the trend over the past decades has been towards splitting household into nuclear family units as an effect of socio-cultural changes. The research area has been subject to rapid social, cultural and economic change in course of modernization over the past decades (Polzer and Schmidt, 2000), however, change is not a recent phenomena of this area with its turbulent history. While the past decades have generally increased the well-being of local people, livelihood vulnerability and the importance of common pool resources is still high. Combined mountain agriculture as the mainstay of livelihoods in the research area is inherently dependent on common pool resources. Livelihood vulnerability may have changed in quality with a higher reliance of households on the market economy, both, in terms of income opportunities and provision of basic needs. The threat to livelihood assets by natural disasters is believed to have persisted.

To date, reciprocal community support mechanisms are said to be as important to local people as in the past. To some extent they may have even gained importance as joint family systems have been abandoned.

Income Inequality is increasing in the research area. Apart from existing inequalities regarding household’s natural assets, it can be attributed to the unequal distribution of non-farm income opportunities and to the unequal access of households to such opportunities (e.g. mining and tourism sectors).

4.2 Natural resources and their utilization

This section describes the natural resource available and the common resource utilization patterns, based on an understanding of the pressures currently felt in CKNP.

Most practices involving use of common pool resources and regimes span across several different ecoregions (Exhibit 34). This is obvious, e.g., for the summer pasture migration cycle, which makes use of the different and temporally shifting productive potentials of ecosystems in different altitudes. However, this also applies to fuel and fodder harvesting. It implies that simple associations, such as “Forest (resource) → Fuel harvesting (activity) → Regulations (use regime)” and “Pasture (resource) → Grazing (activity) → Pastoral migration/open access (use regime)” are inappropriate for research and management (Flury, 2012).

So, an ecoregion can be subjected to the dual use (as pasture grounds and fuel harvesting areas) and their condition is affected by the interplay of different regimes (summer pasture migration cycles for small ruminants, dairy cattle, and fuel harvesting regulations).

The extent of pressure on these resources depend on a range of interrelated factors related to the landscape, extent and distribution of resource areas and their productivity, resource use patterns, regulations, regimes, composition of livestock, and prevalent fuel-portfolios and demographic variables. Local patterns of resource management vary from valley to valley and are limited by the ecological potential as well as by the rights of access to natural resources (e.g. access to pastures and forests) and local rules.

Consequently, problems, potentials and effective solutions vary greatly and are highly context-specific.

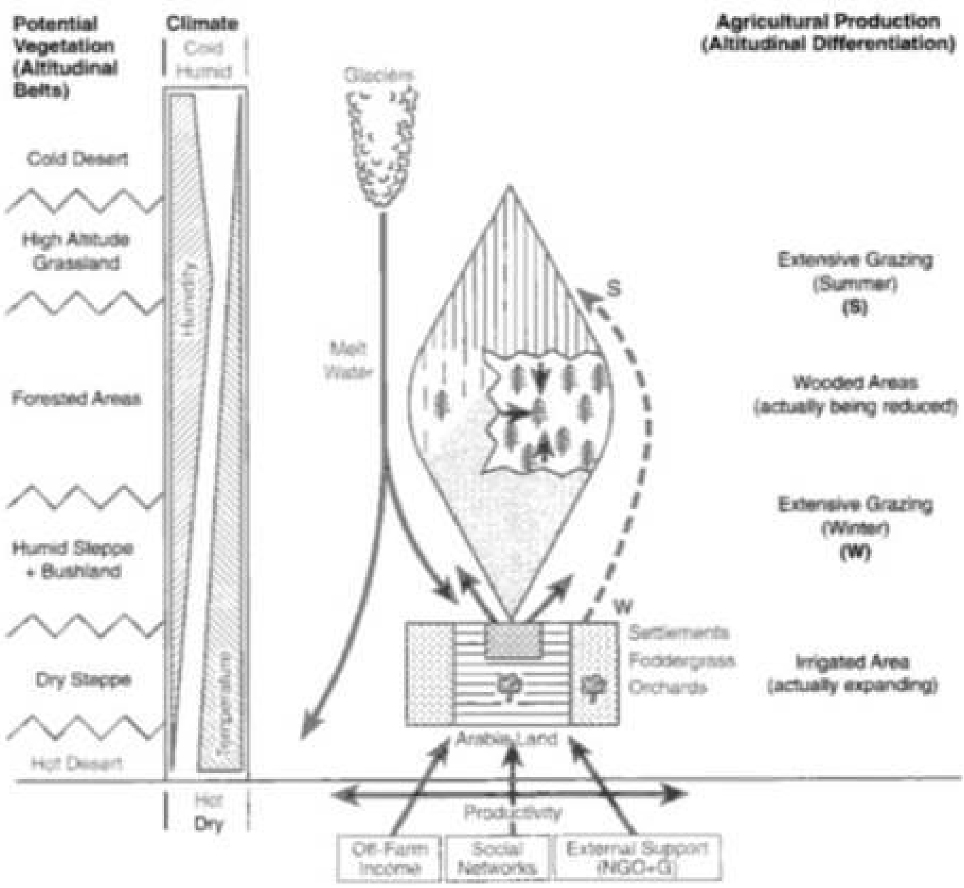


Exhibit 34 Vertical arrangement of natural resources and agricultural productivity. (Ehlers and Kreutzmann, 2000).

4.2.1 Valley – or Village – Conservation Planning, VCCs and VCPs

In this study, Flury (2012) has carried out an analysis to assess the capacity and potential of community-level institutions to play the envisioned role in the CKNP management and planning process with regard to NGO-initiated community-based natural resource management initiatives in order to provide recommendations for the development of a conclusive concept for community participation.

In the 1990s international non-governmental organizations (NGOs) have started with the establishment of Valley and Village Conservation Committees (VCCs) around CKNP area. The initiative was based on Community-based natural resource management (CBNRM) approach, which was first implemented in Africa, and then adapted and applied in CKNP area.

A key objective was the development of community-based trophy hunting programs. A monetary valorization (commodification) of wildlife resources among local communities should encourage protection of key wildlife species of the area and to curtail poaching (Hagler-Bailly, 2005).

Establishment of VCCs
(Valley or Village Conservation Committees)

Approach: Community-Based natural resource management (CBNRM)
Key objective: Community-Based trophy hunting (TH) programs

Key process

- Trophy Hunting programs = funds → other funds for implementation of conservation and rural development projects at community-level according to VCP (Valley or Village Conservation Plan);
- Official ratification by district administration results in the declaration of a community-controlled hunting area (CCHA);
- CCHA is managed by VCC;
- Periodical verification of wildlife population data by NGO and government agencies;
- Government agencies allocate hunting quotas for trophies to VCC;
- Quotas are sold in the open market.

Valley Conservation Planning

Currently, CKNP area borders with one CCHA, in Hushey Valley, Ghanche District. The development of VCCs in valleys surrounding CKNP has mushroomed since the initiation of the first program. In many areas the preconditions for a CCHA are not given and the VCCs are established as a means to foster community-based conservation efforts in its own regard. In the research area, unsettled areas around Askoli and Arandu are considered to have potential for establishment of a trophy hunting program.

WWF (NGO) and CKNP Directorate carry out valley conservation planning processes through:

- **Establishment of VCC;**
- **Development/approval of a VCP**, carried out in the following 4 step process (steps 1 of key process):
  1) Participatory resource need assessment with VCC (RNA), resulting in a report, → standard structure
  2) Participatory valley conservation planning with VCC (PCP), → table of results of thematic areas
  3) VCP drafting and review with VCC, resulting in a draft VCC,
  4) VCP submission and approval by the district administration. → elaboration of the summary PCP table

Most valley conservation planning processes further include the establishment of a valley conservation fund (VCF) to facilitate initiation of conservation projects and activities, and, in case of a trophy hunting program a wildlife baseline survey: 3 consecutive seasonal wildlife surveys and notification of the area as CCHA.

Responsibilities mostly assign the lead role to the VCC and technical/financial support to different INGOs, NGOs and government agencies. Claiming to be a successful model for implementation of CBNRM trophy hunting programs have received substantial and controversial attention by different scholars and practicioners.

Since 2009 VCCs have been envisioned to play a role in fostering community participation in the in the framework of CKNP management planning process[6]. Furthermore, VCPs would ideally provide the means for "grassroot"-level planning and implementation within the management process[7]. The aim of the research was to carry out a preliminary evaluation of the valley conservation planning processes in the research area with regard to these envisioned functions. The findings do not claim to be representative for all valley conservation processes relevant to CKNP, but may shed light on some general opportunities and shortcomings for further, systematic, evaluation. Consideration was given to the fact that the processes are in different stages of progress.

Valley Conservation Committees

A significant factor influencing participation in the process seems to be the condition and effectiveness of the Local Support Organizations (LSOs) in the area (established by AKRSP). VCCs lack a clear structure rooting the valley level-process in municipality governance and communal NRM. LSOs on the other hand have an explicit link to the municipality-level through the definition or development of village organizations (VO) and their integration into the LSO at the Union Council-level.

LSOs and VCCs should be supported for integration into integrated conservation and development bodies (ICDB). This would allow the community-organization process for CKNP management to:

i) <u>Institutionalize an integrated conservation and development approach at the community-level.</u>
CBRNM initiatives generally struggle with the creation of incentives for conservation efforts. Especially VCCs without the trophy hunting programs, which were initially conceived as providing incentives for conservation efforts, lack such means. LSOs are created with the aim to allocate and implement development projects at community-level. An ICDB would allow communities to link conservation and development initiatives, e.g by establishing social and environmental criteria for allocation of projects to municipalities whereby creating incentives for conservation efforts. The benefits of many rural development-projects exceed the boundaries of municipalities, especially in the health and education sector, as well as larger infrastructural projects. In contrast, NRM is largely considered to be strictly a municipality-affair. Such a linkage would therefore also foster coordination of conservation activities at the valley level.

ii) <u>Increase effectiveness of project implementation</u>
LSOs feature a trained administration and transparent project implementation and monitoring mechanisms. Drawing on this capacity for conservation-related activities could substantially increase their efficiency and effectiveness.

iii) <u>Empowering women and strengthening representation of communities in the CKNP management processes</u>
Although the involvement of women in policy making is generally low or non-existent, within an ICDB, women organizations, established in the framework of the community-organization process for development projects, could provide a means to empower women in policy making for environmental issues.

[6] The HKKH Partnership Project conceptualized the valley conservation planning process as „level 2 management planning", which would be integrated with the „level 1 management planning"-process. The latter includes the development of a management framework, vision statements, zoning, institutional setup, and general regulations in accordance with international agreements, conventions and national legislation.

[7] CKNP Directorate started with implementation of the valley conservation planning processes in the research area in 2010.

Recommendations

CKNP Directorate should support such an integration process, and by nominating functioning ICDBs as community partner organizations for CKNP management, provide them with further official recognition. Already acquired recognitions, e.g. as NGOs (LSOs) or acknowledgement through the district administration (VCCs) would further empower these bodies.

Further, CKNP Directorate should ensure participation of all municipal representatives in key meetings of the conservation planning process and devise a system to provide performance-based incentives for the leading protagonists of the process (see Table 28).

Table 28 Valley Conservation Committees, Local Support Organizations and Communities Partner Organization of CKNP Directorate (CKNP Directorate, Pers Comm.).

DISTRICT/VALLEY	**CBO NAME**	**WWF** Functions as Valley Conservation Committee (VCC)	**AKRSP** Functions as Local Support Organization (LSO)	**CKNP** Established as Communities Partner Organization of CKNP Directorate
GILGIT				
HARAMOSH	Haramosh Development Organization (HDO)	VCC	LSO	yes
BAGROTE (including ALALABAD,BATKOR,CHAMOGARH)	Dobani Development Organization (DDO)	VCC	LSO	yes
DANYORE (SULTANABAD to be included)	Local Support Organization Danyore (LSO Danyore)	-	-	not yet
RAHIMABAD (JUGLOTE AND JUTAL to be included)	Rahimabad Conservation and Development Organization	VCC	-	not yet
HUNZA-NAGAR				
SIKANDERABAD	Akbar Development Organization (ADO)	VCC In Progress	-	yes
NAGAR (I&II)	Nonihal Development Organization (NDO)	-	LSO	yes
RAKAPOSHI (SAS Valley and Gulmit, Minapin, Pisan)	Rakaposhi Development Organization (RDO)	VCC	-	not yet
RAKAPOSHI (SAS Valley and Gulmit, Minapin, Pisan)	Local Support Organization Rakaposhi (LSO Rakaposhi)	-	LSO	not yet
HOPER	Hoper Conservation and Development Organization (HCDO)	VCC	-	not yet
HISPER	Falahi Tenzeem Bray Tahafuz Qudrati Wasail	VCC	-	not yet
SKARDU				
NAR GORO (CCHA in progress)	Social Welfare Association Nar-Goro	VCC	-	not yet
TISSAR	Local Support Organization Tissar (LSO Tissar)	-	LSO in progress	not yet
BASHA	Local Support Organization Basha (LSO Basha)	VCC	LSO	in progress
LOWER BRALDO	Local Support Organization Lower Braldo	VCC in progress	LSO	in progress

DISTRICT/VALLEY	**CBO NAME**	**WWF** Functions as Valley Conservation Committee (VCC)	**AKRSP** Functions as Local Support Organization (LSO)	**CKNP** Established as Communities Partner Organization of CKNP Directorate
	(LSO Lower Braldo)			
UPPER BRALDO	Local Support Organization Upper Braldo (LSO Upper Braldo)	VCC In Progress	LSO	not yet
ARANDU	Arandu Conservation Committee	-	-	Village Conservation Committee
BAGICHA & KHOMERA (RONDU)	Agha Welfare Organization Baghicha-Kumera	VCC	-	not yet
TORMIK	Valley Conservation Committee Tormik	VCC	-	in progress
ASTAK	Jamsheed Welfare Organization Astak	VCC	-	not yet
SKARDU - Shigar				
MARAPI	Local Support Organization Marapi (LSO Marapi)	VCC	LSO	yes
MARKUNJA	Shigar Town Management Development Society	VCC	LSO in progress	not yet
ALCHORI	Alchori Conservation Committee	VCC	-	not yet
CHURKA	Valley Conservation Committee Churka	VCC	-	not yet
WAZIRPUR	Valley Conservation Committee Wazirpur	VCC	-	not yet
GHANCHE				
HUSHEY	Village Conservation Committee Hushey	VCC	-	yes
KANDAY	Wildlife Conservation Welfare Committee Kanday	VCC	-	yes
KERIS	Valley Conservation Committee Keris	VCC	-	not yet
THALLEY	Local Support Organization Thalley (LSO Thalley)	VCC	-	not yet
DAGHONI-BALGAR	Local Support Organization Daghoni & Balgar (LSO Daghoni & Balgar)	VCC	LSO	not yet

Valley Conservation Plans

VCPs provide a good account of the general situation in the valley regarding potentials for development and valuation of ecosystem services, general environmental problems in the area. They report in detail on the prevalent flora and fauna. provide an overview of the needs of the local population and suggest development and conservation projects and initiatives.

However, they have the following fundamental structural weaknesses:

Internal consistency: The relation between "Problems" and "Solutions" is not elaborated. The internal consistency between the summary table of the PCP, planning narrative and the subsequent action plan is weak: The action plan. "Activities" of the action plan are not clearly related to the narrative section and include outputs as well.

Conceptual clarity: The plan does not have an overall vision, goal, objectives, intended change or impacts. "Solutions" include partly outputs, seldom results, in few instances approaches, mostly activities or normative statements. "Strategies" include outputs and activities. "Targets" in the action plan correspond largely to outputs, but sometimes include a specification of the activities, or describe results.

Clear timeframe and responsibilities: The temporal disaggregation of the action plan is annual. Activities are not scheduled in a timeline that shows temporal and conditional relations.

Commitments, indicators and monitoring mechanisms: The plans do not include any indicators to evaluate achievement of results, whatsoever. "Support" for activities through NGOs and government agencies is not specified. The lack of indicators, ambiguity of results and responsibilities does not allow for a monitoring of performance or change.

Required resources: The plans do not specify the human, financial, technical, and institutional resources required for implementation. It does mention generic small-scale projects, which are suggested to support its implementation, but relate them only vaguely to results. Due to the lack of indicators, the size, cost, and location of these projects remains undefined.

Recommendations

It is strongly advised to revise and amend the VCPs according to a tested and universally acknowledged planning instrument, such as the logical framework approach, for example, if they are to fulfill their function as a instrument for grass-root planning and implementation within the CKNP management process[8].

Despite these weaknesses the valley conservation planning process remains a valuable and important part of the CKNP management planning and implementation process, in terms of participation of local communities.

[8] The need for „measurable goals“ and „monitoring of effectiveness“ was highlighet by a review carried out by Shackleton (2001).

4.2.2 Agricultural fields, Pasture and Livestock

Introduction

The land ownership system of the natural resources is a mix between state-claimed ownership, community and household uses rights that was established with a mix of traditional customs, legislation, legal practices and ongoing informal appropriation.

An analysis about this matter was conducted by Steinsholt and colleagues (1998), which concerns the Basho valley (Skardu District), but main findings can be extended to the whole CKNP's area.

- As general rule, and according to local informants, we could assume that the areas below the water channels are privately owned and areas above water channels are under Governmental jurisdiction.
- Cultivated land is, generally, individually owned, and pastures are village commons. Rights to the utilization of pastures are collectively conferred on entire villages and are not confined to kinship groups.
- For mountain farmers animal husbandry still plays an important role in the agro-pastoral economy: it guarantees different products, gives the possibility to sell some heads if there are special needs for cash, and keeping a large number of animals assures a social status inside the community.
- The seasonal use of the pastures through the year follow the altitudinal gradient of the vegetation availability, and it also depends from the herd characteristics (e.g., see Exhibit 35). It also seems that the forages present in these arid areas assure a high quality only during the early vegetation stages, declining as forage mature (Seim and Holand, 1999).
- In general the sheep and goats herds are guarded during the day, while lactating cows are unguarded during the day, but both the groups are kept in pens for the night. Yak, male cattle, dry cattle and crossbreeding (yak-cattle) are free ranging from early spring to late autumn.

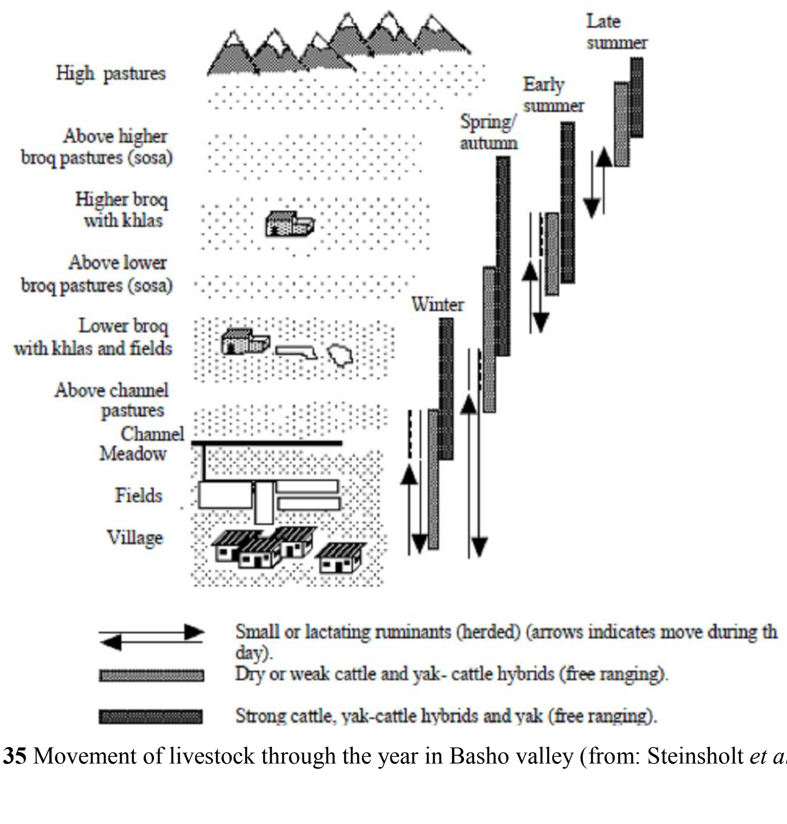


Exhibit 35 Movement of livestock through the year in Basho valley (from: Steinsholt *et al.*, 1998)

Agricultural fields and Farming

Field data

An analysis of agricultural fields and farming has been conducted as part of the field research on “Livelihoods and Natural resources management in the CKNP area”, carried out in the framework of SEED project (Flury, 2012), in Basha and Braldo Valleys (see Section 4.1 for details on research area).
Subsequently, data referred to the survey are reported and general considerations, reliable for the whole CKNP, are derived.

Description and main findings

- The average arable land property per household in Dassu Union Council, and the lower-lying villages of Basha Union Council, ranges between 0.25 to 0.5 acres with the exception of the village “Foljo”, which has substantial arable land. Households located in villages of the transitional or single cropping zones at higher altitudes in Basha and Braldo Union Councils own on average 1.3 to 2 acres of arable land, while in some villages of Braldo Union Council average land holdings per household can be as high as 3.7 to 5 acres. Hidden behind these average figures are variations between marginal arable land holdings and properties ranging between 5 to 10 acres. On the other hand, landless households are rare. Their number ranges from a couple to 5 families to maximum 10-12% of the households in a community.

The key environmental factors limiting the extent to which agriculture can be carried out in the arid valleys of the research area are irrigation, altitude, topography and vegetative characteristics. Cropping and fruit production is generally carried out on irrigated land, which is formally and informally acknowledged as household property.

- All households of the research area cultivate grains, predominantly wheat and/or barely and buckwheat, often with legumes as catch crop, households maintain commonly a varying number of agro-forestry trees – poplar, willow and russian olive, and on average 5 - 10 fruit trees, except households of some villages in Braldo Union Council, which cultivate only few, if any, fruit trees.

Given the scarcity of arable land, households prefer to cultivate their own land themselves, if required by means of informal reciprocal labour arrangements. However, permanent out-migration often entails sharecropping-arrangements with community members for the arable land left behind.

- Notwithstanding the general food deficit in the research area, some households manage to produce a surplus in the form of peas, fruits, nuts, buckwheat, or potatoes - the latter is cultivated predominantly as a cash crop - which is sold in the district capital Skardu or to local middlemen. Surplus wheat, the predominant staple of the research area, is only sold or traded among the households of the community.

Over the past decades, population growth and splitting of households, formerly managed predominantly in joint-family systems, has led to a reduction of average arable landholding available to households as well as its defragmentation. Currently subsistence production is barely able to meet the households’ food requirements for the entire year. The extent to which subsistence production falls short of the requirements depends on individual factors, however, on average, food supply makes up 50 to 80% of the households’ annual cash expenses. The percentage correlates inversely proportional with land and livestock holdings - a universal criterion for poverty and wealth throughout the research area. The lean period falls into spring to early summer until the first crops are harvested.

Pasture and livestock

Information from bibliography

In this section main results of two researches, concerning some aspects of pasture and livestock (Kreutzmann, 2004; ICIMOD and The Macaulay Institute, 2005) are reported. The main concepts can be considered reliable for the whole CKNP.

A first study from Hunza valley was carried out by Kreutzmann (2004) which illustrates the dynamics and changing importance of animal husbandry in non-stationary practices and highlights societal and agro-pastoral variations overtime and space.
For the scope of this study, the following three classes/categories are introduced which are linked to the utilization of high mountain pastures by distinguishing mobility patterns, socio-economic organization and property rights (Exhibit 36):

i) Mountain Nomadism

In mountain nomadism, nomadic economy and labour activities are predominantly based on animal husbandry. Mixed herds are composed of sheep and goats, cattle/yaks for livestock production and camels, horses and donkeys mainly for transport of tents, household goods and utensils. The whole group covers great distances between lowlands and highlands during their seasonal migrations towards suitable and accessible pastures. The mobile communities show strong kinship relations. As a rule they distinguish themselves from their neighbours and business partners as a social group of livestock proprietors and traders. Nomads utilise pastures to which they claim rights of access based on customary law; nevertheless grazing taxes are levied and paid to the state or private individuals. Such are the business relations regarding pastures, in addition to barter trade with farmers for basic goods, such as grain. Traditionally, mountain nomads have engaged only in very few side activities beyond animal husbandry such as transportation, trade, services and other commercial activities, and crop cultivation was not a practice attributed to them. The absence of permanent settlements and village lands resulted in a mobile society of which movable property, including tents and yurts, was characteristic and provided shelter in the grazing grounds.
Both traditions have changed quite drastically in all these societies in recent years. Planned and forced sedentarisation of nomads, the introduction of permanent winter camps, agrarian reforms and general socio-economic change have resulted in adjusted and comparatively confined migration cycles. All factors have contributed to a controlled mobility with features of permanency, such as houses and stables in a community settlement. The expansion of crop cultivation and village lands, the reduction of available space and the progression of bureaucracy have limited the rangelands and pastures accessible to nomads. Territorial, political and private delineation of boundaries has increased the phenomenon of nomadism executed under 'closed frontier' conditions (Shahrani, 1979).

ii) Transhumance

The term 'transhumance' has gained many connotations and global applications in recent years. Sometimes it is used in a wide sense, synonymous with pastoralism and nomadism; sometimes it describes pastoral practices linked to certain ethnic groups, while a narrow interpretation with a focus on flocks prevails in non-English language usage (Blache, 1933; Rinschede, 1979, 1988).
Transhumance involves seasonal migrations of herds (sheep and goats, cattle) between summer pastures in the mountains and winter pastures in the lowlands. In contrast to mountain nomadism the shepherds of a migrating team are not necessarily so strongly affiliated with one another as to form a group of relatives managing their own resources. They serve as wage labourers hired by the livestock proprietors on a permanent basis. As a rule, they are neither related to them, nor do they have livestock of their own. The proprietors of the flocks can be farmers or non-agrarian entrepreneurs. In terms of management, the year-round migration between suitable grazing grounds is independent of other economic activities of the proprietors. In cases where they are farmers, their farm management and agricultural activities are not related to their livestock breeding. Nevertheless, sometimes proprietor farmers provide shelter and grazing on their fields after harvest or on meadows. Usually common property pastures are used in the mountains, while customary rights or contracts with residents in the lowlands establish the winter grazing conditions. Shepherds live in mobile shelters (tents, carts etc.) or in permanent houses provided for them.

Transhumance of this kind is found in mountainous regions on all continents (Rinschede, 1988), and there is no general trend of decline observable, although its share in pastoralism varies widely.

iii) Combined Mountain Agriculture

The example of the Hindukush-Karakorum-Himalaya region shows that not only can herd sizes be increased by incorporating high pastures into the domestic economy, but simultaneously the quality of natural grazing in the high pastures has been estimated as between twice and four times that in the lower zones of the arid mountain valleys (Sheikh and Khan, 1982; Streefland et al., 1995). On the one hand agricultural production in the homestead is strongly linked to the livestock sector by growing grass and storing hay for the winter provision of fodder. During the winter period the flocks are kept in stables or out in the open close to the permanent dwellings of the mountain farmers. The shepherds are traditionally members of the extended family, although in recent years a tendency to employ hired professional labourers can be observed. With growing job opportunities it becomes more difficult for mountain farming households to provide the manpower, especially during the summer season when the agricultural workload is high and other financially lucrative employment might be available. Thus it is fairly common for households to pool their livestock and send their herds with a trusted person or hired professional to the summer pastures, which are mainly common lands.

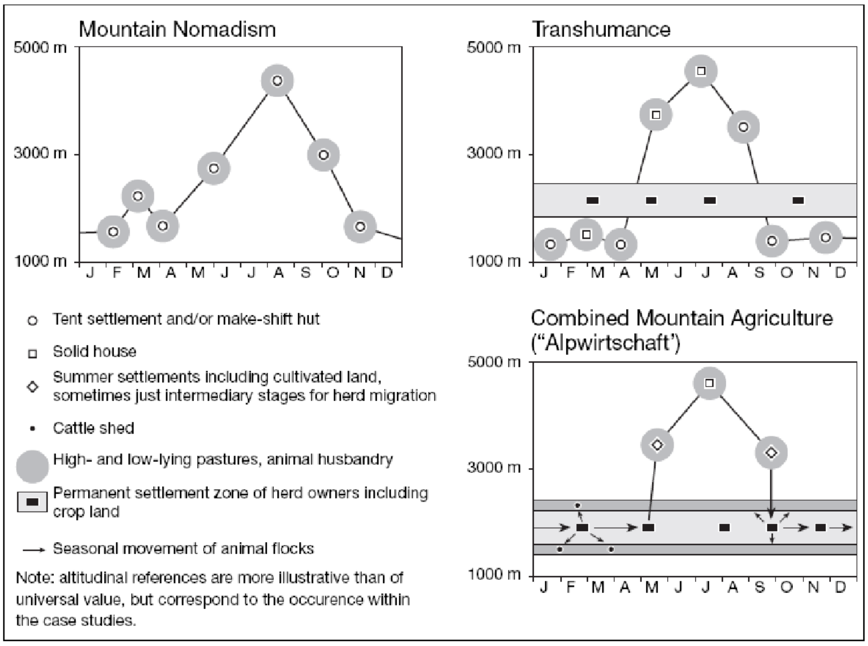


Exhibit 36 Time-Space diagram for different types of pastures utilization in High Mountain Regions (Kreutzmann, 2004).

All three practices mentioned above are to be found in the northwestern Karakorum mountains although it seems nowadays that combined mountain agriculture has replaced mountain nomadism and transhumance.

Generally, changes in political conditions over time and subsequent socio-economic transformation have affected all walks of life in the Hunza valley as in the whole CKNP's area; in particular, in the research area, Kreutzmann identified changes in the following aspects:

i) The importance of animal husbandry;
ii) The availability and division of labour;
iii) The contribution of the livestock sector to present-day income.

A second survey on pastures and livestock, referred to the Gilgit Baltistan, was carried out by ICIMOD and the Macaulay Institute (2005) in the framework of the Agri-Karakorum Project.

The aim of the this study was to examine the influence of infrastructural change on livestock management.

The study was conducted in villages from two geographical transects, differing in ease of access, and from three agro-ecological zones. The Karakorum Highway transect (KKH) ran along the Karakorum Highway and benefited from the associated improvements in infrastructure. The Gilgit-Ghizer Region transect (GGR) was mainly served by unmetalled roads with a less-developed communication infrastructure.

The project focused on:

i) Livestock production and nutrition.

The results showed that among the major stored feeds, wheat straw was used in highest quantity, followed by alfalfa, maize stovers, and wild grass. Overall, the average liveweight and body condition scores were highest in late summer and then declined, reaching the lowest levels in February. The summer maxima were higher in the GGR transect than in the KKH transect. The households in the GGR transect kept more livestock, but the amount of feed resources stored for use over winter relative to herd requirements for maintenance were significantly lower than in the KKH transect. In winter, livestock in the GGR transect lost liveweight and body condition faster than in the KKH transect. Also, average milk production per mature adult cow was greater, and reproductive efficiency higher, in the KKH than in the GGR transect. The amount of fodder sold was significantly higher in the GGR than in the KKH transect.

ii) Pasture resource utilization

The pasture ecology component of the project emphasised the important role that pastoral resources play in the overall livestock enterprise. Until now there has been little information available on the nature of the pasture resources and the extent to which they are over- or under-utilised. The project classified the vegetation communities present in the Gilgit Baltistan for the first time. Pasture productivity was found to be low on foothill rangelands, intermediate on dry-temperate pastures, and high on alpine pastures. There was also a change in vegetation type from predominantly shrub-based vegetation on foothill and drytemperate pastures to a vegetation resource dominated by grasses and forbs on alpine pastures. Seasonal data on pasture utilisation indicated that production and utilisation were reasonably well-matched on alpine pastures, but that a potential biomass surplus existed on dry-temperate pastures in spring. The utilisation of alpine pastures appeared to be lower in the KKH transect than in the GGR transect, suggesting that more animals could be grazed on the KKH pastures. Quantitative data on the seasonal availability of biomass for utilization by livestock will help to inform decisions about potential changes to patterns of pasture management. Such information is particularly important with current changes in traditional patterns of transhumance which are being driven by external changes such as improved infrastructure, and educational and off-farm employment opportunities.

iii) Socio-economic aspects of livestock production

The final component of the project addressed socioeconomic and external issues surrounding livestock production in the Gilgit Baltistan. An important focus of this part of the research was on farmers' perceptions of opportunities and constraints in the livestock subsector. The results showed that farmers keep livestock for a number of reasons with milk and dung production being high among their priorities.

In synthesis, livestock production remains a very important component of the household economy. Infrastructural development appears to have improved opportunities for non-livestock related activities.

Field data

Several surveys on pastures and livestock in CKNP were carried out in the framework of SEED Project Subsequently, we report the data and the main findings of three studies conducted, respectively, i) by WWF-Pakistan ("Pasture and Pastoralism in Central Karakurum National Park", 2011), ii) Flury ("Livelihoods and Natural resources management in the CKNP area", 2012) and iii) Ev-K2-CNR (unpublished data). Each survey is presented as a "case-study": data are referred to the specific survey, while main results can be considered reliable for the whole CKNP.

Description and main findings

i) Case-study of 23 selected Valleys of CKNP (WWF-Pakistan, 2011)

WWF-Pakistan (2011) carried out a study which tried to understand the current livestock trends, management practices and their impact on pastures and the prey-predator interface in the context of CKNP valleys. To investigate these objectives, a total of 23 valleys were selected, on the basis of the level of stake, livestock population, nature and extent of depredation in CKNP resources.

Livestock

The current study covered an average of 39% of the CKNP villages in the districts encompassed by the Park and identified a population of 0,42 million domestic animals (Table 29). Among this population, goat is the dominant type, followed by sheeps, cows and yaks (including crossbreeds).

Table 29 Districts estimated livestock population

DISTRICT	Number of valleys	YAK and YAK crossbreedings	COW	SHEEP	GOAT	HORSE	DONKEY	TOTAL
Skardu	11	30389	60987	87340	79991	573	837	**260117**
Ganche	3	2318	4062	17638	15440	107	643	**40208**
Gilgit	3	1445	15920	21650	45040	149	1496	**85700**
Nagar	6	1278	7466	15274	11330	2	464	**35814**
Total	**23**	**35430**	**88435**	**141902**	**151801**	**831**	**3440**	**421839**
		8,4%	**21%**	**33,6%**	**36%**	**0,2%**	**0,8%**	

The number and type of species of domestic animals reared are correlated with the expanse of the grazing areas and local climatic conditions. As environmental conditions, climate and altitude vary widely; therefore, the preferred animals would be the small ruminants, yaks and their crossbreeds. For that reason, goats represent the largest number of animals kept by the households and then sheep because they are very well adjusted to graze on scarcely growing fodder on Karakorum mountains.

Pastures

In Gilgit-Baltistan, alpine and sub-alpine pastures are two major categories of land use. The extent and the spread of this resource are much more compared with other renewable natural resource in the area. These pastures are not only located in alpine and sub-alpine zones, but also spread in the scattered stands of natural forest. In general, these intermediate pastures are the result of deforestation over the past. The alpine pastures are covered with snow from early winter to late spring. The animals graze these lands as and when the snow melts, in this way, the grazing pressure is gradually shifted to higher altitude pasture

Main findings

- On average, 90 % of the total livestock is grazed in high pastures from June to end of August while in spring and autumn, these animals are grazed free in catchments near villages/ settlements. Rest of the 10% can be young under two years and lactating cows and goats are kept in the village almost throughout the year to meet the households' dairy requirements.
- Transhumance is the seasonal movement of people with their livestock over relatively short distances, typically to higher pastures in summer and to lower valleys in winter. Herders have a permanent home in valleys. Only the herds travel, with the people necessary to tend them. There are defined customary laws for seasonal movement of livestock to the pastures throughout the entire region. These laws define the

timing for seasonal movement of animals and determine pastures for utilisation by the different livestock types.

- Pastures can be classified into three categories equally applicable throughout Gilgit-Baltistan, namely spring pastures, summer pastures and winter pastures. Winter and spring pastures are same in terms of geographic location, located in the vicinity of the respective villages and grazing rights are owned by the closest village. The summer pastures are located above 3000 m a.s.l where, livestock are grazed from June to September and animals are tended by family members or grouped and given to people specialized over the generations to collect animals from one or more villages and keep them in pastures for the whole summer season (Exhibit 37 and Table 30). In summer pastures, sheep and non-lactating goats are allowed to graze freely with no or little attention while, lactating cattle and goats are attended by the owners or shepherds.

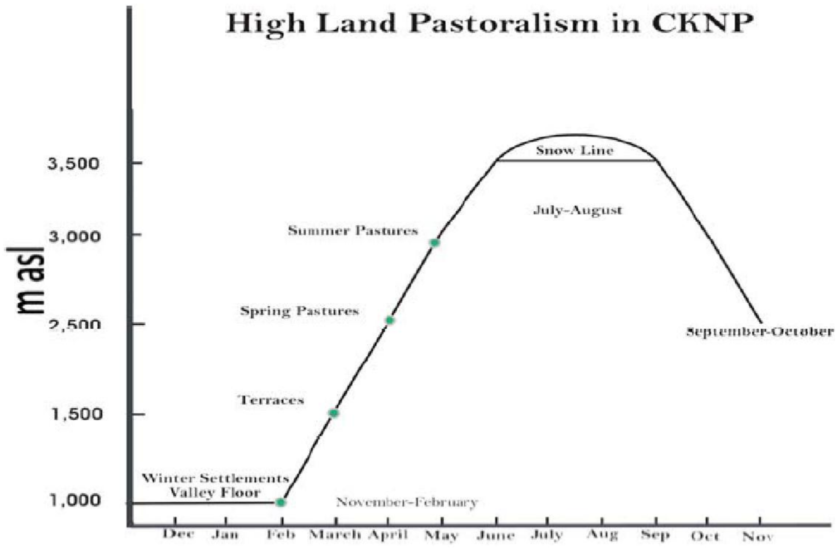


Exhibit 37 Seasonal movement of livestock to the pastures in CKNP valleys.

Table 30 Information on livestock movement

S.#	Valley	Transitional pastures	Spring pastures	Summer pastures
1	Upper Braldo	March-April	May-June	July-October
2	Lower Braldo	March-May	June-July	August-November
3	Basha	March-April	May-July	August-October
4	Wazirpur	March-May	June-July	August-September 20
5	Markunja	March-May	June-July	August-September 20
6	Marapi	March-May	June-October	June-October
7	Stak	November-April	May-June	August-October
8	Tormic	March-April 15	April 15-June	July-October
9	Bagicha	February-April	May-July	August-October
10	Khomra	February-May	June-July 15	July 15-October 30
11	Nar	April-May	June-July	August-October
12	Keris-Gone	April-May 20	May 21- June 15	June 15-September 15
13	Thalay	April-June 15	June 15-July 15	July 15-September 30
14	Hushey	May-June	July-August	July-September

- Access to natural resources is a crucial element of mountain farming, which is characterized by the seasonal utilization of different ecotopes. Seasonal pastoral migration, as well as daily grazing on the pasture settlements, covers a variety of pasture ecotopes. Besides grazing, firewood for the settlements are collected from the surrounding natural forests.
- The local trends of utilising natural resources throughout the region is identical in general, however, the extent of exploitation and management patterns vary from valley to valley. The rights of access to pastures and natural forests are also same throughout the four districts of CKNP. Pastures are village commons. Under the Forest Act 1927, concessionary rights are granted to the communities inhabited in the same watershed for collective utilisation of forests and pasture resources and are not confined to kinship groups, except in some exceptional cases. Generally, the areas covering grazing rights and forest utilisation are mostly delimited by natural boundaries,(i.e., rivers or ridges).

ii) Case-study of Braldo and Basha Valleys (Flury, 2012)

The survey carried out by Flury (2012) focused also on natural resource use of Braldo and Basha valleys. Subsequently considerations about livestock and use of pastures (grazing) are discussed.

Livestock

Livestock is composed primarily of goats and sheep, cattle, and crossbreeds between cow and yak, and in higher areas yaks. Unlike the female crossbreeds, the males are sterile (the term “cattle” as used in the following shall include yaks and crossbreeds between yak and cattle as well).

In the research area, the size of a household’s livestock in the research area can vary greatly. Households in Dassu and Basha Union Councils own on average between 8 and 15, and in Braldo Union Council 20 to 25 small ruminants. An average of 10 to 15 cattle per household is common throughout the entire research area. However, these numbers can very greatly between households, and also between different villages of the same area.

Livestock rearing relies to a large extent on common property resources and is subject to communal institutions and use-right-regulations and mechanisms.

In the framework of combined mountain agriculture, the alpine pastures constitute a key resource for animal farming and are rendered productive by communal herding mechanisms employing multi-stage migration patterns between summer pasture settlements - “Alms” - at different altitudes during the summer months. This practice also spatially separates the livestock from the valuable crops cultivated in and around the settlements in summer, preventing conflicts between grazing animals and growing crops.

The different migration cycles and herding practices are motivated by different functions these animals fulfill within livelihoods, and their own nature. Until recently, male bovines were used for threshing and had to be rounded up and brought down to the homestead before end of the summer season. Yaks are considered to be well adapted to rough and steep terrain, as found in high altitudes and therefore able to migrate to higher situated areas. Dairy cattle are held for milk production and have to be tended to daily for milking, while small ruminants are able to feed on different vegetation in areas not easily accessible for cattle.

Key limiting factors for the size of livestock at these levels are general features of the summer pastures under management of the community, predation through wildlife, diseases, and the scarcity of available fodder during the lean season, which starts in late autumn with the return of the animals to the settlement and peaks in April and May before the start of the next summer pasturing cycle. During this time all animals except yaks are fed in and around the settlement by any means available to the households in an attempt to minimize the impact of the lean period on the animals’ health. During this time, the diet includes grazing on the harvested fields, river marshes, and shrubs near the village, hay, leaf litter, and dried fruits of low quality. Common strategies to cope with the acute fodder shortage during the lean season are reducing livestock sizes by slaughtering and selling animals in autumn, purchasing fodder, and to put animals in the temporary care of households living in areas where fodder shortage is less prevalent.

Pastures

Pasture are subject to grazing by different categories of livestock. The different migration cycles and herding practices are motivated by different functions these animals fulfill within livelihoods, and their own nature. In table 31 (Flury, 2012) are reported the natural resource use practices, regimes and involved ecoregions.

The main regime regulating resource use is the seasonal pasture migration cycle which commonly regulate use activities in the artemisia steppe and intermediate and high pastures. Unregulated are grazing activities (mainly small ruminants) during the winter season affecting artemisia steppe and riverbanks, and to a large extent fodder collection activities in intermediate and higher pasture areas and summer to year-round grazing of non-dairy cattle and yaks in intermediate and higher pasture areas.

Subsequently each practice is analyzed.

Table 31 Natural resource use (grazing): use practices, regime and involved areas (from Flury, 2012, modified)

Use	Practice	Artemisia Steppe	Riverbanks	Intermediate Pastures with forest	High Pastures	Main Actors	Regime
Grazing	**Winter grazing**	Not regulated	Not regulated	NA	NA	Household	NA
	Fodder harvesting	NA	Not regulated	Not regulated	Not regulated	Household	NA
	Summer grazing of small ruminants	Managed	Managed	Managed	Managed	Collective (noress)	Pasture migration
	Summer grazing of dairy cattle	NA	NA	Managed	Managed	Collective (baress), Bjon	Pasture migration
	Summer grazing of non-dairy cattle	NA	NA	Designated areas	Designate d areas	NA	NA

Summer Grazing of small ruminants and dairy cattle

The key regime regulating the use of pasture resources in the summer season, between March/April and October/November, is the pasture migration cycle - a collectively managed seasonal migration pattern of livestock across communal areas situated in higher altitude to ensure optimal use of temporally shifted productive potentials of resource areas for livestock rearing within an annual cycle. It is a key component of the combined mountain agriculture and found to be practiced by all surveyed communities. The collective management is carried out by households of a management unit through noress and baress[9] and is coordinated by the lorapa[10].

Small ruminants and dairy cattle commonly follow different migration patterns, although the herds may converge at certain stages in the cycle. The pasture migration cycle is well adapted to the local conditions, however, as regimes regimes they possess little adaptive capacity. Being unique they are also strict in their spatial and temporal patterns and have changed little, if at all over the past decades. Although the temporal sequence within the cycles may vary slightly between years according to climatic variations, arrival and departure dates of livestock at the stages vary only within a period of days.

The general direction of migration takes place along an altitudinal gradient. Caused by increasing and decreasing levels of solar radiation between spring and autumn in the northern hemisphere, peaking at the summer solstice, areas located in increasingly higher altitudes become snow-free and covered by vegetation,

[9] *Ress* is a customary mechanisms of rotational duty assignment among the households entitled to benefits on a common pool resource within a system of collective action. In particular noress and baress are referred to herding of small ruminants and cattle in summer pastures (Flury, 2012).

[10] The local institution of *lorapa* is mandated by the governance system to monitor the implementation of natural resource management regimes and sanction non-compliance with regulations and duties as issued by the local governance system (Flury, 2012).

fed through snow- and glacier-melt water. The maximum extent of snow-free and vegetated areas is reached between July and August. The vegetative period and extent of vegetation that develops in these areas is influenced by many factors, first and foremost, by aspect, slope, soil, and hydrological features and regimes. Additionally, not all areas, which are potentially productive for livestock rearing are accessible. Therefore, the migration pattern is seldom a simple up- and downward movement, but a complex spatial rotational pattern across multiple altitudinal stages and horizontal dislocations between areas that figure grazing potentials. The complexity of the migration commonly increases as the season progresses and higher-laying areas become accessibly, starting with daily migration of livestock from the homesteads to pastures located closer to the settlement, and feature permanent stays in higher areas, migrating between stages (brangsa) during the peak season.

Every stage features accommodation facilities for the herders, and summer settlements, where dairy cattle is reared, also for the dairymen:

In the research area, at stages in the migration cycle of small ruminants these facilities consist of 1 – 3 small huts for overnight stay of the usually 2 herders. Stages in the migration cycle of dairy cattle are generally fewer, but host larger settlements consisting of 8-20 huts, corrals, sheds and are sometimes surrounded by agricultural fields for subsistence production. These summer settlements (khlas), are permanently inhabited by the dairymen and their families for the scheduled duration of stay at the stages, and are assisted by baresspong visiting within the rotational baress-system. Arable land in the khlas is commonly de jure private property of households or clans and as such registered in the settlement records, however, it is in many cases used collectively and according to regulations regarding cropping pattern and crops to be cultivated, which seem to be practices dating back to early times.

During the peak summer season, dairy cattle is cared for by dairymen (bjonpong), residing in, and moving between the khlas within the dairy-cattle pasture migration cycle. Milk is immediately processed to butter for longer storage life. It is common practice of households in areas with lower number of dairy-cattle, to give their animals in the care of a bjonpa for the duration the summer season against remuneration, which is predefined by community regulations and only in rare instances subject to free bilateral agreements between the animal owner and dairymen. It commonly involves the bjonpa to provide a share of the butter he produced to the respective cattle owner. In return the bjonpa may be provided with food supplies prior to his ascent to the pastures. Most municipalities in the research area have restricted this practice to cattle-holders belonging to the community, and banned earlier practices, which allowed herding of cattle of households from outside of the municipality.

Summer Grazing of Non-dairy Cattle and Yaks

Male bovines and yaks are commonly shifted less frequently, or remain in the same area throughout the entire summer season, at the end of which they are rounded up and brought to the homesteads. Yaks are left to graze in an area throughout the entire year. Although, these grazing areas are mostly defined they can include, especially for yaks, an extensive territory. Areas grazed by yaks and male bovines are usually different.

Winter Grazing

During winter season, before and after completion of the pasture migration cycle, livestock is reared in and around the settlements. It is herded individually by households or in rokh, and during the peak winter season, it roams freely in lower-laying areas to feed off any available fodder source, including agricultural fields. Cattle often remain in sheds during this time and feeds of different sources.

Fodder Collection

Fodder collected from pasture areas in the summer season and households' fodder resources from agriculture and agro-forestry play a major role in bringing cattle during through the winter season. The ability to feed livestock during winter is the key factor limiting the size of livestock and households use whatever means available to them to ensure survival of their livestock during this time. The scarcity of resources and the

flexibility this situation requires may be an important cause for the lack of regimes regulating grazing in communal resource areas during the winter season.
Although these practices are generally not regulated by common property resource regimes, they are also not open access situation, as the group of users entitled to the resources is defined as resident households of the respective municipality.

iii) Data synthesis of natural resources in Hushey and Thaley valleys

Ev-K2-CNR (unpublished data) carried out a data survey, considering the household level (HHs), of natural resources and their utilization in Hushey Valley (Hushey and Kandey villages) and Thaley Valley (Kashomik and Daltir villages).

Field data and quantification of natural resource

In Table 32 are reported the number of domestic livestock maintained by surveyed CKNP villages, the statement of livestock heads expressed as AUMs and equivalent forage grazed from pastures of research area.

Table 32 Comparative statement of number of livestock heads (A), expressed as AUMs (B) and equivalent forage grazed (C) in surveyed CKNP villages.

A - Number of livestock heads							
	CATTLE						
Village	YAK	COW	DONKEY	**SubTotal**	SHEEP	GOAT	**Total**
Hushey	1,200	480	80	**1,760**	3,000	1,800	**6,560**
Kandey	930	310	90	**1,330**	1,860	1,240	**4,430**
Kashomik	720	180	60	**960**	1,200	900	**3,060**
Daltir	1,750	700	70	**2,520**	2,625	1,750	**6,895**
Total	**4,600**	**1,670**	**300**	**6,750**	**8,685**	**5,680**	**20,945**

B - Number of livestock heads (as AUMs)							
	yak=1.0 AUM	cow=0.8 AUM	donkey=0.7 AUM		sheep=0.2 AUM	goat= 0.2 AUM	
Hushey	12,000	2,304	336	**14,640**	3,600	2,160	**20,400**
Kandey	9,300	1,488	378	**11,166**	2,232	1,488	**14,886**
Kashomik	7,200	864	252	**8,316**	1,440	1,080	**10,836**
Daltir	17,500	3,360	294	**21,154**	3,150	2,100	**26,404**
Total	**46,000**	**8,016**	**1,260**	**55,276**	**10,422**	**6,828**	**72,526**

C - Equivalent Fodder used (Lbs)							
Hushey	10,800,000	2,073,600	302,400	**13,176,000**	3,240,000	648,000	**17,064,000**
Kandey	8,370,000	1,339,200	340,200	**10,049,400**	2,008,800	446,400	**12,504,600**
Kashomik	6,480,000	777,600	226,800	**7,484,400**	1,296,000	324,000	**9,104,400**
Daltir	15,750,000	3,024,000	264,600	**19,038,600**	2,835,000	630,000	**2,503,600**
Total	**41,400,000**	**7,214,400**	**1,134,000**	**49,748,400**	**9,379,800**	**2,048,400**	**41,176,600**

It is assumed that the average pasture areas in Gilgit-Baltistan Region is 30% of the total land based area. The status of pastures in villages like Hushey could be taken above average i.e. say 40%. The assumption is made on the basis of very large number of domestic cattle maintained by villagers as indicated in Table 32 (section A). Reliable requisite information on estimated number of domestic animals seasonally grazed in each pasture of Hushey could not be obtained from community representatives. Community members tended to disagree not only on average number of animals maintained by each house hold but also disputed on number of animals grazed in different pastures. To overcome this situation the total number of animals reported by community has been converted into AUM units (Table 32 - section B) and equivalent quantities of forage consumed from each pasture (Table 32 - section C). These figures though may not give accurate estimates of grazing pressure sustained by respective pastures, but a vague picture of the position can be drawn. The actual position of carrying capacities of the pastures is yet to be assessed under a research program.

Main findings

Use rights

The Hushey community enjoys exclusive grazing rights over pastures located in the sub valley. These pasture have common boundaries with adjoining villages namely; Kandey in the south, Thaley valley in the west and Upper Braldu villages in the north and separated from each other by prominent natural features. Legal status of the grazing rights exercised by the community inside CKNP pastures is questionable. The community is also obliged to adopt rotation grazing practice to induce desired level of regeneration of palatable forage species and increase vegetative cover in pasture areas to reduce soil erosion.

Khasomik and Daltir have common usufruct rights in the pastures.

Local Rules and Regulations

- There are no restrictions on grazing a particular forage species in a pasture;
- Shifting of animal herds from one pasture to another i.e. winter pastures at lower elevations to spring pastures and onward to summer (Alpine and sub-alpine) pastures and back to village at the on-set of winters is regulated by community leadership including VCC by enforcing a fixed date for all families obviously with a view to ensure uniformity and equity in quantity of forage grazed by each household;
- There is no restriction on number of animals reared and grazed in pastures by families;
- Milk animals borrowed from outside the village on rental basis are liable to payment to the Hushey community a fixed amount of grazing fee at flat rate of Pak Rs.40.00 per animal per year;
- Dry animals are grazed in separate valley pastures;
- Rotational grazing is much talked about but seldom practiced;
- Shepherded grazing is not much practiced with the result that predation by Snow leopard and wolf is reported.
- Corals temporarily built in mountain pastures are delicate in structure and often torn apart by predating beasts.

4.2.3 Water resources

CKNP represent the largest source of freshwater for Pakistan (and one of the largest mountain glacial system in the world) with the Siachen, Baltoro and Hispar-Biafo glaciers all originating within the park boundaries. In a mostly dry country that is highly dependent on agriculture, these glaciers are quite literally the life-blood of Pakistan, feeding the Indus and other major river systems. Furthermore, these glaciers are also the key source of water (besides groundwater extraction, to a much lesser extent) for drinking domestic and industrial use and, increasingly for generation of mega-power through hydro-electricity.

Mountain hydrology

Economy of Karakorum is relying upon agriculture, and thus is highly dependent on water availability and irrigation systems (Akhtar et al., 2008). The Indo-Gangetic plain (IGP, including regions of Pakistan, India, Nepal, and Bangladesh) is challenged by increasing food production in line with demand grows ever greater, and any perturbation in agriculture will considerably affect the food systems of the region and increase the vulnerability of the resource-poor population (Aggarwal et al., 2004; Kahlown et al., 2007). The human settlements within CKNP are tightly bound for their survival to agriculture, including wheat and more important sources of food integration (orchards, potato, tomato, Weiers, 1995). Agricultural irrigation in Pakistan rely heavily upon use of groundwater, and most of groundwater recharge is made up by irrigation water losses, with rainfall providing only some 10%. Due to high evapotranspiration (ET) and severe salinity environment under which the irrigated agriculture is practiced, the available water is only marginally sufficient for year round cropping (Sarwar and Perry, 2002; Bhutta and Smedema, 2007).

Water quality

Glaciers and snow deposits are the principal sources of all water in the Gilgit Baltistan. The melted water enters streams, which subsequently feed man-made channels – Kuhls – that bring water into the settlements for agriculture, livestock and domestic requirements.

Given the high quality of the water in the area of CKNP they could be used for many uses, however since very scarce are the information a conservative approach should be used in order to assure the possible biodiversity loss. It is incourage to develop an extended surveillance programme in order to evaluate the consistency of the biodiversity of the river in the CKNP area.

The availability of sufficient water of good quality throughout the year very often remains a core issue within the community realm with many communities having settled in present locations based on water, agricultural land and accessibility to pasture for grazing. In many respects, the management of water within communities living in the Park surrounding area is advanced with traditional irrigation and domestic supply system long in place based on numerous well established criteria (e.g. amount of labour/resources contributed to channel construction, social status within the community, etc..).

4.2.4 Hunting

Hunting has deep roots in Pakistani culture and today it is regulated by a law that banning hunting without a license in most of the country including GB. The Northern Areas 1975 Wildlife Preservation Act, prescribes that in a National Park it is not allowed both to carry any fire arm or hunting weapon, and kill or capture any animal or be found in circumstance showing this intention.

Though considerably reduced in the last few years due to efforts of NGOs such as IUCN and WWF, illegal hunting is still carried out in CKNP. Reports of illegal hunting have come, in the most recent past, from the areas associated with the Braldu, Stak-Tormik, Haramosh, and Hispar regions of CKNP.

Trophy hunting programs could provide an effective venue for conserving wildlife resources while improving livelihood conditions of local communities (see Section 4.2.1, "Valley Conservation Planning"). This approach could lead from a diminution to a complete halt in illegal hunting in the area. The Hushe village community, for example, in collaboration with IUCN formed a village conservation committee (VCC) in 1997 and started an Ibex trophy-hunting program that continues to bring in revenues that are shared by VCC and government.

4.2.5 Mining

CKNP is thought to be abundant in minerals, metals, with about 32 varieties of precious and semi-precious stones like: quartz and aquamarine, various other gemstones, marble, mica, calcite, soapstone, graphite, china clay, granite, sulfur, and topaz are also found in the area. There is also evidence of gold in the area, with a Pakistan Mineral Development Company report citing Bagrot as a potential gold mine (PMDC, 2001).

With the discoveries of gemstones in the area local miners have been engaged in the exploration, mining and marketing of the rough and unpolished gemstones locally as well as internationally.
It is pertinent to mentioned that Gilgit-Baltistan contributes 90% in the total export of gemstone in the country, despite the fact that the miners from Gilgit-Baltistan practice primitive and unscientific mining techniques for the extraction of gemstones (Ev-K2-CNR, unpublished).

Data source

Information from bibliography

A first survey on mining activities in CKNP area and adjourned valleys was conducted in 2008 by WWF Pakistan (WWF-Pakistan, 2008) supported by Ev-K2-CNR in the framework of Participatory Management and Development of CKNP project.

Field data

A further analysis was conducted as part of a field research Boundaries Analysis with the aim to promote a better and more sustainable delineation of the CKNP border. In this study a survey GPS campaign was launched comprising the location of the mining areas near the CKNP's boundaries.

In the framework of SEED project, a deep evaluation of mining sector in CKNP has been carried out in Braldo and Basha valleys, considering also socio-economic and livelihood implications (Flury, 2012). In this research area, mining for semi-precious gemstones is omnipresent; however, the majority of mines are located in summer pastures areas of villages/municipalities in Dassu Union Council.

Description and main findings

The mining is most intensively practiced in the Braldu, Shigar, Basha Valleys, and in some parts of Haramosh Valleys, and the WWF reports the location of the 17 main mineral sites that are showed in the following map (Exhibit 38).

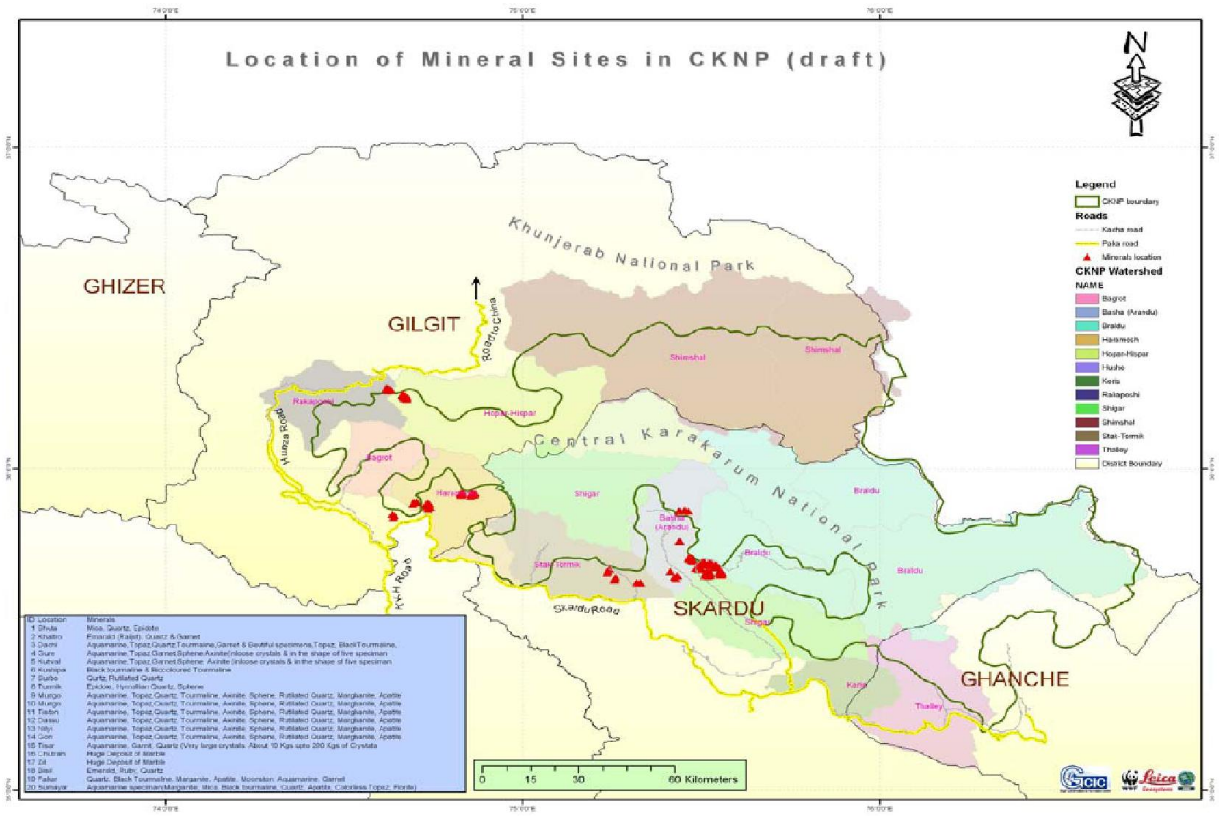


Exhibit 38 Location of mineral sites in CKNP (from WWF-Pakistan, 2008).

This report considers a total number of about 1.650 mines in these areas, hiring about 24.000 local workers, most of them above 10.000 feet up to 14.000 feet a.s.l. and are managed using primitive systems.

Currently used mining techniques in the peripheral areas of Central Karakorum National Park are very primitive. The typical mining system consists of a group from five to ten members equipped with the most basic tools (explosives, pickaxes, basic food and clothing) that dig holes of about 1 – 2 feet in pegmatite zones using hand drilling machines or small compressors, in few situations, and blast the rock using wahbox explosive detonators and safety fuse. This type of mining is called Foxhole mining, and the mines are about 3 - 4 feet wide and 3 – 4 feet high.

Majority of the miners use hand drilling machines. In mining sites like Dassu, Shigar, small compressors are used for drilling the holes in rocks, often keeping the compressors at the base of the gemstone mine and use long hose pipe (WWF-Pakistan, 2008).

The use of these traditional techniques provoke the damaging both of almost 50% of the produced, and of the mines that due to this, the leak of water and consequence thermal expansion, and the frequent geological activities in the area, are potentially dangerous for the miners.

The inadequate mining activities in the region have been causing serious damage of the products and significantly affect the value of crystals and fine specimens. However, damaged stones for the cutting grade can be recovered if accurate cutting and polishing techniques are applied (Ev-K2-CNR, unpublished).

Furthermore uncontrolled mining practices, such as blasting with dynamite, impact the fragile mountain ecosystem and disturbance to wildlife (WWF-Pakistan, 2008).

Case-study: mining sector in Dassu Union Council (Braldo valley)

In Dassu Union Council mining has emerged during the nineties in the lower-lying villages and expandend to the upper villages of the UC (Exhibits 39). The lower-lying villages feature the largest number of mining groups and the highest overall revenue from mining operations. In spring 2012, altogether 138 Mining groups operate in Dassu Union Council and Baha (Shigar). The overall revenue from raw stones extracted in Dassu Union Council and Baha between 1995 and 2011, after sale to the first middlemen, amounts to over 200 Million Pakistan Rupees (approximately 2 Million USD), however, considering the substantial investment, only few groups have made profit or can be considered to operate on an economically sustainable basis.

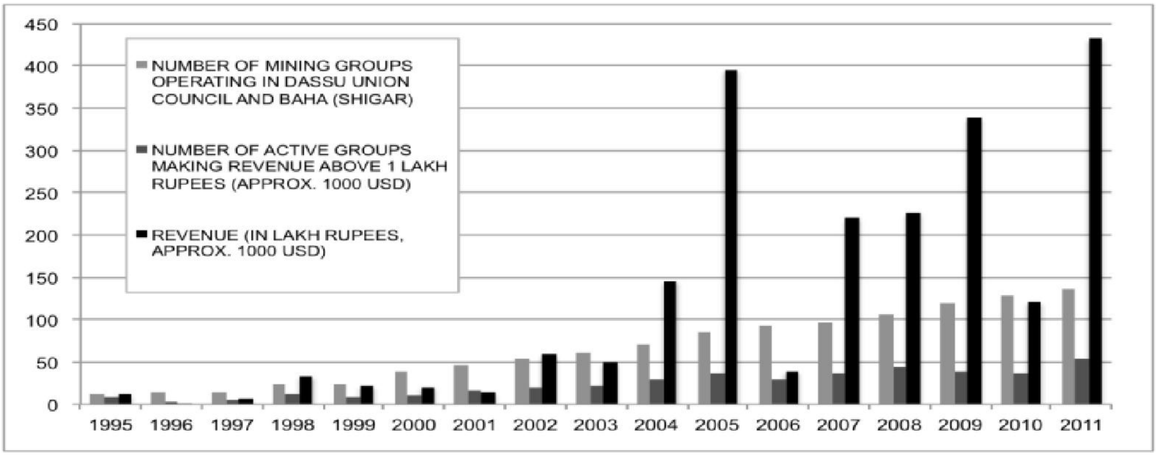


Exhibit 39 Development of mining activities in Dassu Union Council (and Baha) over the past 16 years. Mining operations, which have been abandoned before 2011 are not included in this Exhibit (Only currently operating mining groups have been surveyed, however, according to local accounts such cases are rare; Flury, 2012).

Socio-economic context and implications: although revenue is not equally distributed among the households and villages/municipalities and entails an increasing disparity of income and living standard between households, exacerbating the trend of increasing indebtedness of households in the core mining area, it has provided local households with an important new non-farm income opportunity with comparatively low access barriers.

Mines are operated by informal cooperatives, referred to as mining groups, which comprise investors and miners. Group members invest in different production factors (i.e.: investors: machinery, explosives, catering; miners: labour). The distribution of revenues from the sale of raw stones to the first middlemen is regulated by fixed rules, accounting for the type of investment made.

The majority of mines are situated on land under collective usufruct rights of a village/municipality and its residents enjoy exclusive right to work as miners or initiate new mining operations. In contrast, many investors are non-residents. Investors are entitled to two or more shares per type of investment, increasing proportionally to the extent of operation as indicated by the size of the mining group. Unlike miners, who can only hold one share at a time corresponding to the investment of their physical labour, investors are often involved in several different mining operations at the same time or hold all non-labour shares of a single mining group. The return per investor-share and per miner, is variable, so income inequality in the area is on the rise.

Mining rights secure the entitlement of local resident to labour opportunities originating from the exploitation of local endowments and therefore also spatially restrict household diversification through labouring in the mining sector. There is no such restriction to the mobility of investment capital. Miners have to rely on the quality and productivity of the mines situated in the area on which the respective village or municipality they belong to has usufruct rights. Investors, on the other hand, can secure membership in the most productive mining groups without limitations.

The socio-economic structure of the local mining sector resembles rather a complex web penetrating the middle to higher social strata. Due to lack of reserves and alternative income source, poor households can often not afford to invest their valuable labour in a potentially no-return activity. Many of the households involved in mining make investments and do laboring, often in different mining operations at the same time. Dealing is the most profitable activity in the local mining sector. The small number of local dealers are considered to be the key driving force behind the continued investment and expansion of local mining operations, which has constantly increased, from 40 in 2000 to 138 groups by 2012 and seems to attract ever further investment in spite of the substantial cost involved. The major obstacles for expansion of the mining sector are the unavailability of explosives, the legal insecurity, and the lack of effective extraction techniques.

Livelihood implications: in general, the mining sector in Dassu Union Council has become an important pillar of local livelihoods in this area. In lower Dassu Union Council, 80-100% of the households are involved in mining with at least one or two household members. In upper Dassu Union Council, household involvement varies between 25% and 60%.

An understanding of the role of mining in local livelihood dynamics and strategies has to be considered.

The high variability of revenues in the mining sector implies a disproportion between investment in the form of labour and expected income, resulting in a high unreliability of income on one hand and a slim prospect of improving the household's living standard instantly and substantially. The unreliability of income from labouring in mines in this context prevents households from engaging exclusively in mining as a livelihood strategy. Diversification of the investment is the key to increase the chance for returns in the mining sector. The extent to which households engage in labouring the mining sector depends primarily on the number of physically strong young men who can afford to spend time in the mines, which usually entails foregoing (further) formal education, since unlike occasional wage labour, labouring in mines commonly entails a full-time engagement of the miners. It also depends on the willingness of the households to take up loans and credits to cover for the lack of income from labouring in mines, which is presumably a lot higher in the core mining areas. The trend of increasing indebtedness of households in the core mining area is exacerbated by unequally raising living standard and the higher social expectations this entails. Although households employ other livelihood cash income activities or coping strategies to clear loans and debts accumulated in this context, the risk to become trapped in a debt spiral is high. High amounts of debt reduce household's livelihood resilience, which is an important quality in a context characterized by high risk of natural disasters.

However, labouring in the mining sector also has specific opportunities and advantages that no other low-entry income activity provides. It has a low entry-barrier: Mining requires informal skills, which can be acquired on the job. It does not require formal education, natural or financial capital, and the growing mining sectors provides many opportunities. Competition for these opportunities is low due to the exclusive right of local residents to labouring in mines. Mining is well integrated with the households' livelihood activities. Unlike other low-entry non-farm income activities, which are scarce, infrequent, and often limited to the season of general labour shortage, mining commonly takes place during 8 month per year. The mining groups suspend activities during festivals and labour-intensive agricultural activities and arrangements within the groups allow miners the flexibility to suspend their work temporarily to exploit opportunities for other income activities as they arise. Working as miner does not require migration and allows men to reside with their household and family.

4.2.6 Forest use

Data source

Ev-K2-CNR together with University of Padova evaluated the local communities wood consumptions in Bagrote Valley (Ferrari and Anfodillo, 2011). Additional information were recorded during missions in Haramosh, Khaltaro, Jaglot Gor, Minapin Nagar and Hispar (Gilgit district) and Basho, Tormik, Stak, Hushey (Skardu district) valleys.

Legal framework

All the forests in CKNP are denominated "Protection forest" according to the Pakistan Forest Act of 1927 (IUCN, 2003). This means that forestland is governmentally owned but local communities maintains access rights and some marginal use-rights. Specifically, grazing in forest area is allowed as well as the collection of firewood & timber from dead-dying-or-disease trees only. Community based forest management however is not a common practice and the top-down, non-participatory approach of the provincial and national forest policies (Shahbaz et al., 2007) mark out a deep division between local communities dependence on forest resources and government/Forest Department will of reducing deforestation and forest degradation.

Land tenure

Officially all the CKNP forests are governmentally owned. In practice, however, each community have historical use rights on specific portion of forest and pasture land. Those are well marked and most of the locals knows where the boundary of each village forest limits lies.

Utilization

The communities living around CKNP are heavily dependent on forest resources located inside and around the park boundary. Forest is essential for providing grazing ground for the livestock, for covering the firewood necessities (heating and cooking) and for the supplement of timber for construction. From an economical point of view, communities which can entirely rely on self-collection of forest products, even if it is a time consuming activity, save large amounts of money which can be used to purchase other products from the market (Flury, 2012). The different forest condition among the Gilgit and Skardu district have historically brought some differences in forest use: the forest of Skardu district are mainly used for communities subsistence due to the lack of high-value timber, whereas the richest forest in the south-eastern sector of Gilgit district have been (and in some cases are still) illegally felled for selling timber in the local markets (Ali et al., 2005; Ali et al., 2006).

From the Bagrote survey and other interviews conducted in different villages of CKNP, it emerged that local households are dependent on forest resources and, realized that most of them are under pressure, have tried with different degrees of success to limit their exploitation through the creation of specific forest committee. Those committees in some areas have been successful in reducing the forest degradation (as in Bagrote and Khaltaro) while in other areas like Haramosh and Jaglot Gor deforestation and corruption are still very common.

Timber

Most of the high value timber (mainly Pine and Spruce) is located in the southern valleys of Gilgit district. Illegal harvesting is common is some valleys (Jaglot Gor, Haramosh among others) while in others the local communities were able to organize specific "timber committees" to control and manage felling amount per household (like in Bagrote valley and Minapin Nagar). According to the survey in Bagrote valley (Ferrari & Anfodillo, 2011) at high altitude, closer to the largest forests tracts, the villages are more dependent on the natural wood resources. This dependence has fostered the creation of committee to organize or limit the harvesting of trees. A different situation is present in the lower villages, far away from forests and with limited amount of timber-wood. Those villages organized private/common poplar plantations for obtaining construction wood and firewood is the only product harvested from natural forests. It is in those realities that accessibility to the forest has not been regulated or restricted yet. Average annual timber wood consumption per household has been estimated to be 500 Mg per household per year.

Firewood

Firewood is by far the most important wood products harvested from CKNP forests, covering more than 80% of the total forest utilization. This is a consequence both of the cold climate and the high cost of purchasing firewood from local markets. The preferred firewood is Juniperus, a very common but slow growing species. Most of the trees, therefore, shows clear signs of cuttings (on branches or parts of the main stem) and usually the stands are degraded.

Regarding firewood, in most of the villages there is no restriction/indication on firewood amount and harvesting location, but there are exception like Hushey village (where a ban has been imposed on some degraded forests close to the village).

Considering wood consumptions, from the Bagrote survey (Ferrari and Anfodillo, 2011) the amount of firewood yearly used decreases from the higher villages (apr. 4000 kg/household/year) to the lower one (2000 kg/household/year). Similarly the share of firewood collected from natural forests decreases from 100% for the villages in proximity of forested areas (higher altitude) to 40% of the ones far away from them. Those amount seems to be quite constant around the CKNP area (similar values were obtained from interviews conducted in Hushey, Kande and Braldo villages (Flury, 2012). A key aspect in the future will be the provision of plantation specifically designed for the production of firewood (i.e. coppice system).

Table 33 Wood Consumption and village organization in Bagrote valley (Ferrari and Anfodillo, 2011).

Village	N° Household	Participant	Firewood Consumption (Kg/Hou./yr)	% from forest	For. Committee
Bulchi	**250**	25	4000	100%	Yes
Chirah	**100**	20	4000	100%	Yes
Farfoo	**250**	15	4000	100%	Yes
Datuchi	**150**	40	3750	65%	No
Hopey	**140**	50	2400	75%	Yes
Sinaker	**130**	30	3200	40%	No
Bilchar	**250***	15	2000	100%	Yes
Taysote	**150***	8	2000	100%	Yes

Regulation

Officially, forest harvesting is strongly regulated in Gilgit Baltistan, since only Forest Department can select trees to be cut and plan the management of forest resources. Practically, however, the situation is much different, with local household free to collect wood from each village’s forests. As already explained, some villages have implemented on their own or with the support of Forest Department (as in Bagrote valley) forest committees to control and limit the harvesting of timber. Those valley now can manage their forest independently.

5. TOURISM SECTOR

5.1 Historical Analysis

5.1.1 CKNP Salient features attracting tourists

CKNP is the largest glacial complex with its Baltoro Glacier, the Biafo-Hisper Glacier and the Siachen. The glaciers are covering great part of the Park. The CKNP is the highest Park all over the world. Its area in the world is the one with the greatest concentration of highest mountain peaks in a relatively small area: four peaks above 8.000 m a.s.l. (K2 8,611 m; Broad Peak 8.047 m; Gasherbrum 8.068 m; Gasherbrum 8.035 m) and almost 60 peaks above 7,000 m a.s.l..

With its unique scenic attractions, wilderness, cultural and historical resources the CKNP is a potential tourism destination in Gilgit Baltistan as well as a hub for research on natural and cultural resources. It is the home of unique biodiversity and globally significant species: rare and threatened large mammals, such as snow leopard, astore markhor, musk deer, ladakh urial; bird species.

5.1.2 Tourism flow and predictions

First Karakorum explorers have been the English during the period which coincide with the period of the possession of the area. We have to wait early twentieth-century to find a real interest which can be defined “climbing-touristic” as well as “exploratory”.

- Duke of Abruzzi arranged the first expedition toward the Baltoro Glacier on 1909.
- in 1929 Duke of Spoleto with Prof. Ardito Desio to climb K2;
- Eric Shipton and other climbers started a more extensive frequentation of the area up to the first expeditions till years of postwar period, which can defined as the real start of Karakorum Tourism for the climbing of its high peaks;
- the Italian expedition to K2 of 1954 has seen the first ascent of this mountain and some years after, in 1957, the German expedition to Broad Peak marks the turning towards a touristic development of the area included in the present CKNP.

From the sixties the touristic flow of climbers and trekkers has progressively increased, also for the concentration in the area of unique opportunities for mountain adventure activities, of peaks and sceneries which are the only all over the world. Simultaneously a lot of services, provided from the rising travel agencies, have increased their potential and new job opportunities for local communities.

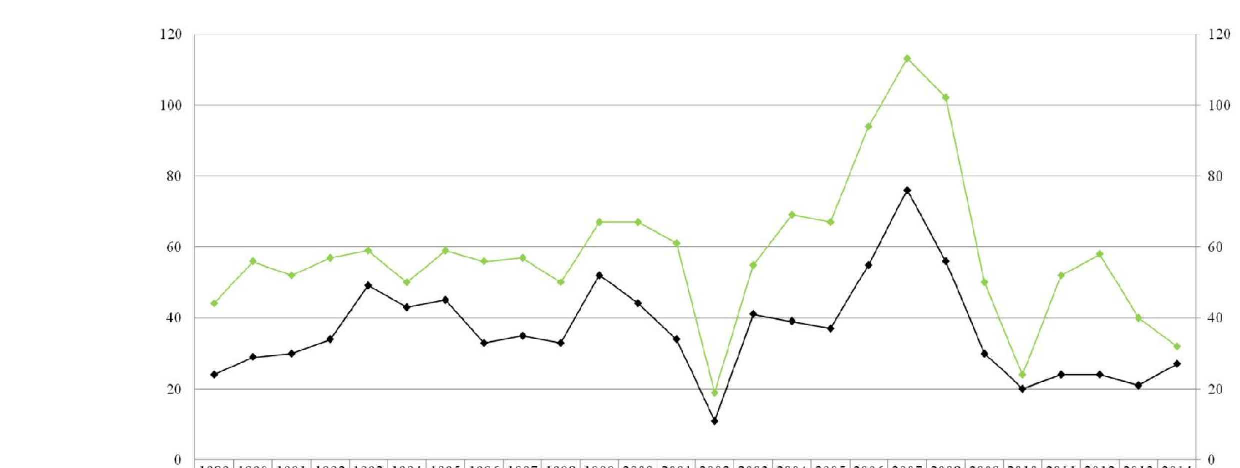
CKNP hosts a number of important peaks and landscapes, which attract a substantial number of mountaineering expeditions and trekking groups during the summer season, between May and September. This highly specialized tourism industry provides important opportunities for cash income generation of local residents in the area.

Here below, historical trends over the last 20 years is analyzed, in relation to the available data gathered by the Alpine Club of Pakistan. These data regard the authorizations issued by the Ministry of Tourism for mountaineers expeditions, which are divided into two zones Baltoro area and Gilgit-Baltistan Area.

It is important to underline that the Baltoro Area does not correspond to the CKNP boundaries. To be precise, there are various peaks that are not within the Baltoro area, which instead are within the CKNP. These peaks are often climbed by mountaineers, for example the K7 and K6, the Spatnik Peak and the Latok, and many others. We can therefore carry out an historical analysis through the following paragraph, in order to identify future trends, keeping in mind that 80% of total expeditions occur within the CKNP.

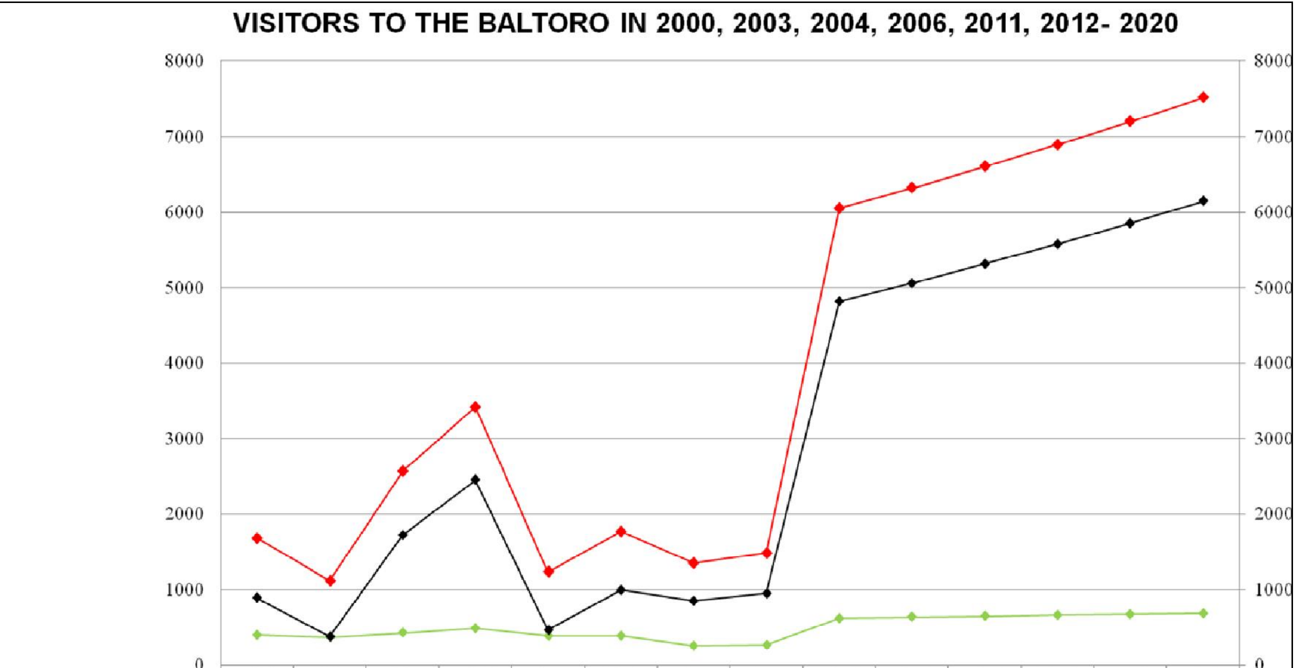
As we can see in the graph here below, the whole time-period can be divided into three parts. The first part is going to go from 1989 until 2003, the second part from 2004 until 2007, here we have some high values. Finally we have the last part, which develops in the last few years, where we can see a more regular trend with lower values.

During last years a change of climbers, and most of all of trekking groups, behavior, has been observed: they are now covering a corridor which start in Askoli and, going across the Gandogoro La with the assistance of the Hushey Rescue Team, they reach Hushey by crossing the Park along a corridor highly spectacular and avoiding the classic round trip route along Baltoro. In 2011 65% of visitors which entered the Park followed this itinerary, in 2012 this percentage arrives at 75%, and even considering tourists intentions the 90% of them, would like to cross the Gandoghoro La Pass to reach Hushey. But a lot of them must renounce for technical or meteorological difficulties, or for acclimation problems.



	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL pakistan	44	56	52	57	59	50	59	56	57	50	67	67	61	19	55	69	67	94	113	102	50	24	52	58	40	32
BALTORO REGION	24	29	30	34	49	43	45	33	35	33	52	44	34	11	41	39	37	55	76	56	30	20	24	24	21	27

Exhibit 40 Estimated number of expeditions per year over the past 26years (Source: unpublished data and information from Alpine Club of Pakistan)



	2000	2003	2004	2006	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
No. of Total Visitors	1285	746	2143	2927	846	1378	1099	1215	5437	5690	5955	6234	6525	6832
No. of Climbers	396	369	422	482	383	385	251	267	620	633	645	658	671	685
No. of Trekkers	889	377	1721	2445	463	993	848	948	4817	5057	5310	5576	5854	6147

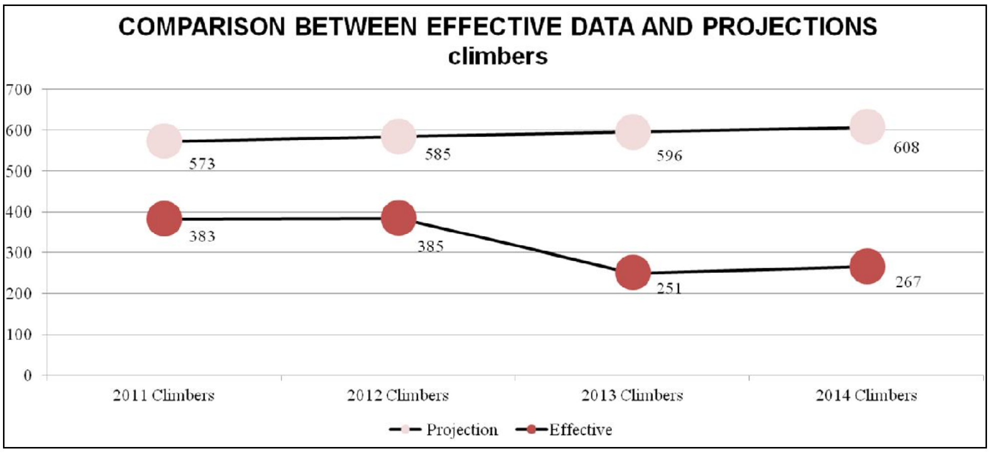
Exhibit 41 Visitors to the Baltoro in 2000, 2003, 2004, 2006, 2011-2020 (Source: unpublished data and information from Alpine Club of Pakistan)

Analyzing these data, after the peak values of 2004 and 2006 for trekkers, and 2007, for climbers, it is believed that the values of the tourists demand has returned to lower levels than those which have characterized the decennial 1990-2000. Many forecasts, completed only 5 years ago, while considering the trend with maximum values, had brought to evaluations with an highly increased touristic impact, which in reality never happened and which with the current data available it isn't absolutely foreseeable for the next future. If, from one side, these considerations thwart the pessimistic forecasts which invoke to restrictive measures to avoid high negative impacts of touristic presence in the Park, on the other doesn't have to let people think that this presence is absolutely irrelevant. We can assess that the situation, particularly near the campsites along Baltoro it isn't optimal and requires proper planning and management of several interventions.

Analyzing the historical sequence of tourists flow data, a considerable variability along the years course is noted and doesn't allow to formulate any reliable prediction for the future. It can be reasonably believed that values of tourists flow will remain steady in the brief period. The projections of tourists flow which has been calculated soon after the peaks of tourists visits have inevitably brought to not reliable data as we can see in the Table 35. The socio-economic and politic conditions and the lack of mountaineering expeditions sponsorship have brought to seasonal climbers constant presence and to a slight increase of trekkers numbers, but however on reasonable data and lower than the maximum peaks registered in 2006.

Table 35 Visitors to Baltoro in 2011-2014. Comparison between effective data registered (from unpublished data and information of Alpine Club of Pakistan) and data projected (Source: Mrak, I. 2011. High Mountain Areas and Their Resilience to Tourism Development)

CLIMBERS/TREKKERS	EFFECTIVE/PROJECTED	2011	2012	2013	2014
No. of Climbers	Effective	383	385	251	267
	Projected	573	575	596	608
No. of Trekkers	Effective	463	971	848	948
	Projected	3963	4161	4369	4587



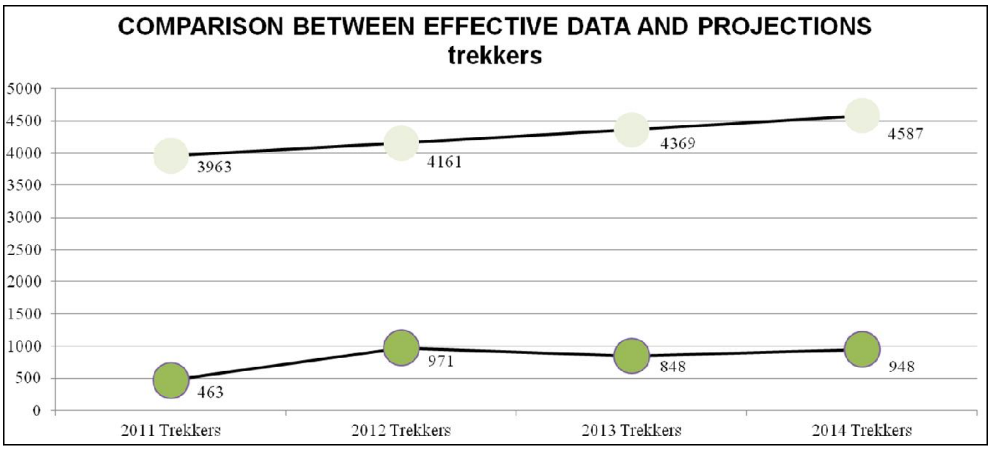


Exhibit 42 Trends of compared data of 2011-2014.

Table 36 Projection of visitors to Baltoro 2015-2020 (Source: Mrak, I. 2011. High Mountain Areas and Their Resilience to Tourism Development)

EXPEDITIONS-TREKKERS	2015	2016	2017	2018	2019	2020
No. of Climbers	620	633	645	658	671	685
No. of Trekkers	4817	5057	5310	5576	5854	6147

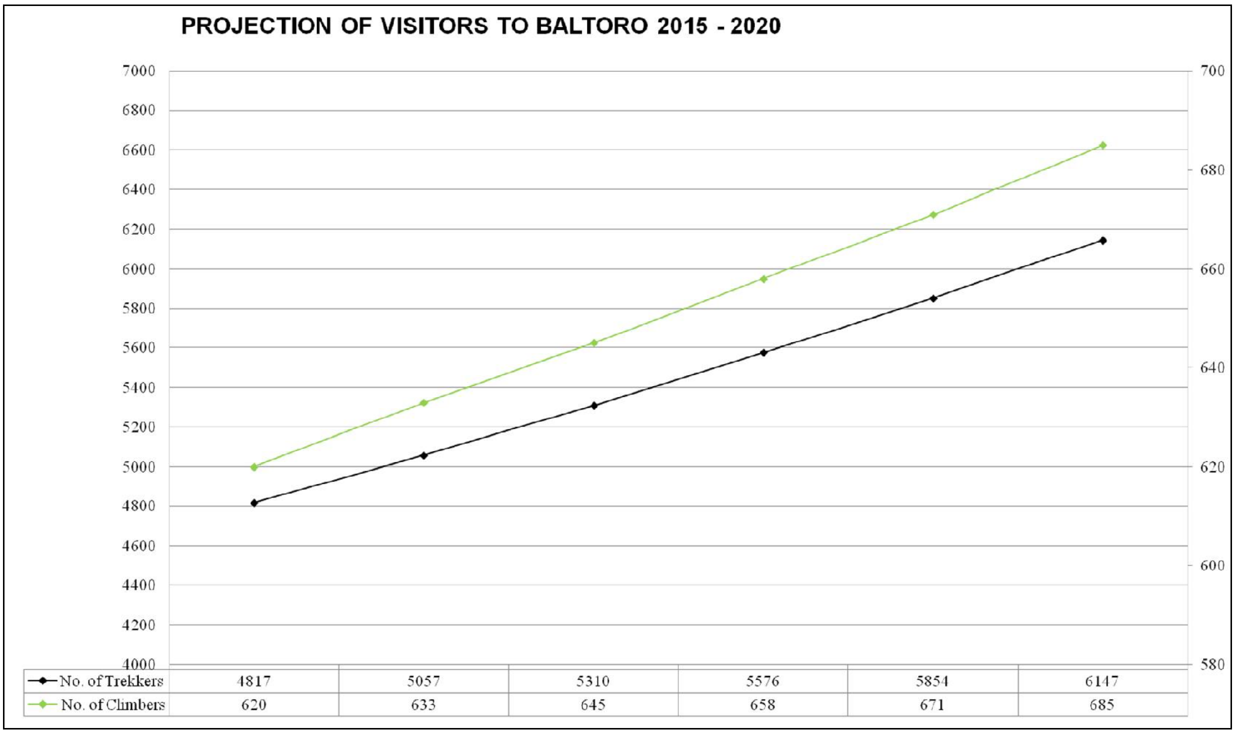


Exhibit 43 Trends of the projections of Visitor to Baltoro 2013-2020 (Source: Mrak, I. 2011. High Mountain Areas and Their Resilience to Tourism Development)

5.1.3 Tourism Income for Local Communities

A few villages hold usufruct rights on *unsettled areas*, which are used by expeditions as camping grounds. Another set of income opportunities center around provision of services and goods at these sites.

Moreover there are services provided at local level which represent an essential component for the economy of some villages: carrying loads (*porter*), preparation of meals (*cook*), supervising and coordinating the local expedition staff (*sardar*), and guiding (*guide*) - are procured per expedition, directly or indirectly by the tour operator from local people. Guides need recognition from the Ministry of Tourism. They are either affiliated with a tour operator or work on freelance basis. Sardars are mostly hired by the guides.

Table 37 Overview of local opportunities for non-localized service provision in the framework of expeditions (we have to consider other expenses for food, kit, etc.)

FUNCTION	TERM	AVG. NUMBER PER EXP.	AVG. REMUNERATION IN PKR	AVG. DAYS OF INVOLVEMENT PER EXP.	AVG. OVERALL REVENUE PER EXP. IN PKR	ACCESS TO OPPORTUNITIES
Guiding	Guide	1	1200 - 2000 per day	15 or 21	18'000 – 35'000	License to be annually renewed. Affiliated with a tour operator or hired on freelance basis
Supervision of local staff	Sairdar	1-3	per expedition	21	15'000 – 25'000	Hired by guide
Carrying loads	Porter	varies (up to 200) average 10 porters/member exp average 5 porters/member trekking parties	505 per stage (including meals), 11 stages to K-2 basecamp	varies	5000 – 6000 per way (10 – 12 days)	Hired through guide or sardar, or recruited at the spot.
Carrying loads	Animal (mule)	Varies	2000 per stage	Varies	1 animal four loads	Hired in accordance with local rules
Cooking	Cook	1	1000/1500 per day	21	18'000	Hired by guide or sardar
Assisting Cook	Assistant	varies	800 per day	21	16'800	Hired by cook

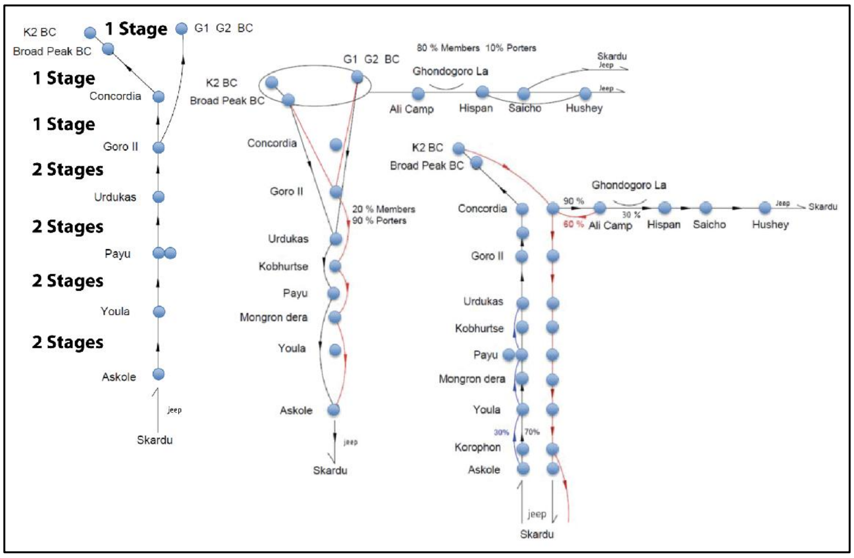


Exhibit 44 Campsites, stages and overnight-stays during ascent and decent of expeditions (routes on the left and in the middle) and trekking parties (route on the right)

Carrying loads for trekking parties and expeditions as portering is the most prominent opportunity for local people. Guides and cooks are paid per day, sardars in the form of a lump-sum payment (See Table 38 Overview of local opportunities for non-localized service provision in the framework of expeditions (we have to consider other expenses for food, kit, etc.). Porters, carrying one load each, are paid per expedition-stage, regardless of the time required to move from one stage to the next. There are 9 stages between Askoli and Concordia (Baltoro) and further 2 stages between Concodia and K2 Basecamp. Porters usually ascend with the expeditions and trekking parties with overnight stays at all major campsites on the route. The ascent includes rest days for acclimatization in Jhula and Concordia campsites. Most trekking parties continue from Concordia to Hushe and often hire new porters in Concordia for this second part of the route. The porters who leave the groups at Condordia return to Askoli without payment to be hired with a new expedition or trekking party.

Until recently, formal and informal quota systems based on administrative divisions secured a certain share of loads for local residents. Within the latter, for expeditions and trekking parties starting from Askoli, a mutual understanding among the villages of Braldo valley ensured equal allocation of loads to members of the villages/municipalities. Other than at the starting point of expeditions, porters can obtain loads either at the tour operator office branches in Skardu, at the starting point of the expedition, in Askoli or Arandu, or through the expedition guide or a sardar. The first two options involve investment for travel, board and lodging without guarantee for a load. All options require social capital.

From the perspective of local livelihoods portering is one of a number of different non-farm income opportunities, which are characterized by a high level of unpredictability and, therefore, unreliability with regard to sustaining a livelihood. Additionally, opportunities coincide with the cropping season, during which labour shortage is prevalent.[1]

Today, tourism income are going prevalently to few villages around CKNP, and especially to Askole, Testay and Hushey. This is due to the absence of criteria for sharing the income among communities and also because the percentage of loads transported by animals is highly increased.

On this matter we believe opportune to proceed as follows (considering as expected and not alterable the use of animals for transportation for the military basis located along Baltoro):

- to authorize transportation with animals for touristic groups only along Baltoro and Hushey;
- to assess in cooperation with local communities new rules for a more fair distribution of tourism income;
- to develop an evaluation of the impact caused by transportation with animals along the authorized routes;
- vaccination campaign and veterinary control on all the animals.

5.1.4 Environmental Impact of Tourism Presence

Waste

Tourism in the Park is now present since 60 years. Parallely also the interest for mountain adventure tourism increased. Few climbers have become in few years and high number with consequent environmental, social, cultural and economic impacts.

These negative impacts increased in the time also because proper politics for their surmounting in some areas, as the Baltoro one, that is already vulnerable, have not been undertaken.

[1] Source: Livelihoods and Natural Resource Management in Central Karakorum National Park Area. Research report developed for SEED Project, July 2012. Author: Bastian Flury.

With regard to the environmental impacts, the most significant is surely the one related to waste management, with a progressive increase of waste left at the base camps and along all the Baltoro trekking. For what concern the use of wood to cook, common in low part of the trekking in Akole and Paju, but also in the high campsites, after years of uncontrolled use, it has been introduced an absolute prohibition of collect wood and the obligation to use kerosene.

From the other side economic benefits related to the development of touristic sector have become, years after, years the main subsistence contribution for a large part of population, which not only concentrates in villages around the interested tourism area. Also indirect benefits are offering advantage to the near villages, which provide porters for transportation, to tour operators (almost an hundred), to transport services companies, to every kind of shops in the villages bazaars and in the main towns (Skardu and Gilgit). Economic benefits of tourism sector are giving advantage also to the system of hotels and restaurants involving thousands of families incomes.

Problems connected to the seasonality of this kind of works remain, and create a system *stop and go* which needs the maintenance of several opportunities of work and the creation of some concentration situations and the monopoly for some services to be solved and surmounted.

Two important and positive factors which happened in the last years should be underlined.

First of all the awareness process which is becoming always and more common among climbers and frequent visitors of mountain areas, about the need to preserve the unique environment of mountains from pollution, which now it is a phenomena not only localized but global with pollutants circulation on long distances[2]. The new consciousness of climbers about environmental problems has been also assessed through the questionnaires shared among Baltoro tourists during 2011 summer season: from data analysis it results that over 90% of visitors believe that during last years glacier condition is radically changed and improved, it is now clean, also if some problems in the most frequented campsites should be solved. Almost 100% of tourists agree that this new climbing must follow the principle of *leave no trace*[3]. Again it is underlined that a specific fee dedicated to the environmental protection must be introduced, applied and used by CKNP Directorate to make sustainable the waste management system.

Secondly the number of expeditions which have as main aim mountains cleaning and not peaks climbing is increased in the last years: from nineties these expeditions are intensifying A lot of things must be again done, but we are surely on the good way to go out from the conception that tourists are the origin of an heavy deterioration of the environment and to see visitors as actors in the area for the restoration of pre-existing conditions. To this factor, also the sensible loss of the touristic presence in the last years and its concentration in limited corridor is contributing, while simplifying and making more effective the activities of waste management.

The Management Plan must become the instrument through which definitively cross from an isolated cases of interventions to a situation of total process sustainability in order to ensure the positive effects also on long period. CKNP Directorate management of all the process through a multidisciplinary and multi-objectives approach will be paramount.

If this situation will happen, without any difficulty we could assert that the mountain tourism in this Park could be considered to all intents and purposes an example of eco-tourism.

[2] Ref. to the studies on Asian Brown Cloud which dominates Himalayas and Karakorum and caused by the out of control development of rising economies of China and India.

[3] A notable interest towards this direction can be noted with continuous examples of expeditions which make of clean up principles their main target.

Cleanup Activities

Mostly in the last 10 years, several international projects have given high amounts for cleaning these areas and for sensitizing local populations on the need to preserve a clean environment.

Table 38 Clean up expeditions in Baltoro Area

YEAR	ORGANIZERS	TOTAL COST	WASTE COLLECTED (KG)	FINANCING PROJECT
1994	Alpine Club of Pakistan	n/a	1.500	n/a
1998	Alpine Club of Pakistan	n/a	2.000	n/a
2000	Alpine Club of Pakistan	PKR 450.000	2.500	n/a
2002	Alpine Club of Pakistan	PKR 500.000	2.500	n/a
2005	Alpine Club of Pakistan	PKR 567.230	3.000	n/a
2006	Ev-K2-CNR & Alpine Club of Pakistan	PKR 350.000	3.250	Karakorum Trust
2009	Ev-K2-CNR & Alpine Club of Pakistan	PKR 1.694.320	9.318	Promosso
2010	Ev-K2-CNR & Alpine Club of Pakistan	PKR 4.351.920	12.319	SEED & Promosso
2011	Ev-K2-CNR & Alpine Club of Pakistan	PKR 3.819.741	8.821	SEED
2012	Ev-K2-CNR	PKR 1.136.205	4.000	SEED
2013	Ev-K2-CNR	PKR 1.833.687	3.200	SEED
2014	Ev-K2-CNR	PKR 1.670.858	4.100	SEED

In few years more than 50 tons of waste has been collected, differentiated and disposed at the Askoli incinerator, installed in 2009, and at present the glacier situation has been really improved, so that we can assert that today Baltoro glacier is one of the less polluted glaciers of the whole range Himalaya Karakorum. Not only the glacier has been cleaned up but also the high camps of 8000 mt. peaks of Baltoro, during which have been verified conditions not as heavy as on Mount Everest and bringing down tons of waste. These expeditions reached altitudes of 7.500 mt.

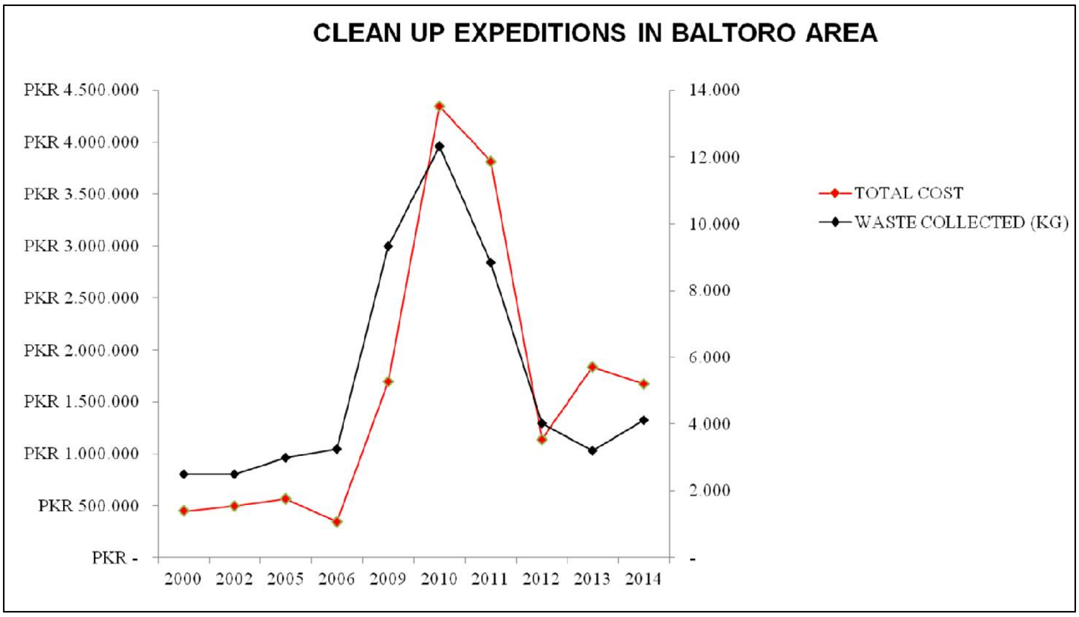


Exhibit 45 Trend of costs and quantities of waste collected of the clean up expeditions in Baltoro Area

Table 39 Average cost per kg of each cleanup campaign

YEAR	AVERAGE COST PER KG
2000	PKR 180
2002	PKR 200
2005	PKR 189
2006	PKR 108
2009	PKR 182
2010	PKR 353
2011	PKR 433
2012	PKR 284
2013	PKR 573
2014	PKR 408

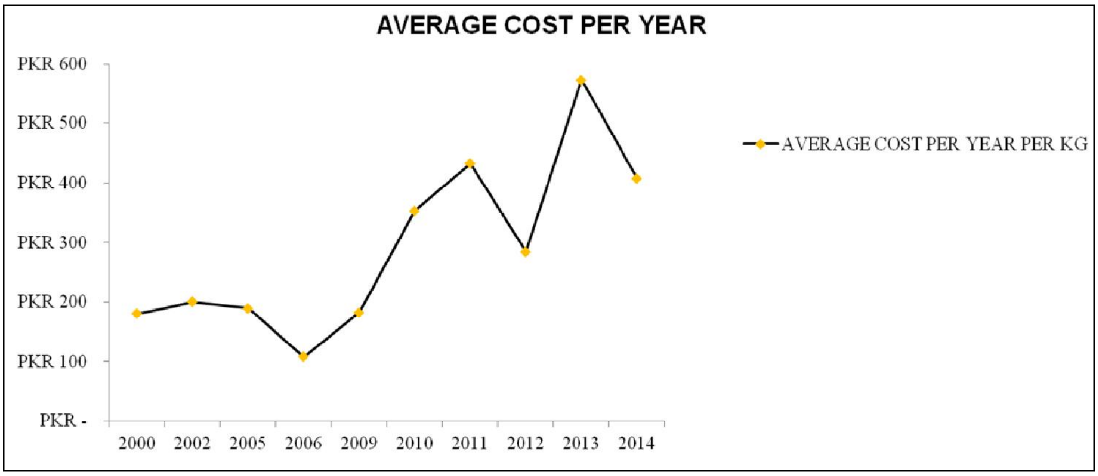


Exhibit 46 Trends of the average cost per kg of the clean up campaigns in Baltoro Area

Table 40 Average cost per kg for clean up activities

TOTAL WASTE COLLECTED [2000-2014] (KG)	53.008
TOTAL AMOUNT SPENT	PKR 16.373.961
COST PER KG (IN PKR)	PKR 309

Table 41 Assessment of waste produced by each trekker per day.

WASTE PRODUCED BY TREKKERS PER DAY	
Biodegradable	300 grams
Burnable	25 grams
Non Burnable	145 grams
Hazardous	30 grams
Total	**500 grams**
Total kg to be transported	**200 grams**

Table 42 Assessment of waste produced by each climber per day.

WASTE PRODUCED BY CLIMBERS PER DAY	
Biodegradable	300 grams
Burnable	25 grams
Non Burnable	200 grams
Hazardous	50 grams
Total	**575 grams**
Total kg to be transported	**275 grams**

Table 43 Esteemed waste production in Baltoro Area, calculated on the basis of trekkers and climbers who visited Baltoro Area in 2012 summer season (Source: unpublished data and information from Alpine Club of Pakistan). For the esteemed waste produced, the formula used is the following: *T(or C) x aD x n*, where *T* stands for Trekkers, *C* stands for Climbers, *aD* stands for average duration in the park, *n* stands for the estimated number of kg produced by each trekker, or climber, per day as per data in the Table 41 and Table 42.

ESTEEMED WASTE PRODUCTION IN BALTORO AREA CASE STUDY	
Number of trekkers	971
Number of climbers	385
Number of porters	7.734
Esteemed waste produced (Trekkers) - KG	3.884
Esteemed waste produced (Climbers) - KG	4.235
Esteemed waste produced (Porters) - 10% of visitors waste- KG	7.347
Esteemed total waste produced - kg	**15.466**
Esteemed total cost for clean up of waste produced in one season	**4.350.949**

Based on the above data the projection for an individual fee to keep Baltoro Clean (without considering cleaning of campsites) can be calculated as follows:

Esteemed total cost for clean up of waste produced in one season/(number of trekkers+number of climbers)

PROJECTION OF INDIVIDAL FEE TO YEARLY KEEP BALTORO CLEAN	PKR	3.523
	USD	**38,83**

Also human waste situation should be considered while talking about remote areas like Baltoro. In Baltoro particularly the situation became from bad to worst by every passing year. The human waste does not disintegrate due to snow and low temperature. Thus, apart from being an eye sore it gave a pungent smell, and some of the waste also washed downstream, thus polluting the water and making it unhygienic for use. Beyond the negative impacts on natural resource, the porters and local staff contracted different water borne diseases. In 2010, on experimental based, eight high altitude toilets, particularly designed for use on the glacier, have been installed in Concordia. Local support staff has been employed to make sure toilets operations and hygienic conditions. Trekkers, Mountaineers and their staff, have been motivated and deployed to use the ecological platforms and they have been asked to urge the porters to the facility as well. The initiative has been prosecuted also in 2011, 2012, 2013 and 2014, by increasing the network of eco-platforms.

Table 44 Yearly management costs for the eco-toilets installed in Baltoro Area

YEARLY ECO-TOILETS MANAGEMENT COST		
2010 - Management cost for 8 eco-toilets installed in Concordia	PKR	1.957.400
2011 - Management cost for 6 eco-toilets installed in Concordia, 2 in Ghoro II, 3 at Gasherbrum BC	PKR	2.199.994
2012 - Management cost for 2 eco-toilets installed in Ghoro II, 6 in Concordia, 3 at Gasherbrum 2 BC and 2 at K2 BC	PKR	2.902.902
2013 - Management cost for 2 eco-toilets installed at Ali Camp, 2 Ghoro II, 6 in Concordia, 3 at Gasherbrum 2 BC, 2 at K2 BC	PKR	3.359.123
2014 - Management cost for 2 eco-toilets installed at Ghoro II, 5 in Concordia, 2 at Gasherbrum 2 BC, 2 at K2 BC , 2 at Broad Peak BC	PKR	1.107.492
Average yearly management cost	**PKR**	**2.305.382**

Based on the above data the projection for an individual fee to guarantee the installation and the management of Eco-Toiltes in Baltoro Area can be calculated as follows:

Average yearly eco-toilets management cost/(number of trekkers+number of climbers)

PROJECTION OF INDIVIDULA FEE TO GUARANTEE YEARLY ECO-TOILETS MANAGEMENT IN BALTORO AREA	PKR	1.700
	USD	**18,74**

Askoli Incinerator

One of the problems to be addressed when facing management of waste is the disposal of collected waste. Often clean up campaigns are being carried out for waste transportation without affecting really on the global system. Also in the Sagarmatha National Park for years stakeholders tried to solve the problem by involving the tour operators, but then they realized that all the waste were concentrated in Namche Bazar and Lukla, where they were being burnt in the open air by with high dioxin emission or burnt in ditches always more extended and diffused.

An effective disposal system can not leave out of considerations two factors: recyclable waste disposal with the transportation of glasses and tins to the Skardu market where they are going to be recycled; incineration system at high temperature which allows to burn other materials without significant emission. With this aim the CKNP cleanup has been managed through the installation of an high technology incinerator outside CKNP borders in Askoli village. The incinerator has been installed in 2009 and today is still in optimal conditions also after having burnt more than 10 tons of multi-materials, included plastic, textiles and others. It is not just a case that in the Sagarmatha National Park it is being installed a first incinerator of the same typology and that the installation of others two is also foreseen (in Sagarmatha National Park the number of visitors entering the Park is around 30.000/-per year against the 1.000 of CKNP).

In order to have an optimal incineration system also in the CKNP, the net of incinerators must be completed with other two units, one to be installed in Hushey and the other in Hunza, by selecting the best localization.

Table 45 Waste incineration facility in Baltoro Area

YEARLY MANAGEMENT COST - ASKOLE INCINERATOR		
Yearly cost for fuel and staff	PKR	1.854.000
Yearly cost for spare parts and transportation	PKR	700.000
Total yearly cost for incinerator management	**PKR**	**2.554.000**

AVERAGE COST PER KG BURNT		
Esteemed waste production in Baltoro Area per year		15.466
Total kg burnt		9.280
Average cost per kg	**PKR**	**275,22**

Based on the above data the projection for an individual fee to guarantee the installation and the management of the incineration facility in Askole can be calculated as follows:

Average cost per kg x Total kg burnt/(number of trekkers+number of climbers)

PROJECTION OF INDIVIDULA FEE TO GUARANTEE YEARLY MANAGEMENT OF INCINERATION FACILITY IN ASKOLE		
	PKR	1.883
	USD	**20,76**

Individual Waste Management Fee

By summing up all the individual fees to guarantee clean up campaigns and eco-toilets management in Baltoro Area and running of incineration facility in Askole, a Waste Management Fee for each CKNP visitor could be equal to:

INDIVIDUAL **WASTE MANAGEMENT** FEE		
	PKR	7.107
	USD	**78,32**

All these calculations have been done starting from data of real costs supported during the last years to guarantee clean up campaigns and eco-toilets management in Baltoro Area and running of incineration facility in Askoli.

The calculation for the individual fee has been done starting from the number of tourists separated between trekkers and climbers and their esteemed waste production.

The waste collected in the past years is higher than the estimate of quantity which should be yearly produced by visitors. This is due to the fact that during the past cleaning activities, great quantities of waste left in the past have been collected.

An increase of tourist flow will imply also an increase of waste produced and therefore also an increase of the proposed individual waste management fee should be evaluated in the next year.

Rising Problems

Campsites and Localized Services

Exercising localized services is restricted to members of villages please use always the valleys/villages holding the usufruct rights on the respective *unsettled* areas, where the services and goods are provided, which is for the major campsites en route to Baltoro: Askoli (Jhula), Testay (Paju), Kurfay (Urdukas), and Goro 2. These campsites charge for pitching tents and use of facilities and are managed by committees with institutional and technical support from a non-governmental organization - in case of Jhula and Urdukas - or by means of traditional community institutions of the respective villages/municipalities. A common feature of all campsite management setups is the rotational assignment of paid duty shifts among all households of the respective villages/municipalities, whereas the composition of seasonal "campsite management teams" is fixed.

Table 46 Overview of local opportunities for localized services provision in the tourism sector

FUNCTION	TERM	AVG. NUMBER	AVG. REMUNERATION	AVG. DAYS OF INVOLVEMENT PER SEASON	AVG. OVERALL REVENUE PER SEASON	ACCESS TO OPPORTUNITIES
Camp site maintenance	Supervisor	2 - 8	1500 – 4000 per month	180	9000 - 24000	Among residents of village/municipality with usufruct rights on campsite area mostly rotational allocation
Provision of goods	Vendor	varies	varies	180	varies	

Campsite records of 2011 show an overall net profit made at Jhula and Urdukas campsite, excluding retail revenue, of 30'000 to 40'000 Pakistani Rupees (approx. 300 – 400 US$), after payment of campsite staff, procurement and stocking of consumables for cleaning, and expenses for basic maintenance. The managing villages utilize profits for community projects that are not related to campsite facilities. Cost for waste management, repair and development of the facilities are fully borne by NGOs. Internalizing such expenses into campsite management operation at current campsite fees would result in a significant net loss.

In the Park area, starting from 2003, several equipped campsites have been arranged, for the first time on the Baltoro side with 3 campsites: Joula, Paiju and Urdukas, to which in the last years other interventions both on the trekking towards Concordia and on Hushey side have been managed by local communities with property rights.

While for the first mentioned campsites modern technologies have been used for services in plastic reinforced by incorporated fiberglass and with western toilets, for the second a more poor technology has been used also with a minimum environmental impact.

The campsites managed by local communities, present two opposing aspects. From one side they are absolutely needed to receive touristic demand, on the other the management of these years and the few maintenance interventions have brought to a general deterioration state and to the concentration in these areas of ditches for waste burial (not coherent with the project of waste management which this document aim to establish).

Table 47 Campsites assessment

CAMPSITES	SERVICES	USE	TODAY CONDITIONS	WORKS NEEDED
KOROFONG	1. Not garded 2. Water (river) 3. Shadow 4. Campsite fee (Askole)	1. Lunch stop 2. Few trekkers up/down	i. Clean	1. two new toilets traditional style
JOULA	1. Organized campsite 2. Water 3. Toilet + lavatory 4. Shop 5. Campsite fee (200 PKR per small tent - 300 PKR large tent) 6. Waste fee (group) 500/100 PKR for kerosene	1. Intensive 2. More up than down 3. In 2011 701 presences	i. Water quality not good ii. 4 toilets for tourists iii. 5 toilets for porters iiii. Lavatory not working iv. Waste not properly managed	1. Plantation 2. Restore water supply 3. Restore lavatory 4. New toilets traditional style (3 for tourists and 1 for porters) 5. Fence for campsite 6. Area for animals
MONGORN DERA	1. Organized campsite 2. Water 3. Shop 4. Campsite fee (200 PKR per small tent - 300 PKR per large tent) 5. Waste fee (group)	1. Increasing 2. Especially trekkers up/down	i. Few services	1. Water pipe 250 mt 2. Plantation 3. New toilets traditional style (3 for tourists and 1 for porters) 4. Area for animals
PAJU	1. Organized campsite 2. Water 3. Toilet + lavatory 4. Shop 5. Store 6. Monsk 7. Campsite fee (200 PKR per small tent and 300 PKR per large tent) 8. Waste fee (group)	1. Super intensive 2. Rest two days going up	i. Shortage of water ii. 6 toilets tourists iii. 6 toilets porters iv. bad smell and dirty surface in the porters toilet area v. waste not properly managed (open holes smelling)	1. Water pipe 500 mt 2. Water tank 3. Repair lavatory 5. New toilets traditional style (4 for tourists and 3 for porters) 6. Area for animals
KHOUBURSE LILIGO	1. Organized campsite 2. Water 3. Toilet (traditional) 4. Shop 5. Fresh vegetables 6. Campsite fee (200 PKR per small tent and 300 PKR per large tent) 7. Waste fee (group)	1. Increasing 2. Trekkers up and expeditions down		1. Water pipe 2. New toilets traditional style (2 for tourists and 1 for porters) 3. Camping places

CAMPSITES	SERVICES	USE	TODAY CONDITIONS	WORKS NEEDED
URDUKAS	1. Organized campsite 2. Water 3. Toilet + lavatory 4. Shop 5. Store 6. Campsite fee (200 PKR per small tent and 300 PKR per large tent) 7. Waste fee (group)	1. Intensive 2. In 2011 618 presences	i. Shortage of water ii. 4 toilets tourists iii. 5 toilets porters iv. lavatory not working	1. Water tank 2. Restore water pipe 3. Restore lavatory 4. New toilets traditional style (4 for tourists and 2 for porters) 5. Fence for campsite 6. Area for animals
GORO 2	1. Over the glacier 2. Eco platform (2 toilets) 3. Shop (small store)	1. Intensive	1. Few services	1. Two more toilets (eco-platform) 2. Porters shelters
CONCORDIA	1. Over the glacier 2. Eco platform (6 toilets) 3. 2 Shops 4. 2 Big stores	1. Super intesive - several nights especially for trekkers	i. Now clean and good conditions	1. Porters shelter 2. Rescue services
ALI CAMP	1. Over the glacier 2. Water 3. Gondogoro cross Fees (1/3 members 2500 PKR - 1 member more 1500 PKR)	1. Increasing almost all tourists try to cross to hushey	i. Few services	1. Two more toilets (eco-platform) 2. Porters shelters
KHUISPANG	1. Organized campsite 2. Water 3. Toilets (traditional) 4. Shop 5. Campsite fee (200 PKR per small tent - 350 PKR per large tent)	1. 1 night possible to rent a tent for 1000 PKR	i. Clean and hospitality ii. Two toilets traditional style	
DALSANG PA	1. Water 2. Toilets (traditional) 3. Shop 4. Campsite fee (200 PKR per small tent - 350 PKR per large tent)	1. Few	i. two toilets traditional style	
GANDOGHORO	1. Water 2. Toilets (traditional) 3. Shop 4. Campsite fee (200 PKR per small tent - 350 PKR per large tent)	1. Few	i. Two toilets traditional style	

CAMPSITES	SERVICES	USE	TODAY CONDITIONS	WORKS NEEDED
SAICHO	1. Organized campsite 2. Water 3. Toilets (traditional) 4. Shop 5. Campsite fee (200 PKR per small tent - 350 PKR per large tent) 6. Hut 7. Restaurant	1. Intensive	i. Full service	

The not good present conditions are highlighted from the 80% of interviewed visitors which express a favourable opinion on their presence but at the same time they wish a substantial renovation with low environmental impact and use of local material and technologies.

However, the current campsite management systems are struggling with economic and environmental sustainability, as well as quality and reliability of campsite services.

The system of waste management can run only if campsites managers take care of transportation of differentiated waste to the eco-centers of Askoli and Hushey as specified afterwards, under direct control of CKNP supervisors.

Campsite Management System for Paju

The management team for Payu campsite comprises of a permanent “manager”, supervisors and vendors. Supervisors are employed by the village at fixed rates to maintain the facilities at the site and to collect fees. Vendors are entitled to carry out retail at the site. They often work in partnership with supervisors for procurement, shipping, and resale of supplies to expeditions, while the profit is shared equally among the members of the campsite management team at the end of the term. Profit earned through campsite fees, on the other hand, is common property of the village/municipality. In terms of income, the campsite management mechanism applied by Testay municipality features a registration, bookkeeping and audit process. The village governance (Yulstrung) is mandated to verify the campsite records against the overall campsite income at the end of the season. Since it is constituted on a rotational basis, a certain element of independence of this process can be assumed. However, the Yulstrung does not possess the means to verify the accuracy of the records. The rotational campsite supervisors work under the supervision of the campsite manager and a coupon-system applied at the campsite ensures accurate reporting and handover of the collected fees to the manager. Since the supervisors are paid on salary basis and not on commission their incentive to check and balance record keeping by the manager at the campsite is presumably low. Hence, the accuracy of campsite record keeping is based entirely on trust towards the campsite manager, which is a permanent position. The tsarma council acknowledges this weak link in the internal control system and plans to create a new position with the mandate to verify the accuracy of record keeping at the campsite. The tsarma council considers campsite management an income generation activity for the community and its members and does currently not see a prospect to turn campsite management into a profitable service provision-enterprise. The salaries of the supervisors are low compared to the revenue that could be generated by alternative opportunities in the tourism sector during a season. Consequently campsite supervision is often considered a duty rather than entitlement to a benefit. The profit made by vendors, which is shared equally among the members of the seasonal campsite-“team”, including the supervisors, was not assessed, but implies that the potential profit from business at the site is already connected, and therefore provides an incentive for, maintenance-duty.

Eco-Tourism

Principles of Ecotourism

Ecotourism is defined as "responsible travel to natural areas that conserves the environment and improves the well-being of local people"[4].

CONSERVATION	COMMUNITIES	INTERPRETATION
Offering market-linked long-term solutions, ecotourism provides effective economic incentives for conserving and enhancing bio-cultural diversity and helps protect the natural and cultural heritage of our beautiful planet	By increasing local capacity building and employment opportunities, ecotourism is an effective vehicle for empowering local communities around the world to fight against poverty and to achieve sustainable development.	With an emphasis on enriching personal experiences and environmental awareness through interpretation, ecotourism promotes greater understanding and appreciation for nature, local society, and culture.

Ecotourism is about uniting conservation, communities, and sustainable travel. This means that those who implement and participate in ecotourism activities should follow the following ecotourism principles:

- minimize impact.
- build environmental and cultural awareness and respect.
- provide positive experiences for both visitors and hosts.
- provide direct financial benefits for conservation.
- provide financial benefits and empowerment for local people.
- raise sensitivity to host countries' political, environmental, and social climate.

Tourism causes damage. Ecotourism strives to minimize the adverse affects of hotels, trails, and other infrastructure by using either recycled materials or plenty fully available local building materials, renewable sources of energy, recycling and safe disposal of waste and garbage, and environmentally and culturally sensitive architectural design. Minimization of impact also requires that the numbers and mode of behavior of tourists be regulated to ensure limited damage to the ecosystem

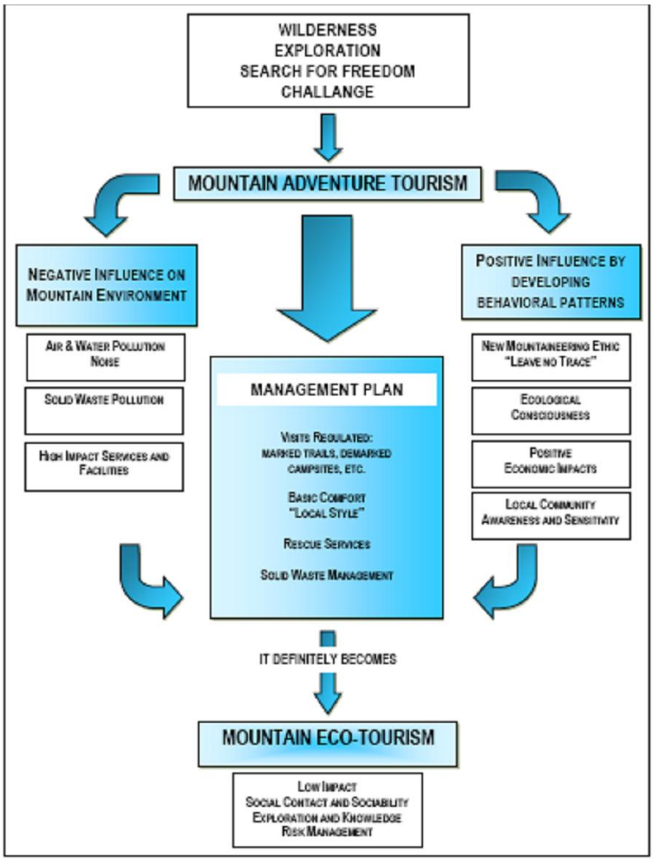


Exhibit 47 Mountain Tourism can become Eco-Tourism

Provides financial benefits and empowerment for local people: National Parks and other conservation areas will only survive if there are "happy people" around their perimeters. The local community must be involved with and receive income and other tangible benefits(potable water, roads, health clinics, etc.) from the

[4] TIES, 1990

conservation area and it's tourist facilities. Campsites, lodges, guide services, restaurants and other concessions should be run by or in partnership with communities surrounding a park or other tourist destination. More importantly, if Ecotourism is to be viewed as a tool for rural development, it must also help shift economic and political control to the local community, village, cooperative, or entrepreneur. This is the most difficult and time-consuming principle in the economic equation and the one that foreign operators and "partners" most often let fall through the cracks or that they follow only partially or formally.

These are the definitions, we see that if well oriented and realized in a correct way the activities which are being carried out in the Park can be included within these parameters if managed under strict control of Park itself particularly for waste management, total control on infrastructures and management. To these already existing activities others, as cultural and environmental routes of 2/3 days which rely on structures realized following eco-tourism criteria, can be added so to complete the offer also for the touris m demand not interested in long climbing trails.

In this direction all the new initiatives which can be retraced to eco-tourism must be incentive most of all near park borders, but most of all the efforts must be concentrated to effectively render the activities which are being carried out in the Park as an eco-tourism experience.

5.2 Management Strategies

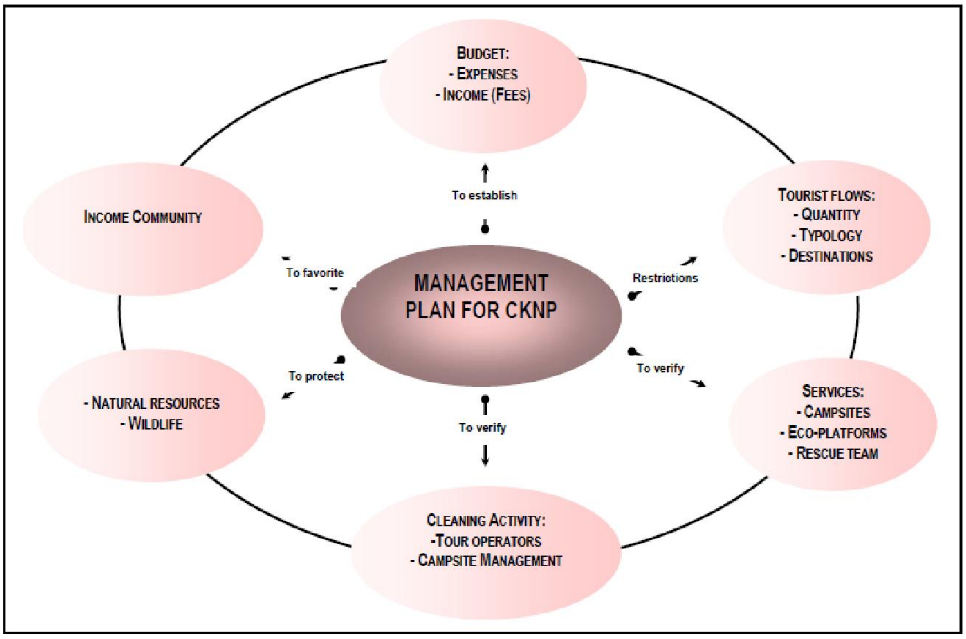


Exhibit 48 Awareneness process sustainable tourism

5.2.1 Rules for Visitors and Group Leaders (Trekking Guides And Sardars)

The following activities are severally prohibited within the Park territory:

- to use motorized ways of transfer;
- camp outside the designated camp sites areas (especially in the Baltoro corridor and Gondoghoro trek);
- practice hunting and fishing (permitted only inside Trppy Hunting areas which may not be inside may be in buffer zone);
- to damage park signs;
- pollute water sources and glaciers surfaces;
- light fires (to cook or burn waste);
- collect wood and shrubs;
- disturb the peace with bothersome noises;
- to collect flora and rocks;
- disturb the wildlife with high noise;
- carve graffiti or any other inscriptions on the stones;

The introduction in the Park of the following objects is strictly prohibited:

- nylon bags and nylon boxes;

5.2.2 CKNP Tourism Zones and Sectors

Sectors, with different touristic influence, can be identified within the Park as:

SECTOR 0 BUFFERZONE

SECTOR 1 MAIN TOURIST CORRIDOR

ZONING - TOURISM FOCUSED ZONE (indicated in the map):

i. Baltoro Passage and 8000mt Base Camps
ii. Gondogoro

SECTOR 2 LOW FREQUENCY TOURISM AREA[5]:

i. Biafo Hispar
ii. Spantik (Basha)
iii. K6, K7 (Hushey)
iv. Trango

SECTOR 3 OCCASIONAL TOURISM AREA[6]:

i. Latok Ogre and other peaks Biafo
ii. Other peaks Baltoro
iii. Shigar – Thalley treks and peaks
iv. Bagrot-Haramosh treks and peaks
v. Pisan Minapin
vi. Rakaposhi - Diran
vii. Others treks and peaks

SECTOR 4: TOURISM NOT ALLOWED AREA

ZONING: INTENSIVE CONSERVATION ZONE (WILDERNESS):

i. Intensive conservation zone (total wilderness). To identify these area please see the zonation map of the park.

[5] This is a free area with an automatic entrance authorization.

[6] The entrance authorization for this sector is subjected to CKNP Directorate authorization.

Sector 0: Buffer Zone

Within the Buffer Zone there are various tourist trails, offering interesting destinations and excellent panorama inside uncontaminated natural settings. These trails can be also trekked by tourists that have not undergone any particular training.

Regulation

- Total freedom to move also outside the trekking trails
- Tourists have to carry out with them their produced waste.
- Horses and mules are not allowed

Services

- No services available

Visitors Entry Fees

Double Fee System:

- **CKNP Entry fee.**

  This fee is the same as the one applied in the other National Parks of Gilgit-Baltistan.

- **Waste Management Fee.**

  The Waste Management Fee contribution must be used to support the CKNP in the activities of campsites control and cleaning campaigns. However, this fee is going to be paid only if the tourists are going to stay in the Buffer Zone for more than 3 days (2 nights).

Sector 1: Main Tourism Corridor

Almost all the touristic flows, entering the CKNP area, go through the Baltoro - Gondogoro – Hushey Corridor. Along this route all the campsite services for the tourists are also located. This is the area where the biggest problems with waste-management are concentrated. Therefore, the activities for the correct implementation of the Management Plan have to be planned very accurately in this particular area.

The trekking paths have to be indicated as the equipped campsites are located along them. These campsites are managed by the local communities, which also hold usufruct rights on the area. However these usufruct rights are exercised under a tight control provided by CKNP.

On these campsites, extraordinary maintenance interventions have to be planned in order to make campsites services adequate to tourist requests. However, at the same time, these extraordinary interventions must not have a negative impact on the environment. This is the reason why only natural materials have to be used. Moreover the campsites will have to be limited in number and dimensions, in accordance with a specific plan which will have to be arranged by the Park Offices.

The most important interventions are the ones related to assure the availability of drinking water, which will have to be controlled through chemical and physical analyses in order to certify its quality. The hygienic services will have to be developed by respecting local customs, so that it is going to be easier to use and maintain them. In the surroundings of each campsite, a fenced area should be arranged in order to stop animals from free grazing.

Particularly in Concordia campsite, where usually animals should stop for some days, waiting for new loads, a service of daily cleaning of the spaces dedicated to the animals is needed. These spaces must be delineated and limited with collection of excrements in drums and transportation outside the glacier (in connection with eco-platform management).

Inside the campsites, managed deposit and selling of goods are authorized, however the infrastructures for these deposits will have to be approved by the Park Offices, which are going to arrange a plan of interventions, which pursues minimal impact objectives. In any case, it will not be possible to increase the actual volumes of built area.

Regulation

- Obligation to follow the marked paths;
- Mandatory to camp inside the designated campsites;
- Payment of camping service (this cost must be paid to the campsite managers in order to maintain and manage waste including the related costs for waste transportation down to valley);
- Segregated waste disposal, solid waste and human waste disposal;
- Prohibition of lighting up fires (to cook and to burn wastes and papers), only kerosene and butane gas can be used for cooking;
- Possible use of horses and mules for transportation purposes (see specific regulation)[7].

Services

- Equipped campsites;
- Outside the glacier: local style/traditional toilet only);
- On the Glacier : eco-platforms/eco-toilets with drums;
- Deposit of material only inside the campsite;
- Rescue team Concordia (RTC): medical and first aid facility;
- Rescue team Hushey (RTH) (Ali Camp/Gandogoro la): medical and first aid facility;
- Tracks;
- Foot bridges;
- Signage. Trail, view points, etc.;
- Incinerators at the entry point Askoli and Hushey;
- Waste management at three levels: campsites; tour operators; CKNP staff.

Visitors Entry Fees

[7] The use of mules for transportation is authorized only following the below rules:

- All animals need to have passed a certified veterinary visit and vaccinations (annual visit with certification by CKNP);
- Obligation to remove straight away dead animals and transport them outside CKNP borders.

Double Fee System:

- **CKNP Entry fee.**

  This fee is the same as the one applied in the other National Parks of Gilgit-Baltistan.

- **Waste Management Fee.**

  The Waste Management Fee contribution must be used to support the CKNP in the activities of campsites control, management of the eco-platforms installed on the glacier, management and maintenance of incinerators installed in Askole and Hushey, and extraordinary cleaning campaigns arranged for particular locations where clean up is needed for the continuous waste accumulation.

Sector 2 Low Frequency Tourism Area

In this sector we find trekking routes and peaks seldom or never frequented, but in any case every year they attract a fair number of visitors. This sector is not equipped with services and campsites and management of waste is under total responsibility of Tour Operator. Tour Operators guides must be trained by CKNP staff about procedures to be followed for proper management of waste. CKNP staff must check and verify that this procedures are being applied and must also apply sanctions in case behaviours not consonant to the criteria of environmental protection which in this sector are more binding than in the Sector 1.

In this sector in order to guarantee a wider accuracy of eco-system protection, the garbage deposit should be asked also to trekking parties and it should be increased its amount for the expeditions of 10% respect the one requested in the Sector 1.

Regulation

- Prohibition of making fires (to cook and to burn wastes and papers), only kerosene/gas can be used for cooking;
- Mandatory waste transportation outside the Park or, if possible, up to nearest equipped campsite, to be carried out by the tour operator;
- No horses and mules can be used for transportation purpose (except for Trango).

Services

- Main Tracks;
- Main Foot bridges;
- Main Signage.

Visitors Entry Fees

Double Fee System:

- **CKNP Entry fee.**

  This fee is the same as the one applied in the other nearby National Parks.

- **Waste Management Fee.**

  The Waste Management Fee contribution must be used to support the CKNP in the activities of campsites control, management of the eco-platforms installed on the glacier, management and maintenance of incinerators installed in Askole and Hushey, and extraordinary cleaning campaigns arranged for particular locations where clean up is needed for the continuous waste accumulation.

Sector 3 Occasional Tourism Area

In this sector trekking routes and peaks seldom or never frequented in last years have been included and we believe that these trails must be inserted in a sector for which main objective is to further reduce the tourist presence with regard to the wildlife protection. After having considered and assessed wildlife and natural resources conditions, CKNP Directorate should decide if authorize (or not) the entering of tourists in this sector.

In this sector, in order to guarantee a greater accuracy of ecosystem protection, the garbage deposit will be requested also to the trekking parties. The deposited amount should be higher than applied in the Sector 2. Also the garbage deposit for the expedition should be increased of 20% respect the one requested in the Sector 1.

Access Authorization

Accesses must be authorised by the CKNP, considering the fauna protection plans. For example, permissions can be granted for more years, to be defined by the specific plan.

Regulation

- Prohibition of making fires (to cook and to burn wastes and papers), only kerosene can be used for cooking
- Mandatory waste transportation outside the Park, to be carried out by the tour operator;
- No horses and no mules can be used for transportation purpose;
- Environmental protection criteria must be totally and striclty respected (behaviours not conformed will be sanctioned by CKNP staff).

Services

No service.

Visitors Entry Fees

Double Fee System:

- **CKNP Entry fee.**

  This fee is the same as the one applied in the other nearby National Parks

- **Waste Management Fee.**

  The Waste Management Fee contribution must be used to support the CKNP in the activities of campsites control, management of the eco-platforms installed on the glacier, management and maintenance of incinerators installed in Askole and Hushey, and extraordinary cleaning campaigns arranged for particular locations where clean up is needed for the continuous waste accumulation.

Sector 4 No Tourism Allowed Area

Zoning: Intensive Conservation Zone (Wilderness)

Access Authorization

Total prohibition of granting permission. Visitors are not allowed to enter. Peaks inside this zone can not be climbed. The identification of this zone has to be referred to the Park maps. This zone is a fully protected reserve zone. For research purpose with specific permission this sector can be visited.

5.2.3 Streamlining Entry Fee System for Visitors proposal to be discussed with partners and local communities

Present System

Today two levels of fee are being applied:

I. Main taxation, applied from Islamabad for expedition or trekking groups. These fees are being collected by KANA.

PERMIT FEE:

Mountaineering Expeditions:

K2 → 7.200 USD till 7 participants (+ 1.200 USD for each additional member);

Other 8.000 Peaks → 5.400 USD till 7 participants (+ 900 USD for each additional member);

Peaks with altitude between 7.501 and 8.000 → 2.400 USD till 7 participants (+ 300 USD for each additional member);

Peaks with altitude between 7.001 and 7.500 → 1.500 USD till 7 participants (+ 180 USD for each additional member);

Peaks with altitude between 6.501 and 7.000 → 900 USD till 7 participants (+ 120 USD for each additional member);

Trekking Groups:

50 USD per person (also for expeditions under 6.500 m);

POLLUTION FEE:

200 USD for each group.

The Tourism Department of Gilgit-Baltistan Government's request is that this fund can be transferred to the provincial Government. The request is outstanding.

II. Local taxation.

CAMPING RATE:

150 PKR per small tent;

250 PKR per big tent.

Proposed System

Tourism Department Gilgit Baltistan

Permit Fee

A similar system to the present one can be hypothesized. The fee could be paid at the GB tourism department in Gilgit, or Skardu. These places will be more suitable also for the tour operators, taking the occasion of the briefing. To this briefing a representative of the CKNP should also always participate, in order to collect the

Garbage Deposit, which should be paid back during the de-briefing while checking all the equipment and waste transported back.

CKNP

Entry Fee

Pakistani National Parks, contiguous to the CKNP, have an entry fee equal to:

8 USD for **foreigners** tourists;

20 PKR for **national** tourists;

0 PKR for inhabitants of GB.

These amounts are being decided and they could be modified along the years and it is suggested to keep the same entry fee.

Waste Management Fee

At present a *pollution fee* of 200 USD for each expedition above 6.500 m is being paid in Islamabad and GB Tourism Department requests its transfer to provincial Government. It is opportune to propose a substantial change of this fee. This should be named Waste Management Fee and should be transferred to the CKNP Directorate, since the 90% of the trekking and expedition tourists is visiting the territory of this Park.

The Waste Management Fee contribution must be used to support the CKNP in the activities of campsites control, management of the eco-platforms installed on the glacier, management and maintenance of incinerators installed in Askole and Hushey, and extraordinary cleaning campaigns arranged for particular locations where clean up is needed for the continuous waste accumulation.

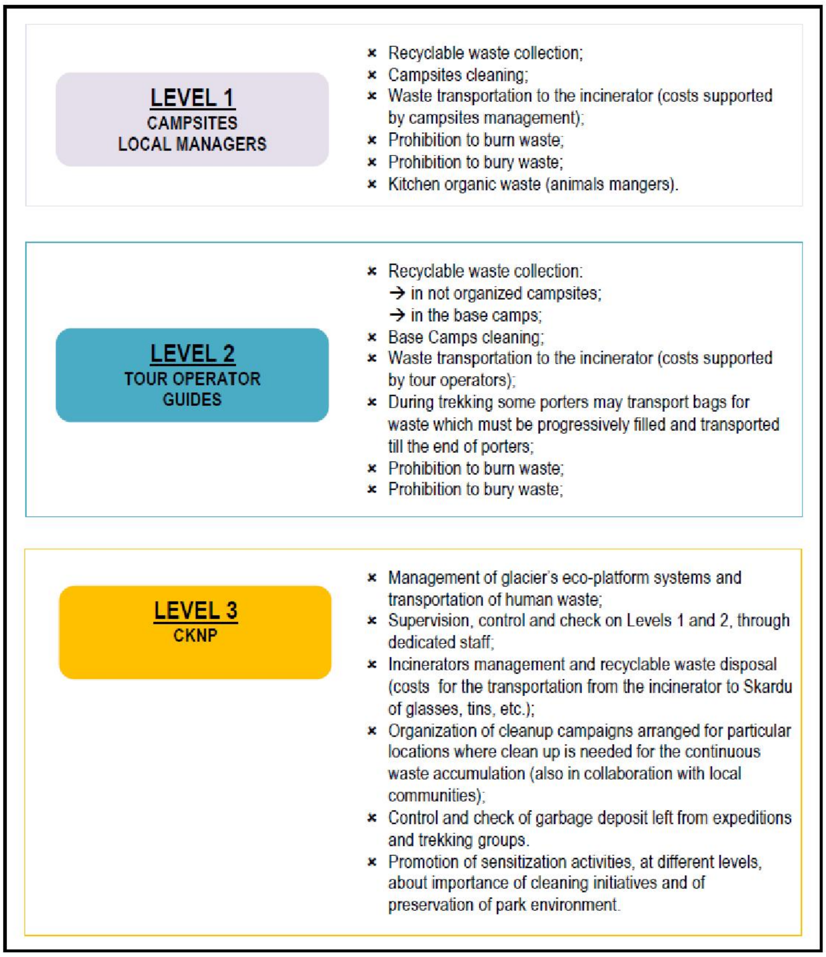


Exhibit 49 Solid waste management

These Waste Management Fees can be considered fair to the following amounts:

85 USD for **mountaineering expedition** members;

50 USD for **trekking parties** members;

0 USD for inhabitants of GB.

For the expeditions outside the Park (for example at Nanga Parbat), the same amount could be kept and increased of 30 USD/-per participant in case of expeditions with a number of participants above 7 members.

Garbage Deposit

Mountaineering Expeditions Groups

The deposit should be paid at the CKNP Entrance Points of Askoli or Hushey or Hisper before the departure. The amounts[8] to be deposited are fixed as follows:

Peaks in Sector 1

Peaks above 8.000 m → 1.500 USD till 7 participants + 100 USD for each additional member;

Peaks between 7.000 m and 8.000 m → 1000 USD

Peaks between 6.000 m and 7.000 m → 800 USD

Peaks in Sector 2

Increase of 10%

Peaks in Sector 3

Increase of 20%

For each expedition group, CKNP staff must check the following equipment list:

- At the entrance:

Oxygen cylinders		Q.ty ____
Batteries – Solar panels		Q.ty ____
Small tent BCs and High Camps		Q.ty ____
Mess tents and Kitchen tents		Q.ty ____
Epigas bottles		Q.ty ____
Climbing ropes and fixed ropes		Q.ty ____
Kerosene stoves		Q.ty ____
Special equipment	Type___________	Q.ty ____

- At the exit:

Oxygen cylinders	Q.ty ____
Batteries – Solar panels	Q.ty ____
Small tent BCs and High Camps	Q.ty ____
Mess tents and Kitchen tents	Q.ty ____

[8] These amounts should be deposited by all expeditions visiting **Sector 1** and/or **Sector 2** and/or **Sector 3**.

Epigas bottles Q.ty ____

Climbing ropes and fixed ropes Q.ty ____

Kerosene stoves Q.ty ____

Special equipment Type__________ Q.ty ____

Waste (3kg/-per member every 10 days in the CKNP)[9] Kgs ____

In case between the two lists will not match and the quantities of waste consigned to the decided collection point (Askole Incinerator, CKNP Headquarter, Hisper Nagar Side, etc.) will not correspond to the right calculated amount, the Garbage Deposit will be withheld as indemnity to cover further expenses for the material, and left waste, transportation. Assumption of proportional class:

To the quantity of left waste;

To waste not transported;

Starting from a minimum of 200 USD.

Trekking Parties

No check list equipment will be needed. To guarantee management of the waste, two hypothesis are proposed:

Baltoro Corridor And Gandogoro La Track To Hushey[10]

These routes are completely served by managed and controlled campsites (for which a Rate is also foreseen). The amount for trekkers visiting these areas is equal to:

Garbage Deposit: 200 USD

Other treks or peaks without managed campsites[10] Sector 2

Garbage deposit: 300 USD

Other treks or peaks without managed campsites[10] Sector 3

Garbage deposit: 400 USD

Hypothesis of class proportional to waste not transported. The refund of the deposited amount it will depend on the waste effectively transported outside the Park and verified in CKNP check point.

In case the weight of waste will not correspond to the right calculated amount, the deposited will be partially refunded on percentage basis.

Local Communities

Campsite Rate

The equipped campsites along Baltoro Corridor and Hushey Trek are managed by the communities which hold rights under the supervision of CKNP staff. For each campsite, an adaptation plan with the least

[9] This amount must be proportionally increased or decreased according to the days spent in CKNP.

[10] For trekking parties the calculation of kg of waste to be brought out the Park is equal to: 2,5/-Kg per member every 10 days in the CKNP. This quantity must be proportionally increased or decreased according to the days spent in the CKNP.

environmental impact and which considers the use of poor technologies, should be designed for what concerns potable water, services, tents area and animals corrals.

The management of each campsite is directly decided by the respective villages/municipalities through a rotation system among the different families. The community autonomously decides the amount to be paid as salary of the staff in charge for the management of the campsite and the yearly staff number which must work in the campsite.

At Askole(Jhula) and Urdukas camps (two of the main camps en route to Baltoro), the Campsite Rate is being paid by tourists directly to MGPO, while at Paju directly to the campsite manager. The rate is calculated considering the nights effectively spent in the campsite.

Campsites managers must assure:

- cleaning;
- recyclable-waste collection;
- ordinary maintenance, agreed with CKNP supervisor;
- waste transportation to the incinerator (transportation costs supported by campsites keepers), under of supervision of CKNP staff. Waste burying is severally prohibited;
- keeping of attendance register;
- keeping a rate register.

CKNP should:

- supervise every campsite with at least one appointed operator/supervisor;
- verify correct management;
- contribute to the payment of costs for the extraordinary maintenance, where and when needed.

Within this framework it is proposed to change the system from a “/-per tent rate” to a “/-per person rate”. The amounts suggested are:

10 USD/-per person/-per night (**Foreigners**);

500 PKR /-per person/-per night (**Pakistani**);

0 USD for local inhabitants.

The profit should be entirely (100%) hand-over to Local Communities.[11]

This scheme must be applied for all the campsites located in the tourists corridor of Sector 1.

The cost for the intervention of the Hushey Rescue Team is considered separately and doesn’t include the payment of Ali Camp which will be the same of other Baltoro Campsites.

[11] A sanctions system has to be set up by CKNP Directorate, considering waste management criteria. Local communities have to respect these criteria otherwise they will incur in these sanctions.

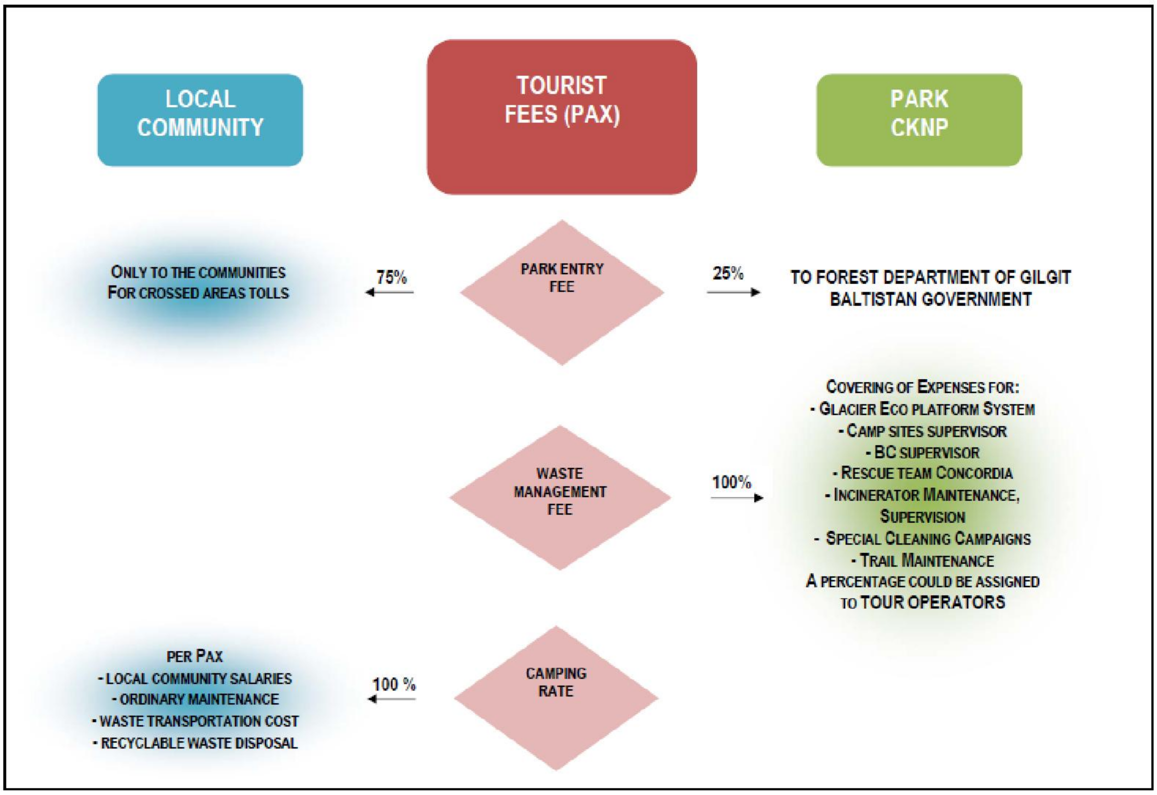


Exhibit 50 System of fees for CKNP Visitors

Tour Operators

The law foresees that tour operators are responsible for the park cleaning and for the transportation of waste produced during trekking or expeditions outside the park.

For tourists who are going through Baltoro Corridor this service is guaranteed by campsites managers. For tourists who are travelling to base camps or to not equipped trails, the tour operators are obliged to collect all the waste produced and cover the transportation cost till the nearest waste check point (which could be an entry point or other decided by CKNP).

If the quantity of waste transported doesn't correspond to the one indicated in the chapter Garbage Deposit, the deposited amount will not be entirely paid back.

At the base camps CKNP staff should check that tour operators collect waste, while in case of trekking, drum and bags should be foreseen along routes so to be progressively filled and be transported till the end of the trekking itself.

5.2.4 Limitation of Tourist Flows in CKNP

Limitation Hypotheses

During each season, the Park can only accommodate the following visitors:

- Max 600 mountaineers per expedition :
    - max 8 expedition per peak;
    - max 80 mountaineers per peak.
- Max 2400 trekkers.

These maximum entrances threshold must be yearly evaluated by CKNP according to the environmental impact of tourism in the previous years.

It could therefore happen that if during one year the visitors exceed these entrances, during the next season, it is mandatory to proceed with an entrances reduction which should exactly correspond to the number of people in excess the previous year.

The result of Tourism Sector analysis and assessments meet in the Fee System Imposition, promulgated by the Gilgit Baltistan Government on the 7th March 2014, as described in the CKNP Management Plan, Version 2 of October 2014.

6. MAP COVERAGE

6.1 Overview (Sciences and Technologies Applied to the Environment)

The aim of this research line is to implement a GIS for the support of the CKNP management plan and the other researched developed. For this reason this specific line could be consider in the middle between a vertical and an horizontal research. Regarding the GIS program the specific objectives are to organize a geographic database with the different environment parameters useful as indicators in a monitoring system; to share experiences about application of remote sensing and GIS processing between different specialist and to test this on an environmental model.

6.2 Digital Elevation Model (DEM)

NASA and METI have released a second version of the ASTER GDEM (GDEM2) in mid-October 2011, using Aster images. The GDEM2 has the same gridding and tile structure as GDEM1, but benefits from the inclusion of 260,000 additional scenes to improve coverage, a smaller correlation kernel (5x5 versus 9x9 for GDEM1) yielding higher spatial resolution, and improved water masking. Also, a negative 5 meter overall bias observed in the GDEM1 was removed in newer version. This product was checked using field data and used as base for other products.

The absence of topographic maps in appropriate scale and available for the research groups has led to the need to use the DEM as a reference basis for the extraction of some parameters. This activity aims to extract topographic features from the GDEM data.

The new available data in this phase of the project are:

- GDEM Version2
- Slope map
- Aspect map
- Hillshade map
- The contour lines (50, 100, 250, 500, 1000 m)
- The river network classified by Strahler order
- The watersheds delineation on the basis of Strahler order confluences as pour point.

A high resolution model is under development, and will be ready for the end of 2012.

6.3 River Network

As it is described in the previous paragraph some topographic features were extracted from DTM through the application of a unsupervised model. In this phase of the project the river network extracted from GDEM was used as the basis for the watershed delimitation and for the definition of the valleys in a physiographic methodology.

The river network extracted from digital elevation model is an automatic data and the output cannot be controlled by the user mainly in the areas covered by glaciers.

A specific activity was dedicated to the photointerpretation of available satellite data for water courses extraction. The Landsat TM image acquired on 2010 were used as the basis of interpretation and the main rivers were digitalised. As it is visible in the Exhibit 51 there is a good fitting between the data extracted from GDEM and the photointerpretation process.

The two data have to be used for different purposes:

- for automatic analysis and modelling like watershed extraction or hydrological analysis the GDEM data are useful;
- for map production (field use), geomorphological analysis like water courses change the data from photointerpretation are necessary.

The limit of the interpretation is the accuracy of the data that are based on the spatial resolution of the satellite images and the photointerpretation process. A scale of 1: 30.000 was set to the system for the photointerpretation of the Landsat image (spatial resolution of 30 m).

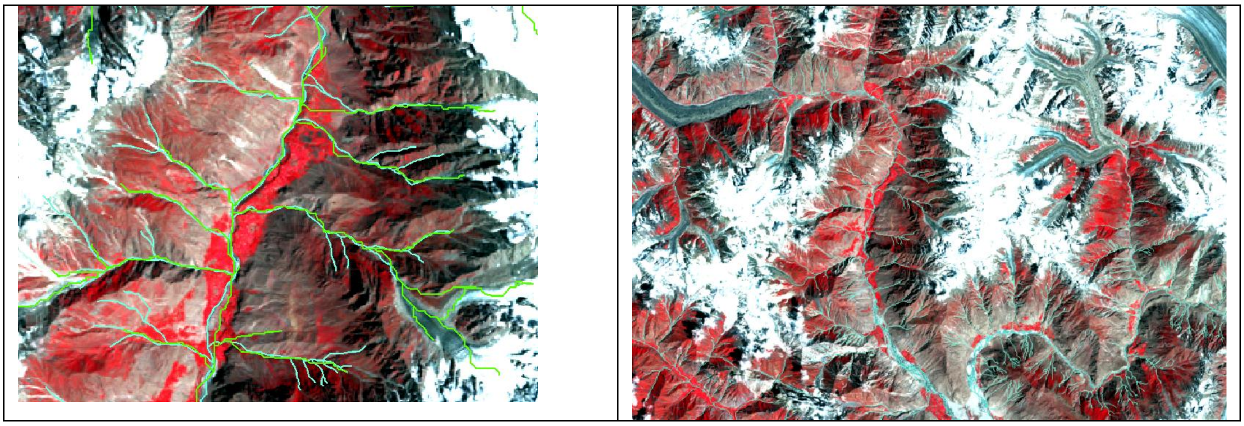


Exhibit 51 River network: on the left the comparison between the GDEM river network (in green) and the data from photointerpretation (in cyan), on the right a sketch of the interpretation.

6.4 Land Cover Map

The methodological approach implemented in this project involves the construction of a database on the land cover and land use, populated with processed data by analysis of remote sensing and field-acquired data.

The data from different sources contribute to create a knowledge system that can be used in the different stages of management of the Park: in the programming phase when they are the basis for knowledge of the environment dynamics and of the distribution of resources and during subsequent monitoring activities. In this way, it becomes mandatory to follow a replicable methodology in time and in space based on calibrated data to the ground.

The classification schema utilized in land use mapping include the main components of the landscape:

- vegetation features: forest, herbaceous cover, crops;
- mineral features: water, rock and soil;
- human component: villages, roads and other artifacts.

The cartographic process that allows to manage this information is often summarized in a single land cover / land use map. This product, having to represent in a static way phenomena dynamic in itself, suffers from serious limitations of use and a not always easy application in the several fields of work which it relates. Moreover, given the complexity and variability of natural phenomena, the interpretation that the cartographer gives during the reporting of observations on a map may not coincide with the perception of that phenomenon by a different user.

These problems of interpretation become more marked by:

- the need for appropriate base data;
- the difficulty of field data acquisition;
- the lack of topographic maps;
- several map accuracy (scales of acquisition and processing).

For the reasons mentioned above in this project it was decided to work in an integrated way in the GIS environment, acquiring information from different sources and populating the geographical database.

The method proposed in SEED project follows the remote sensing method and it is based on vegetation indexes and spectral classification of forest classes extracted from field sample plots. Models to estimate biomass derived from remote sensing need further calibration with ground data before using to predict AGB (Above Ground Biomass) for a given landscape. In this work a direct radiometric relationship (DRR) was created, linking spectral values extracted from vegetation indexes to measured forest variables.

The extension of the model of correlation between NDVI and AGB to the whole area of the CKNP was held on the following steps:

- reclassification of the index in three classes;
- statistical comparison between NDVI developed from data of August and April for the Bagrot valley and reclassification in the three classes. This process has helped increase the value of NDVI more generic and could apply the same values of class to the entire set of data acquired in different seasons.

The output of this process is a map containing details of 3 classes of legend related to vegetation cover:

- Herbaceous vegetation /shrub- land/ single sparse trees;
- Open forest;

- Closed forest.

These classes are added:

- cultivated areas extracted by photo-interpretation of satellite data;
- areas covered by snow and ice, extracted from the images through the Snow Index;
- glaciers by the inventory under way at the University of Milan;
- the bare rock, extracted by the difference compared to previous classes.

In general, the comparison between the maps and the ground truth has given good results. The first validation fields were conducted in the western sector of the park, in the valleys east of Bagrot that responded correctly with regard in particular to areas covered by forest. On the other hand the validation on the field has highlighted a possible over- estimation of the first class of land cover. The area of analysis was Hushey valley and the relative ASTER data was acquired on august. In the summer season a widespread vegetation cover the landscape and the signal is influenced more from this featured than from the bare soil and rock outcrops that are present.

From the land use point of view these areas can‘t be considered as pastures and so it is necessary to divide them from the higher dense herbaceous areas.

There are several solutions:

- to acquire highest spatial resolution data, in which the component of the signal in the pixel is more accurate;
- to acquire data in two seasons (different phonological stages);
- to change the NDVI/AGB correlation with a particular attention to herbaceous biomass.

It is therefore proposed to divide the class into two sub-classes that highlight the best areas in which seasonally is a herbaceous plant cover, in terms of use is grazing.

This reclassification will be applied to two valleys in which the field work is planned, which will allow further validation.

Another aspect of attention must be given to the areas above 3.950 meters in which a high value of biomass is detected. This value is associated in legend with the presence of forest, but is instead attributable to the presence during the summer to high altitude pastures, which have a very high value of NDVI. In this case we will proceed to the correction of the data using the parameter discriminating altitude. In this case too the better solution is a multi-temporal NDVI processed on two seasonal images.

For these reasons new satellite images were choosed. The best available data for this analysis is now offered by Landsat5 TM images, proposed by the U.S. Geological Survey. They have a temporal resolution of 16 days an so it is possible to find images cloud free or with a cloud coverage < 10%. A lower spatial resolution than ASTER images is compensated by the simplification of the atmospheric correction and in the pre-processing phase. In this way the images are more comparable each other and a multi-temporal (multi-seasonal) analysis is well supported.

Two set of images were chosen: the first acquired on November 2009 (minimum snow cover in that year) and the second acquired on May 2010 (winter image).The main metadata about these data are reported in the Table 48 below.

Table 48*ORIGIN = "Image courtesy of the U.S. Geological Survey"

Date	Image type	Scene identification No.	Path-row	Resolution (m)
2000/08/04	TM	LT51480352009216KHC00*	148/35	30
2009/08/27	TM	LT51490352009239KHC00*	149/35	30
2010/05/03	TM	LT51480352010123KHC00*	148/35	30
2010/05/26	TM	LT51490352010146KHC00*	149/35	30

In the Exhibit 52 a subset of the two images is shown.

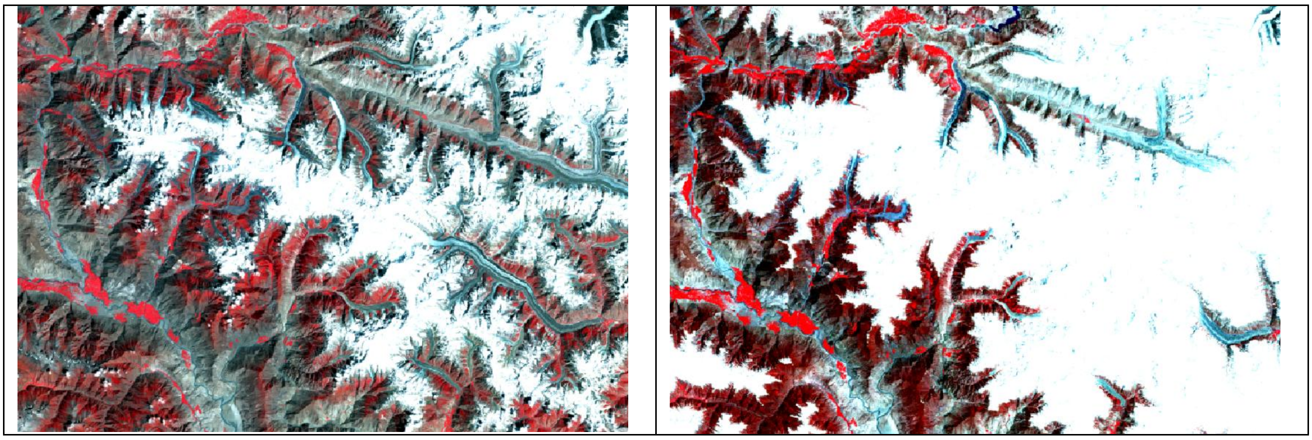


Exhibit 52 Subset of the two images of the western part of the Park: on the left the Landsat acquired on November 2009 (low snow cover and high radiometric signal from vegetation cover), on the right the same area acquired on May 2010 (high snow coverage)

The Landsat data were atmospherically corrected. The steps of the image processing for the extraction of NDVI are indicated below:

- Application of a masking procedure with the Snow Index as mask data;
- NDVI application and density slicing classification on the areas with NDVI >0;
- Raster to vector transformation for the input as a shape layer in the GIS system.
- The classes of NDVI were chosen on the basis of the field biomass calculation.

A further processing was applied on the class with highest NDVI to divide closed forest from pastures, which in some cases gave a similar spectral response.The identification of pastures was based on the altitude. In the areas above 3750/4000 meters of elevation the forest can't grow and during winter the ground is covered by snow. During the summer the herbaceous vegetation covers these areas and an high NDVI is received by the sensor. These consideration are well represented in the images in Exhibit 53.

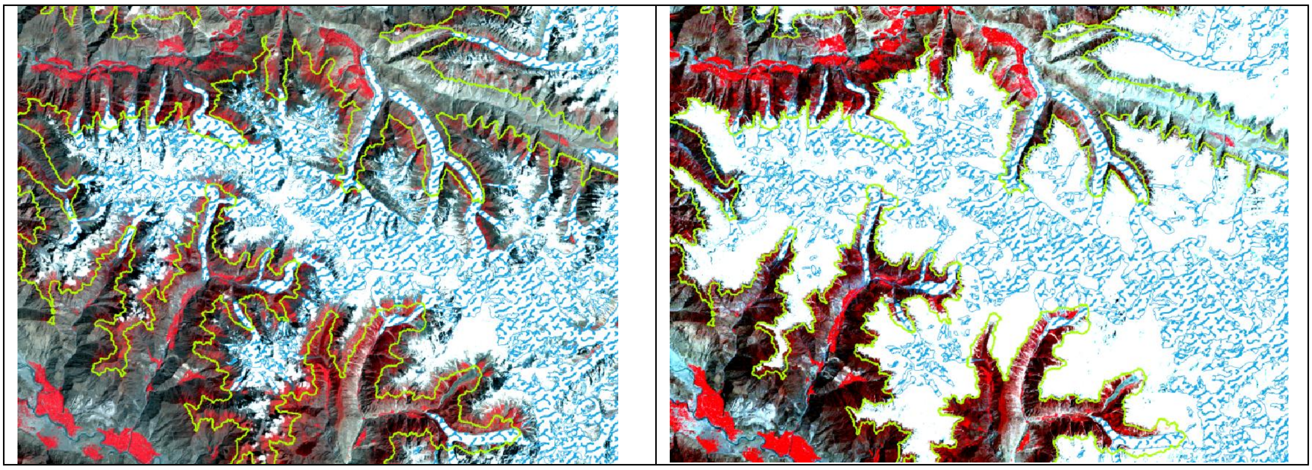


Exhibit 53 Subset of the two images of the western part of the Park with the overlay of the contour line of 3750 mt (in gree : on the left the Landsat acquired on November 2009, on the right the same area acquired on May 2010

The results of the classification and the legend of land cover classes are reported in the Exhibit 54

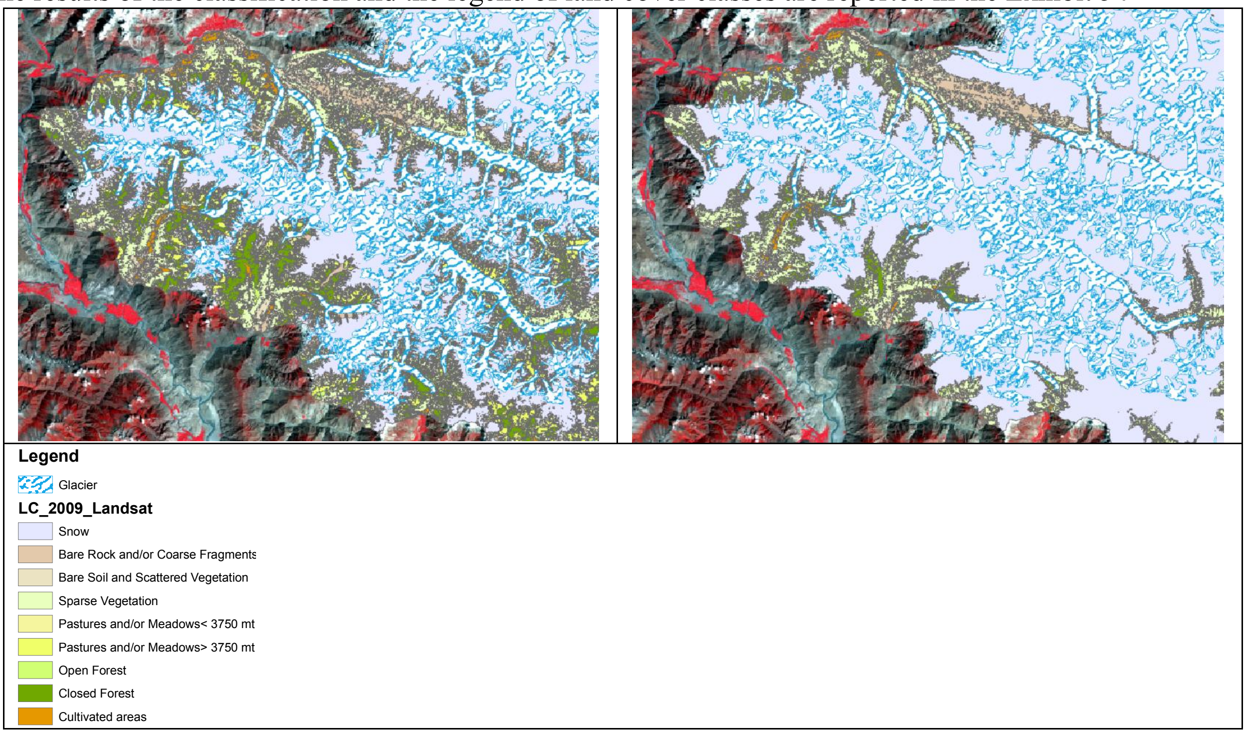


Exhibit 54 Subset of the two Land cover classification of the western part of the Park: on the left the Land cover from the image of November 2009 on the right the same area classified on the basis of the data acquired on May 2010

6.5 Glacier cadastre

Among the possible methods to analyze the ongoing evolution of glaciers, collection and analysis of glacier inventories (e.g. glacier area) can be used to investigate mountain glaciers in a changing climate (Paul et al., 2004), and potential scenarios on a regional scale (Zemp et al., 2006). Glacier geometry changes are staple variables for early detection of enhanced greenhouse effects on climate (Kuhn, 1984, Hoelzle et al., 2003). Glacier inventories allow comparison of long-term behaviour of different mountain ranges upon extended areas, thus integrating high resolution (ground) measurements that can be carried out on a few selected glaciers, but may not be fully representative of climate signal within a whole mountain range (Hoelzle et al., 2007). Glacier inventories should be carried out at intervals compatible with the characteristic dynamic response times of mountain glaciers (a few decades or less in the case of small glaciers), and the currently observed glacier down-wasting calls for frequent updates of inventories (Paul et al., 2007).

Moreover complete detailed glacier parameters such as glacier area, length, elevation, hypsography and ice volume in particular are needed for those glacierized regions that are currently missing from global mass-balance records or have only preliminary data in the WGI (World Glacier Inventory), such as the Arctic, Himalaya, Karakorum and Patagonia (Braithwaite, 2002; Dyurgerov and Meier, 2005; WGMS, 1989; 2007). Moreover, coupled models for assessing the impact of climate change on glacier evolution (e.g. Gregory and Oerlemans, 1998; Raper and others, 2000; Raper and Braithwaite, 2006) require detailed glacier parameters, in particular glacier area and hypsography.

On a global scale, glacier outlines can be derived using automated classification algorithms from multispectral satellite data (e.g. Paul and others, 2004a;b; Paul and Kaab, 2005), as recommended in the the Global Terrestrial Network for Glaciers (GTN-G, Haeberli, 2006). The main advantages of using remote sensing for glacier delineation, summarized by Racoviteanu and others (2009), are the following:

1. Sensors such as the Landsat Thematic Mapper (TM) have a relatively large swath width (185 km) and cover large areas with a medium spatial resolution (30 m). Since the end of 2008, the entire United States Geological Survey (USGS) Landsat Archive, containing 35 years of nearly complete global coverage data from the Landsat TM and Landsat Enhanced TM Plus (ETM+) sensors, has been available at no charge from the USGS (http:// landsat.usgs.gov/).

2. Automated methods for multispectral glacier classification have been developed and tested in the past decade using Landsat TM and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer sensor) imagery (Bayr and others, 1994; Sidjak and Wheate, 1999; Paul, 2002; Paul and others, 2002; Kaab and others, 2003, 2005; Paul and Kaab, 2005; Racoviteanu and others, 2008a). These methods are simple, robust and accurate for detection of clean to slightly dirty glacier ice and fresh snow (Albert, 2002; Paul, 2007).

3. Remote-sensing-derived glacier outlines combined with Digital Elevation Models (DEMs) in a Geographic Information System (GIS) are used to derive topographic glacier inventory parameters such as hypsometry, minimum, maximum and mean elevations in an efficient manner (Klein and Isacks, 1996; Duncan and others, 1998; Kaab and others, 2002; Paul and others, 2002; Paul, 2007).

4. Digital elevation data from remote sensing are increasingly available for conducting glacier change studies at various spatial scales. The global DEM derived from ASTER data (GDEM) was released in July 2009 and is freely available from the Japanese Earth Remote Sensing Data Analysis Center (ERSDAC) at http://www.gdem.aster.ersdac.or.jp/ and from NASA’s Land Processes Distributed Active Archive Center (LP DAAC) at: https:// wist.echo.nasa.gov/~wist/api/imswelcome/. Moreover the Near-global (608 N to 578 S) elevation datasets at _90m spatial resolution are available from the Shuttle Radar Topography Mission (SRTM), flown in February 2000 (Rabus and others, 2003; Farr and others, 2007). Various versions of the SRTM data are available at no cost over the internet (http://srtm.usgs.gov/data/obtainingdata.php, http://www.ambiotek.com/topoview).

To help in standardizing the calculations from remote sensed data for compiling glacier inventories a list of recommendations were prepared by a working group also with the aim to contribute to the ESA project GlobGlacier. The document prepared by Paul et al., (2010) follows the former UNESCO manual for the production of the World Glacier Inventory (WGI) published in 1970, identifies the potential pitfalls, and describes the differences from the former methods of compilation.

The guidelines outlined by Paul et al., (2010) are designed to help in the efficient compilation of glacier-inventory data from digital sources (vector outlines, digital terrain models or DTMs) according to the standards set in the former UNESCO manual (UNESCO/IASH, 1970). The importance of such compilations is growing in response to the need for regional to global assessments of climate change impacts.

The most important changes in the new document introduced by Paul et al., (2010), compared to the former UNESCO manual for the production of the World Glacier Inventory (WGI), are due to the availability of modern data generation techniques, such as Geographic Information Systems (GIS). In part, the applied methods result in parameters that differ from those obtained previously and thus cannot be compared directly (Manley, 2008). The second important difference is that two dimensional (2D) glacier outlines in a digital vector format are now used in addition to the point information available in the former inventory (WGMS, 1989). The related format specifications have been developed within the framework of the Global Land Ice Measurements from Space (GLIMS) initiative (Raup and others, 2007) and a database that stores the information is maintained at the National Snow and Ice Data Centre (NSIDC) in Boulder (Colorado) in the United States. While the 2D-outlines strongly facilitate assessment of glacier changes, rules have to be applied that allow the clear identification of glacier entities independent of the geographic region or the data source, for example aerial photography or satellite imagery. These rules have been compiled in the ’GLIMS Analysis Tutorial’ (Raup and Khalsa, 2007). Practical recommendations for glacier mapping are given by Racoviteanu and others (2009). A comprehensive overview of the WGMS database was given by WGMS (2008), and a review of the available WGI data is given by Cogley (2009).

For the compilation of the CKNP Glacier Inventory we follow these new and updated recommendations.

In compiling the CKNP Glacier inventory we considered the following main parameters:

- Identification (ID), i.e.: each glacier entity has a unique identification code.
- Coordinates, i.e: we reported the coordinates describing the location of a glacier as accurately as possible.
- Date, i.e.: each glacier outline is associated with the date of its acquisition, if possible day, month and year.
- Surface area,
- Length, i.e.: we evaluated and inserted for each glacier the longest flowline value.
- minimum elevation,
- maximum elevation,
- mean elevation,
- median elevation,
- mean orientation / aspect. On this latter it is important consider that the aspect or orientation of a glacier is a useful parameter for all kinds of modeling (Evans, 2006). We derived the mean aspect from a DTM allows one to consider the value of all individual cells that are covered by the glacier and to derive a mean value in the full 0-360° range.
- slope , i.e.: the mean slope was derived from elevation range and glacier length.

Data source

The *National Aeronautics and Space Administration (NASA) has provided the world community with downloadable Landsat images at no charge. The images used in this study are Landsat TM and ETM+ scenes of 2001 and 2010, which can be found at the site* http://earthexplorer.usgs.gov/. In table 49 the scene codes are reported.

The image resolution of Landsat 5 is 30 m, while Landsat 7 scenes have been implemented up to 15 m through the PAN-chromatic band. Unfortunately, a malfunction in the Scan Line Corrector sensor onboard the Landsat 7 satellite has caused all the scenes after 2003 to show up with gaps in the form of black strips. A procedure to fill these gaps does exist, but since it requires two or more images of the same area to be merged together, it has been difficult to find similar scenes to produce a good gap-filled one, due to the high variability of environmental condition (mainly snow coverage) through time in a mountainous region. Therefore, for the year 2010 Landsat 7 gap-filled images with enhanced resolution (PAN_sharpened) have been used simply as support, that is whenever it was not possible to recognize some parts of the glacier boundaries in the reference Landsat 5 scene (because hidden by shadows for instance). For the year 2001, Landast 7 PAN-sharpened images were used as the base for glacier delineation.

The scenes have been selected so that they present the lesser coverage of clouds and snow over glaciers as possible, as well as for the shadows. Moreover, a Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM3) has been used to extract important glacial parameters other than glacier area size (i.e. minimum, maximum and mean elevation, hypsographic curve). SRTM DEMs are available at different websites, but they present spatial differences depending on the source they are downloaded from. Bolch et al. (2010) found out the best source is the void filled CIGAR SRTM, version 4 (http://www.cgiar-csi.org), with a deviation from the Landsat scenes of less than one pixel. Therefore, no orthoprojection was needed.

A DEM from another source was available as well: the ASTER GDEM. Although it has a better resolution than the SRTM3 (30 m against 90 m), it also contains several gaps, and does not represent well the areas of steep slopes. These phenomena are common for DEMs derived from ASTER data (Bolch et al, 2010, quoting Kamp et al., 2005, Toutin 2008) and thus they were not used in this study.

Table 49 The Landsat imagery we analysed in this work.

Date	*Image type*	*Scene identification No.*	*Path-row*	*Resolution (m)*
21/07/2001	*ETM+*	*LE71480352001202SGS00*	*148/35*	*15*
30/09/2001	*ETM+*	*LE71490352001273EDC01*	*149/35*	*15*
23/07/2010	*TM*	*LT51480352010235KHC00*	*148/35*	*30*
17/10/2010	*TM*	*LT51490352010290KHC00*	*149/35*	*30*

Glacier outlines and main parameters extraction

Firstly, glacier outlines were digitized manually on the 2001 Landsat ETM+ scenes. This was done using two different combinations of the available satellite bands, namely the 321 combination, which consists in the true colour image, and the 543, false colour composite image, which permits to distinguish snow and ice from rock exposure and bare soils. By applying such selection ice and snow appear blue instead rock and soils are colored from light to dark red. The 2010 Landsat TM images were used to describe 2010 glacier outlines thus evaluating the changes occurred in the time frame 2001-2010. Automatic glacier delineation procedures, like those presented in Paul et al. (2002), have been tried as well, but they mostly failed to recognize glacier boundaries properly, as the majority of the glaciers in the study area are debris-covered. Algorithms to deal with debris-covered glaciers as regards automatic techniques do exist (e.g. Paul et al., 2004; Bolch et al., 2007), but they were not used since they require manual correction afterwards anyway. Then we digitized glacier boundaries manually.

Area size of each polygon then was computed using a GIS software. Other glaciological parameters, such as minimum, maximum and mean elevation, and the hypsographic curves, have been obtained by means of the DEM, combined with the glacier outlines.

Accuracy and error assessment

When performing a temporal analysis, errors may occur due to positional and mapping errors. The latter ones depend on the image resolution and its conditions at the time of acquisition, namely cloud- and snow-cover, presence of shadows and debris (which hamper correct mapping).

i. *Georeferencing error*

This type of error depends on the processing phase of an image while referencing it to a specific system. The scenes used in the present study are both from the USGS and orthorectified in the best available level (L1T) and well co-registered. The L1T correction process utilizes both ground control points (GCPs) and digital elevation models (DEMs) to attain absolute geodetic accuracy (Landsat7_Handbook). The first ones are taken from the 2005 Global Land Survey, while the primary terrain data is the Shuttle Radar Topographic Mission DEM. The SRTM DEM is known to be of good accuracy (Falorni et al., 2005 from Bolch et al., 2010), and has also the advantage that it is more accurate in areas of low contrast (e.g. due to snow) (Bolch et al., 2010). Moreover, visual inspection of the two overlapped images reveals an almost perfect match, thus we considered in this work negligible the georeferencing.

ii. *Linear resolution error (LRE)*

Imagery resolution influences the accuracy of a glacier mapping. The higher the resolution, the more precise the outlines, the lower the error. Following Salerno et al. (2012), the Linear Resolution Error (LRE) is included in the following equation combined with the term li; which represents the perimeter of each shape.

AEi is the Aerial Error of a shape drawn on a pixel-based image. The measurement uncertainty of a shape depends both on the LRE and its perimeter, meaning that a bigger surface will have a lower error than a smaller surface, proportionally. The term within the brackets represents the RMSE of the resolution of one or more scenes. In this study case, it is interesting to calculate the error of the surface changes that have occurred from 2001 to 2010, along with the aerial error in each single image. Final results will be discussed in the following chapters.

As suggested by Gorman (1996), the precision error is considered to be half a pixel, therefore the LRE should be half the resolution of a single image which is, in this case, 7,5 meters for the 2001 scene (whose resolution was previously implemented by the PAN-sharpening technique, so that its precision error is now 15 meters divided by 2) and 15 meters for the more recent one (30 m divided by 2).

iii. *Scene-conditions depending error*

Seasonal snow, cloud cover and presence of shadows and debris can introduce errors in glacier area determination.

When choosing a scene, it is very important to search for an image which shows the area of interest as clear as possible.

Most importantly for glacier studies, the image to be used should present as few little snow cover as possible. In facts, seasonal snow covers glacier bodies and most of the time leads to misinterpretation of the boundaries, especially for the smaller glaciers. In such cases, a satisfactory identification of glacier limits can be achieved anyway if the digitizer is an expert, and by the comparison with other sources (e.g. other satellite images, orthophotos, etc.), better if the latter ones have higher detail. It's the case of this work, where LANDSAT scenes have been visually inspected with respect to SPOT imagines (available through Google Earth (c)). To avoid mapping errors related to different acquisition times, when comparing two different sources, attention has been paid to match the periods.

Cloud-cover is another source of error in the area identification. Again, the choosing phase of a scene is crucial. Anyway, even if a scene contains a high percentage of cloud-cover (which is possible to inspect from the metadata file before downloading), it doesn't mean it is not suitable for an inventory purpose. In fact, the operators should well know the zone of interest, and they can choose any scene which is free of clouds only where it matters (i.e. above the glaciers). Cloud-cover of the scenes used in this study is shown below, (in percentage):

Table 50 Cloud coverage (%) of the Landsat imagery we analyzed.

Scene identification No.	**Cloud coverage (%)**
LE71490352001273EDC01	1.41%
LE71480352001202SGS00	5.67%
LE71490352010234EDC00	2.60%
LE71480352010291SGS00	2.77%

Shadows can hamper the identification of glacier boundaries. To limit this problem, attention was paid to the acquisition time, meaning there would be less shadows when sun rays are perpendicular to the Earth's surface. As the area of interest is a mountainous region, this aspect grows in importance.

Supraglacial debris is one of the major sources afflicting automatic classifications, as most of the time debris-covered glaciers are misclassified by algorithms as non-glacierized areas and therefore they are not included in the inventory. So far, many authors have suggested different methods to delineate debris-covered glacier outlines automatically (Paul et al., 2003; Bolch et al., 2007), but manual corrections are still needed. Then we manually mapped glacier outlines thus including actual debris covered glaciers and glacier snouts affected by supraglacial rock debris coverage.

Critical discussion on the 2001 results from SEED project with respect to 2001 glacier data from ICIMOD (2005)

The Glacier Inventory of the CKNP, as above stated, also represents a revision of the 2001 ICIMOD glacier inventory. To perform such revision we compared the geometry data of some selected glacier basins with the ones reported in the ICIMOD inventory. This latter activity was performed also aiming at evaluating accuracy and precision of this glacier source. In addition all the recent literature dealing with those glacierized areas was analysed.

From a general point of view data from ICIMOD database agrees with SEED ones, but in several cases the glacier boundaries reported in the 2001 ICIMOD data base have to be improved and refined in particular in zones affected by debris cover presence. Probably our analysis based on a manual classification and performed also considering DEM and slope map sin addition to imagines obtained by combining bands 321 and 543 and from the ratio TM4/TM5 permitted a more accurate evaluation of glacier coverage and of glacier limits. A further improvements was also given by considering SPOT imagines available on Google Earth ©.

Exhibit 55 A view of a glacierized area in the CKNP from 2001 ICIMOD shape file. In blue are reported glacier areas.

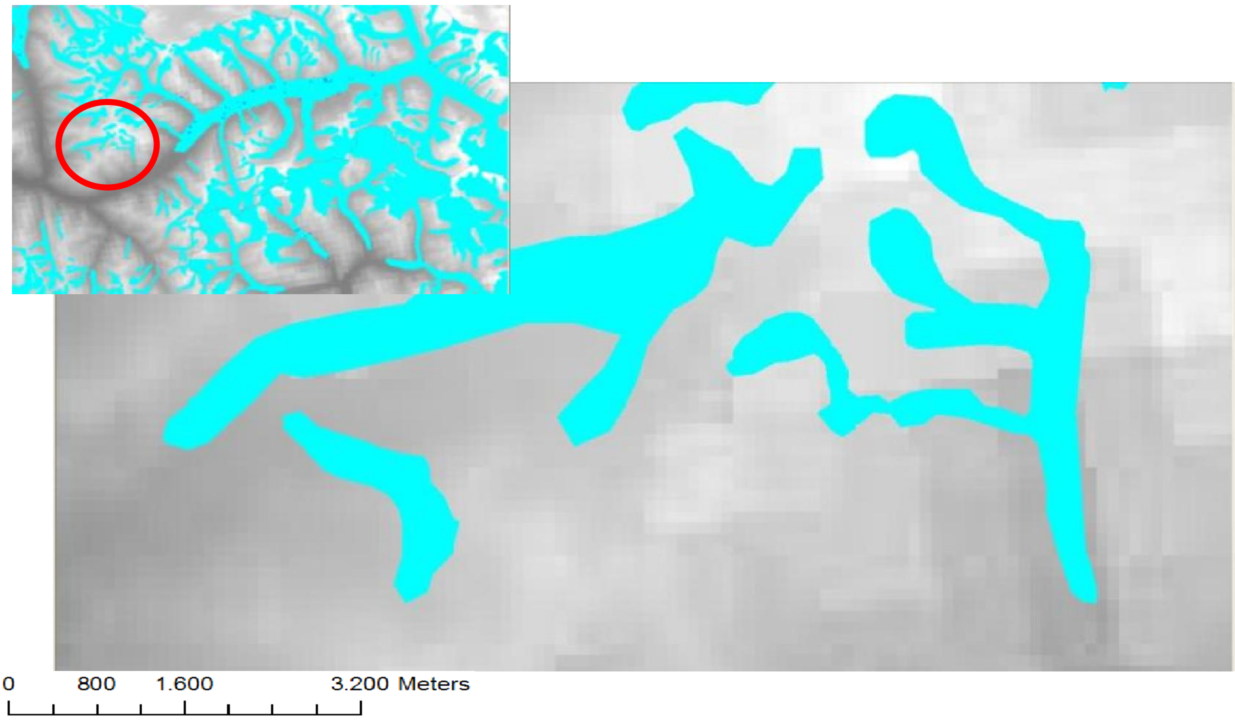


Exhibit 56 A zoom view of a glacierized area analysed in the 2001 ICIMOD data base

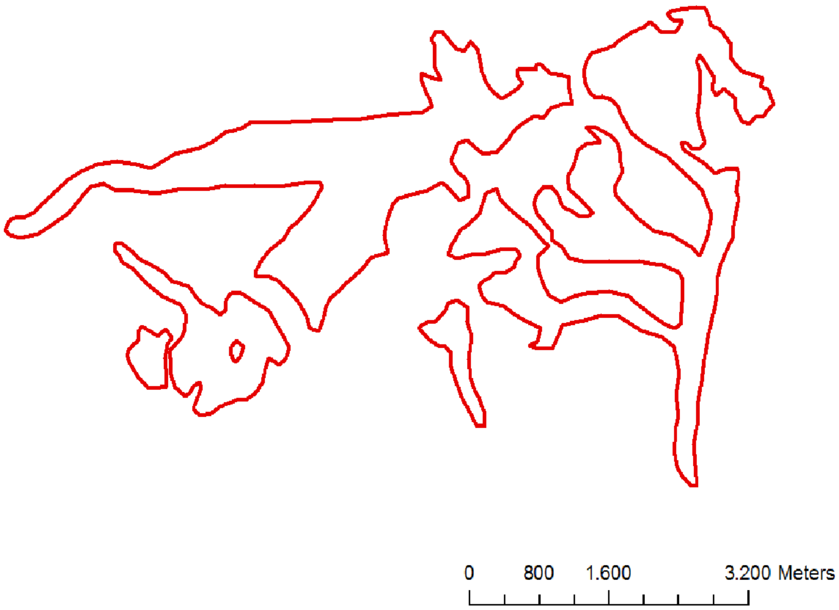


Exhibit 57 The same area delimited in the CKNP Glacier database. Glacier limits are more accurate.

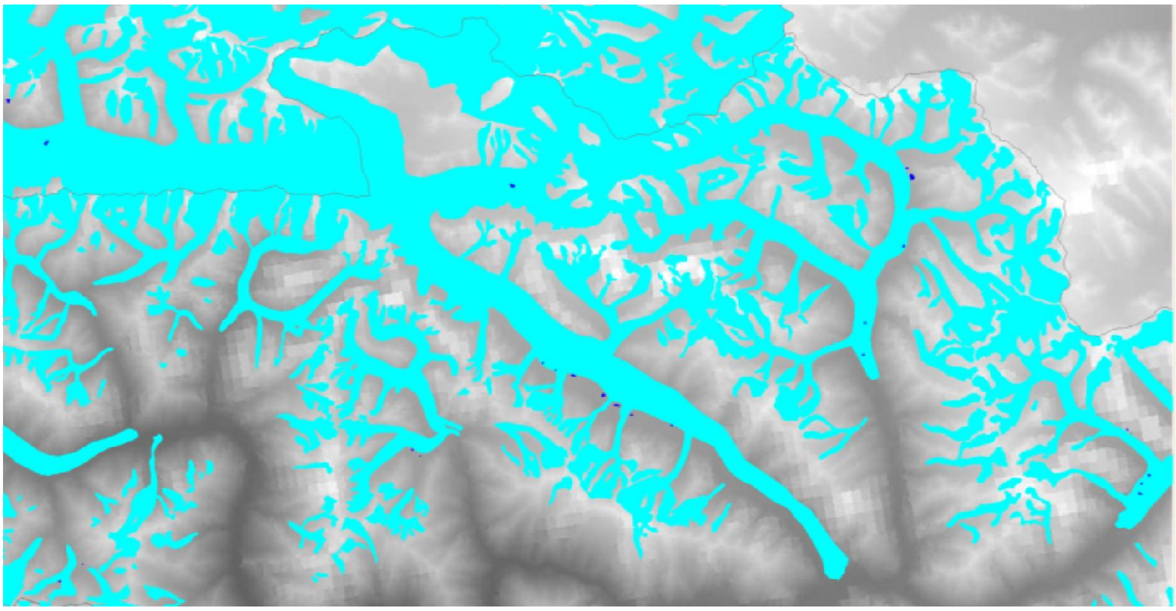


Exhibit 58 Biafo Glacier delimited in the 2001 ICIMOD data base. The area coverage results 426 km^2.

Exhibit 59 Biafo Glacier in the CKNP Glacier Inventory. Area coverage is 433.9 km^2.

The above reported pictures illustrate the improvements obtained by applying a manual classification and the difference in area coverage thus resulting. Since glacier areas represent crucial input data for hydrological modeling aimed at evaluating glacier derived water resource it is important an accurate delimitation and mapping of glacier boundaries. Moreover to evaluate glacier changes over time periods of a decade or shorter (especially in the Karakorum where glacier changes are small and several cases of surge phenomena occur thus complicating our assessment, see Hewitt, 2005) is important to describe accurately glacier coverage and features.

Then this work, based on the same sources used by 2001 ICIMOD to describe the whole Pakistan glaciation, could really improve our knowledge of glaciers in the CKNP and be input or base data for further investigations and analysis. Moreover since glaciers are fundamental environmental resources their knowledge is important for managing a protect area.

6.6 Catchments Division Areas

The main part of the CKNP's valleys are large areas that comprises some sub-valleys. For the purpose of different researches it is important a more accurate delimitation of these sub-areas. To delimitate these areas an analysis was implemented focused on the delineation of watersheds and stream networks, created from DEMs using the sample extension, as primary input to most surface hydrologic models. These models are also used for locating areas contributing pollutants to a stream, or predicting the effects of altering the landscape.

6.7 Geological map

One of the main theme to consider for a risk assessment analysis is the geology of the area, even if, for a geostatical investigation the lithological characteristics are even better. When the SEED project started, there were any geological digitized data for the CKNP area. For this reason, and seen that the geological theme is one of the main parameter to define the landslide prone areas map, a digitized version of the available geological data was realized. The obtained map is a digit format of a collage of different geological maps, realized from different authors at different scales in different years and especially, two maps were mainly used:

- Le Fort P. and Pecher A. (2002) – An introduction to the Geological Map of the area between Hunza and Baltistan, Karakorum-Kohistan-Ladakh-Hymalaya Region, Northern Pakistan (scale 1:150,000); Geologica, 6, 1-140; ISSN: 1025-2541.
- Searle M.P., Khan A., Quasim Jan M., DiPietro J.A., Pogue K.R., Pivnik D.A., Sercombe W.J., Iazatt C.N., Blisniuk P.M., Treloar P.J., Gaetani M. and Zanchi A. (2006) - Geological Map of North Pakistan and adjacent areas of northern Ladakh and western Tibet (scale 1:650.000). Edited by Searle M.P. and Khan A.

On this base a first draft of the geological map (Exhibit 60) is here proposed, of course it is not a final work, there are still a lot of references that need to be studied and included into the final map (see the list below) but it is a complete overview of the main geological formations, locations and characteristics.

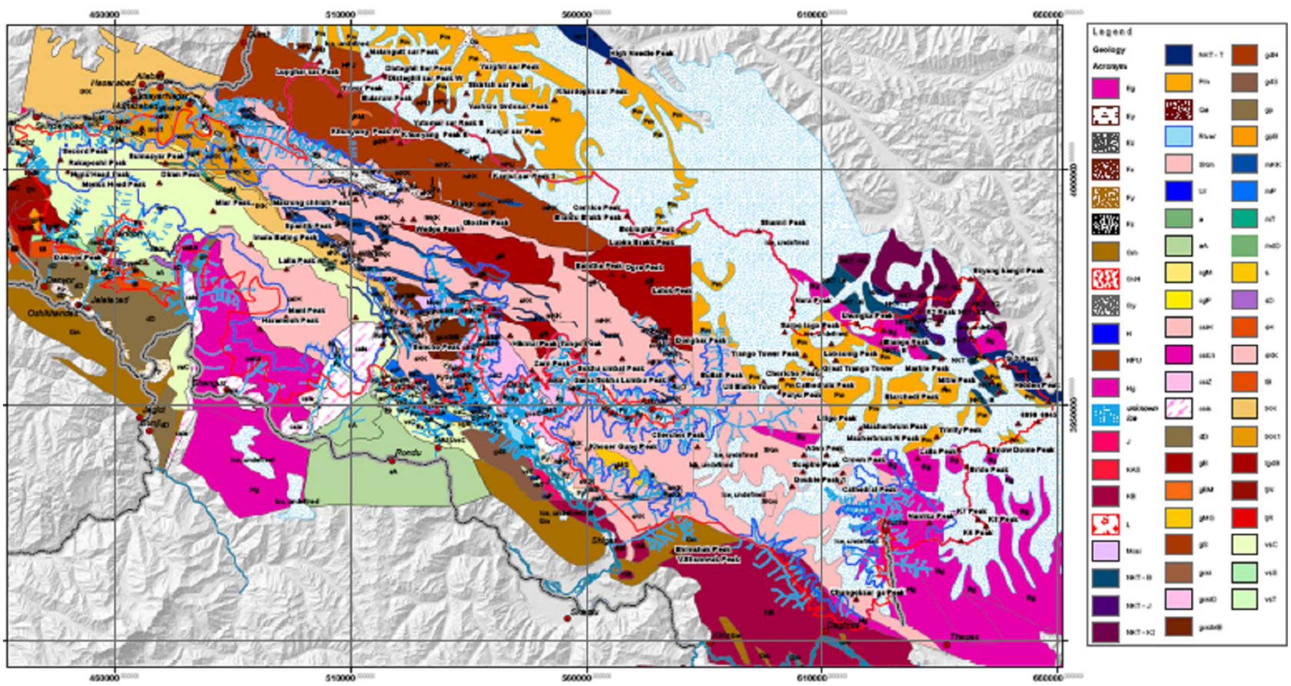


Exhibit 60 Geological map of the Central Karakorum National Park

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6.8 Landslide Susceptibility Map

Through the multidisciplinary SEED project, a tentative to produce a slope instability susceptibility map was done, taking advantage of GIS and remote sensing tools (Gardner et al., 2004; Guzzetti et al., 2012).

To reach the defined goal, it was decided to analyze the area through Digital Elevation Models (DEMs) derived from ASTER images (30 m X 30 m), which can be considered powerful tools for visual and mathematical analysis of the topographic surface at a regional scale (Gullà et al., 2008; Kamp, 2003, Tarolli et al., 2012). These documents, used in a barren territory, visited mainly by mountain climbers and porters, are valuable in order to identify landforms and deposits, modeled by surface processes. The landslide susceptibility study (Fell et al., 2008; Van Wasten et al., 2008) was analyzed with the application of the Analytical Hierarchy Process (AHP) (Ayalev et al., 2004; Bajracharya et al., 2008; Komac, 2006; Moradi et al., 2012; Othman et al., 2012; Phukon et al, 2012) based on the indexing on data layers as slope angle, slope aspect, slope curvature, geo-lithology, distance to tectonic structures and vegetation (Ruff et al., 2008) seen that these intrinsic variables determine the susceptibility of landslides (Dahal et al., 2007).

The method was tested in the Bagrot valley, located in the extreme north west of the park and then applied to the rest of the park area (see Section 2.1.2, for details). Through the analysis of the DEM, different slope morphologies were pointed out and the main landslides identified (areas subjected to rock falls, single rock falls and debris flows) (Varnes, 1984).

7. THREATS TO ECOLOGICAL AND SPECIES INTEGRITY

7.1 Pasture and livestock

Livehood of local communities living in the vicinity of the Park strongly depends on the use of its natural resources, with a particular role played by livestock breeding. The assessments of this document mainly focuses on the animals which use the pastures inside the CKNP Boundaries, in which the communities hold use rights. Around the CKNP area livestock is composed primarily of goats and sheeps, followed by cattles (local cows, yaks, and crossbreeds between cow and yak) and equines. From Autumn to Spring all animals, except yaks, are fed in and around the settlements, and in some areas the fodder shortage involve a winter starvation in the livestock.

There are different situation able to reduce the livestock health conditions, and affecting their surviving and productivity, but the main could be traced back at the occurrence of endemic and eventually epidemic diseases, at the fore mentioned fodder shortage in winter and the degradation of pastures.

Though specific surveys conducted in the Central Karakorum area, it is reasonable to assume that over 300000 domestic sheep and goats are raised in a region which chronically suffered from poverty and remoteness. For limited available veterinary cares, there is still a widespread presence of small ruminants transmissible diseases as PPR (Peste des Petits Ruminants), CCPP (Contagious Caprine Pleuro Pneumonia), Infectious ketatoconjunctivitis (IKK) and Sarcoptic mange. Their transmission affect not only the livestock productivity, but could spread in sympatric wild Caprinae present in the CKNP area, with dramatic effect as suggested by the recent and severe outbreak of sarcoptic mange that affected Blue sheep in Shimshali Pamir, Pakistan, whose likely source was indicated in infected livestock (Dagleish et al., 2007). Similarly, contact with infected livestock was suspected on occasion of a deadly Contagious Caprine Pleuropneumonia episode amongst threatened Markhor in Tajikistan (Ostrowski et al., 2011).

With the aim to assure the conservation of the CKNP nature and to support the livelihood of the local communities it is important to prevent the spread of diseases in the livestock as well as the spill-over of pathogens from the domestic reservoir to wildlife in conservation areas where contacts between livestock and zoologically related wildlife occur.

This also in the perspective of the possible sustainable exploitation of wild ungulates for the benefit of local communities (e.g., through ecotourism and trophy hunting) not practicable in the absence of targeted health management of sympatric livestock.

Alpine pastures represents a key resource for livestock and are used in summer following a communal herding mechanisms, employing multi-stage migration patterns between summer settlements at different altitudes (lower, intermediate and higher pastures). Pastures are also a key resource all the year round for valuable wildlife such as Caprinae, *Capra sibirica*, *Capra falconeri* and *Ovis orientalis vignei*.

From a general point of view, the higher pastures and most of the intermediate ones seem to be in good conditions, while the lower pastures more near to the village suffer by the matched effect of water scarcity and overgrazing by livestock due to the long use of these areas also to face up to the winter fodder shortage.

The overgrazing implying low levels of primary productivity (MACP and IUCN, 2001), changes in the plant species composition, overall reduction in the vegetation cover, less quantity of litter, and gullies and rill formation. Pasture degradation contributes to shift the grazing pressure to other pastures, which in due course of time would undergo the same process. The degraded pastures have also negative impact on the health and productivity of the wild and domestic animals. Specific management activities are under development to reduce this impact in the lower areas.

7.2 Forest and vegetation

Threats for forest resources in CKNP are mainly a consequence of:

- *Lack of management guidelines*.
  All CKNP forest are public and managed by the Forest Department. Locals have use rights like grazing and collection of firewood/timber from dead-dying-or-disease trees only.
- *Historic illegal harvesting*.
  Practically illegal harvesting of timber and firewood collection is much more widespread and forest degradation is common. Forest department is not effective in managing forests.
- *Overexploitation* (especially related to firewood).
  Firewood harvesting is more widespread (between 2000 and 4000 Mg x household x year) and is mainly concentrated on Juniper trees. No regulation is usually in place and many stands are heavily degraded.
- *Illegal harvesting of timber* (in some valleys).
  Timber harvesting (500 Mg x household x year), which is limited to the South-Western portion of CKNP, is in some valleys regulated by forest committees. Those were established independently or with the support of Forest Department by the local villagers. Illegal harvesting, however, is still diffuse in some valleys.
- *Un-organized grazing by livestock*
  Grazing by livestock is hampering natural regeneration, slowing forest recovery capabilities.

In particular in SW valleys, in the area of mountain dry temperate forest, illegal timber harvesting in some valleys is widespread and can pose serious threats for the conservation of forest resources.

Firewood harvesting, which is more by far more common, is causing degradation of forest resources (especially Juniperus forests) and mitigation measures as firewood plantation and/or improved cooking stove should be implemented to reverse this dynamic.

Grazing is limiting the natural regeneration capabilities of CKNP forests.

Also we can considered climate changes as a possible threats for forests. Projection were based on (ICIMOD, 2011) and (SDPI, 2012).

The evaluation of climate change effects on forests of CKNP is a very complex issue since temperature and precipitation projection show only partially clear trends (ICIMOD, 2011). Moreover specific studies on the subject have not been yet conducted. The expected rise in temperature and the partial increase in precipitation might be reflected in a rise of tree limit, actually located at an altitude around 3800 m a.s.l.. Accordingly, the lower tree limit might rise as well. This will probably result in an net increase in forest area inside the CKNP borders. The area change of high altitude alpine pastures and meadows is more difficult to project: on one side warmer and wetter climate might increase pasture area at the disadvantage of bare soils/glaciers on the other since topography and surface roughness of CKNP are very complex it is difficult to make an estimate.

7.3 Water resources

7.3.1 Mountain hydrology

Concerning water resources, climate change represents a main source of threat, including the issues of floods and droughts, the latter cascading into food security of the populations living within the area of CKNP. Despite the importance of this issue and the interest it has raised within the international scientific community, few studies were carried out assessing the impact of climate in this area. Maybe less developed seems the assessment of water resources therein. Long term measurements of hydrological and climatologic data of the highest glacierized areas are seldom available (Chalise et al., 2003), thus making assessment of hydro-climatic trends difficult to say the least. Recent studies indicate that glaciers of south-eastern Tibet have negative mass balances (Aizen, 1994). Ageta and Kadota (1992) suggested that small glaciers in the Nepal Himalaya and Tibetan Plateau would disappear in a few decades if air temperature persistently exceeds a few degrees above that required for an equilibrium state of mass balance. Moreover, air pollution and in particular atmospheric soot seem to affect Himalayan glacier albedo, increasing ice and snow melting (Ming et al., 2007; Xu et al., 2009). Global warming should intensify the summer monsoon with consequent increased moisture fluxes, which could end the rise of local air temperature, and the mechanism of air temperature–precipitation and glacier interaction requires further scientific efforts (Aizen et al., 2002). Akhtar et al. (2008) investigated hydrological conditions pending different climate change scenarios (using data from PRECIS initiative, Providing REgional Climates for Impacts Studies model, A2 storyline) for three glacierized watersheds in the HKH (Hunza, 13925 km^2, glacierized 4688 km^2; Gilgit, 12800 km2, glacierized 915 km^2; Astore, 3750 km^2, glacierized 612 km^2). Their results indicate temperature and precipitation increase towards the end of 21st century, with discharges increasing for 100% and 50% glacier cover scenarios, whereas noticeable decrease is conjectured for 0% scenario, i.e. for depletion of ice caps. Albeit the authors stress low quality of the observed data, they claim transfer of climate change signals into hydrological changes is consistent. Immerzeel et al. (2009) used remotely sensed precipitation from TRMM (Tropical Rainfall Measuring Mission) satellite and snow covered area (henceforth SCA) from MODIS (Moderate Resolution Imaging Spectroradiometer), together with ground temperature data and a simple Snow Melt Runoff Model (SRM), to calibrate an hydrological model and then projected forward in time (PRECIS, 2071–2100) the hydrological response of the strongly snow fed Indus watershed (Pakistan, NW Himalaya, 200.677 km^2, including the Hunza and Gilgit basins). They found warming in all seasons, and greater at the highest altitudes, giving diminished snow fall, whereas total precipitation increases of 20% or so. They found snow melt peaks shifted up to one month earlier, increased glacial flow due to temperature, and significant increase of rainfall runoff. While southern Himalaya is strongly influenced by the monsoon climate and by abundant seasonal precipitation therein, meteo-climatic conditions of Karakorum suggest a stricter dependence of water resources upon snow and ice ablation, and therefore the needs of its believable projection for the future (Mayer et al., 2010). Bocchiola et al. (2011) preliminarily developed a framework aimed to evaluate potential impact of prospective (until 2100) climate change in the area of CKNP upon the water resources, i.e. the in stream fluxes within the Shigar river. This study, along with others in the available literature, demonstrated the needs for i) Explicit modelling of water resources dependence upon climate within the CKNP area, and ii) Including of potential climate change scenario when modelling prospective water resources in the same area.

7.3.2 Water quality

The increase of water use to produce energy and possibly the expansion of agriculture activity may led to the decision of building dam in the Park or in the buffer zone. This decision have to be submitted to an evaluation of the impact on the ecosystem.

The important factor affecting the water quality is the human and the animal activities in the surrounding of the water delivery systems. Usually no protection is given to the sources of water from possible fecal contamination.

The SEED Water Survey have highlighted that no protection is given to the water sources in order to reduce the possibility of water contamination.
In the buffer zone it is necessary to assure an appropriate protection of the water sources used for drinking and in the areas of the park subjected to intense use by tourism a surveillance program should put on place to minimize the impact of water discharge on the natural water.
It is strongly recommended:

- -to introduce small-scale storage pods/tanks at the farm or command level and lining of these tanks using the geo-synthetic liners, where it is cost-effective;
- -to introduce sand filters to provide safe and clean water for drinking and stockwater use especially during the winter months.

7.4 Wildlife

Mammals

Limited range and low numbers make populations/species vulnerable to poaching and habitat loss. Furthermore, wildlife numbers may be negatively affected by livestock numbers. This is mainly due to human activities, including habitat modification, direct and indirect extermination and denial of access to resources, as well as disease transmission from livestock. Summarising, the main threats for large mammals in CKNP are:

- habitat loss, due to destruction, fragmentation or degradation of habitat: healthy habitats are a vital part of ecosystems and are essential to the survival of wildlife. Habitat loss occurs when an ecosystem has been negatively impacted by human activities or natural disasters. Three major types of habitat loss are: (*i*) *habitat* destruction - the harvesting and exploitation of the earth's natural resources by man (*eg* deforestation for agricultural expansion) is the leading cause of habitat destruction; (*ii*) *habitat fragmentation* **-** the development often cuts directly through habitats, creating fragmented sections of land that are not large or well-connected enough to support the species living there; (*iii*) *habitat degradation* **-** this occurs when there is a disruption to an ecosystem that leaves it unable to support the species that inhabit it. Pollution, climate change, invasive species and occurrences such as fires can lead to habitat degradation.

- hunting and poaching. Where subsistence hunting is practised, law enforcement is complicated, because such hunting usually take place in the vicinity of remote villages. Bringing subsistence use under effective control has to be a main goal for a National Park, although it is a complex problem, usually requiring knowledge of local conditions and attitudes. Poaching rarely can be accomplished from centralised offices, but rather will most often require a serious effort to understand the roots of the problem and to work with local people in finding solutions.

- feeding competition with livestock: domestic animal grazing may cause a significant reduction in the standing crop of forage (Mishrea et al 2004). High diet overlap between livestock and wildlife, together with density-dependent forage limitation, may result in resource competition and a decline in wildlife density. The coexistence of livestock and wildlife is threatened by declining profits and increasing costs for wildlife production.

- poaching of large carnivore for limiting their impact on livestock: some indications are reported regarding the presence of poaching activities on large carnivores (mainly on wolf) for limiting the impact on livestock.

- disease transmission from livestock: the dynamic state created by livestock and wildlife movements to the same pastures results in frequent contact between them and a probably high incidence of pathogen transmission and transboundary diseases. Many parasites, especially if environmental changes occur, can infect multiple host species and these are primarily responsible for emerging infectious disease outbreaks in humans, livestock and wildlife (Woolhouse, 2002). Multi-host situations are also of concern for wildlife management and conservation, as diseases can affect the productivity and density of wildlife populations with an economic or recreational value (Gortázar et al., 2006).

Metapopulation theory suggests that dispersed and reduced populations of endangered wildlife (as they are in CKNP) are more prone to extinction through stochastical events, such as disease outbreaks (Macdonald, 1993). Among ungulates, several diseases are shared between wild Caprinae and domestic sheep and goats, having important consequences on wildlife numbers and animal welfare. Usually, the disease spread from domestic livestock to wildlife and is responsible for repeated outbreaks that affect hunting harvest and population dynamics. Disease transmission between wildlife and livestock can undermine conservation efforts, either by challenging the viability of threatened populations, or by eroding public tolerance of actual or potential wildlife disease reservoirs.

7.5 Mining

The mining activities in CKNP area are conducted at high elevation, usually between 10.000 to 14.000 feet a.s.l., where, due to the critical conditions, ecosystems are fragile and highly vulnerable.

Considering this sector of activity, two types of threats can be identified (Ev-K2-CNR, Unpublished, Ev-K2-CNR and KIU, 2011):

- The environmental impact of current mining techniques
  Since long time miners in CKNP use inadequate mining tools for the extraction of gemstones, which results in wastage of time and money of the miners. Miners use explosive to blast the hard rock in the mines and during blasting massive boulders damage the vegetation on alpine slopes, create rock falls and damage the mountain ecosystem in various ways. Without the change of the existing mining techniques substantial environmental threat is expected for the entire region.
  Key impacts are also attributed to blasting and increased human presence in and access to wildlife habitats and ecosystems (WWF-Pakistan, 2008; Flury, 2012).
  Furthermore, indirect environmental impacts have been also indicated by local accounts, i.e.: an increased share of purchased wood in household's fuel portfolio and decreasing livestock numbers as possible effects in the core mining area (Flury, 2012).

- Impact of current techniques on health and well being of miners (safety)
  It was observed that very poor and conventional methods for the safety and health are used. The miners working on rugged terrain do not have access to even basic health facilities.
  There is no awareness among miners about their own safety, furthermore, they are unaware of basic safety equipment and protocols. Miners are not using any equipment as they don't understand its important. The owners of mines also do not provide the miners or labor in mines the equipment; whereas, the usage and availability of first aid box was not seen anywhere in a mine while working.

Concerns regarding negative impacts of mining on natural resources should be subjected to empirical research. Considering the complex interaction between livelihoods and natural resources, investigations should not exclusively direct impacts of mining activities on the environment, but also socio-economic changes and livelihood dynamics entailed by an increasing importance of the mining sector for local household economies. Support for a controlled, socially equitable and ecologically sustainable development of a locally-driven and owned mining sector should be a primary aim of stakeholders operating in CKNP's area with a rural-, social-development or conservation focus (Flury, 2012).

Preliminary Recommendations for Management

At present, mining sector has been excluded in CKNP due to the new delineation of Park's boundaries (see Part II - Park Management Guidelines), so this human activity does not represent a possible threat to CKNP's; however some remarks about management would be considered (EV-K2-CNR, *Unpublished*, Ev-K2-CNR and KIU, 2011; Flury, 2012).

The current state of knowledge regarding the environmental impact of mining in CKNP and surrounding areas points to some potential negative developments, which have been highlighted by experts and local respondents (WWF-Pakistan, 2008). Those can and must serve as starting points for scrutiny and evaluation through empirical research. However, indirect environmental and socio-economic impacts resulting from changes in livelihoods and the social structure through developments in the mining sector have to equally be considered and further elaborated upon.
In the framework of an integrated conservation and development approach acknowledging involvement of local communities in decision-making and management of natural resources, a ban of mining operations is precluded. However, the mining sector certainly poses a challenge for CKNP Directorate in the framework of establishing a management plan for the park, but it may also provide an opportunity.

Currently, local mining groups operate in a legal grey-zone. The municipalities' usufruct rights on unsettled areas for livestock rearing enjoy a semi-legal status. Mining as a recent phenomenon is not referred to in legal documents. With the notification of CKNP, acknowledged implicitly the status of the municipalities' usufruct rights for livestock rearing in unsettled areas, there are no indications regarding mining activities, which would be prohibited under most protected area-categories. Securing legal rights for mining operations in unsettled areas is a key concern, primarily with regard to keep the mining sector under local control. Precluding a ban on mining, CKNP Directorate would be concerned with a controlled development of socio-ecologically sustainable mining operations.

A solution, which satisfies all interests, could be a dialogue between CKNP Directorate, local municipalities and key stakeholders in the mining sector. The dialogue would aim at securing legal rights for local mining operations in the framework of a planned, socially responsible development committed to environmental standards through the CKNP management plan. It could be initiated by CKNP Directorate within the management planning process for CKNP and use the *Northern Area Mining Concession Rules 2003* as a starting point, fleshing out the environmental and social standards to be made applicable within CKNP and surrounding area and establishing CKNP Directorate as a facilitating partner for local mining groups in the application for concession under the mutually agreed standards.
This would require:

1) an inventory of existing mines;
2) an environmental impact assessment of the local mining practices including further research on indirect environmental, livelihood and social impacts.

Environmental Impact

It was observed that the excessive blasting in the buffer zone of CKNP area is badly impacting the ecosystem. It is undoubtedly perilous for the wildlife. Blasting and dumping of debris on the grass is endangouring grass.
Therefore, it should be covered with earth to allow fast regeneration of vegetation. Similarly for the blasting chemicals should be used which can be beneficial for two reasons including it is eco friendly and it is useful for safe excavation of gemstones.

Safety and Health

To improve the situation, it would be necessary to first of all raise awareness for the need of simple safety features and measures (such as wearing a helmet and apply simple safety techniques) before introducing and training the miners in the use of new safety equipment and protocols.
Therefore, through frequent sessions with miners and with the owners of mines it should be emphasized to use all safety equipment used in mines including, e.g., masks, torches, gloves, and equipment to reach a mine if it is somewhere on a high altitude in a mountain including proper rope.
The CKNP region also needs uttermost attention for providing education/training to the local communities for its sustainable development in gem sector for reduction of poverty in the area.

8. RECOMMENDED RESEARCH AREAS

8.1 Glaciers

Overview

Data reported in the paragraph dealing with the cryosphere in the Park underlined the wide ice coverage in the park and then the strong role played by glaciers which are fundamental landscape elements and not negligible water suppliers. Glaciers react in a complex manner to climatic variations. Their advances leave behind landscape markers as moraines which serve to help us reconstruct past glacial conditions and past climate. Glaciers store information about past climates in the ice as enclosed air bubbles, layers of dust, and ice chemistry. As water reservoirs they are essential to the regional water supply. The understanding of their changes with changing climate is vital for future water policy and water management. To understand and interpret these different aspects it is necessary to know glaciers' actual extent and to describe features and changes (thus including mass exchanges and glacier growth/shrinkage).

Kaser et al. (2003) underlined that methods and theories of glacial processes are predominantly based on results from studies in temperate zones and do not entirely apply to glaciers in other climatic regions. Glaciers of the monsoonal dominated region of Hindu Kush - Himalaya are not well understood and it is unclear how results from the temperate zones apply. The glacier-climate-hydrology interactions in the lower latitudes are of great interest for both global and regional purposes. A network of well-chosen and carefully measured glaciers is important to establish for climate and water related studies (Kaser et al., 2003). Moreover also a more complete description of glacier coverage and features is needed for HKH regions as a base for developing hydrological models.
These facts have to be analysed and considered with further details in the case of protected areas characterized by glaciers and perennial snow coverage.

Moreover also risk and hazard have to be considered, especially on protected areas: glacier-related hazards are well known in the low latitude regions of the HKH and the South American Andes. They include ice avalanches such as the earthquake triggered one from the Nevado Huascarán (Cordillera Blanca, Peru) which killed more than 10,000 people in 1970. Also hazards develop from pro-glacial lakes, which formed during the glacial retreat of the past century. Several of these lakes have caused significant damage in the Himalayas. Several such lakes have been controlled by extensive safety structures. To assess such hazards, particularly future hazards information is required on the rate of mass loss and subsequent glacier retraction, and meltwater production.

Another "hot topic" to be considered is glacial runoff which is essential to the regional water balance in the mountainous regions of HKH and elsewhere. In fact, it occurs a temporarily delay in the meltwater runoff due to storage in glaciers and this contributes essentially to the runoff during dry periods.

This storage can reduce peak runoff during periods of intense melt and rain. Alternatively, the stored water can be catastrophically released from reservoirs hidden from view in the interior of the glacier. Knowledge of the glacier ablation is crucial for the planning and management of the corresponding
water supply.

Moreover the observed global sea level rise is a matter of international concern since it threatens vast low-lying areas including numerous highly populated coastal regions. The contribution from retreating mountain glaciers is one of the important factors in sea level rise today. One of the main regions contributing to sea level rise is the HKH region. However, its precise contribution is not well known because little information exists on the magnitude, rate, and spatial extent of change. These further underlines the needing of accurate glacier mapping and of assessing glacier changes on short (and periodic) time frames.

Last but not least, like a thermometer, glaciers are sensitive to the climatic environment and the resulting adjustment of mass balance is the direct link between the climate and a glacier. Like a thermometer, a glacier has to be "calibrated" by defining the local relation between mass balance and climate. If the monitored glaciers form a network, they provide a highly useful tool for monitoring spatial and temporal climate and climate change for reconstructing and modeling past and future climate scenarios (Kaser et al., 2003). The knowledge gained is of essential value for hydrological and hazard assessment and management. In addition, the mass balance series are of crucial use when processes on other, unmonitored glaciers are required. For evaluating glacier changes over large areas glacier inventories result the most suitable tools then they have to be compiled and updated periodically thus permitting data comparison and evaluation of area and geometry changes.

One basic question always arises in glacier monitoring programs, especially inside a wide protected area, is the question of scale. Does one need to monitor changes over time intervals of seconds and across distances of millimeters, or are time intervals of years and distances of kilometers important The answer depends on the purpose of the monitoring network. Also, each kind of measurement may have different time scales. For example, for meteorological measurements it is typical to take readings every minute and record the 15 minute average at one station on a glacier whereas mass balance measurements are taken 1-2 times a year at 10-30 locations over the glacier. Glacier inventory could describe glacier coverage at decadal time intervals on a regional spatial scale.

If the program is designed for assessing effects of climatic influences on glacier mass balance or for assessing glacier hazards will have dramatically different strategies and data collection procedures. One program typically cannot cover all areas of interest because of limited funds and logistical constraints. Therefore, judicious choices must be made early in the program development.

Strategy for glacier monitoring in the CKNP area

According to the above reported considerations (see also Kaser et al., 2003) in the CKNP protected area a correct monitoring strategy should involve:

- a glacier inventory compiled according to the international standard and protocols (see WGMS, World Glacier Monitoring Service and Paul et al., 2010), available on line (and thus permitting data sharing with the international scientific community), linked to a WEB GIS system (thus offering data and information also to common people, tourists and trekkers) and periodically updated (thus permitting to evaluate glacier changes);
- some selected glaciers to be field-surveyed to evaluate glacier mass balance (according to WGMS recommendations, see also Kaser et al., 2003);
- some selected glaciers to be field-surveyed to evaluate glacier length changes
- some selected glaciers to be analysed (field and remote sensed data) to describe glacier energy budget
- some selected glaciers to be field-surveyed to evaluate meltwater runoff amount and seasonal and interannual variability and than water budget;
- thematic trails and paths to visit glacier forefield and glacier surface whenever possible. The trails also will permit to see glacier behavior and recent changes thus allowing visitors and trekkers to understand high elevation glacier environments.

Benefits coming from the application of the suggested strategy

This strategy could provide**:**

- Fundamental input data for local and regional hydrological models to describe water availability and to forecast future trends (also impacting on agriculture and farming) according to different climate change scenarios ;
- Information on glacier behaviour on the studied sites;
- Information on the climate fluctuations on the studied sites;
- Results defining the most important climatic processes controlling glacier growth and shrinkage;
- Data defining the hydrological impact of glaciers on local and regional streamflow;

- A way to estimate the behaviour of the non-monitored glaciers in the region. Many of these other glaciers may be important but otherwise impossible to monitor;
- Information on glacial response to climate fluctuations on a local, regional, or global scale;
- Ideal sites to launch other intensive investigations of glacial process against the background of data collected on the glacier and its environment;
- Promotion of the protected areas (tourist exploitation, etc..).

Field investigations at some selected benchmark glaciers

The identification of benchmark glacier is fundamental to a proper management of the glacier resource located in a protected area. Field data could describe magnitude and rates of glacier ablation (and of meltwater production) over short (a season or a month or a day) periods. Moreover field data are needed to calibrate and validate remote sensing investigation and data modeling. The most important measurement to be performed on benchmark glaciers are mass balance evaluations. The most correct protocols of performing such measurements are the ones reported into the well known handbook by Kaser et al (2003) and briefly summarized in the Integrated Park Management Plan Glaciology – Research Protocols - *Guidelines to Perform Field Surveys*. In the CKNP some benchmark glaciers have to be selected. We proposed the Baltoro Glacier, a debris covered glacier where several investigations had already performed and where mass balance data could improve the already ongoing data modeling (see Mihalcea et al., 2006; 2008). Moreover other glaciers to be studied could be Hinarche Glacier, in the Bagrot Valley (see Mayer et al., 2010) and Liligo Glacier, a Baltoro tributary which experienced surge type phenomena in the recent time.

8.2 Water resources

We report here suggestions for assessment of water resources and their timing, based upon:

1) Installation of a hydrometric network;
2) Modeling of hydrological regime within the CKNP area.

Given the utmost variable conditions of (natural) streams, there are no hydrological monitoring protocols that we know of, and measuring method has to be chosen depending upon ad hoc reasoning.
For the building of hydrological stations we propose here use of Eulerian methods (as we implemented for the two case studies catchments), that entail explicit assessment of flow geometry and velocity, rather than of simple volume as in non-Eulerian methods. Eulerian methods require measurement of:

• *Flow velocity*. Flow velocity is measured spot, and flow discharge is deduced from velocity and flow area $Q = V \cdot$ A, and a stage-discharge curve is built.

• *Flow depth*. Flow depth is measured continuously, and flow discharge is estimated by way of stage-discharge curve.

A suitable (but not the only available) method for velocity measurements is Doppler flow meter *flow tracker* uses Doppler velocimetry to the measure fields of flow velocity in 3-D (XYZ), and estimate discharge through *velocity/area* (1 measure of speed at 0.6*h for $h < 0.6$ m, 2-3 points for $h > 0.6$ m, rules ISO-USGS). The *flow tracker* is used with wading technique, and section geometry is calculated to allow extrapolation of the stage-discharge relationships, either by way of proper hydraulic (*e.g.* Manning) equations, or by polynomial interpolation.
Flow depth may be measured using a continuous monitoring device, such as a sonic gauge, or pressure transducer, depending upon the features of the measured stream.
Some relevant traits may be highlighted for deployment of a hydro network, and some consideration can be drawn. Some main issues have to be verified in the realization of a hydrographical station to be inserted within a network, especially in this very high altitude region. Some of these issues can be thus schematized as follows, depending upon type of installed devices (*i.e.* sonic gauge or pressure transducer).

1) Easy accessibility of the interest sites, also considering the transport of material necessary to installation.
The chosen sites may to coincide with the presence of roads near the river bed, and in particular in presence of narrowing and bridges. Even when accessibility is given only by trails, accurate choice of the station site may be carried out so that they are more accessible. The necessary tools me be carried by porters during an expedition.
2) Instrumental functioning (e.g. intrinsic of the device, due to cold climate, and/or for suspension load, bed load). This is especially for pressure gauges, but applies also for sonic gauges, say if cables and other pieces are nearby the floodplains.
The stations should be installed in a repaired as possible position, to decrease the chance of malfunctioning due to environmental conditions and hydraulic stressing, e.g. for high turbulence and solid load. However the stations will demand continuous monitoring, likely by CKNP staff, with regard to possible malfunctioning, but even for data downloading, etc.
3) Possible positioning in thalweg (i.e., at channel bottom, for pressure gauges).
The pressure devices should be in the thalweg line, or lowest bed part, to avoid null reading of the sensor in presence of water. Positioning of the sensor in thalweg would however expose the sensor to current and solid load. So the device should be protected by use of hoses, either in plastic o metal, and shielded from the intrusion of sand and gravel.
4) Complicate installation by hanging, i.e. from bridges (sonic gauge).
Mounting a sonic gauge may be complicated, due to the requie hanging frame. Also, presence of strong wind may hamper measurement by vibration or by movingthe device. This needs be taken into account when planning installation.

5) Possible flow measurements by wading and/or tracer for bigger flow sections.
Wading techniques are suitable for measurement of stream flows in mountain torrents of small size, or better with acceptable flow depth and velocity. The calibration of the stage-discharge equation is easier under these conditions. Use of tracer is suitable, but some knowledge of flow depth in the section is still necessary. For higher flows, as Shigar river here, cross section depth was taken, but flow velocity could only be established by use of float and stopwatch. In such case, more trials such be carried out, and surface velocity interpreted using hydraulic laws for flow velocity based upon logarithmic profiles.
6) Relative stability of morphologic conditions of the river bed, evolving in time, and modifying stage-discharge relationship.
Flow measurements and section survey should be made ad least yearly, at the onset of thaw season, to account for variation occurring during seasonal high flows. Ideally, for the most accessible sections, surveys should be done after each noticeable flood event. Also, because for high flows immersed devices (pressure gauges) may be damaged, maintenance is necessary therein.

7) Choice of a design discharge (i.e. for hydro-station dimensioning) for given frequency of occurrence.
Ideally, a design flow discharge should be estimated whenever it is necessary to install a hydro-station, aimed to i) know the greatest flow conveyed in the section when it is naturally defined, ii) define the width of the section whenever artificial confinement would be necessary (*e.g.* by side walls). This could be done by way of critical flow design, pending the choice of a reference return period.

Also, optimal design of the network may be dealt with further on, considering technical requirements, budget constrains, etc.
Concerning network building, i.e. (optimal) positioning of hydrometric stations, no unique solution is available. As a rule of thumb, one may consider at three targets, namely:

i) Installing a number of stations that allows monitoring all (or most) of the out-flowing streams from the target area (the CKNP here),
ii) Monitoring catchments of increasing size (i.e. basin order according *e.g.* to Horton-Strahler approach),
iii) Monitoring of especially interesting sections (*e.g.* glaciers here).

However, the final choice is based upon subjective decision. Here, we propose, in Exhibit 55, and Table 40 a preliminary sketch for deployment of the network. The CKNP park is not a hydrologically closed area (i.e. the catchments therein do not join within the park). Because we imagine that all the hydro stations should dwell within the park's boundary, or at least reasonably close, we propose to install a number of stations which allow to measure water from the catchments out-flowing from the park at their outlet sections. This will allows assessment of water resources from the whole park area. Also, we suggest to monitor with special emphasis smaller catchments, at the outlet of some specially significant glaciers. Because most of water resources in the CKNP comes from glaciers, and ice bodies are very sensitive to climate warming, long term monitoring of such catchments seems utmost important. Shigar station, nearby the South border of the park, and Paiju station, at the front of Baltoro glacier, are also reported. We also indicate a highest and lowest priority, based upon catchment size and glaciers' presence, *i.e.* for expected amount of delivered water (the more water, the higher priority).

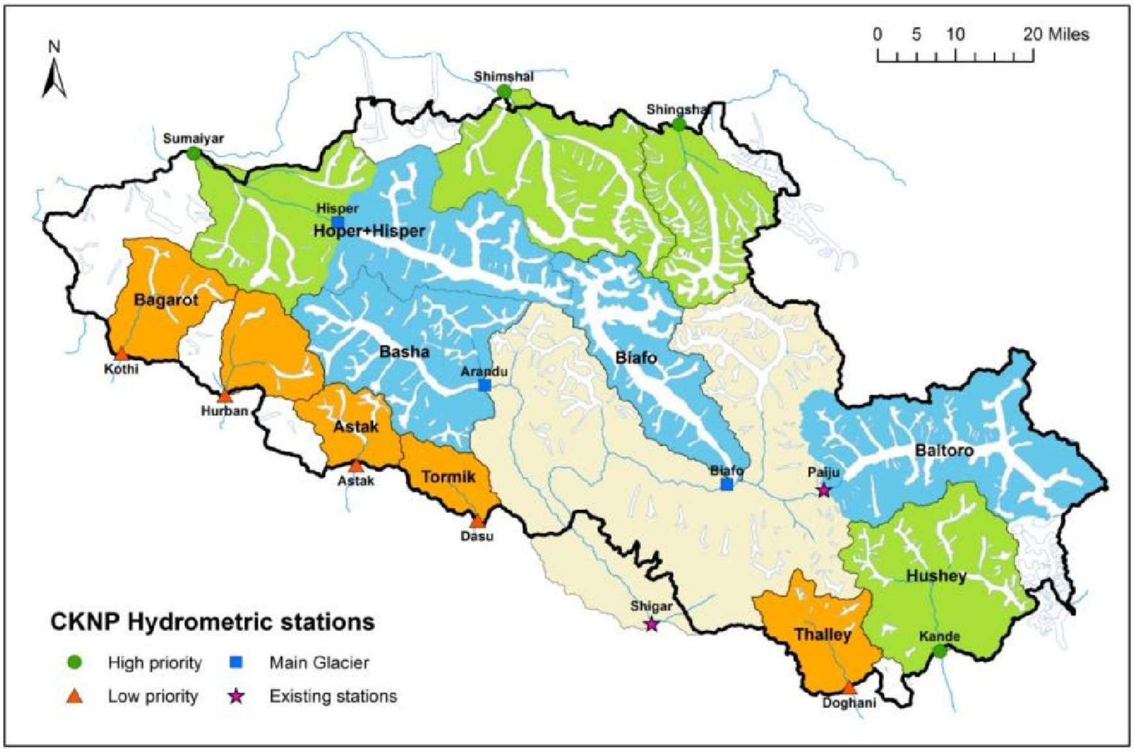


Exhibit 61 A proposed hydrometric network for the CKNP.

Table 51 Features of the proposed hydro network.

Catchment size	Expected deliver	Priority	Village	Valley	Basin Area (km^2)
Large	High	1	Sumaiyar	Hisper + Hoper	1778
Medium	High	2	Shimshal	?	1101
	High	3	Kande	Hushey	1040
	High	4	Shingshal	?	690
Small	Low	5	Doghani	Thalley	394
	Low	6	Kothi	Bagarot	431
	Low	7	Hurban	?	361
	Low	8	Astak	Astak	271
	Low	9	Dasu	Tormik	221
Glacierized	Gauged		Paiju	Baltoro	1331
	Glacier study		Arandu	Basha	1049
	Glacier study		Hisper	Hisper	962
	Glacier study		Biafo	Biafo	845
Main	Gauged		Shigar	Shigar	6923

Albeit no real protocol is available for hydrological modeling, like for instance for meteorological data retrieval, it is possible to provide a sketch of the procedures and tools necessary for setting up a hydrological model of the area.

a) _Hydrological model_: this can be either lumped, semi-distributed or distributed, in order of complexity. Lumped models provide non spatially varying representation of hydrological processes, so they do not account for variations of climate in altitude, including temperature drift, etc. Semi-distributed (tipically, altitude belt based) models allow accounting for such variability, but not for fully distributed values.

However, these models are normally computationally fast, and provide a good trade-off between representation of spatial variability, and short computational time. Fully distributed models give reason of full spatial variability (pending data availability), and are namely very complete tools. However, relatively high computational burden may be a liability, especially for large catchments (greater than 100 km^2 or so). For the purpose of water resources assessment, daily simulation of stream flows is enough.

b) *Stream flow data*: these can be used for direct assessment of water resources, and for calibration/validation of the hydrological models. Notice that a semi-distributed or distributed hydrological model, once calibrated, can provide flow estimates for ungauged catchments of interest, therefore increasing knowledge with respect to direct gauging.

c) *SCA pictures:* in mountain snow fed catchments, investigation of snow covered areas (SCA) by way of satellite data is utmost important. Indeed, use of SCA is widespread, as it provides a benchmark for snow cover dynamics simulation. Satellite SCA data at medium to moderate resolutions are now available easily at virtually no cost, and can be downloaded at least weekly (bundles) if not daily for the purpose of hydrological model calibration/validation.

d) *Snow cover data:* some information about snow cover depth and density is necessary for model setup. SCA pictures provide area coverage, but not absolute values. Also, snow depth data may provide indication of Winter accumulation, necessary for glaciers' feeding.

e) *Ice cover data:* glaciers' area cadastre is fundamental also for hydrological modeling, because the latter include ice melt and related discharge. Also, hydrological models can explicitly track ice cover in time, so that validation via ice area cover is necessary.

f) *Ice melt data:* seasonal melting of ice need be tracked for calibration of ice melt modules within hydrological models, and to track ice depth.

g) *Weather data necessary, rainfall, temperature, radiation, evaporation, wind, air moisture:* it is assumed that the CKNP will develop a meteorological network providing the necessary input data for the development of hydrological models. Minimal models, like the one developed by the author, and reported hereon, need only precipitation and temperatures. However, more sophisticated modeling requires more information.

h) *Soil moisture data*: information of soil moisture, say by way of *time domain reflectometry* TDR probes, may be used to infer soil storage, fundamental for hydrological modeling.

Water resources assessment exercise may be also carried under climate change scenarios. This requires use of the properly calibrated hydrological model, which will take a inputs future climate scenarios. This requires at least three types of information

i) *Historical reference data base (at least 30 years backward)*: weather and possibly hydrometric data, including at least temperature, precipitation, discharge, should be available for thirty years backward or so. This is necessary to i) identify recent trends of weather and water resources, ii) benchmark outputs of control runs from GCMs models, and iii) project hydrological cycle under the *what if* hypothesis of future trends mirroring past ones, i.e the simplest hypothesis for climate projections.

j) *Data from GCMs: control runs, projections:* General circulation models GCMs suggested by IPCC can be used to provide future climate scenarios. Ideally, one should choose those GCMs which provide the *control runs* (i.e. simulations of the past climate) closer to observed climate locally. Under the hypothesis that reasonable coincidence may remain valid in the future, GCMs projections under the IPCC storylines (A1, A1B, A2, B1, B2, etc..) can be used

k) *Locally tailored downscaling schemes*: because GCM do not respect small scale climate variability, especially enhanced within mountainous area, locally tailored *downscaling* is required. This is especially true for precipitation, which exhibits high non linearity and non homogeneity in space and time.

Whenever real time flood forecasting would be of interest within the CKNP, some particular issues would need be faced. As a baseline, hydrological forecasting is based upon hydrological modeling carried out using real time weather data, or forecast of such data, which provides present (now-casting), or future (fore casting) flows. Depending upon combination of i) basin response time, and ii) lead time of forecast issuing, different approaches are needed. When lead time is smaller than response time, flood fore casting is carried out using hydrometric data and flood wave equations, so only hydrometric data are necessary. Conversely, with greater lead time than the response time, weather forecasting are needed. In the following we assume as a mere example that lead time is in the order of 12 hours.

l) *Real time weather forecasting, rainfall, temperature*: for small catchments, *i.e.* those with response time smaller than 12 hours or so, forecast of weather variables (at least temperature and rainfall) is necessary. Therefore, the CKNP should develop a system for assimilation of weather forecast in real time, and subsequent calculation of forecast discharges by way of the hydrological model

m) *Real time hydrometric reading*: use of implementing a real time hydrometric reading system may be twofold. For small catchment (in the sense explained above), it is necessary for real time hydrological model calibration. For bigger catchments, hydrometric data can be used to provide flood wave propagation via solution of flow routing equations, which needs either downstream or upstream boundary conditions.

n) *Rainfall thresholds:* flood alert may be issued by way of rainfall thresholds, *i.e.* calculation of values of precipitation during a given time window above which a flooding is probable. This can be done by i) analysis of historical flood events, ii) simulation using he hydrological model

o) *Online and/or offline model calibration schemes:* the hydrological model to be used for flood forecast may be calibrated i) *offline*, i.e. based upon historical data, or ii) *online*, i.e. during the flood event. The second approach should provide better performance, but requires development of a proper online calibration tool, allowing update at fixed time intervals during forecast exercise.

Water management based upon a quantitative framework requires a number of steps, summarized here. The underlying hypothesis is that some hydraulic structures (*e.g.* dams, impoundments, etc..) are present within the CKNP that can be managed to obtain an optimal water allocation.

p) *Assessment of water demand/conveyance for multiple purposes (agriculture, cost of hydropower, flood warning):* a quantitative assessment is necessary of the amount of wate required for each and every type of use within the park. This should be carried out by the park authorities based upon interviews, historical comsumption data, indirect estimation.

q) *Multipurpose water management optimization tools*: numerical models could be developed to simulate optimal allocation strategies, based upon the water demand as explained above, and knowledge of the available water management structures and regulations.

The issues sketched here constitute the backbone of a possible protocol for development of comprehensive water resources assessment within the CKNP.
The study already presented in Section 2.2.2. displays application of some of the procedures that can be included into a preliminary proposed protocols for hydrological monitoring and modeling of water resources in the CKNP area. Clearly, within the park management plan, a choice of priority should be made to envision an order of priority and a time table of implementation of the several activities. This should be discussed with park authority, and stakeholders of the park. Further issues/requirements may arise in the discussion concerning management plan implementation.

8.3 Wildlife and Vegetation

One of the priority is to have more information regarding the flora and fauna of the CKNP, on size and distribution to assess its status, i.e. declining, or stable, or increasing and in this way its management could be properly addressed.

We started monitoring the large mammals, as umbrella species, to develop the zone system and to give reliable management indications (see Section 2.4.1). Therefore it is suggested to maintain a routinely and standardized monitoring of the large mammals, but it is necessary to implement this monitoring program focusing on other groups like:

- small mammals
- birds (a research is conducted by KIU and the results will be available by end of 2014)
- reptile and amphibians
- fishes (also for this group a research is conducted by KIU and the results will be available by the end of 2014)
- insects
- floral species
- vegetation
- medicinal plants (also for this topic a research is conducted by KIU and the results will be available by the end of 2014).

8.3.1 Large mammals

To obtain reliable data on so large area a minimum three years research plan was considered for the different priority research fields activated in the framework of SEED project.

SEED emphasised how a standardised assessment of the distribution and, possibly, of the numbers of large mammals was urgent. For this purpose, ecological overlap and potential competition between large carnivores (snow leopard, wolf, lynx, brown bear), as well as their non-invasive genetic monitoring to assess minimum numbers, deserve to be estimated. In fact, besides the effects of human-related encroachment (e.g. hunting, poaching, logging, livestock raising), the distribution and numbers of wild ungulates are usually a function of the predator impact, as well as of distribution and quality of food resources.

A *questionnaire* relevant to flag/umbrella species in each valley of the CKNP was prepared, distributed and filled in with the help of the local communities and the support of the Snow Leopard Foundation. Also if some information need a deserve field confirmation this approach allowed us to obtain quickly basic data on such a vast area as the CKNP, and was used to draft the annexed maps and to fill in the following tables with minimum numbers.

Several steps have been already planned to test this information: (*i*) to control "blank" areas (*i.e.* areas where information is flawed and/or the presence of some other species, beside those mapped, is suspected) in the field. Data should be scrutinised to test their reliability; (*ii*) to assess in the field the reliability of focal areas for conservation of large mammals, *i.e.* areas where the distribution of flag/umbrella species is overlapping. This step is very important for such a large protected area as the Central Karakorum National Park, encompassing the distribution of four "threatened" species of large mammals.

The main constraint to the draft of the maps and the writing down of numbers of large mammals in CKNP is related with seasonal movements that animals make and the problem that usually neighbour valleys may share the same population. As to large carnivores, for example, they tend to live in low densities, especially at high altitudes, moving over very wide areas because of dispersion of their main food resources (wild ungulates). These habits make their conservation particularly difficult because the same individual may visit different valleys, which could upset counts carried out just through sightings or signs of presence. To reduce this problem, data on individual distribution of large carnivores in one study site were obtained trough DNA analyses of scats collected over different valleys with a standardised approach. However, collection and evaluation of these data are difficult, e.g. fresh scats yield better results than old ones.

As to numbers, some surveys were carried out in the main valleys of the park, where ungulates occur, to cross-check data in order to also train CKNP personnel. Data on abundance could provide a measure of the relative density of herbivores, which could be used to compare the status of subpopulations from different areas and that of each area in different years.

In one study site (Hushey valley) data have been intensively collected through:

(A) counts of large mammals: *Wild ungulates.* Counts have been carried out through standard methods for mountain ungulates, adapted to local terrain. Locations have been mapped and key-areas GPS-recorded. For each direct observation, number of individuals and group structure have been noted down. *Snow leopards and wolves.* Counts have been carried out through DNA analyses, from scats. Scats of large predators have been collected along fixed itineraries and analysed genetically (to assess the species, the individual and the sex). Minimum population estimates will be obtained as soon as we get back results from genetics.

(B) assessment of predation: Scats of large predators will be analysed to determine their food habits and to detect the effects of carnivores on their natural prey and on livestock. Prey species will be identified out of phaenotipic micro-characters of their hair (*e.g.* structure of *cuticula* and *medulla*) and other indigestible remains in their scats. These data, as soon as they are available, will be useful for the conservation of snow leopard and wolf, as well as for management purposes, *e.g.* through the suggestion of reliable dissuasive measures of predation on livestock.

8.3.2 Forests

Assessment of CKNP forest area & biomass and forest uses per village/valley

It is necessary to assess, of all forest areas felling inside CKNP borders, the village from which are belonging, the surface area, stand biomass and increment. This can be achieved by interpolating landcover classification maps with the average stand biomass and increment developed by University of Padova. Additionally, it would be important to extent this analyses to the whole buffer zone. Evaluation of wood consumption (timber and firewood) as well as other forest uses (non-wood forest products, grazing) on a valley basis is important to understand the feasibility of sustainable forest management: only where forest increment is comparable to harvesting rate SFM can be successful. Otherwise additional measures, as forest plantation and reforestation initiative must be implemented.

Management guidelines and regeneration potential

In specifically designated “training forests” examples of community based forest management should be promoted. This training area for local communities forest committees will rise awareness and skills of the locals. Study to evaluate the regeneration capabilities of locals forests according to different management practice should be promoted.

Develop a rationale grazing activity

By rising the awareness that grazing in forest leads to serious damages to natural regeneration, formative training on management of grazing inside/outside forest should take place. Specific research aimed at quantifying damages caused by livestock on forest regeneration capabilities should be promoted.

Firewood plantation

To reduce the need of firewood from CKNP forests it would be important to evaluate the feasibility of firewood coppice plantations using local plant as Poplars (*Populus* spp.), willows (*Salix* spp.) and Chinar (*Platanus orientalis*).

Recommendations

- Expand knowledge about forest area &biomass and forest uses to the whole CKNP area, buffer zone included.
- Study the reaction of local forests to different management techniques with particular attention to regeneration.
- Study the effect of grazing on local forest regeneration and estimate a threshold.
- Implement coppice plantation for the production of firewood and monitor growth and productivity in different areas of CKNP.

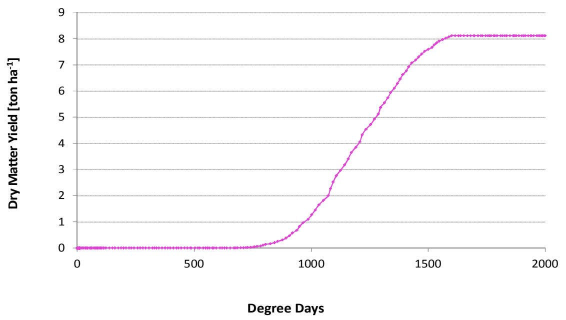
8.4 Livestock and pastures

Available pasture biomass may be approximately estimated by coupling hydrological modeling, for water availability, and biomass growth modeling, pending availability of proper data. This would allow assessment of potential sustainable grazing for bred and wild animals.

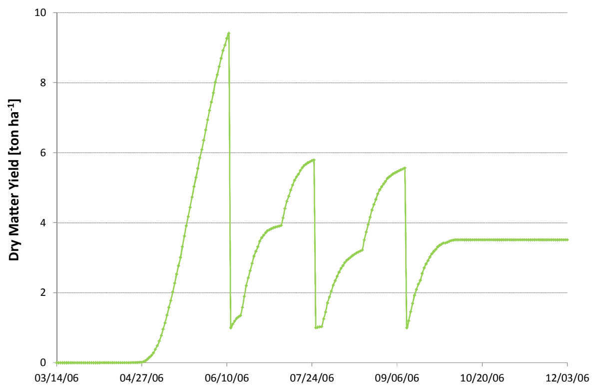
Here, we demonstrate an application of pasture biomass we carried out by developing a simple vegetation growth model. It is a daily time step model that simulates water budget and crop phenology leading to biomass production over a single land block fragment with uniform soil, weather, crop species and management. The model is inspired by the software *CropSyst* (Stöckle *et al.*, 1992; 2003), widely used to evaluate crop yield, and climate change effect therein (e.g. Bocchiola *et al.*, 2012), but it is explicitly developed to be used jointly with the hydrological model illustrated here (Bocchiola *et al.*, 2011).

The model requires as inputs meteorological data (temperature, precipitation and radiation), soil data (texture and depth), management data (clipping, irrigation, …), phenological data upon the crop considered (biomass transpiration coefficient - BTR, light to biomass coefficient - LBC, specific leaf area - SLA and others).

We investigated Alfalfa production in Askole (2980 m a.s.l.) for the period 2005-2008. According to Pakistan Generalized soil map published by Soil Survey of Pakistan, we hypothesized a loam soil. The parameters regarding the phenology of the crop where taken within a literature range, and we hypothesized an irrigation of 250 mm during the growing season. The average production simulated is 8 ton ha^{-1}(Exhibit 62a).



a)



b)

Exhibit 62 Alfalfa dry matter simulated in Askole in 2006. a) No cutting. Degree day is cumulate temperature above 0°C during growing season. b) Three cuttings.

We then hypothesized to cut the cultivar 3 times during the growing season, obtaining an average yield production of 19.9 ton ha^{-1} (Exhibit 56). We compared this result with a study of the FAO/UNDP Project PAK/86/027 on fodder crops production in the Gilgit Baltistan. This study evaluated the potential green and dry matter yield of different Lucerne cultivars subjected to up to 7 cuts per season, in Chilas, Gilgit and Skardu, during 1994-1997. In Skardu, the location closest to Askole, the study reported an average yield of 20.38 ton ha^{-1}, which is close to yield as simulated by our model. Even though the reference period is different and many of the input parameters would require a specific calibration, this preliminary validation of the model in the Gilgit Baltistan displays that pasture growth model by way of coupled hydrological-growth model has some potential for application.

8.5 The Tourism Sector

Socio-Economic Implications

The change in modalities of carrying service provision and procurement for expeditions and trekking parties had its origin at the local level – the difficulties faced by the ad hoc coordination between demand and supply of the 20% of loads, which commonly takes place in Askoli village, the repercussions, however, are widespread: Endogenous developments and external triggers overwhelmed existing ad-hoc coordination mechanism, and triggered a transition towards a new system, which became a viable alternative due to initiatives coincidentally taking place at the same time. The new system includes fewer actors with higher stakes, spatially concentrated in a few villages/municipalities close to the expedition starting point (Askoli), and constant supply of carrying capacity. It therefore has less need for collective action and institutions addressing coordination between demand and supply The change of modalities comes at the expense of a breakdown of the quota allocation mechanism, which ensured fair distributions of portering opportunities among villages/municipalities and households of Braldo Union Council. Socially, this breakdown bears a high conflict-potential. The reduction of carrying service opportunities to a small spatial extent and the increased entry barrier the change in modalities is believed to contribute to income inequality, both, among households and among villages/municipalities of the area. It also comes at the expense of a lower availability of load carrying opportunities in the entire district, since an estimated 80% of expedition loads are currently already carried through pack animals. From a livelihood-perspective this change does not only withdraw an important livelihood cash income activities from the majority of households in Braldo Union Council, and presumably poorer household of adjacent Union Council, but also removes adaptive capacity, i.e the possibility to use portering as a means to overcome a temporary shortfall of income or to cope with disruptions from local livelihoods in the wider research area.

The establishment and management of campsites en route to Baltoro through the communities holding usufruct rights on the respective areas was conceptualized and initiated by a national NGO before the notification of CKNP and the establishment of the Park Directorate. Due to the existence of shared usufruct rights on some areas, the municipalities' entitlements to the management of campsites are not in all cases conclusively resolved, the association of these entitlements with usufruct rights on the respective areas, as well as the rotational campsite duty shifts among the resident households of these municipalities corresponds to the local understanding (Flury, 2012).

Environmental Considerations

In the course of this development, households of upper Braldo Union Council have acquired overall 200/300 hundred equines, since an attempt to secure an opportunity in the course of the changing modalities for carrying services. Some households have sold their *zos* in exchange for mules, donkeys or horses. The environmental changes caused by the shifting livestock composition in pasture areas as well as on the expedition route could be very significant. For the development of regulations, zoning, management and development plans for campsites situated in CKNP, as well as for a conservation plan for upper Braldo, an environmental impact analysis regarding the rearing and use of pack animals for carrying services is indispensable.

Equines have different grazing habits and patterns as compared to livestock traditionally reared in these areas. According to local accounts, unlike cattle and small ruminants, equines are unable to cross steeper terrain and reach higher pasture areas. Due to this inability as well as the different grazing pattern and habits, the increasing number of equines is believed to exert pressure on shrub land surrounding villages, whereas summer pastures located in higher areas are not affected. Due to this relative immobility the death rate of equines is comparatively high, in connection with extreme climate conditions, especially during winter months. Loss of equines on the route to campsites is also reported to be high, caused by accidents while crossing difficult passages, lack of fodder, and extreme climatic conditions. Although fodder for pack animals is supposed to be arranged by the contractor prior to ascent and carried to the campsites, grazing of pack animals at these sites, as well as along the route is reported to take place. Also, the impact of animal waste, along the route, in campsites, especially with regard to contamination of water sources, and on the glacier, is different from human waste (Flury, 2012).

RESEARCH BASELINES FOR CENTRAL KARAKORUM NATIONAL PARK

MANAGEMENT PLAN

FINAL RESULTS

1. GEOLOGY AND RISK ASSESSMENT A methodology to define the susceptibility for landslide in the Central Karakoram National Park[1]

1.1 Introduction and project progress

The area interested by the study of the landslides of the Central Karakorum National Park, extends over a wide zone that goes from the Hunza river, tributary of the Indus river, to the Baltoro glacier, covering the so-called Karakoram mountain range and bounded to the south by the Indus river and to the north by the Biafo and Hispar glaciers and beyond these it extends up to the Karakoram axial Batholite.

The SEED project activities are focused mainly on a management approach, with the aim of creating a management strategy for the CKNP and a sustainable development for the local communities living in the adjacent valleys to the CKNP.

In this framework, fits the risk assessment topic having the aim to create a landslide susceptibility map by means of GIS techniques associated with the in situ surveys. Knowing the potentialities of an area is the first step for a future rational territorial planning and this passes through the data collection and their organization in a GeoDatabase environment. Data analysis becomes easier, while queries permit achieve a deeper insight of the phenomena.

GIS analysis was applied to the whole CKNP area, while data validation was realized only in the surveyed valleys.

In addition, a Landslide Identification Form was expressly created for the Park area, as a Landslide Manual where a short description of the possible events is clarified. Manual and Form are the tools that the rangers could use for the landslide identification. Once identified and photographed, a landslide is ready to be added to the inventory prepared as GeoDatabase where alphanumeric and spatial informations are able to coexist.

Valleys along the tracking routes which are potentially important from an agricultural, residential and touristic point of view were surveyed.

The field trips were organized in two different years. The first visit concerned the Hunza Valley with a detour to Nagar and beyond it up to the Hopar glacier. The second part of this first campaign regarded the Dassun valley up to the last settlement in view of the Haramosh glacier. A deviation from this trail took the researchers to the area of Kaltaro where an enormous landslide is threatening the underlying settlements below. Later on, the Bagrot valley was visited up to the Bagrot glacier that comes from the Rakaposhi massif.

The second surveying campaign was dedicated to the Chogo Lungma glacier that also comes from Harmosh down to the village of Arandu. Starting from Skardu and following the Shigar River it was possible to reach Arandu and then the Chogo Lungma glacier. Back in Dassu and trekking up the Braldu River, the survey proceeded along the Biafo glacier that begins not far from Askole in the NNWest direction towards the Snow Lake and down to Nagar along the Hispar glacier that was not reached.

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[1] Authors: Chiara Calligaris, Giorgio Poretti (University of Trieste, Italy) with the contribution of Shahina Tariq (COMSATS, Pakistan), Hawas Khan (KIU, Pakistan) and Maria Teresa Melis (University of Cagliari, Italy)

This research provided unique information about geostatic problems in the area and can be linked with other projects, like meteorology, contributing to analyse the future scenarios of climate and hydro-geological risks for both the Karakorum region and the whole upper part of the Indus basin.

Experience in recording, processing and interpretation of GPS data, was used to install a GPS benchmark equipped with a choke ring antenna and placed at the KIU University. This reference GPS station can be used as starting point for differential GPS measurements as well as while monitoring landslides. The content of the "Landslide_Point" feature class, for example, was completely surveyed and points were collected using a portable GPS.

Geological and geo-morphological data were collected on every possible landslide.

These new investigations provided crucial information for a better understanding of the complex interactions between the high mountain ranges and geostatic processes that created them.

All the activities listed in the Term of Reference were carried out with the contribution of the PhD student Mr. Hawas Khan. For this purpose a manual was created that can be given to the Park Guards for reporting new land sliding phenomena. This information must be entered in a computer that will be able to process and present them to the geologists, engineers and to the members of the Earth Sciences Department of the Karakorum International University where a proper Geomatics Laboratory must be installed, capable to accept and process the landslides data to present them on proper maps. The Laboratory is already equipped with a permanent GNSS station that will broadcast the RTK corrections in order to provide a very high accuracy to the GPS instruments operating in the surrounding area.

1.2 Identification of landslide-prone areas: a methodological approach

The present research focused on the production of a slope instability susceptibility map, taking advantage of GIS and remote sensing tools [Gardner et al., 2004; Guzzetti et al., 2012]. A multidisciplinary approach was applied to determine the meaning of event-controlling parameters in triggering the landslides [Kamp et al., 2008; Ruff et al., 2008]. The evaluated parameters [Dahal et al., 2007] included geology, tectonic structures as thrusts and faults, plan curvatures, slope angles, aspect, drainage network and land cover. According to Kamp [2008], there are three steps that need to be taken into account in order to study, with a good accuracy, an area affected by landslides.

The first step involves the implementation of a landslide inventory map, providing the location and outlines of landslides [Spiker and Gori, 2000; Chacon et al., 2006].

The second step consists in the production of a landslide susceptibility map, which includes the spatial distribution of event-controlling parameters, that means that the intrinsic parameters have to be defined and prepared for the GIS analysis. This will allow landslide-prone areas to be defined, independently of temporal controls, and will indicate where landslides may occur in the future [Chacon et al., 2006].

The third step is the production of a landslide hazard map.

Considering the present research started in 2011 in the first test area, the first step, was accomplished through field surveys, the second one was realized through the GIS analysis of the geological and DEM data.

The inventory of landslides and their distribution were mapped using the available topographic maps (1:25,000 scale topo-sheet). First, the geological and lithological conditions were analyzed, then the main geomorphologic parameters (slope angle, aspect and plan curvatures) were extracted from the ASTER images.

The obtained parameters were later combined using the Analytical Hierarchy Process (AHP) method and plotted as output in the landslide-prone area raster map [Ayalew et al., 2004; Intarawichian et al., 2010; Komac, 2005; Moradi et al., 2012; Phukon et al., 2012]. These preliminary results were validated in the field, using GPS, identifying the main landslides present in the study area. As for all these types of analyses, the quality of the results is mainly dependent on the DEM resolution [Kamp et al., 2003; Sarkar et al., 2004; Tarolli et al., 2012].

In detail: a landslide susceptibility map was obtained combining the different factors in accordance with their relative influence to the landslide occurrence. The AHP is the methodology that permits to assign a rate not only to the parameters but also to the classes in which each parameter is subdivided [Saaty, 2000]. For the present research the pair-wise comparison matrix presented in Table 2 was used. The considered parameters were arranged in hierarchical order of priorities in rows and columns to generate a pair-wise comparison matrix. At the same time, also the classes in which each parameter has been subdivided were arranged with the same technique using the 9 points defined in Table 1. The parameters were arranged in hierarchical order of priority in rows and columns to generate a pair-wise comparison matrix [Calligaris et al., 2013]. This method may be defined a Weighted Linear Combination (WLC) where secondary – level weights are opinion-based scores [Ayalew et al., 2004].

The weights of each parameter were calculated dividing the geometric mean of each row of the matrix by the total of geometric mean in a column of a matrix. The weights were later normalized.

Afterwards ranks and rates were linearly combined (WLC) obtaining the Landslide Potential Index (LPI) according to the formula:

$$LPI = \sum (Ri \times Wij) \qquad [1]$$

where i = 1 – 9, Ri is the rank for parameter i and Wij is the weight for class j of i factor.

The map obtained as a result of the overlapping weighted raster datasets, represents the distribution of the LPI index values that were later classified into 6 potential landslide susceptibility classes obtaining a landslide susceptibility map (ANNEX 3) [Davis, 1986; Sarkar et al., 2004].

The complete list of numerical grades adopted for the present research is summarized in the Tables from 1 to 6.

Table 1 Pair-wise comparison table [Saaty, 2000].

Intensity of importance for each considered parameter	Importance definition	Explanatory notes
1	Equal importance	Both parameters contribute equally to the objective
3	Moderate importance	One parameter is considered, based on experience, slightly favoured over another
5	Essential or strong importance	One parameter is strongly favoured over the other
7	Very strong or demonstrated importance	A parameter is very strongly favoured over another
9	Extreme importance	The evidence is favouring a parameter over another
2,4,6,8	Intermediate values between the categories	If and when a compromise is needed

Table 2 1. Slope, 2. Plan curvature, 3. Geology, 4. Distance from drainage, 5.Distance from lineaments, 6.Aspect, 7. Geometric mean, 8. Factor weight.

Parameters	1	2	3	4	5	6	7	9	10
(1) Slope	1	5	2	6	7	3	4	3.38002	0.37846
(2) Plan curvature	0.2	1	3	5	7	1	2	1.70566	0.19098
(3) Geology	0.5	0.33	1	3	5	3	2	1.47024	0.16462
(4) Distance from drainage	0.16	0.14	0.33	1	2	4	4	0.81388	0.09113
(5) Distance from lineaments	0.14	0.14	0.2	0.5	1	4	4	0.60981	0.06828
(6) Aspect	0.33	1	0.33	0.25	0.25	1	2	0.54128	0.06061
(7) Land cover	0.25	0.5	0.5	0.25	0.25	1	1	0.41017	0.04593

Table 3 Weights assigned to the slope angle and slope aspect parameters.

Slope angle [°]	Factor weight	Slope aspect	Factor weight
0°-10°	0.1	N	0.2
11°-20°	0.4	NE	0.4
21°-30°	0.8	E	0.6
31°-40°	1	SE	0.8
41°-50°	0.6	S	1
51°-60°	0.2	SW	0.8
61°-70°	0.1	W	0.6
>70°	0.1	NW	0.4

Table 4 Weights assigned to the distance from lineament, distance from drainage net and plan curvature parameters.

Distance from lineament (m)	Factor weight	Distance from drainage net (m)	Factor weight	Plan curvature	Factor weight
0-50	0.7	0-50	0.7	Hollows	0.8
50-100	0.2	50-100	0.2	Noses	0.1
>100	0.1	>100	0.1	Planar regions	0.3

Table 5 An example of the Weights assigned to some of the geological formations and quaternary deposits parameters present in the area of interest.

Geological description	Acronym	Factor weight
Active scree and elluvium	Ez	0.9
Highest terrasse	Fx	0.9
Quaternary deposit	Fy	0.8
Lowest terrasse	Fz	0.8
Hummocky moraine	GvH	0.6
Askor amphibolite	aA	0.2
Iskere gneiss (predominantly orthogneiss)	csiUi	0.2
Stak gneiss (predominantly paragneiss)	csis	0.1
Dainyor and Thowar heterogeneous diorite	dD	0.3
marble	mKK	0.4
amphibolite	mdD	0.4
Sulfide and sulphur mineralization	s	0.2
Dobani - Dasu ultramafics	sD	0.1
Bilchar tonalite to granodiorite - Skoyo tonalite	tB	0.1
N-Barti tonalite to granodiorite	tgdB	0.2

Geological description	Acronym	Factor weight
Chalt formation and Turmik greenstone group	vsC	0.5
Sinakkar volcano-sediment	vsS	0.7

Table 6 **Weights assigned to the land cover categories.**

Description	Code	Assigned weight
Sparse vegetation	3	0.7
Cultivated areas	61	0.2
Snow	11	0.5
Bare soil and scattered	2	0.8
Open forest	4	0.3
Closed forest	5	0.4
Pastures and/or meadows >3750mt	6	0.5
Pastures and/or meadows <3750mt	7	0.5
Bare rock and/or coarse fragments	1	0.9

1.2.1 Geological setting

One of the main themes to consider for a risk assessment analysis is the geology of the area, even if, for a geostatical investigation the lithological characteristics are even better. When the SEED project started, there were no geological digitized data for the CKNP area. For this reason, and seen that the geological theme is one of the main parameters to define the landslide-prone areas, a digitized version of the available geological data was realized. The obtained map is a digit joint format of different geological maps, made by different authors at different scales in different years and especially, two maps were mainly used:

Le Fort P. And Pecher A. (2002) – An introduction to the Geological Map of the area between Hunza and Baltistan, Karakoram-Kohistan-Ladakh-Hymalaya Region, Northern Pakistan (scale 1:150,000); Geologica, 6, 1-140; ISSN: 1025-2541.

Searle M.P., Khan A., Quasim Jan M., DiPietro J.A., Pogue K.R., Pivnik D.A., Sercombe W.J., Iazatt C.N., Blisniuk P.M., Treloar P.J., Gaetani M. and Zanchi A. (2006) - Geological Map of North Pakistan and adjacent areas of northern Ladakh and western Tibet (scale 1:650.000). Edited by Searle M.P. and Khan A.

On this basis a first draft of the geological map (ANNEX 1) is proposed here. The map does not claim to be exhaustive, it is only a preliminary map that covers the whole area. As ANNEX 2 a list of possible references that can help in the future detailing of the proposed map.

The area covered by the presented map is located on the right bank (north) of the Indus River, along the watershed of two of its major tributaries: the Hunza River to the west and the Shigar River to the east. It covers some of the main glaciers present in the Karakoram such as the Biafo, Hispar and Chogo Lungma that form some of the most mountainous and rugged regions of the planet. The area is highly metamorphosed and contains metamorphic rocks in its major portion. The Karakoram plate and Kohistan occurred along the Shyok Suture during the Late Cretaceous. This resulted in metamorphism and deformation of the earlier plutons in the batholith. Magma generation continued long after the suturing, resulting in the younger, post-collision granites which are at least partly derived from crustal melts. Rolland Y. (2002) suggested that the plutons may have been emplaced along extensional fractures developed in the over-riding Karakoram plate.

As Le Fort says (2002), the area comprised in the map groups the 3 major units of the Himalayan collision zone: the Karakoram mountain range, the Kohistan-Ladakh arc and the Nanga-Parbat Haramosh massif, the NW protruding end of the Himalayan mountain range [Le Fort et al., 1994; Le Fort et al., 1998; Searle et al., 1987, 1993, 2006; Tahirkheli, 1979; Zanchi et al., 2001; Zanchi et al., 1994; Zanchi et al., 1993].

The Karakoram mountain range

The Karakoram mountain range is built on Peri-Godwanian continental crust rifted away from Gondwana during Late Paleozoic and accreted to the southern Eurasian margin during the Upper Mesozoic [Gaetani et al., 1990; Gaetani, 1997]. It is bounded to the south by the Shyok suture or Main Karakoram Trust [Tahirkheli et al., 1979]; whereas to the north, the limit lies along the Tas Kupruk zone defined by Kafarskyi and Abdullah (1976) and its eastward prolongation, associated with alkaline femic volcanic evidences [Gaetani et al., 1996; Zanchi et al., 1997] that may represent the Paleo-Tethyan suture separating the Karakoram from the HinduKush-Pamir. The most ubiquitous feature in the Karakoram is the Axial Batholith [Desio 1972; Desio et al., 1966; Desio, 1964; Ivanac et al. 1956; Le Fort et al., 1983; Schneider et al., 1999a; Schneider et al, 1999b], which forms the central part of this belt and hosts the tallest mountain peaks of the region, including K2. It is comprised of a number of large parallel or en echelon plutons. They range in age from Jurassic to Miocene [Searle, 1991; Searle et al., 1991]. The granitic rocks and the surrounding sedimentary sequence have been metamorphosed to varying extents during at least three main thermotectonic events and a later retrograde phase. The Karakoram Batholith divides the region into a northern and southern sedimentary belt that following Gansser (1964) the Karakoram unit is usually subdivided into three main parallel sub-units, from North to South:

- the northern sedimentary belt, made up of a pile of thrusts sheets [Zanchi e Gaetani, 1994];
- the Karakoram batholith, or central plutonic belt (frequently named “axial batholith” after the axial zone IV defined by Schneider (1957), it covers about 30% of the range;
- the southern metamorphic belt, as the northern sub-unit, is also predominantly made up of sedimentary series, but the metamorphism accompanying the polyphased deformation usually reaches the amphibolites grade facies [Rolland, 2001].

The Kohistan-Ladakh Unit

The Kohistan-Ladakh Unit formed one of the two large areas stretching on both sides of the Nanaga Parbat-Haramosh massif and it is attributed to a large section of an oceanic island arc, since the pioneer work of Tahirkheli (1979, 1982), Tahirkheli et al. (1979) and Le Fort (1975). Kohistan is an intraoceanic island arc bounded by the Indus Suture zone (MMT) to the South and the Shyok Suture zone (Main Karakoram Thrust or MKT) to the north. This E-W oriented arc is wedged between the northern promontory of the IndoPakistan crustal plate and the Karakoram block. The island arc is usually considered as a result of the north-dipping subduction of the Tethys oceanic floor during the northwards drift of the Indo-Pak continental plate. Khan T. et al. (1994) and Treloar et al. (1996) have identified back-arc formations in the northern part of the Kohistan. Rolland et al. (2000, 2001) have shown that this back-arc basin extended eastward in Ladakh, with geochemical signatures suggesting the eastward progressive implication of the Asian continental margin. The back-arc zone forms a greater part of the reworked and sliced terrains of the Shyok suture. The Kohistan-Ladakh Unit may provide the most complete exposed section of an arc crust, from the upper mantle base to the subaerial volcanic rocks [Tahirkheli et al., 1979; Le Fort et al., 1980]. A revised lithostratigraphy of the volcanic and sedimentary formations of the Kohistan arc have been propounded by Treloar et al. (1996) and help them to pinpoint the four major phases of magmatism, linked to extension phases that they date as Middle and Late Cretaceous, Eocene and Oligo-Miocene. The two first phases have been deformed and the plutonics orthogneissifide. Up till now, the equivalence between Ladakh and Kohistan was broadly assumed and based on large scale correlation. Gravity data modelling indicates that the MMT and MKT dip northward at 350 to 500 and that the Kohistan arc terrain is 8 to 10 km thick [Malinconico, 1986]. Seismological data suggests that the arc is underlained by the Indian crustal plate [Seeber and Armbuster, 1979; Finetti et al., 1983). The northern and western part of the area, along MKT, is covered by a sequence of Late Cretaceous to Paleocene volcanic and sedimentary rocks. The central part of the arc terrain is mainly composed of Kohistan Batholith which comprises an early (110-85 Ma) suite of gabbro and diorite, followed by more extensive intrusions of gabbro, diorite and granodiorite (85-40 Ma) which are intruded by much younger dykes and sills of leucogranite (30-26 Ma) [Le Fort et al., 1987].

The Himalayan Unit

The Himalayan Unit is represented by the north-south promontory of the Nanga Parbat – Haramosh massif and comprises the north-western margin of the Indian plate and forms a relatively narrow belt South of the MMT (Indus Suture zone). It extends westward from the Nanga Parbat-Haramosh massif and continues up to the Afghan border. It is comprised of a thick sequence of Proterozoic basement gneisses and schists unconformably overlain by variably metamorphosed Phanerozoic cover sediments [Kazmi et al. 1982; Lawrence et al. 1983]. Culminating at 8125 m, Nanga-Parbat consists of a wide variety of high-grade gneisses in which Madin (1986) has distinguished a large western anticlinorial area of orthogneisses, the Iskeere gneisses, covered by a thick succession of meta-volcanic and meta-sedimentary para-gneisses, called the Shengus gneisses. Ages obtained by Chamberlain et al. (1991), Zeitler et al. (1989, 1993), Schneider et al. (1999a, 1999b) and also Treloar et al. (1991, 2000) show the complexity of the evolution of the zone in which an old Precambrian magmatism and metamorphism have been largely obliterated by the Himalayan thermal evolution probably starting before 40 Ma, culminating around 20Ma, but continuing up to recent Neogene. Crystalline Proterozoic basement rocks are also involved in thrusting. According to Coward et al. (1982, 1985, 1986) the granitic basement assemblage contains slices of cover rocks in synclinal folds and shear zones. Collision and subduction have thickened the Indo-Pakistan plate margin through formation of a thick sequence of ductile mylonites, and imbrication of cover and basement along north-dipping crustal-scale thrust stacks. The latter are comprised of a number of lithologically distinct nappes which form a 5 km thick tectonostratigraphic sequence. Six major thrust nappes have been identified in this region.

1.2.2 Digital Elevation Model (DEM) and its derivatives

The research used, as topographical basis, the maps derived from the high-spatial-resolution multispectral images known as ASTER images. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra spacecraft collects in-track stereo using nadir- and aft looking near infrared cameras. Since 2000, these stereo pairs have been used to produce single-scene (60 x 60 km) DEM at resolution of 30m, having vertical accuracies (RMSE) generally between 10 m and 25 m. On June 29, 2009, NASA and the Ministry of Economy, Trade and Industry (METI) of Japan released a Global Digital Elevation Model (GDEM) for users worldwide at no charge, as a contribution to the Global Earth Observing System of Systems (GEOSS). NASA and METI have released a second version of the ASTER GDEM (GDEM2) in mid-October, 2011. The GDEM2 has the same gridding and tile structure as GDEM1, but benefits from the inclusion of 260,000 additional scenes to improve coverage, a smaller correlation kernel (5x5 versus 9x9 for GDEM1) yielding higher spatial resolution, and improved water masking. While the ASTER GDEM2 benefits from substantial improvements over GDEM1, users are nonetheless advised that the products may still contain anomalies and artifacts that will reduce its usability for certain applications, because they may introduce large elevation errors on local scales. The GDEM2 used in this research was acquired by downloading it from http://reverb.echo.nasa.gov/reverb with the bounding box of the Northern Areas limit. With reference to the limitation expressed above, a comparison between the GDEM1 and GDEM2 datasets on CKNP has been done. The main problem in GDEM1 was the lack of data on some of the peaks due probably to the high reflectance of snow and ice. This mistake in GDEM2 has been corrected.

The resulted DEM presents some artifacts visible as a regular grid that may produce irregular data in the derived maps. The minimization of this noise was resolved with the application of a neighborhood operation that computes an output raster where the value for each output cell is a function of the values of all the input cells that are in a specified neighborhood around that location. A kernel of 5x5 was chosen and the mean was calculated for the output pixel.

1.2.3 Geomorphometric analysis: slope, aspect and curvature parameters

From ASTER DEM it has been possible to calculate three different geomorphic parameters such as slope angle, aspect and plan curvature that are a first step to describe the geomorphologic landforms and processes [Chang et al., 1991; Ohlmacher, 2007; Milevski et al., 2009].

The slope angle value, calculated by the 3D Analyst tool, was divided into 8 classes [Ruff et al., 2008], from 0° to more than 75°. It is known that highest susceptibility consists in slope angles between 20 and 40° [Ruff et al., 2008]. Rock falls are instead the main type of mass movement at higher angles. Eight classes characterize the aspect value, which may be used as an indicator for valley asymmetries. Southward orientations imply a high susceptibility for soil slides. As defined by Ruff, a high susceptibility weight was given to the southward orientated slopes and medium to low weights were assigned symmetrically to the other directions.

The curvature of the surfaces may be used to describe the physical characteristics of a drainage basin in order to better understand the geomorphic development of landslide terrains [Olmacher, 2007; Tarolli et al., 2012]. According to Ohlmacher (2007) plan curvature is the second derivative of elevation with regard to aspect, it is the curvature of topography from a map view (following contour lines) [Moreno et al., 2004], that is the curvature of the hillside on a horizontal plane. According to the morphology, using ArcGIS 9.3 version, three different types of curvature may be obtained: profile, plan and a combined version. For the present research the combined curvature has been used. This tool permitted to recognize from the DEM: hollows, noses and planar regions. Trough plan curvature, noses and hollows may be quite easily identified due to their very complex and different profiles [Kimerling et al., 2011]. The acceleration or deceleration of a flow can be highlighted by the profile curvature; while the plan curvature can influence the convergence or divergence of the flow itself. So their combination can help in understanding the flow behavior across a surface.

1.2.4 Land cover framework

Land cover is one of the factors responsible for landslide. It is widely known that barren slopes are more prone to landslides while vegetative areas tend to reduce the action of climatic agents preventing the erosion [Dahal, 2007; Gray and Leiser, 1982; Greenway, 1987; Styczen and Morgan, 1995]. In mountain regions, land use data can easily be obtained analyzing remote sensing datasets. In areas where the reliefs are very high as the CKNP, a supervised land cover classification was obtained by the University of Padua Research Group. Satellite analyses were compared with field observations for selected areas studied in detail, validating the work done.

To classify the areas on the basis of the spectral response variations, 9 land cover classes were identified based on their possible influence on landslide occurrence. They are: sparse vegetation, cultivated areas, snow, bare soil and scattered, open forest, closed forest, pastures and/or meadows >3750mt, pastures and/or meadows <3750mt, bare rock and/or coarse fragments.

The results of the land cover classification defined 46% of the territory covered by snow areas, 15% by sparse vegetation, 14% by bare rock and/or coarse fragments, 11% by bare soil and scattered vegetation, 5% by pastures and or meadows > 3750 m asl, only 1% of the areas are cultivated and approximately close to the 0% the pastures and/or meadows <3750m asl. In this framework, as could be expected, is possible to say that the landscape is dominated by the snow and by bare rocks and soils or sparse vegetation and this situation makes the area fragile as far as landslide tendency is concerned. Agricultural land is restricted to river terraces and alluvial fans along the valleys floors, and terraced steeper slopes. The urban areas are mainly present along the rivers or are set on the stabilized fan of an ancient debris flow, still partially active. The rest of the areas are covered by the glaciers that occupy a huge amount of the whole park area.

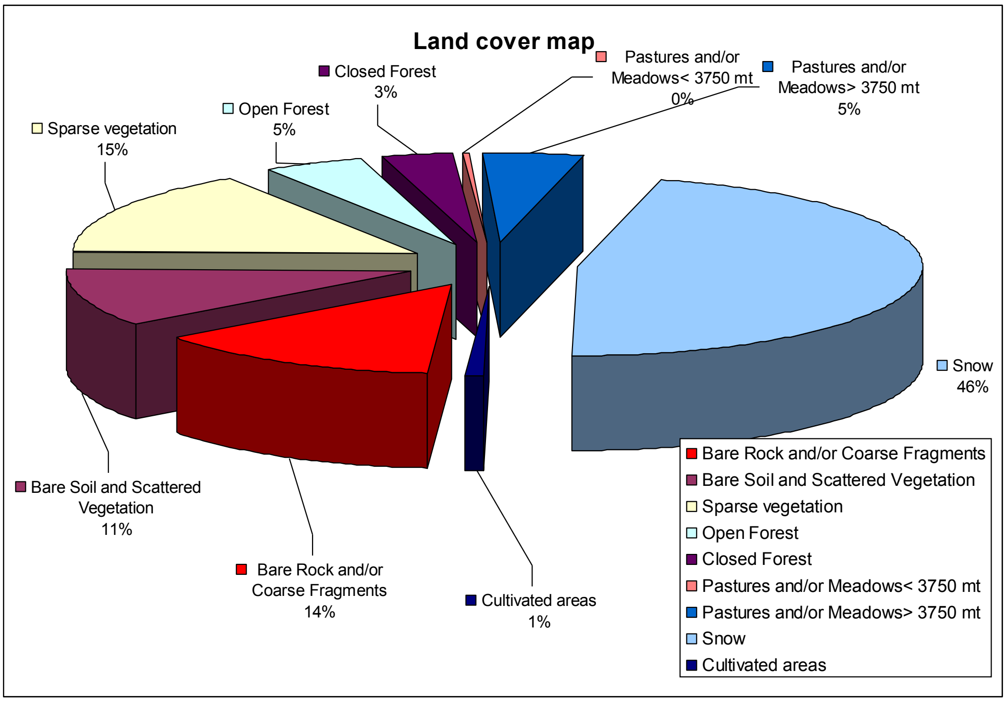

Exhibit 1 Summary of the land use classes identified in the CKNP area.

1.2.5 Landslide distribution map

For the present research two test site areas in the framework of the SEED project were deeply analyzed and surveyed in depth. These operations permitted to have a first geodatabase to start the landslide inventory of the Central Karakoram National Park.

The main landslides were previously identified using DEM hillshade data set and the curvature map derived from the DEM. Due to the lack of vegetation, a high reflectance is present and the identification of the phenomena appears to be easier. All of the mapped landslides were later cross-checked in the field.

To identify and collect data regarding landslide phenomena and the involved territories and infrastructures, a Landslide Identification Form has been created according to the guidelines provided by Amanti et al., 2005 in the framework of the I.F.F.I. Italian national Project and with the precious help of USGS guidelines (Highland et al., 2008). The form is really simple and permits, also for persons who are not used to recognize landslide, to contribute to the data collection. As ANNEX 4 is presented the Landslide Manual: short guideline and the Landslide Identification Form.

The GeoDATABASE

The field activities foreseen the data collection and storage in a Geodatabase (Access/ArcGIS). The two software permit to have available a lot of different informations (coming from different environments) and to query them quickly and widely. A GeoDATABASE was expressly created for the present project. As follows some images showing the GeoDB structure and contents.

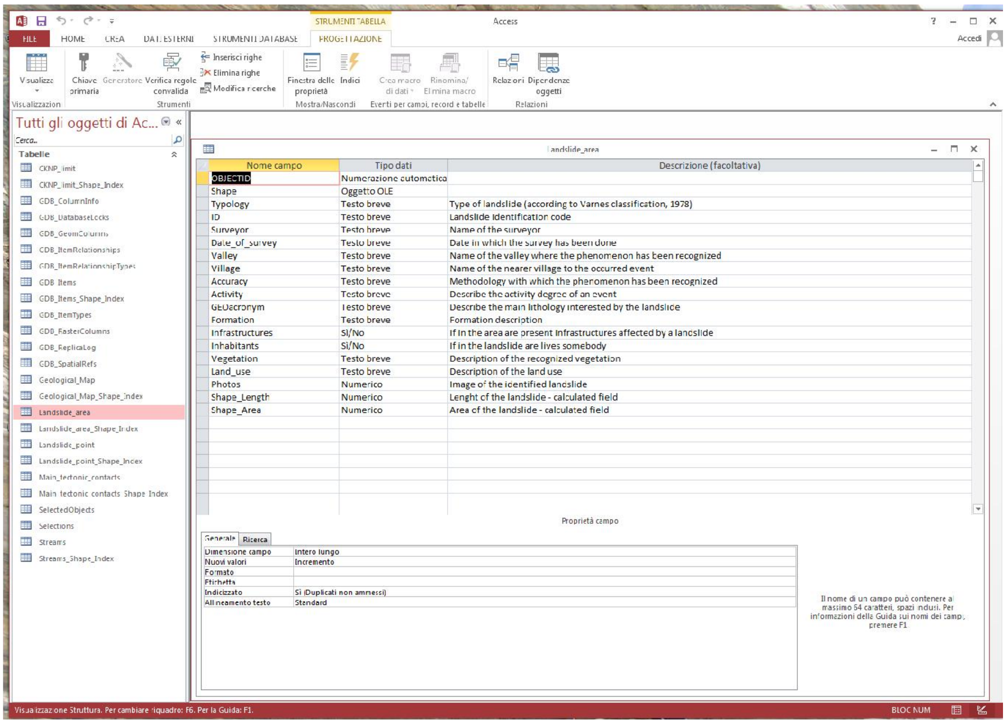

Exhibit 2 Landslide AREA feature class present in the Geodatabase: Access structure.

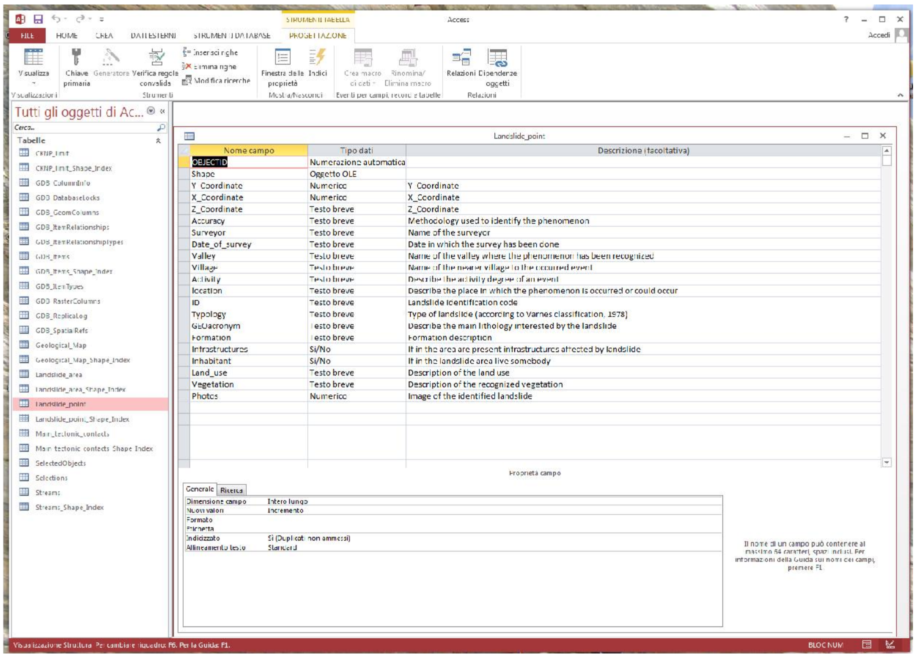

Exhibit 3 Landslide POINT feature class present in the Geodatabase: Access structure

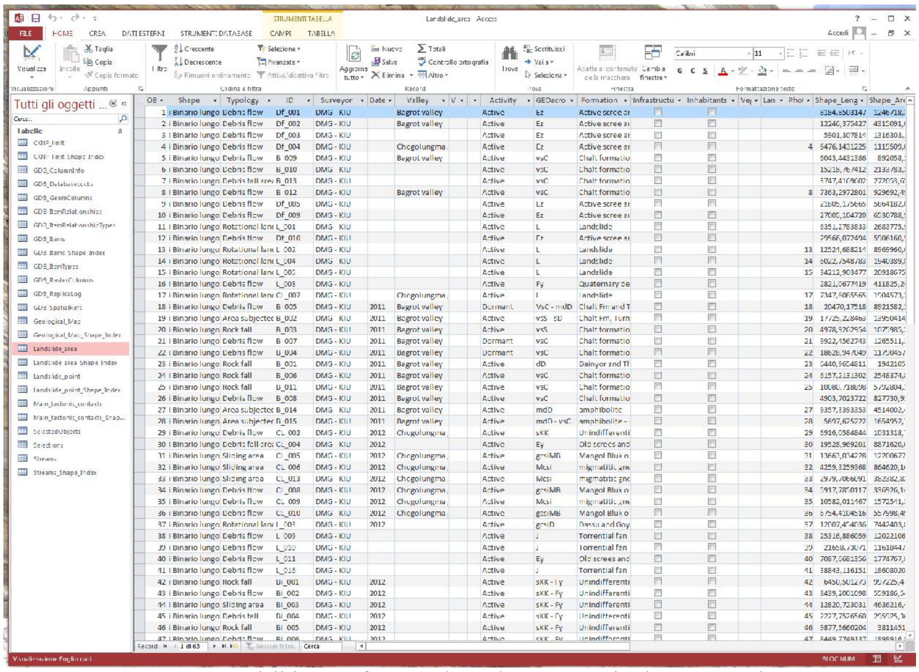

Exhibit 1 Landslide area feature class, data present in the GeoDatabase**.**

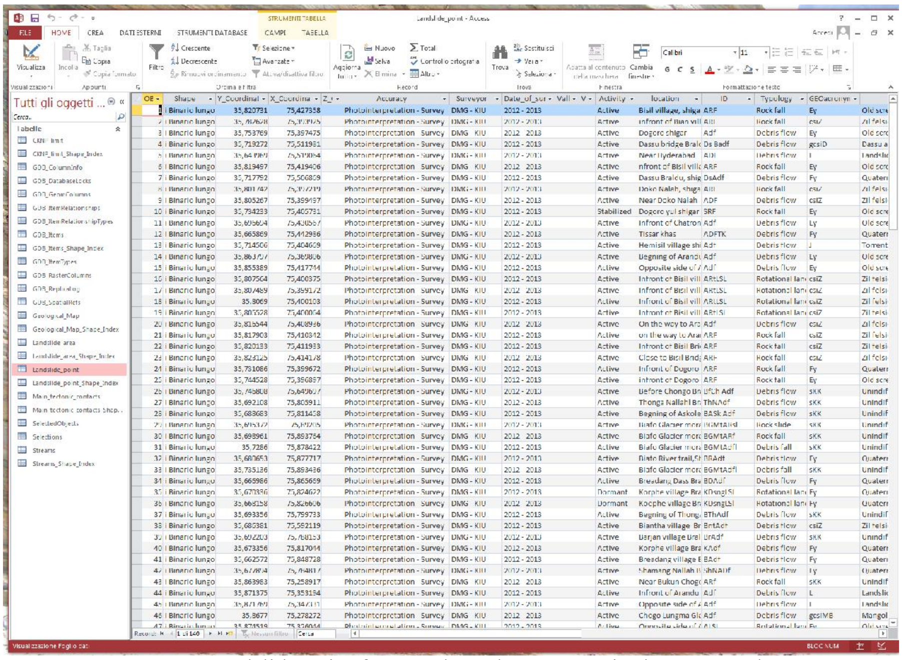

Exhibit 2 Landslide point feature class, data present in the GeoDatabase**.**

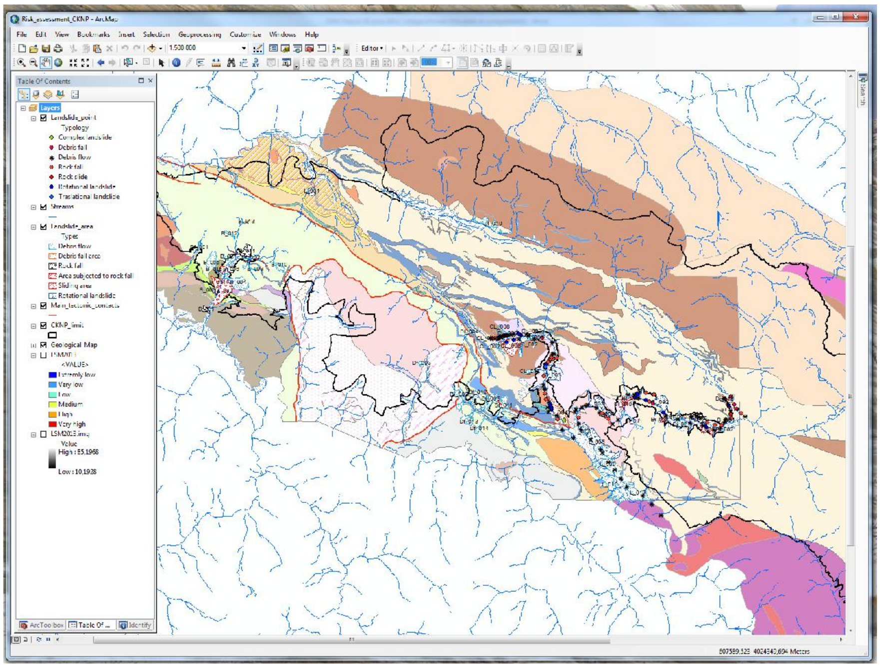

Exhibit 3 ArcGIS environment containing the feature classes realized within the framework of SEED project.

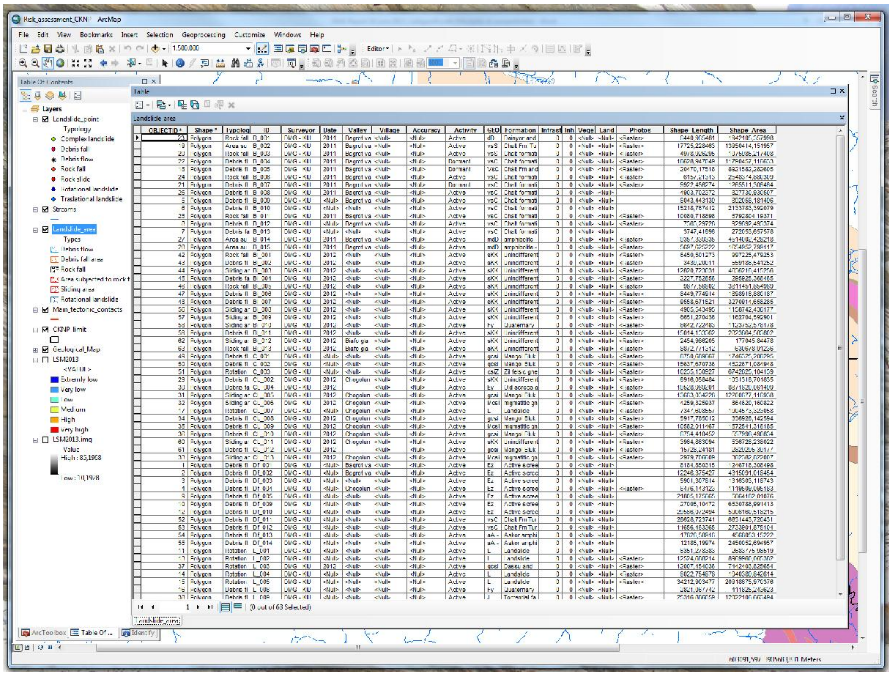

Exhibit 4 Landslide area feature class, an example of the compiled attribute table.

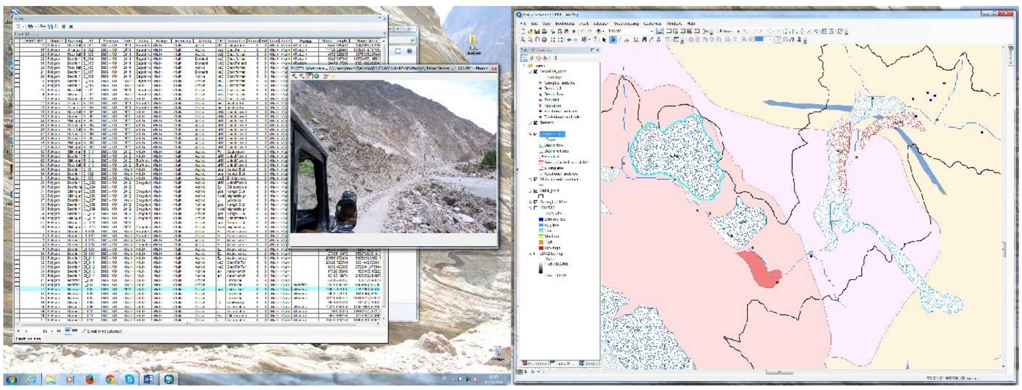

Exhibit 5 Images present in the GeoDB and related to the single landslide phenomenon, an example for L_003 ID code rotational landslide.

The test site areas: the Bagrot valley

The Bagrot valley is a North –South oriented valley in the buffer zone area of the CKNP. From the road located on the hydrographic left of the Gilgit River, a jeepable road goes into the valley. This road is scattered with landslides along its entire route until the meeting point with the glacier. Along both sides of the Bagrot valley the slopes are covered by active detritical fans (Exhibit 9). In several points the road is affected by active landslides that block the road when a paroxysmal event occurs. On the way the traces of an ancient slipped volume that completely blocked the Bagrol Gah river are still visible (Exhibit 9). From the road it is possible to see the presence of old lacustrine deposits located over the alluvial terrace.

Exhibit 6 Panoramic view of the Bagrot valley from S to N.

Exhibit 7 Detritical fans along the road into the Bagrot valley.

Proceeding from south to north, on the road there is an active landslide (Exhibit 11) that causes big problems to the passage of vehicles. The phenomenon started with a rock fall and created a fan of heterogeneous material. Half of the slopes along the whole valley are covered by detritical fans due to rock falls that decrease the slope inclination of the entire valley.

Exhibit 8 An active landslide on the road to the Bagrot valley.

Before arriving in the village of Datuchi, on the hydrographic side of the valley, there is a big debris flow deposit made up of very small sized rocks where gold particles are present.

Exhibit 9 Golden debris flow.

On the slopes over Datuchi, a long belt of detritical fans is present. These fans are active where there is no vegetation, instead where water is present and grass, shrubbery, bushes and trees cover the site, the slopes can be considered stable (Exhibit 13).

Exhibit 10 Scree slopes over Datuchi school.

At the end of the Bagrot Valley, the Hinarche glacier is present at the toe of Diran peak. The valley has a typical U shape due to glacial erosion (visible also in the photo). The slopes of the valley are gentle with a belt of detritical fans at the bottom of the slopes. Frontal and side moraines are present in the valley. Vegetation is quite rare at the frontal part of the glacier.

Exhibit 11 Hinarche glacier.

The test site areas: the Chogo Lungma and Biafo valleys

During the surveying campaign of June 2012 were explorated the glacial valleys of Chogo Lungma (1), part of the Shigar valley including Dasso, the area between Dasso and Askole and part of the Biafo glacier.

The path from Skardu to Dasso is charaterized by events of active debris flows, which are sometimes difficult to cross. During the warm season it is necessary to cross these roads in the early hours of the morning to avoid the flooding of the fusion waters from the glaciers. Exhibit 13 highlights the debris fans partially stabilized (green) where some villages have settled. The debris fans are interconnected, partially overlapped and of remarkable dimensions. Within a single fan an area is present (grey) characterized by high activity, where the neo-formed deposit can be recognized. These deposits sometimes flood also the urbanized areas present on the path. The whole Shigar valley is characterized by the presence of these fanlike formations that partially influenced the morphology of the Shigar River that in the area between Dasso and Shigar presents a structure of anastomized channels typical of a flat area where the dissipation of energy is the origin of these braided channels.

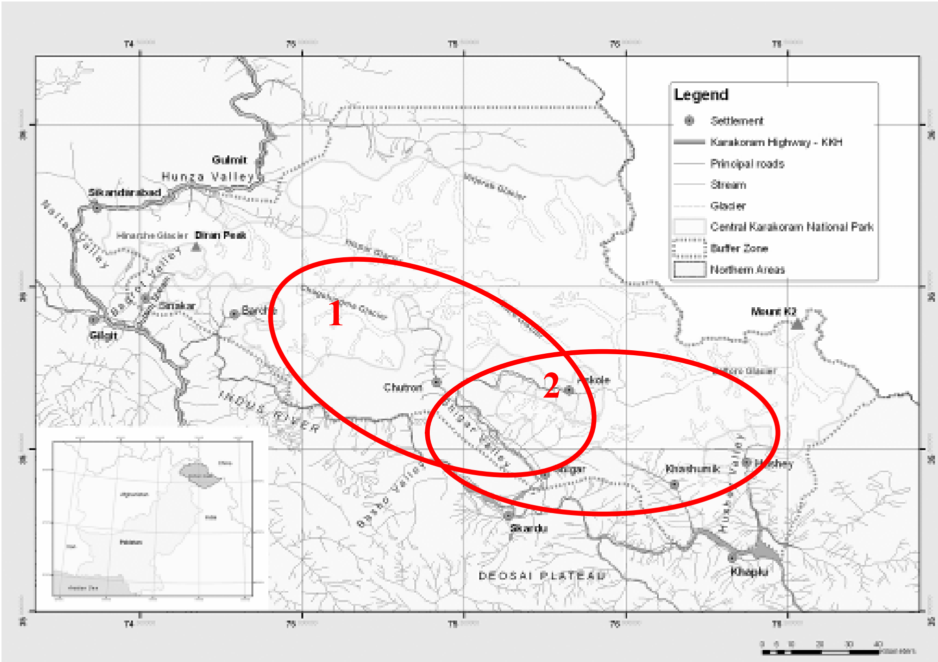

Exhibit 12 The test site investigated areas.

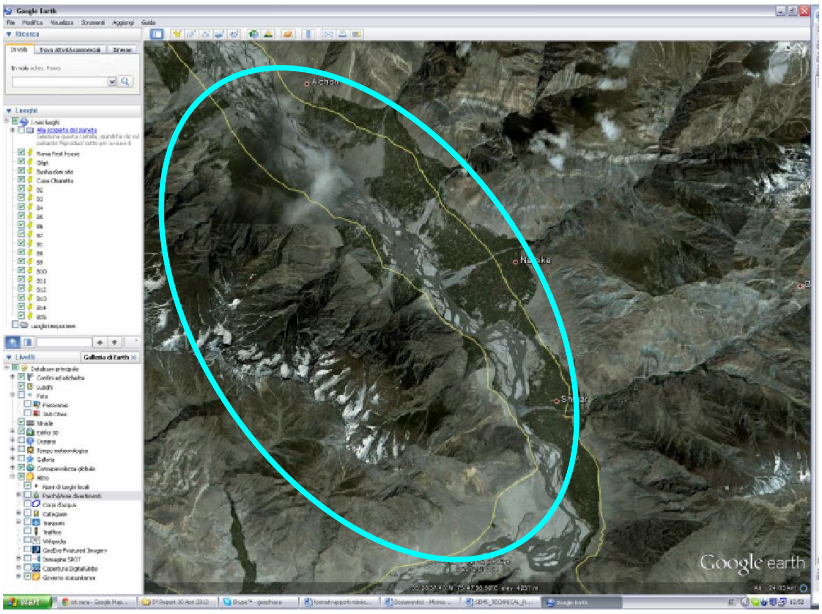

Exhibit 13 Shigar, Namika e Alchori are urban settlements established in correspondence to debris flows.

During the survey carried out inside the CKNP Park in the Chogo Lungma area, landslide phenomena of different dimensions were pointed out, with some of them also having different origins. Progressing from the village of Arandu, after the Basma River bridge, on the left bank, 2 events of sliding rocky material can be identified. Their sliding behavior is similar to the one of a debris seen the very high level of fractures present in the involved material. The outcropping layers are oriented in the opposite direction of the slope direction (dips upslope). The two events are caused by the toe erosion due to the Basma river flow and up to date can be almost identified with a single event due to their present dimension and continuous activity (Exhibit 17).

Exhibit 14 Landslide due to foothill erosion.

Proceeding along the path that follows the hydrographic left bank of the Chogo Lungma glacier, a sliding phenomena of limited dimensions can be identified taking place on fluvio-glacial material (Exhibit 18).

Exhibit 15 Rotational landslide in fluvio-glacial material.

Along the hydrographic right instead, one runs into a large dimension phenomenon: this is a translational landslide of detritical material of glacial origin on a steeply dipping strata oriented like the slope (dips downslope). The main scarp is higher than ten meters and in correspondence to the crown it is possible to point out several events of minor dimensions due to the detensioning of the material involved.

This phenomenon is typical of this side of the valley that initially is east-west oriented and is characterized by having different structures on the two sides. The northern side presents a steeply dipping layer with a very high degree of fracturing, sometimes similar to cataclasis. The southern side instead is characterized by a steep dipping strata tilted like the slope and this leads to sliding phenomena along the layer plains. These large dimensions layers are the consequence of the post-glacial detensioning (Exhibit 19).

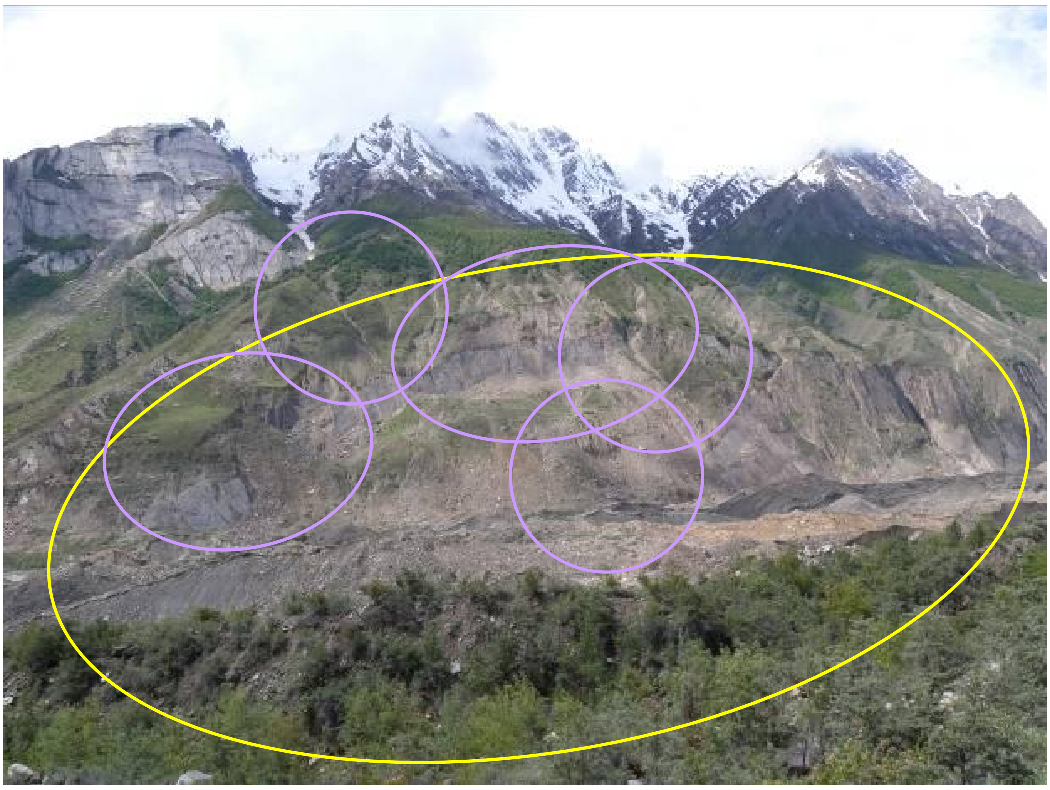

Exhibit 16 The main phenomena are within the yellow ellipse; the collateral events are in the purple circles.

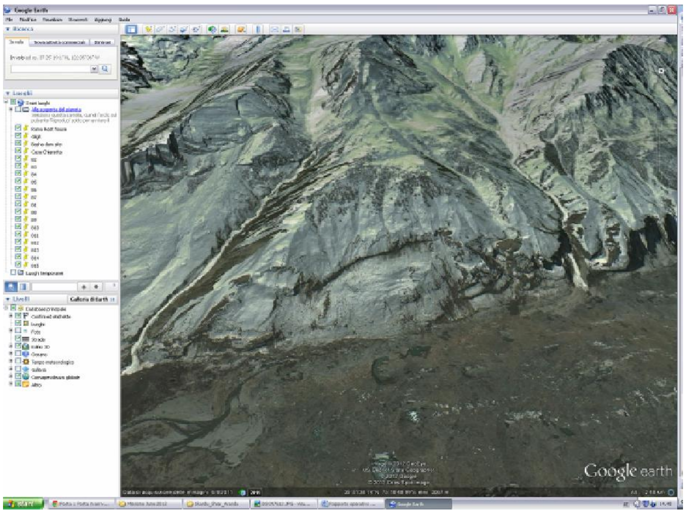

Exhibit 17 Google Earth, 2012 image. The high detail level allows to identify the morphology of the main scarp and the whole phenomena.

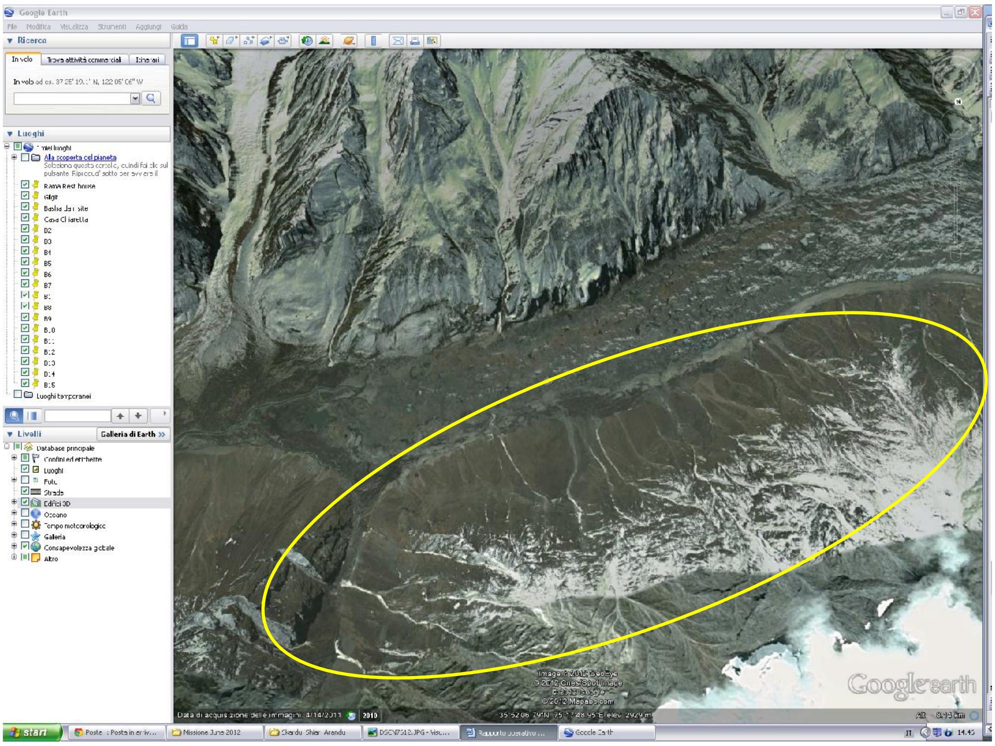

Exhibit 18 Last part of the Chogo Lungma Glacier.

The path runs all along the hydrographic left, and it develops in correspondence to the lateral moraine deposits left by the glacier. The track presents plenty of debris flows (Exhibit 19, yellow) whose deposits cross the path and often hide it completely. One of these phenomena is also present in correspondence to the Buckhum Base Camp.

The road that from Dasso leads to Askole is also reached by landslide phenomena, not only rockfalls of different types, but also debris flows with highly developed debris fans.

Exhibit 19 Rotational landslide in fluvio-glacial deposit. The event caused damage to the infrastructure present in the area making it unstable for a period. Fluvial banks are subjected to high toe erosion that is the main cause of landslides. There are no mitigation measures to avoid erosion along the fluvial banks.

Exhibit 20 The debris flow recent deposits in light grey. During a landslide event, the debris completely flooded the road blocking its use.

Exhibit 21 From upstream to downstream, an example of the damages caused by a debris flow to the road. The road crossing has been completed flooded away.

Exhibit 22 Rotational landslide in colluviums. The morphology helps in indicating the landslide dimension and highlights the safety of the built road.

Exhibit 23 Rock fall at the beginning of the track to Concordia (K2 Base Camp). Boulders partially occupied the track. The first part of the track leading to the Biafo Glacier is subjected to rock fall phenomena. Some of them occurred also while the researchers were surveying. Boulders are present in the area and in the 90% of the cases their runout distances are intercepting and crossing the track.

Exhibit 24 Runout distances of the boulders downstream the track taking to the Biafo Glacier. The track is constantly crossed by a huge amount of trekkers climbing to K2 and Biafo. At the center of the Exhibit, on the hydrographic left of the Braldu river, a debris fan is present.

Exhibit 25 Debris flow event.

Exhibit 26 Rotational landslide of debris material located on the hydrograpic left of the Braldu river.

The left slope of the Biafo valley is very steep with a high rock fall predisposition. The lower side is characterized by the presence of debris fans, interdigitated and laying on the glacier. On both sides of the valley, it is easy to distinguish a lighter area, a paler gray, indicating the older elevation reached by the glacier. Glacial side deposits are continuously interested by shallow landslides modifying the morphology of the area and destroying the existing track. Each valley is subject, during winter and spring time, to avalanches and during the spring and summertime, to debris flows. It is safer to walk up the glacier in the middle instead trekking on the sides where there are two main problems: rock falls coming from the slopes of the high peaks, and the rotational shallow landslides occurring in the lateral moraine deposits and invading the tracks. The following images highlight the 2 most frequent types of landslides present in this area.

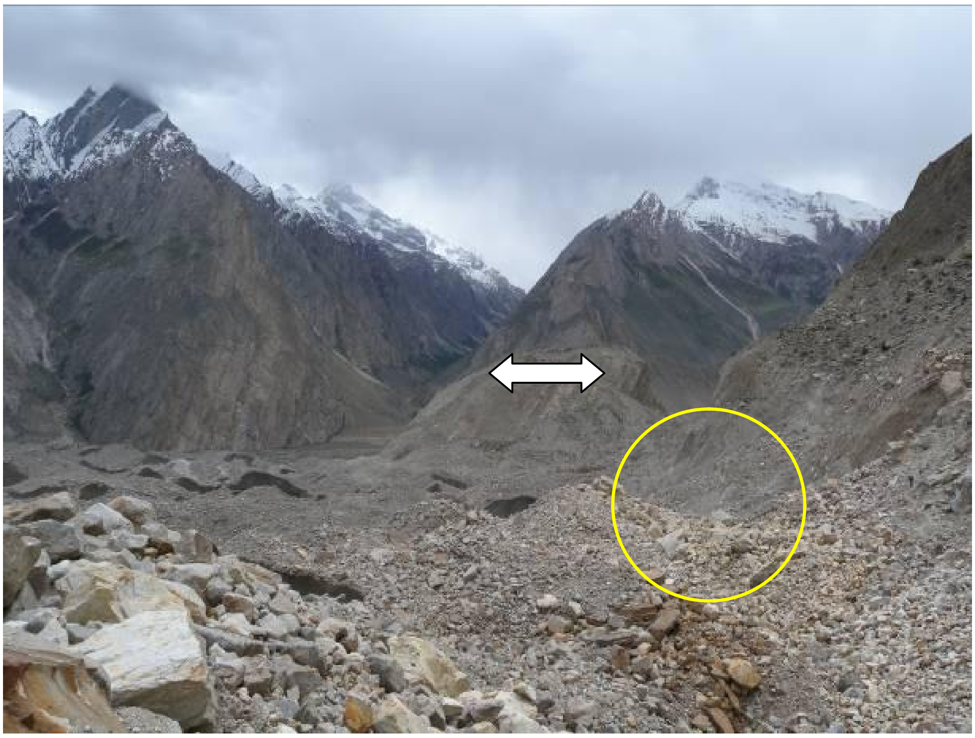

Exhibit 27 Arrows highlight the fault plain. A trekker inside the yellow circle is the reference point used to understand the slope of the sides.

Exhibit 28 Rock fall along the track. The subvertical layers isolate unstable volumes triggered by the weathering (hot/cold).

Exhibit 29 The lower area of the rocky side of the mountain (light grey) indicates the lowering of the glacial level.

Exhibit 30 Focus on an unstable volume**.**

Exhibit 31 From this point upstream, the valley becomes wider and the path becomes easier to climb.

During the survey more than 100 landslides were identified, but only the main ones were recorded (dimensions, intersecting infrastructures as roads or houses). These phenomena are under analysis and are going to be added to the inventory.

In the investigated areas most of the landslides are represented by rock falls, debris falls and debris flows. Rotational or translational slides were identified during the field survey. The rock falls are widely distributed all though the valleys, along both sides, where is possible to identify coalescing debris fans. Steep cliffs are heavily subjected to physical weathering having as a consequence a decrease in the geotechnical characteristics and an accelerated weakening of the rocks thus creating daily rock falls.

Debris falls are common features observed in these areas and terraces are heavily subjected to them. The heights of the terraces may reach 100 m, and the toe erosion is their main triggering cause. The most part of the surveyed landslides may be considered active according to the WP/WLI Multilingual Landslide Glossary [UNESCO, 1993].

Attributes of Landslide_area

FID	Shape *	Id	Typology	Area	Acronym	Activity
0	Polygon	0	Debris flow	892158	B_005	Dormant
1	Polygon	0	Area subjected to rock fall phenomena	139504	B_002	Active
2	Polygon	0	Rock fall	107598	B_003	Active
3	Polygon	0	Debris flow	126551	B_007	Dormant
4	Polygon	0	Debris flow	117904	B_004	Dormant
5	Polygon	0	Rock fall	194210	B_001	Active
6	Polygon	0	Rock fall	254837	B_006	Active
7	Polygon	0	Rock fall	579280	B_011	Active
8	Polygon	0	Debris flow	827730	B_008	Active
9	Polygon	0	Debris flow	892058	B_009	Active
10	Polygon	0	Debris flow	213378	B_010	Active
11	Polygon	0	Debris fall area	272053	B_013	Active
12	Polygon	0	Debris flow	929692	B_012	Active
13	Polygon	0	Area subjected to rock fall phenomena	451400	B_014	Active
14	Polygon	0	Area subjected to rock fall phenomena	165495	B_015	Active
15	Polygon	0	Sliding area	238857	CL_01	Active
16	Polygon	0	Debris flow	105633	Cl_02	Active
17	Polygon	0	Debris flow	235966	CL_03	Active
18	Polygon	0	Debris fall area	887162	CL_04	Active
19	Polygon	0	Sliding area	122006	CL_05	Active
42	Polygon	0	Rotational landslide	339582	L_07	Active
20	Polygon	0	Sliding area	864620	CL_06	Active
21	Polygon	0	Sliding area	382382	CL_07	Active
22	Polygon	0	Debris flow	336926	CL_08	Active
23	Polygon	0	Debris flow	157254	CL_09	Active
24	Polygon	0	Debris flow	557998	CL_010	Active
25	Polygon	0	Debris flow	124671	Df_01	Active
26	Polygon	0	Debris flow	431509	Df_02	Active
27	Polygon	0	Debris flow	131630	Df_03	Active
29	Polygon	0	Debris flow	586418	Df_05	Active
28	Polygon	0	Debris flow	111950	Df_04	Active
30	Polygon	0	Debris flow	331654	Df_06	Active
32	Polygon	0	Debris flow	114936	Df_08	Active
31	Polygon	0	Debris flow	292657	Df_07	Active
33	Polygon	0	Debris flow	653078	Df_09	Active
34	Polygon	0	Debris flow	590616	Df_10	Active
36	Polygon	0	Rotational landslide	268377	L_01	Active
35	Polygon	0	Debris flow	107112	Df_11	Active
37	Polygon	0	Rotational landslide	896996	L_02	Active
38	Polygon	0	Rotational landslide	724523	L_03	Active
39	Polygon	0	Rotational landslide	241098	L_04	Active
40	Polygon	0	Rotational landslide	214918	L_05	Active
41	Polygon	0	Rotational landslide	319663	L_06	Active

Record: 18 Show: All Selected Records (0 out of 43 Selected)

Exhibit 32 Main landslide (areas) surveyed and outlined in the test site areas using the I.F.F.I. methodological approach [Amanti et al., 2012].

Attributes of Landslide_point

FID	Shape	Y_Coordina	X_Coordina	Z_C	Landslide	location	Acronym	Typology
0	Point	35.478475	75.704125		Active	Nimika, shigar	NADF	Debris flow
1	Point	35.501939	75.680753		Active	Hashupi, Shigar	HADF	Debris flow
2	Point	35.522072	75.656725		Active	Between Hashupi and Alchuri	ADBHA	Debris flow
3	Point	35.540442	75.614547		Active	Alchuri, shigar	ADA	Debris flow
4	Point	35.558256	75.598964		Active	After Alchuri shigar	AADF	Debris flow
5	Point	35.577833	75.583156		Active	Second village after Alchuri shigar	ADF	Debris flow
6	Point	35.595322	75.565083		Active	Near yuno shigar	ADF	Debris flow
7	Point	35.615067	75.550122		Active	Close to Yuno	ADF	Debris flow
8	Point	35.622253	75.544786		Active	Yuno	ADF	Debris flow
9	Point	35.643969	75.519064		Active	Near Hyderabad	ADF	Debris flow
10	Point	35.648025	75.47285		Active	Tissar shigar	ADFT	Debris flow
11	Point	35.665869	75.442986		Active	Tissar khas	ADFTK	Debris flow
12	Point	35.686319	75.447767		Dormant	Opposite of Tissar village shigar	DCLSL	Complex landslide
13	Point	35.687986	75.430436		Active	End of Tissar village shigar	RF	Rock fall
14	Point	35.696694	75.430567		Active	Infront of Chatron village/village	Adf	Debris flow
15	Point	35.705261	75.406386		Active	Hemisil bridge shigar	Adf	Debris flow
16	Point	35.710475	75.414772		Active	Infront of Hemisil village, shigar	ALSL	Rotational landslide
17	Point	35.71365	75.413733		Active	Infront of Hemisil village, shigar	ALSL	Rotational landslide
18	Point	35.715633	75.411992		Active	Infront of Hemisil village, shigar	Adf	Debris flow
19	Point	35.719928	75.410992		Active	Infront (end) of Hemisil village, shigar	ALSL	Rotational landslide
20	Point	35.720664	75.410897		Active	Infront (end) of Hemisil village, shigar	ALSL	Rotational landslide
21	Point	35.724861	75.408008		Active	Infront (end) of Hemisil village, shigar	Adf	Debris flow
22	Point	35.714506	75.404669		Active	Hemisil village shigar	Adf	Debris flow
23	Point	35.734233	75.405731		Stabilized	Dogoro yul shigar	SRF	Rock fall
24	Point	35.753769	75.397475		Active	Dogoro shigar	Adf	Debris flow
25	Point	35.761892	75.394375		Active	Niaslo village, shigar	Adf	Debris flow
26	Point	35.731086	75.399672		Active	Infront of Dogoro yul village shigar	ARF	Rock fall
27	Point	35.744528	75.396897		Active	infront of Dogoro Yul village shigar	ARF	Rock fall
28	Point	35.782628	75.393925		Active	infront of Bian village shigar	ARF	Rock fall
29	Point	35.800992	75.398883		Active	Doko village shigar	ATLSL	Traslational landslide
30	Point	35.801742	75.397219		Active	Doko Nalah, shigar	ARF	Rock fall
31	Point	35.802	75.399256		Active	Near Doko Nalah	ATLSL	Traslational landslide
32	Point	35.805267	75.399497		Active	Near Doko Nalah	ADF	Debris flow
33	Point	35.807564	75.400375		Active	Infront of Bisil village, shigar	ARtLSL	Rotational landslide
34	Point	35.807489	75.399172		Active	Infront of Bisil village, shigar	ARtLSL	Rotational landslide
35	Point	35.8069	75.400103		Active	Infront of Bisil village, shigar	ARtLSL	Rotational landslide
36	Point	35.805528	75.400064		Active	Infront of Bisil village, shigar	ARtLSL	Rotational landslide
37	Point	35.812364	75.405422		Active	On the way to Arandu, shigar	ARF	Rock fall
38	Point	35.816544	75.408936		Active	On the way to Arandu, shigar	Adf	Debris flow
39	Point	35.817903	75.410342		Active	on the way to Arandu, shigar	ARF	Rock fall
40	Point	35.820731	75.427358		Active	Bisil village, shigar	ARF	Rock fall
41	Point	35.830672	75.422117		Active	Bisil village, shigar	AdF	Debris flow
42	Point	35.820133	75.411933		Active	Infront of Bisil Bridge, Basha shigar	ARF	Rock fall
43	Point	35.823125	75.414178		Active	Close to Bisil Bridge Basha, shigar	ARF	Rock fall
44	Point	35.830189	75.417928		Active	Infront of Bisil village Basha, shigar	ADF	Debris flow
45	Point	35.819497	75.419406		Active	nfront of Bisil village Basha, shigar	ARF	Rock fall
46	Point	35.855389	75.417744		Active	Opposite side of Arandu Gone, last village	Adf	Debris flow
47	Point	35.871375	75.353194		Active	Infront of Arandu Basha,shigar	Adf	Debris flow
48	Point	35.871769	75.347331		Active	Opposite side of Arandu village Basha,shigar	Adf	Debris flow
49	Point	35.873603	75.326869		Active	Opposite side of Arandu bridge Basha, shigar	ALSL	Rotational landslide
50	Point	35.874519	75.326044		Active	Opposite side of Arandu bridge Basha, shigar	ALSL	Rotational landslide
51	Point	35.874872	75.325783		Active	Opposite side of Arandu bridge Basha, shigar	ALSL	Rotational landslide
52	Point	35.871672	75.332389		Active	Opposite side of Arandu bridge Basha, shigar	ALSL	Rotational landslide
53	Point	35.87225	75.3309		Active	Opposite side of Arandu bridge Basha, shigar	ALSL	Rotational landslide
54	Point	35.872411	75.330303		Active	Opposite side of Arandu bridge Basha, shigar	ALSL	Rotational landslide
55	Point	35.872394	75.329931		Active	Opposite side of Arandu bridge Basha, shigar	ALSL	Rotational landslide
56	Point	35.874094	75.315933		Active	Chogo Lungma Glacier morain trail P1	Adf	Debris flow
57	Point	35.872189	75.30605		Active	Chogo Lungma Glacier morain trail P2	Adf	Debris flow
58	Point	35.87145	75.298492		Active	Chogo Lungma Glacier morain trail P3	Adf	Debris flow
59	Point	35.871447	75.297122		Active	Chogo Lungma Glacier morain trail P4	Adf	Debris flow
60	Point	35.8715	75.295856		Active	Chogo Lungma Glacier morain trail P5	Adf	Debris flow
61	Point	35.871719	75.293133		Active	Chogo Lungma Glacier morain trail P6	Adf	Debris flow
62	Point	35.871025	75.289858		Active	Chogo Lungma Glacier morain trail P7	Adf	Debris flow
63	Point	35.870219	75.288094		Active	Chogo Lungma Glacier morain trail P8	Adf	Debris flow
64	Point	35.869169	75.285194		Active	Chogo Lungma Glacier morain trail P9	Adf	Debris flow
65	Point	35.868194	75.281442		Active	Chogo Lungma Glacier morain trail P10	Adf	Debris flow

Record: 1 Show: All Selected Records (0 out of 140 Selected) Options

Exhibit 33 Main landslide (points) surveyed and outlined in the test site areas using the I.F.F.I. methodological approach [Amanti et al., 2012].

1.3 Synergies with other working groups

The realization of a susceptibility map, aim of the present research, is the output of a huge joint work within the different Units involved into the SEED project. This is due to the need to investigate different parameters that combined, give rise to the landslide-prone areas map. The main parameters are geology, land cover, glaciers, slope and aspect (derived from DEM) and each of them involves a different Group, so the susceptibility map can be considered a sort of summary of the work done by the different Units in the framework of the project.

1.4 Discussion, results and conclusions

Knowing that a simple pair-wise comparison in which only two parameters may be considered at a time means simplifying the weighting process and making it more opinion-based dependent, the method guarantees a widespread knowledge of the territories also having available few parameters. In this context, an inventory of landslides and a map of landslide- or rock fall-prone areas [Guzzetti et al., 2012] should be useful to identify the areas where human settlements must be avoided and consequently it provides to the stakeholders with an important updatable tool for territorial planning, as required by the new management plan for the national park, where a zoning system for ecosystem conservation and promotion of tourism is recommended.

In order to reach the suggested goal, it was decided to analyze the area through Digital Elevation Models (DEMs) derived from ASTER images (30 m grid cell size), which may be considered a powerful tool for visual and mathematical analysis of the topographic surface at a regional scale [Gullà et al., 2008; Kamp, 2003]. These instruments, used in a barren territory, visited only by occasional mountain climbers and porters, are valuable in order to identify landforms and deposits modeled by surface processes. The morphological parameters used for the characterization of the topographic surface are the main derived products of DEMs in remote areas and in areas where no topographic maps are available. A comparative study on the use of different DEMs for terrain analysis is discussed in Ansari et al.(2012). The authors underline that the use of DEMs, as a tool for geomorphological mapping, landslide, susceptibility/hazard assessment, has had a wide diffusion mainly because they provide the foundation for deriving surface morphological parameters such as slope, aspect, curvature, slope profile and catchment areas. In the review of the applications of remote sensing data for earth surfaces processes Tarolli et al., 2009 highlight the use of ASTER data for geological features extraction [Abrams, 2000] for the evaluation and quantification of sedimentary deposits [Bubenzer and Bolten, 2008] and in the landslide hazard assessment [Fourniadis et al., 2007]. The application of ASTER DEM in the evaluation of landslide susceptibility maps is discussed in Chau et al. 2004; Choi et al. 2012; Gokceoglu 2012; Song et al. 2012; Toutin 2008. Moreover, the DEM extracted from ASTER is used in the Artificial Neural Network (ANN) approach for landslide susceptibility mapping, for the generation of geomorphological parameters [Choi et al, 2012; Nefeslioglu et al., 2008; Kawabata et al., 2009]. The interaction of land cover and landslides is analyzed by Peduzzi [2010] on an area of North Pakistan using ASTER DEM for the extraction of landslide susceptibility maps. The landslide susceptibility study [Fell et al., 2008; Van Wasten et al., 2008] was analyzed with the application of the Analytical Hierarchy Process (AHP) [Ayalev et al., 2004; Bajracharya et al., 2008; Komac, 2006; Moradi et al., 2012; Othman et al., 2012; Phukon et al, 2012] based on the indexing on data layers and parameters as slope angle, slope aspect, slope curvature, geo-lithology, distance to tectonic structures and vegetation [Ruff et al., 2008] since these intrinsic variables determine the susceptibility of landslides [Dahal et al., 2007].

The method was tested in different areas of the CKNP considered as test site areas such the Bagrot valley, the Chogo Lungma glacial valley and the Biafo ones. Through the analysis of the DEM, different slope morphologies were pointed out and the main landslides were identified (areas subjected to rock falls, single rock falls and debris flows) [Varnes, 1984].

During the field work in the valleys, mainly rock falls and debris flows were identified and this predominance has been highlighted also by the parameter analysis through the GIS tools. The scale of the available geological map (1:150,000) and the cell size (30 m) did not permit to obtain a detailed map, but guaranteed a wide geomorphological analysis.

The influence of the fault/lineament parameter was considered and simulated creating buffer zones around the fault lines (0-50 m, 50-100 m and more than 100 m). These distances were decided according to the field surveys evidences showing that faults are not equally distributed. The same subdivision was assigned also to the distance to stream parameter. Landslides may occur on the sides of the slopes affected by streams. In the studied area, the proximity to streams is an important parameter considering the erosion capacity of the flowing waters in such a barren territory especially during monsoon seasons.

The importance of the aspect parameter was based on the landslide distribution. According to Dhakal, south- and east-facing slopes were considered to be more susceptible for landslides [Dhakal et al., 2000].

The land cover parameter was provided for the present research by the Padova University Unit. The results of the land cover classification defined 46% of the territory covered by snow areas, 15% by sparse vegetation, 14% by bare rock and/or coarse fragments, 11% by bare soil and scattered vegetation, 5% of pastures and or meadows > 3750mt, only 1% of the areas are cultivated and approximately close to the 0% the pastures and/or meadows <3750mt. In this framework, as could be expected, it is possible to say that the landscape is dominated by the snow and by barren slopes with the vegetation mainly confined to the valley floors, where the slope angles are more gentle (< 15°). Agricultural land is restricted to river terraces and alluvial fans along the valleys floors, and terraced steeper slopes. The urban areas are mainly present along the rivers or are set on the stabilized fan of ancient debris flow, still partially active. The rest of the areas are covered by the glaciers that are occupying a huge amount of the whole park area.

To obtain the landslide susceptibility map, as previously defined, parameters were weighted and a WLC was obtained producing a continuous scale of numerical values (LI). These values were later divided into six susceptibility classes using the standard deviation [Ayalev et al., 2004]. These categories are described in Table 7 and correspond to six relative scales of landslide susceptibility (ANNEX 3).

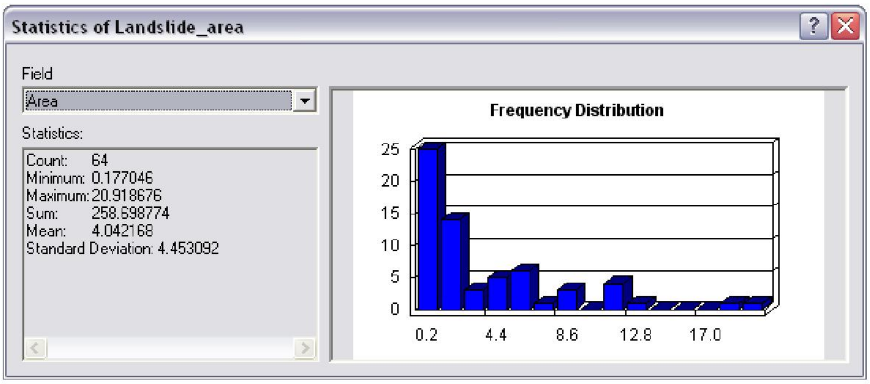

Exhibit 34 Landslide area frequency distribution in [sq km]

Table 7 Susceptibility classes.

Classes	N. of cells	%	Susceptibility description
1	1980684	8.3	Extremly low susceptible
2	6433237	27.0	Very low susceptible
3	8144317	34.2	Low susceptible
4	6459130	27.2	Medium susceptible
5	766350	3.2	High susceptible
6	549	0.01	Very high susceptible

Low susceptible (34.24%), very low (27.05%) and medium (27.16%) are the most populated categories corresponding to areas were the slope gradient is not so elevated (as all the glacial areas present on the valley floors) and the plan curvature is hollow. This demonstrates the importance of the weight of these 2 parameters in the whole computation. Also geology and distance to structural lineaments played an important role: weaker rocks are more fractured and consequently prone to fall. Land cover parameter comprehensive of the glaciated areas provided by the Università di Milano Group, are very interesting. Barren territories are obviously more prone to landsliding especially for the rockfalls and the debris flow phenomena. Using this technique only a small percentage of the territories are belonging to the very high prone to landslide class.

So, in conclusion, the simple methodology presented in this work permits the definition of the areas which have an intrinsic susceptibility to some types of landslides as the rockfalls and the debris flow source areas. The methodology belongs to the generation of maps obtained through the weighted overlay of different data layers.

In this study 7 event-controlling parameters namely geology, aspect, slope, distance from drainage, distance from lineaments, land cover and plan curvature were considered. Their interaction with the analytical hierarchy process and the Weighed Linear Combination permitted to obtain a landslide susceptibility map.

The result of the entire analysis was that the investigated area was divided into 6 classes of susceptibility: extremely low (8.31%), very low (27.05%), low (34.24%), medium (27.16%), high (3.22%) and very high (0.01%).

The quality of these results heavily depends on the quality of the input data, but the methodological approach is so simple that it may be easily upgraded on demand and it provides a relatively quick analysis. So it may be considered a useful tool to identify slope sectors liable to landsliding.

The research has obvious limits mainly due, for example, to the scale of the available geological map (1:150,000), the resolution of the ASTER DEM (30 m X 30 m), the lack of some important information such as the top soil cover and the precipitation but it is just the beginning of a multi-disciplinary study in which different themes are going to converge. A more detailed DEM infact could permit in the future to identify the slope breakings and so the several thousands of landslides present in the investigated area. Indeed a new possible and really interesting evolution of the present research could be the identification of the permafrost areas in order to define their evolution and their contribution to landslide susceptibility also in the perspective of a global climate change.

1.5 Management Constraints

The institution of the Park will probably bring a remarkable economical benefit from the touristic point of view to the population living in or around the area. The products of agriculture will be re-evaluated and the employment will be increased at least during the touristic season with guards, guides and porters. Medical assistance that will be provided for the tourists will be also available for the local population. The National Park will also impose some constraints leading to maintain the natural environment of the area as free as possible from human activities like wood cutting and pasturing some kind of animals. For this reason a proper campaign of information was necessary to present the new aspects that will be introduced by the institution of the Park.

Areas susceptible to landslides can be identified, based on the physical factors associated with landslide activity: past landslide history, bedrock, slope steepness and hydrology. Predicting where and when landslides are going to occur is not possible even with the best available information, but it is, anyway, possible to identify landslide-susceptible areas or landslide prone areas and to outline them in order to foreseen future actions.

In the previous sections were essentially discussed some of the concepts related to landslide susceptibility: the different types of landslides, the relative nature of landslide and their relationship with the development activity. The main point of each territorial plan is to demonstrate the importance of taking into account landslides in the planning studies and to provide a single guide line that can be used at all stages of the planning process. Many advantages can be generated from this behavior. The Landslide susceptibility map obtained from the risk assessment investigation represent only the final product of a wide and deep study conducted during these last years on the CKNP area. The step-by-step combined factor analysis used to prepare the susceptibility map was prepared starting with field surveys and the identification of the main landslide phenomena trough a prepared “landslide form”. The form was shared with the rangers of the CKNP. A landslide inventory started and all the data are now part of a Geodatabase containing feature classes as landslide map distribution, geology, landslide images, glaciers, vegetation, land cover and mitigation works. All the information coming from the study will enable the planner to have a working knowledge of terms, concepts, and the important considerations related to landslides and landslide hazard mapping.

The landslide susceptibility map has been divided into 6 classes of susceptibility: high, moderate, low, very low and extremely low, for each class some activities are allowed and some are restricted due to the general geological conditions. In any case, in all the park area, any building activity as path and camp sites need a previous approval by experts in order to avoid possible disasters:

- **High susceptibility**: extremely dangerous area, were landslides could occur daily, slope angle is very high, and the lithological characteristics are poor; all activities are avoided, only experts for specific purposes could go inside (researchers, climbers…..);
- **Moderate susceptibility**: summer sheep-farming is allowed, as building of new trekking path, camps should be avoided in these areas or at least their construction need to be subjected to a prior verification of a team of experts (engineering geologists, guides and park rangers);
- **Low susceptibility and Very low susceptibility**: summer sheep-farming is allowed, as building of new trekking path and rest camps;
- **Extremely low susceptibility**: perfect areas were to install trekking camps, rest areas, summer sheep-farming and defining new trekking paths.

This analysis offer to the Park Directorate a relevant instrument for the future territorial planning of the CKNP; on the basis of these indications and the related map developed, a risk analysis of the structures and activities present in the different Park areas will be expected in the next years.

In an attempt to propose effective guidelines, few general comments are added to this section as points of reflections.

The planning process that led to the development of these basic guidelines was founded on the stakeholder participation in which Technical sessions of the CKNP working group can serve as a major forum for this participation. These sessions could guarantee opportunities for stakeholders to articulate and prioritize problem issues, share information, identify information needs and work toward long-term solutions.

The working group could organize and guarantee a first level of prevention mainly with 2 actions:

1) a year-round planning strategy focuses primarily on ways to prevent roads and path from being closed and how quickly the workers can safely restore the service;

2) a full range of maintenance throughout the year to prevent or minimize seasonal damages for example during the monsoon seasons.

The main economic activities pass through the maintenance of the roadbed, for this reason the points highlighted just above gain a huge importance in the management behavior. So roads need to be maintained, drained and the vegetation managed, especially during the wet seasons with continuous patrolling to ensure a roadway free of rocks and debris, clear downed vegetation and monitor drainage.

Several techniques and practices exist to reduce and cope losses from landslide hazards. In the following lines, different approaches are suggested in order to reduce the landslide risk.

1 Establish a CKNP landslide hazard identification program

Establish a CKNP landslide hazard identification program by documenting all landslides, bank failures, "washouts", and manmade embankment failures. Each failure should be located on a map with notes about time of failure, repair (if made), and descriptions of the damaged area. This could be done on the form provided by DMG-Units researchers.

2 Restricting development in Landslide Prone areas

Land-use planning is one of the most effective and economical ways to reduce landslide losses by removing or converting existing development or discouraging or regulating new development in unstable areas. Buildings should be located away from known landslides, debris flows, steep slopes, streams and rivers, intermittent-stream channels, and the mouths of mountain channels. In the CKNP area, restrictions on land use should be imposed by local governments trough a land-use zoning districts and regulations.

3 Standardizing codes for excavation and infrastructures construction

Excavation and construction rules needs to be developed for construction in landslide prone areas.

4 Protecting the existing

Control of surface-water and groundwater drainage is the most widely used and generally the most successful slope-stabilization method. Slope stability can be increased by removing all or part of a landslide mass or by stabilizing the toes of potential slope failures. Retaining walls or rock anchors are commonly used to prevent or control slope movement. In most cases, combinations of these options are used.

5 Using monitoring and warning systems

Monitoring and warning systems are necessary to try to protect lives, not to prevent landslides. Anyway, these systems are able to provide warning of slope movements in time to allow the reduction of the immediate or long-term hazard. Sitespecific monitoring techniques as field observations joint with the use of various instruments as GPS can guarantee the long term monitoring also in remote areas. Development of regional real-time landslide warning systems is one of the main goal of landslide research.

6 Public Education

Public education initiatives would make people better aware of the risks that they face living in highly risk areas. It is important to educate the public about tell-tale signs that a landslide is imminent so that personal safety measures may be taken (USGS, 1997).

Furthermore, the following steps need to be taken into account as managing points:

- establishment of a permanent committee for the risk management including also GIS experts;
- establishment of specific courses of capacity building on landslide topic and on risk assessment for the rangers of the CKNP and for the members who will manage the Landslide inventory on the Geodatabase;
- establishment of informative meeting with all the professionals working in the park (e.g. guides, shepherds) and with the majors of the villages located close to the park area;
- establishment of a permanent committee devoted to the road topic (management, construction and mitigation measures) inside and outside the park, especially the main roads outside the park from which all the tourists are coming.

2. GLACIOLOGICAL STUDIES[2]

2.1 Main topics

- Developing a glacier data base (including shape files and dbf) describing geometry and features of Central Karakoram National Park (Pakistan) glaciers.
- Describing 2001-2010 glacier changes in the CKNP area and their climate driving factors as a contribution to the knowledge of the "Karakoram anomaly"
- Collecting glaciological field data to support calibration and validation of ice melt model.

2.2 Introduction

The Hindu Kush Karakoram Himalaya (HKH) stretches for more than 2000 kilometers in length from East to West. Along this mountain range there is a considerable variability in climate conditions, including varying source regions and type of precipitation (e.g. Bocchiola and Diolaiuti, 2013), influencing the behavior and evolution of the cryosphere. The HKH nests about 50000 km2 of ice bodies, glaciers, glacierets and perennial surface ice in varying climatic regimes (Arendt et al., 2012). This large mountain system delivers water for agriculture, human consumption and power production, and likely more than 50% of the water in the Indus river originating from the Karakoram comes from snow and glacier melt (Immerzeel et al., 2010). The economy of the Himalayan regions relies upon agriculture, and it is highly dependent upon water availability and irrigation (Aggarwal et al., 2004; Kahlown et al., 2007; Akhtar et al., 2008).

The most recent observations of glaciers fluctuations indicate that in the Eastern and central HKH glaciers are subject to general retreat, and have lost a significant amount of mass and area (Salerno et al., 2008; Bolch et al., 2011). Rapid declines in glacier area is reported throughout the Greater Himalaya and most of mainland Asia (Bolch et al., 2012; Yao et al., 2012; Gardelle et al., 2013; Gardner et al., 2013), widely attributed to global warming (IPCC, 2007). On the other hand, changes in climate and glaciers geometry are not uniform. Observations of individual glaciers indicate that glacier retreat rates may vary strongly from among di□erent glacial basins. In fact, positive ice mass balances and advancing glaciers have been reported in the Karakoram mountains, since the last decade, in spite of worldwide glacier decline (Hewitt, 2005).

Glaciers in the Eastern part of the HKH receive accumulation from precipitation during the Indian monsoon in Summer, whereas in the West snowfall occurs mainly in Winter, through Westerly atmospheric circulations (Bookhagen and Burbank, 2010; Kääb et al., 2012; Fowler and Archer, 2006). This variability in accumulation conditions may be one reason for the large spread in glacier changes within the region (Bolch et al., 2011; Kääb et al., 2012). Among others, Kääb et al. (2012) indicated a complex pattern of glacial responses in reaction to heterogeneous climate signals. They used satellite laser altimetry and a global elevation model to show widespread glacier wastage in the Eastern, central and South–Western parts of the HKH during 2003–08. The maximum regional thinning rate they found was -0.66 ± 0.09 m yr-1 in the Jammu–Kashmir region. Conversely, in the Karakoram, glaciers seem to have thinned by a few centimeters per year. The glacier mass balance budget in the Karakoram positively affected the 2003–2008 specific mass balance for the entire HKH region, which was estimated by Kääb et al. (2012) into -0.21 ± 0.05 m yr-1 of water equivalent. This is significantly smaller in magnitude than the estimated global average for glaciers and ice caps (Cogley, 2009; WGMS, 2012; Gardner et al, 2013). Some studies display not only balanced to slightly negative mass budgets in the Karakoram range, but even an expansion and thickening of the largest glaciers, mainly in the central Karakoram, since the 1990s, accompanied by a non-negligible number of rapid

[2] Authors: Claudio Smiraglia, Guglielmina Diolaiuti (University of Milan, Italy) and Christoph Mayer (BAW, German) with the contribution of Daniele Bocchiola and his staff (POLIMI, Italy), Minora Umberto (University of Milan, Italy), D'Agata Carlo (University of Milan, Italy), Maragno Davide (University of Milan, Italy), Lambrecht Astrid (BAW, German), Mosconi Boris (University of Milan, Italy), Senese Antonella (University of Milan, Italy), Compostella Chiara (University of Milan, Italy), Gianpietro Verza (Ev-K2-CNR).

glacier advances (i.e.: surge-type phenomena, see among the others Diolaiuti et al., 2003; Hewitt, 2005; Barrand and Murray, 2006; Belò et al., 2008; Mayer et al., 2011; Copland et al., 2011). Hewitt (2005) reported that 33 glaciers thickened (by 5 to 20 m on the lowest parts of their tongues) and/or advanced, or at least were stagnant in this region between 1997 and 2001. For instance, 4 tributaries of Panmah Glacier have surged in less than a decade, 3 in quick succession. Liligo Glacier, a tributary of Baltoro Glacier, advanced by 1.4 km from 1986 to 1997 (Diolaiuti et al., 2003). Batura and Baltoro had stagnant termini, although accompanied by down wasting and debris cover increase in the lowest reaches (Shroder et al., 2010; Mayer et al., 2006). Moreover, Bhambri et al. (2013), reported clearly visible advances in glacier tongues since the end of the 1980s in the Shyok valley, in Northeast Karakoram.

This situation of stagnant and advancing glaciers in the highest parts of central Karakoram was called "Karakoram anomaly" by Hewitt (2005), and more recently the "Pamir-Karakoram Anomaly" name was proposed by Gardelle et al. (2013) , since they recently observed a slight mass gain for glaciers in Western Pamir as well.

It is not fully clear how results from the temperate zones can be applied to understand the dynamics of glaciers within the monsoon-dominated region (Kaser et al., 2003), and also in central Karakoram, with a reduced influence of monsoon precipitation, the climate-glacier relation is not investigated in details. Interactions between cryosphere, climate and hydrosphere in the lower latitudes are of great interest for both global and regional purposes, and a network of well-chosen and carefully monitored glaciers is important to establish a base for investigating these relationships (Kaser et al., 2003). In addition, accurate observation of glaciers' coverage and dynamics is needed to understand the role of cryosphere in hydrology and water resources. The SEED project, also taking advantage from the PAPRIKA project, is focusing upon providing these data, e.g. by developing a data base describing glacier geometry and features of glaciers in the CKNP area for di□erent periods. This is a base for (i) describing the present characteristics of glaciation and its features in a wide and representative glacierized area of the Pakistan (the CKNP) and, (ii) evaluating glacier changes within a time window of about a decade.

An in depth scientific understanding of glacier evolution of the Karakoram was hampered hitherto by the lack of systematic long-term field observations, due to the rugged topography and the complex climatology of the area. The annual glacier mass balances of a few small and mainly debris-free glaciers (Fujita and Nuimura, 2011; Gardelle et al., 2012) are unlikely to be representative of the entire region with some of the world's largest glaciers. Therefore the combination of remote sensing studies and data from field surveys is required for improving the understanding of glacier dynamics related to the specific climate conditions.

In this report we summarize the main results we obtained by i) analyzing Landsat images covering the Central Karakoram National Park (CKNP) area to describe glacier coverage during 2001-2010, ii) quantifying supraglacial debris-coverage variations derived from Landsat images during 2001-2010, iii) studying maps of snow cover area from MODIS satellite during 2001-2011, and iv) studying climate trends from meteorological data provided by the Pakistan Meteorological Department (PMD) during 1980-2009. By these means, we try to draw an updated picture of the CKNP, and Karakoram glaciation, possibly contributing to complement other existing inventories in the same area (ICIMOD, 2012; Randolph Glacier Inventory RGI, Arendt et al., 2012), and we eventually discuss the peculiar behavior and features of the cryosphere of Karakoram against the recent literature upon HKH glacier changes.

2.3 Study site

The CKNP is an extensive, protected natural area within the Karakoram, Northern Pakistan, established in 2009 (Exhibit 38, EVK2CNR, 2011).

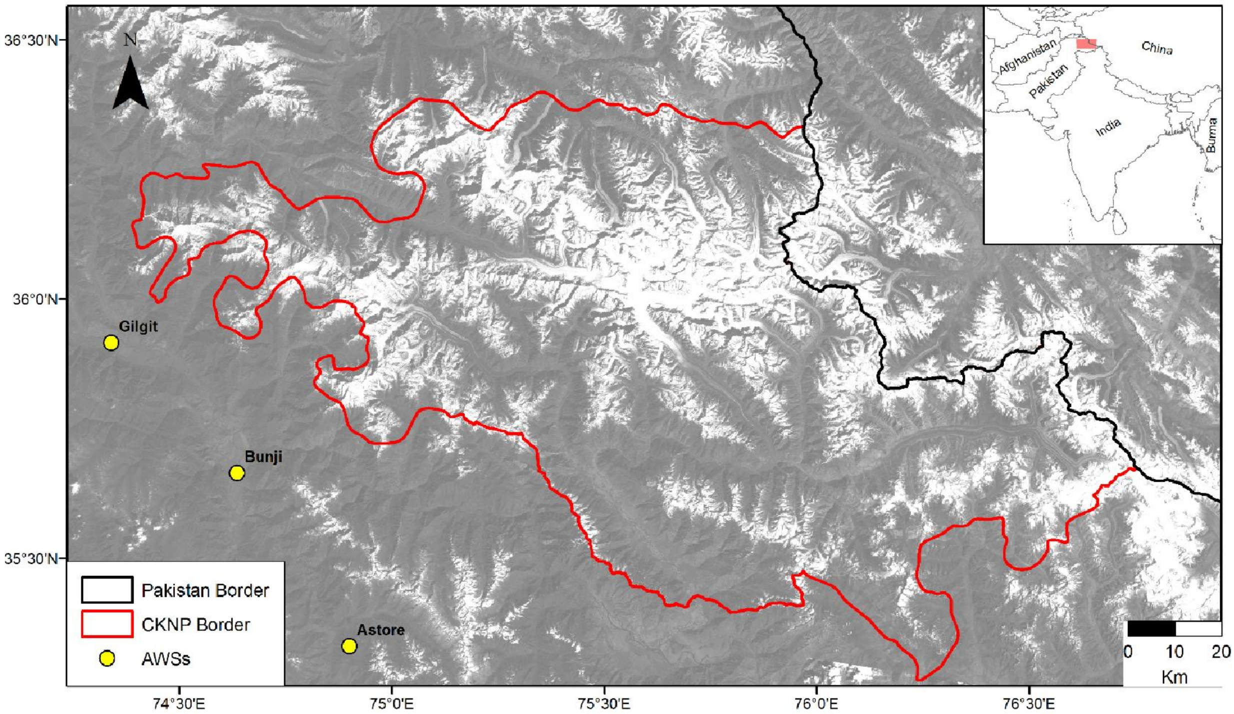

Exhibit 38 Study area, the Central Karakoram National Park (CKNP) in Northern Pakistan following the 1996 Park delineation. AWSs (Automatic Weather Stations) considered in this study are highlighted in yellow. Boundaries may be subject to slight changes

Considering the 1996 delineation of Park boundaries, the park area is ca. 12 162 km2, and roughly 40 % of it is covered by ice. There are some glaciers that intersect the park boundary, and therefore we modified CKNP boundary so as to include all glacier outlines, covering an area of 13 199 km2, which we considered when calculating glacierized area statistics in this report. The highest altitude in the park, and in the entire Western HKH is reached by the summit of K2 mountain (8611 ma.s.l.). According to the Koppen–Geiger climate classification this area is a cold desert region, or BWK region, with a dry climate, little precipitation, and a wide daily temperature range (Peel et al., 2007). The HKH area displays a considerable altitude range, influencing climatic conditions. The Nanga Parbat massif forms a barrier to the Northward movement of monsoon storms, which intrude little into Karakoram. Thus, the hydrological regime in this region is only partly influenced by the monsoon, while a major contribution results from seasonal snow and glacier melt. Precipitation occurs in two main periods, Winter (JFM) and Summer (JAS), i.e. driven by the Westerly currents and monsoon respectively, and the Winter precipitation provides the dominant nourishment for the glacier systems of the HKH (Bocchiola and Diolaiuti, 2013). Some studies postulate that these mountains gain a total annual precipitation between 200 mm and 500 mm, amounts that are generally derived from valley-based meteorological stations and which are less representative for the highest elevation zones (Archer, 2003). High elevation snowfall is still rather unknown, due to the difficulty of obtaining reliable measurements. Some estimates from snow pits above 5000 m a.s.l. range from 1000 mm to more than 3000 mm yr−1, depending upon site (Winiger et al., 2005; the authors of this study, unpublished data from high altitude snow pits within the Baltoro glacier accumulation area gathered in Summer 2011, and Summer 2013). However, there is considerable uncertainty about the spatial distribution and the vertical gradient of precipitation at high altitudes. Among the natural elements within the CKNP glaciers probably show the largest variability, and within the park there are more than 700 glaciers, spanning a broad range of size, geometry, type, and surface conditions (i.e. debris free and debris covered ice). The Baltoro glacier, one of the most prominent glaciers in the park, is about 60 km long, and it is one of the largest debris covered glaciers worldwide. Baltoro glacier has been studied for more than one century, by several scientific expeditions, among others those led by Ardito Desio, a most renowned Italian scientist and explorer (Desio, 1964; Mayer et al., 2006).

2.4 Methods

2.4.1 The glacier data base (also named glacier inventory)

For the compilation of the glacier data base (from here named CKNP Glacier Inventory) we followed the recommendations of Paul et al. (2010), and we considered parameters such as identification code, coordinates, dates of acquisition of the image related to each glacier outline, area, length, minimum, maximum, mean and median elevation, mean aspect, and slope.

The images used in this study are from Landsat ETM+ and TM scenes of 2001 and 2010. Details of the scenes are provided in Table 8. For year 2001; Landsat 7 ETM+ PAN-sharpened images were used as the base for the glacier delineation. For 2010, Landsat 5 TM scenes were used primarily, due to problems occurred in 2003 with scan-line errors in the more recent ETM+ sensor. Landsat 7 ETM+ gap-filled and PAN-sharpened images were used as a support, whenever it was not possible to recognize some parts of the glacier boundaries in the reference Landsat 5 scene (e.g. when hidden by shadows). Scenes have been accurately selected to avoid snow and cloud coverage as much as possible. Moreover, a Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM3) was used to extract elevation related glacial parameters (e.g. minimum, maximum and mean elevation). The DEM type is CGIAR-CSI SRTM DEM version 4 (CGIAR-CSI, 2012), also used in other glacier related studies (Frey and Paul, 2012). No co-registration between Landsat scenes and the DEM was needed as they were both well geo-located. A fully automatic approach to map glacier outline was not suitable, since there are three main factors making glacier boundary assessment uncertain, namely (i) debris cover, (ii) attached seasonal and/or perennial snow, and (iii) the position of drainage divides in the accumulation area. Such items make the accuracy of the final classification largely driven by operator's sensitivity (ESA, 2013). We then proceeded to manually digitize glacier outlines over the Landsat scenes using different band combinations.

Table 8 Landsat imagery used for the analysis.

Date	Image type	Scene identification No.	Path/row	Resolution [m]	Cloud cover [%]
21/07/2001	ETM+	LE71480352001202SGS00	148/35	15	1.41
30/09/2001	ETM+	LE71490352001273EDC01	149/35	15	5.67
23/07/2010	TM	LT51480352010235KHC00	148/35	30	2.60
17/10/2010	TM	LT51490352010290KHC00	149/35	30	2.77

Band combination 543 allowed a clear detection of snow and ice, while the 321 (true color combination) was helpful to recognize supraglacial debris. A Supervised Maximum Likelihood (SML) classification was also used to identify shadow areas, that were excluded from the inventory. In addition, we evaluated our results against our DEM and slope maps, which also supported the detection of morphological evidence of debris covered ice, thus helping to properly identify glacier snouts and termini whenever covered by supra-glacial debris. We also used Google Earth© to have a further control over the inventory by way of high resolution SPOT images from the study area.

Afterwards, glaciological parameters were extracted by combining our outlines with a Geographic Information System (GIS) software, and the DEM. In particular, the longest glacier flow lines were used to extract length parameter, while slope was derived from elevation range and length afterwards.

Eventually, we distinguished glacier-snout movements between advancing and surging type, by visual inspection of the Landsat scenes. We focused upon the magnitude of glacier-termini advance, and we labeled it as a surging type when it exceeded an estimated average velocity of ca. 150 m yr−1 (Cuffey and Paterson, 2010).

2.4.2 Supraglacial debris-coverage

We applied a Supervised Maximum Likelihood (SML) classification to the Landsat false color composite (FCC) image (i.e.: 543 bands) to map the supraglacial debris upon the study area in 2001 and 2010. We first extracted the glacial areas upon the 2001 glacier mask, thus reducing possible misclassifications in the classifier-training, due to out-of-glacier pixel noise.

We chose to consider only glaciers larger than 2 km2, because Landsat resolution was too poor to discriminate debris areas in smaller glaciers. So doing, we considered 4273 km2 of ice cover (ca. 95% of the total area). We then trained the classifier to discriminate between two classes ("clean-ice" and "supraglacial debris"), by choosing appropriate Region of Interests (ROIs). This led to an accurate automatic classification of the debris, validated then by visual comparison of the resulting debris masks against the visible color Landsat images. We then investigated the debris cover change within the studied period (2001-2010). Eventually, to investigate the role of debris cover within glacier ablation area, we set the Equilibrium Line altitude (ELA) to approximately 5200 ma.s.l. (e.g. Bocchiola et al., 2011).

2.4.3 Glacier outline and error assessment

When performing a temporal analysis, inaccuracies may occur due to co-registration and classification errors. The latter depend upon the image resolution and the meteorological conditions at the time of acquisition, namely cloud and snow-cover, presence of shadows and debris hampering ice detection. We dealt with different potential sources of errors and evaluated their weight with respect to the obtained results.

2.4.4 Snow cover data

We used MODIS images to investigate snow-cover variability during 2001-2011 within the CKNP. We downloaded the MOD10A2-V5 product (Hall et al., 2006), i.e. pre-processed raw MODIS images, showing snow and other environmental features (e.g. lakes, clouds, etc.), freely available from the National Snow and Ice Data Center website (NSIDC, 2013). The data set contains fields of maximum snow cover extent over an eight-day period (bundle). All the images have undergone further processing to fit the study area, and a threshold for cloud cover was set to reduce clouds noise over the scenes. The overall process consists of di□erent steps: i) re-projection from Sinusoidal to WGS84 Zone 43N projection; ii) image clipping to fit CKNP area; iii) attribute Tables extraction; iv) table and MODIS scene filenames export to spreadsheet.

All these steps have been cascaded into a script to process all data in batch mode using Python language (http://www.python.org/) combined with a GIS. Cloud coverage was inspected first considering different thresholds, and a best output was taken as a tradeoff between data quality and quantity. In fact, the lower the threshold, the cleaner the scenes, but with a higher loss of area. On the other hand, too high a threshold would lead to poor quality. Thus, we set the threshold to 50 %, as a best tradeoff.

Most of the available dataset have not yet been investigated by the NSIDC group for quality check, so we decided to work only on those images flagged within the NSIDC quality assessment as "INFERRED PASSED". This represented the major factor giving loss of data in our time window. Therefore, we selected five dates during ablation season (from 18 June to 30 September), and a total of 37 images. We chose to analyze dates during the ablation season because a significant analysis of the accumulation season (Fall-Spring) would not have been possible due to lack of a sufficient amount of data. Also, glacier nourishment is related to snow accumulation at onset of thaw season and snow depletion thenceforth, so the considered period seems relevant.

We studied snow cover area SCA in late Summer as per a number of altitude belts. Specifically, we studied SCA in late Summer (Julian day 273, unless for years 2002, day 241, 2003 day 217, 2005, 201, 2006, 169, as per data availability), to evaluate the distribution of remaining snow at the end of the ablation season. We then calculated a late Summer snow line to possibly make some inferences concerning the equilibrium line altitude (ELA), previously dealt with by Mayer et al. (2006), Mihalcea et al. (2008), and Bocchiola et al. (2011) among others for our study area.

Also, we compared our results against those in Tahir et al. (2011), who studied snow-cover in the Hunza basin, North of the CKNP, which required to match as much as possible their same altitude belts (A, B, C, see Table 9). We carried out a linear regression in time of snow cover data for each of these belts. To provide a meaningful comparison between different years, we chose to compare snow cover at fixed dates. Within the available database of reasonably clear images we chose a number of dates when images were available for several years. Given the short series (11 years) of snow cover data, neither we carried out significance analysis of the observed trends, nor we pursued other statistical tests (e.g. Mann-Kendall, Bocchiola and Diolaiuti, 2013).

Table 9 Characteristics of the three elevation zones for snow cover. Slope is value of slope from linear regression analysis upon average snow cover (see section Results). $Slope_{\%}$ is slope weighted upon snow cover area

Zone	Elevation range [m]	$AREA_{zone}$ [km^2]	Slope [km^2/year]	$Slope_{\%}$ [%/year]
A	1900-3300	845	0.1	2%
B	3301-4300	2803	2.3	0.6%
C	4301-8400	9551	14.9	0.2%
A_{TOT}/$Slope_{\%w}$		**13200**	**17.3**	**0.25%**

2.4.5 Climate data analysis

We investigated monthly averaged meteorological variables, kindly provided by the Pakistan Meteorological Department (PMD), derived from measurements at a number of stations in North Eastern Pakistan during 1980-2009. Data from the three closest stations to the CKNP area, namely Gilgit, Bunji and Astore (from North to South, Exhibit 38) are used for this study. Earlier investigations (Weiers, 1995; Winiger et al., 2005; Bocchiola and Diolaiuti, 2013), suggested that in Northern Pakistan three main climatic regions can be identified, depending mainly upon characteristic rainfall regimes. These are

i) Western Himalaya (Kaghan Valley and Nanga Parbat), marginally influenced by the monsoon, with annual precipitation ranging from 900 to 1300 mm in the altitudinal range between 1000 and 4000 m a.s.l., and increasing to 2300 mm at 5500 m a.s.l.,
ii) Chitral-Hindukush, influenced by Mediterranean low pressure systems in Winter and Spring, with average annual precipitation from 500 mm at 1000 m a.s.l. to 1300 mm at 5500 m a.s.l., and
iii) Northwest Karakoram (including the CKNP area), with Winter and occasional Spring and Summer rainfall, where precipitation increases from 150-500 mm at 1500-3000 m a.s.l. to more than 1700 mm at 5500 m a.s.l.

Table 10 Details for the weather stations used in the study. We report seasonal averages (1980-2009) of precipitation amounts and temperature. See also Exhibit 1

Station	North [°]	East [°]	Alt. [m a.s.l.]	E [P_{JFM}] [mm]	E [T_{JFM}] [°C]	E [P_{AMJ}] [mm]	E [T_{AMJ}] [°C]	E [P_{JAS}] [mm]	E [T_{JAS}] [°C]	E [P_{OND}] [mm]	E [T_{OND}] [°C]
Astore	35.20’	74.54’	2168	167	0.5	167	13.8	74	19.3	76	5.8
Bunji	35.40’	74.38’	1372	26	8.6	66	22.0	51	26.8	18	11.9
Gilgit	35.55’	74.20’	1460	23	7.4	61	20.6	37	25.0	17	10.1

All three meteorological stations used here are nested into Northwest Karakoram region. The analysis covers seasonal values of total precipitation, number of wet days and maximum and minimum air temperature. The data are investigated for trends using linear regression (LR) analysis and the non-parametric Mann-Kendall (MK) test, both traditional and progressive (backward-forward). MK highlights not linear trends, and may pinpoint the onset period of a trend, if any (Bocchiola and Diolaiuti, 2010). The station altitudes range from 1460 m a.s.l. (Gilgit) to 2168 m a.s.l. (Astore), which is rather low in comparison with the hypsography of the region and the likely large precipitation gradient in higher altitudes (Winiger et al., 2005; Wulf et al., 2010; Bocchiola et al., 2011). Data from automatic weather stations (AWSs) at higher altitudes (e.g. Askole, 3015 m a.s.l., and Urdukas, 3926 m a.s.l., installed by EVK2CNR committee, see Bocchiola et al., 2011) are available, but for very short periods (2005-now). Eventually, the three chosen stations are the only ones available in our knowledge to analyse recent climate patterns within the CKNP area. Given the relative proximity to the CKNP (Gilgit and Bunji are placed 10-20 km from CKNP boundaries, Astore ca. 50 km), the climate data from the selected stations may be thought as representative of climate within the park area. Also, in spite of the considerable vertical gradients within the area (temperature and precipitation, the latter more uncertain), relative variations observed at the selected stations may be taken as representative of variation also at the highest altitudes, at least in a first approximation.

Unfortunately, no snow gauges are available in the PMD data base, so no direct inference can be made about snow amount and snow water equivalent SWE (see. e.g. Bocchiola and Rosso, 2007, Bocchiola, 2010; Bocchiola and Groppelli, 2010; Diolaiuti et al., 2011; Diolaiuti et al., 2012), but only indirectly through remote sensing of snow covered area SCA, like we do here, and hydrological modeling (see e.g. Bocchiola et al., 2011). The main parameters for the climate analysis are the monthly amount of precipitation Pm (mm), the monthly number of wet days Dw, the monthly average of the maximum and minimum day-time air temperature Tmax (°C), Tmin (°C). Pm provides the hydrological input on the area, while Dw indirectly indicates the frequency (or average duration) of precipitation events (days with rainfall/snowfall). No information concerning splitting of precipitation into either rainfall or snowfall is available here, and Pm is labeled as “monthly amount of precipitation”. Upon analysis of the average minimum Winter temperature Tmin, that are below °C most of the time in our sites, we may assume here that water under snowfall is included and Pm is a measure of total precipitation. The maximum and minimum day-time temperatures, Tmax and Tmin, provide indication about the temperature characteristics in the investigated periods (e.g. arrival and duration of heat waves). Annual and seasonal (JFM, etc..) values of the variables are also derived and used in the analysis, and Pm,Y/SEA is the sum of the monthly values during a year/season, Dw,Y/SEA represents the mean of monthly values during a year/season, and Tmax,Y/SEA and Tmin,Y/SEA are calculated as the mean of monthly values during a year/season.

The significance of LR during the period of observations is given by the p-value (α = 5%, e.g. Jiang et al., 2007). Multiple trends could be identified in the time series analysis, e.g. by assessing slope changes (see e.g. Seidou and Ouarda, 2007). However, in view of the relative shortness of the series here, a single slope regression analysis is carried out. The Mann Kendall test (Mann, 1945; Kendall, 1975) is widely adopted to assess the significance of trends in time series (Zhang et al., 2000; Yue and Wang, 2002; Bocchiola et al., 2008). It is a non-parametric test, less sensitive to extreme values, and independent from the hypothesis about the nature of the trend (e.g. Wang et al., 2005). Here the MK test was applied to raw data, without pre-whitening, according to Yue and Wang (2002). Upon visual inspection of the data, which would not display evident break points or unexpected changes, we did not carry out any homogenization procedure, and we worked upon raw data. Then, we investigated the correlation of the weather variables against the anomaly (vs long term average) of the Northern Atlantic Oscillation (NAO) index (e.g. Hurrell, 1995; Jones et al., 1997; Osborn, 2004; 2006), during 1980-2009. Archer and Fowler (2004) obtained a statistically significant (positive) correlation between Winter precipitation and a monthly index (November to January) of the NAO during 1961-1999, and a significant negative correlation between NAO and Summer rainfall at several stations. Further on, we try and verify the hypothesis that the temperature evolution in the Karakoram is related to warming at global or hemispheric scale. To do so, we investigate the correlation between global temperature anomalies DTG (calculated according to Brohan et al., 2006) and Tmin and Tmax at the stations.

2.5 Results

2.5.1 Glacier changes during 2001-2010

The 2001 inventory displayed 711 glaciers within the CKNP region (Table 12). Their total area is 4587 ±18 km2, 38 % of the total surface of the CKNP, and 35 % of the surface of our study area. This area represents the 30 % of the glacier surface of the entire Pakistani Karakoram range (total area from ICIMOD, 2012). The biggest glacier is 604 km2 large (i.e. Baltoro), while the overall average glacier size is 6.5 km2. Our mapped glaciers were sorted according to the size classes introduced by Bhambri et al. (2011), in Table 12.

Table 11 Glacier termini elevation based on the 2001 inventory data

Minimum glacier altitude [m]	Glacier number	Area coverage [km2]	% of total area	% of total number
2000-2500	3	106	2.3	0.4
2500-3000	12	634	13.8	1.7
3000-3500	24	2153	46.9	3.4
3500-4000	80	95	20.7	11.2
4000-4500	231	437	9.5	32.5
4500-5000	268	253	5.5	37.7
5000-5500	76	36	0.8	10.7
> 5500	17	19	0.4	2.4
Total	711	4587	100	100

Table 12 Number of glaciers within CKNP, sorted according to their area. Number of glaciers reported for two years (2001 and 2010).

Size class [km^2]	2001 glacier number	2010 glacier number	2001 glacier area distribution [%]	2010 glacier area distribution [%]	2001 glacier number distribution [%]	2010 glacier number distribution [%]
< 0.5	291	290	1.4	1.4	40.9	41
0.5-1.0	142	142	2.2	2.2	20	20.1
1.0-2.0	117	117	3.7	3.7	16.5	16.5
2.0-5.0	74	72	5	5	10.4	10.2
5.0-10.0	36	36	5.4	5.3	5.1	5.1
10.0-20.0	18	17	5.1	5.2	2.5	2.4
20.0-50.0	16	16	11.4	11.4	2.2	2.3
> 50.0	17	17	65.7	65.8	2.4	2.4
Total	**711**	**707**	**100**	**100**	**100**	**100**

Only 9 glaciers dwell in the bigger size-class (>50 km2), but they cover more than half of the glacierized surface of the park. The smaller classes (< 1 km2) accounts for ca. 61 % of all glaciers by number, while covering only 3.6 % of the glacier surface (see Table 13).

Glacier minimum elevation (i.e.: glacier terminus altitude) was between 4500 and 5000 ma.s.l. on average, with few bigger glaciers reaching farther down (between 3000 and 3500 m a.s.l., see Table 11).

Smaller glaciers termini tend to be much higher, similarly to what observed in other glaciated regions, including Alaska Brooks Range (Manley, 2005), Swiss glaciers (Kääb et al., 2002), Cordillera Blanca (Racoviteanu et al., 2008), and Italian Alps (Diolaiuti et al., 2012).

Table 13 Area coverage of glaciers within the CKNP according to satellite images (2001 and 2010) (columns 2 and 3). Surface area changes of the CKNP glaciers during 2001-2010 (column 4). Surface area changes of CKNP glaciers with respect to the 2001 class area coverage, and to total area change (columns 5 and 6 respectively). The area changes are computed considering each glacier according to the class it belonged to in 2001

Size class [km²]	2001 Area [km^2]	2010 Area [km^2]	ΔA 2001-2010 [km^2]	Glacier area change (%) with respect to the 2001 class value	Glacier area change (%) with respect to the 2001 total glacier change
<0.5	66	66	-0.1	-0.2	-0.4
0.5-1.0	99	100	0.2	0.2	0.8
1.0-2.0	170	171	0.2	0.1	0.8
2.0-5.0	230	232	1.6	0.7	6.0
5.0-10.0	246	247	0.4	0.2	1.5
10.0-20.0	236	238	1.9	0.8	7.1
20.0-50.0	525	526	0.2	0.0	0.8
>50.0	3012	3034	22.2	0.7	83.5
Total	**4587± 18**	**4613 ± 38**	**26.6 ± 42**		**100**

The hypsography of the glacierized areas (2001) for the size classes and 100 m elevation belts is shown in Exhibit 2 (based on the SRTM DEM of 2000). Glaciers range in elevation from 2250 to 7900 ma.s.l. Small glaciers with an area less than 1 km2 are restricted to elevations above 3500 ma.s.l.. Their elevation range is not very large, but some of them are even found up to 7000 ma.s.l (see Exhibit 40).

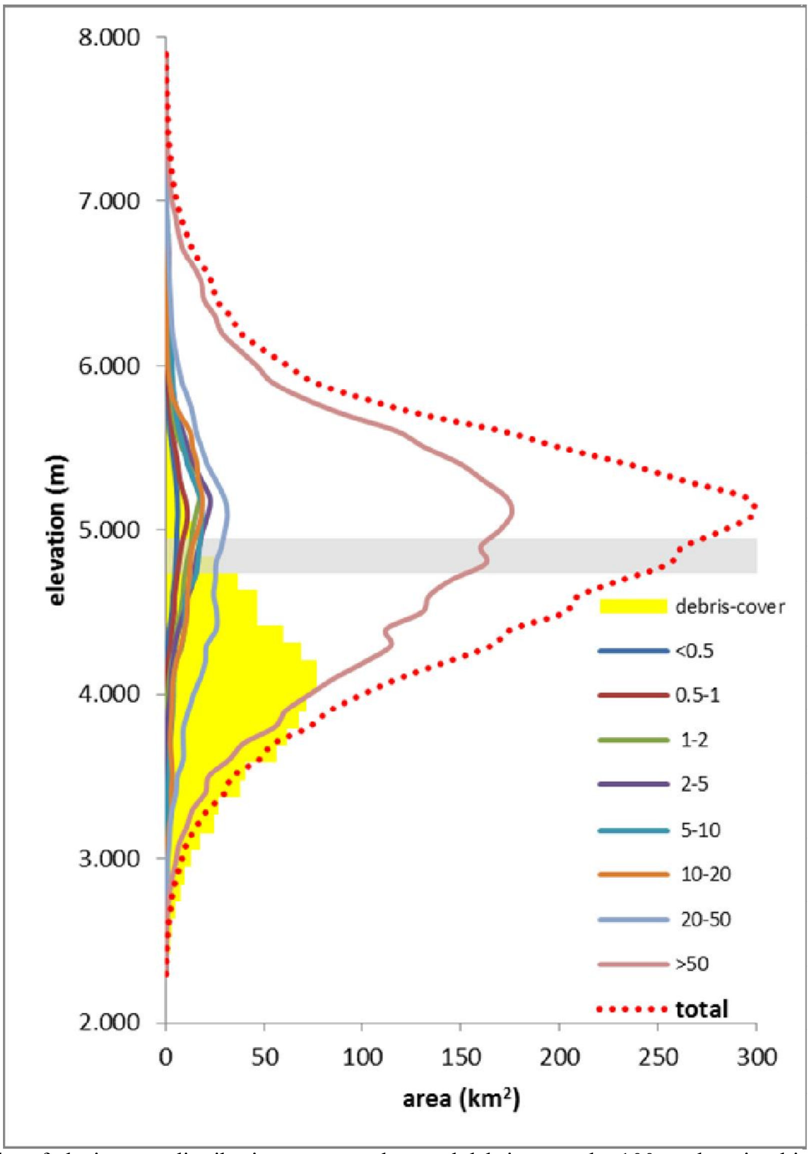

Exhibit 39 Hypsography of glacier area distribution per area class and debris-cover by 100 m elevation bins (based on 2001). The grey bar represents approximate placement of ELA.

Most of the large and prominent glaciers instead originate above 7000 m a.s.l. and have wide elevation range. Moreover, the minimum elevation reached by some of these large glaciers is much lower than in the Greater Himalaya of India and Nepal (Hewitt, 2005).

We found a significant (linear) correlation ($\rho = 0.5$) between the area and the vertical extent of the glaciers (i.e. difference between maximum and median elevation). Glaciers with smaller vertical extent (i.e. maximum elevation close to median) feature smaller areas. In addition, we found a significant correlation ($\rho = 0.5$) of the area vs. the altitudinal range (i.e. maximum minus minimum elevation).

Our inventory gives an overall median elevation of 4990 ma.s.l., which can be used as a proxy of the ELA (Exhibit 2) as suggested by Braithwaite and Raper (2009), and which is in line with the findings of former studies concerning Baltoro glacier, the larger in our area, displaying that ELA therein may be placed approximately between 4800 m a.s.l. and 5200 m a.s.l. (Mayer et al., 2006; Mihalcea et al., 2008). Bocchiola et al. (2011), setting up a simplified hydrological model mimicking snow accumulation upon the same glacier found out an approximate ELA altitude between 4700-5300 m a.s.l.

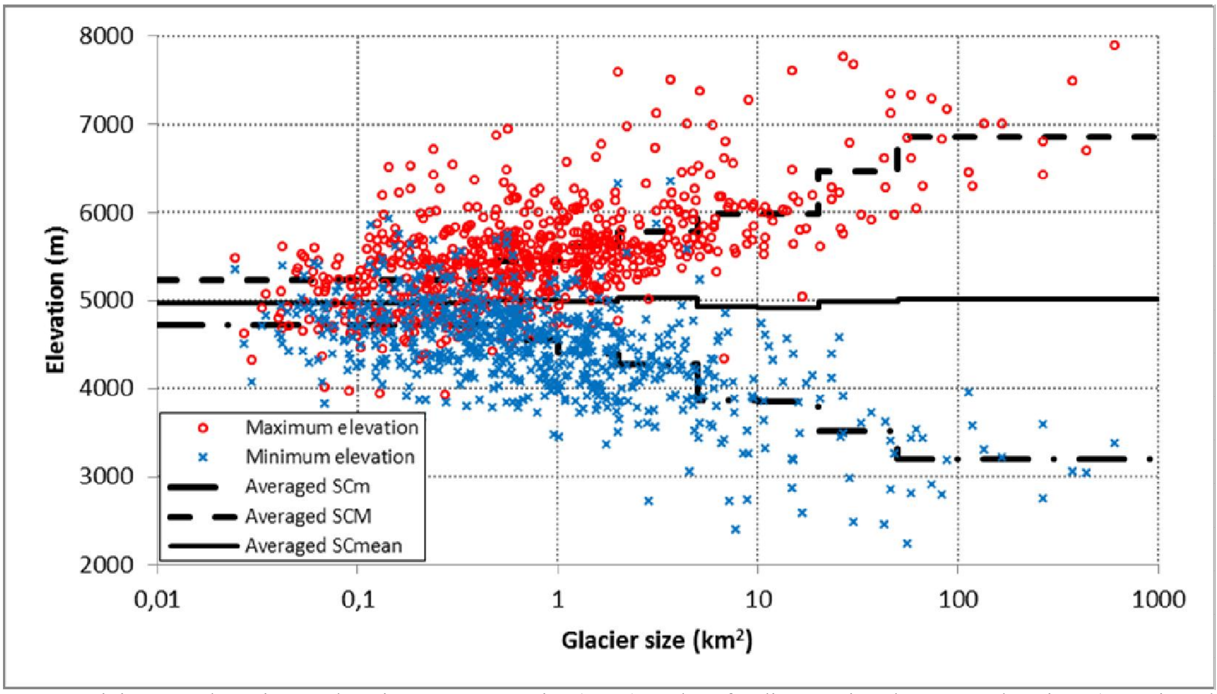

Exhibit 40 Minimum and maximum elevation versus area size (2001). Values for discrete size classes are also given (SC=Size Class; m/M=minimum/Maximum). Notice the logarithmic scale for glacier size.

In the inventory of 2010 the number of glaciers is slightly lower than in 2001, with 707 glaciers (due to some individual glaciers advancing to merge with neighboring glacier bodies), covering an area of 4613 km2 ±38 km2. To avoid inconsistencies, Table 13 shows the contribution of each glacier according to the class it belonged to in 2001.

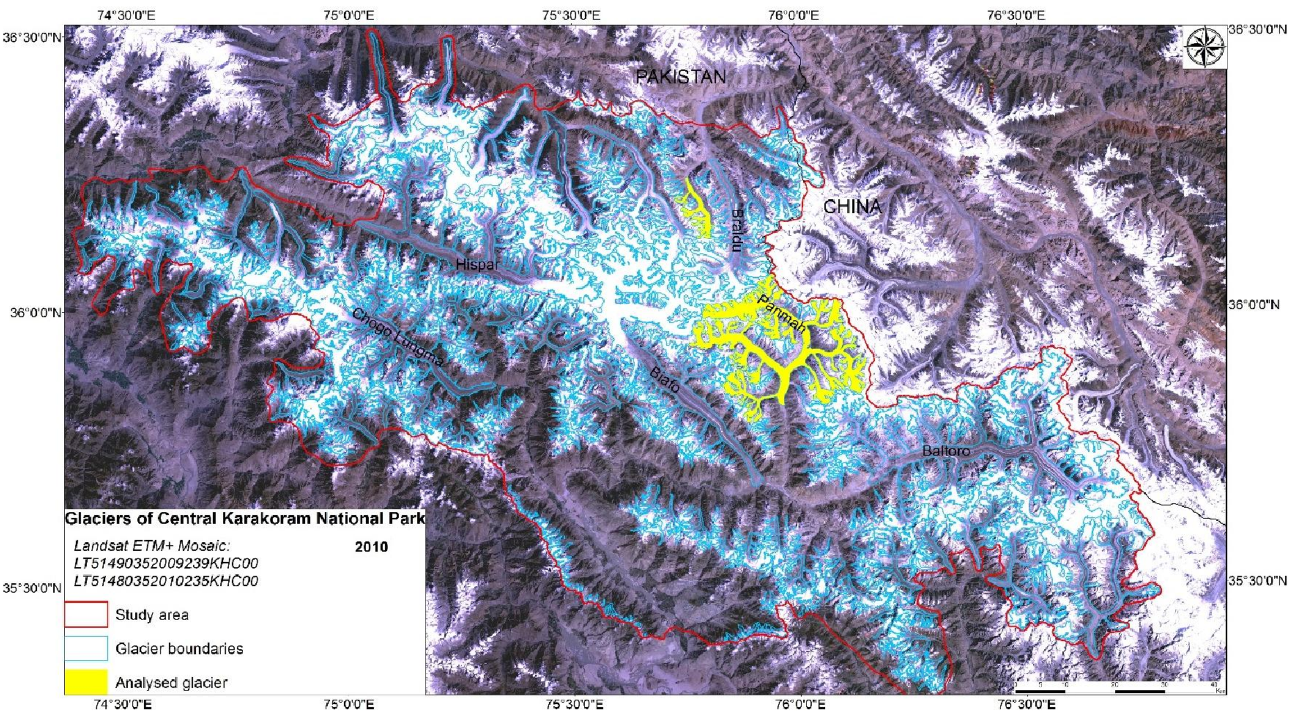

Exhibit 41 2010 CKNP glacier coverage, based on the Landsat 2010 (channels 321). Yellow outlines represent glaciers further analyzed in detail. Boundary line delineation is only a tentative.

Based on our analysis, the total glacier surface seems rather stable during 2001-2010. The relative area change found in this study (+0.6 % of the 2001 area), is indeed smaller than the error we calculated from Eq.

(1) (±42 km2). Moreover, we found 40 glaciers (over the whole sample of more than 700) with changed area, i.e. only 6 % of our sample.

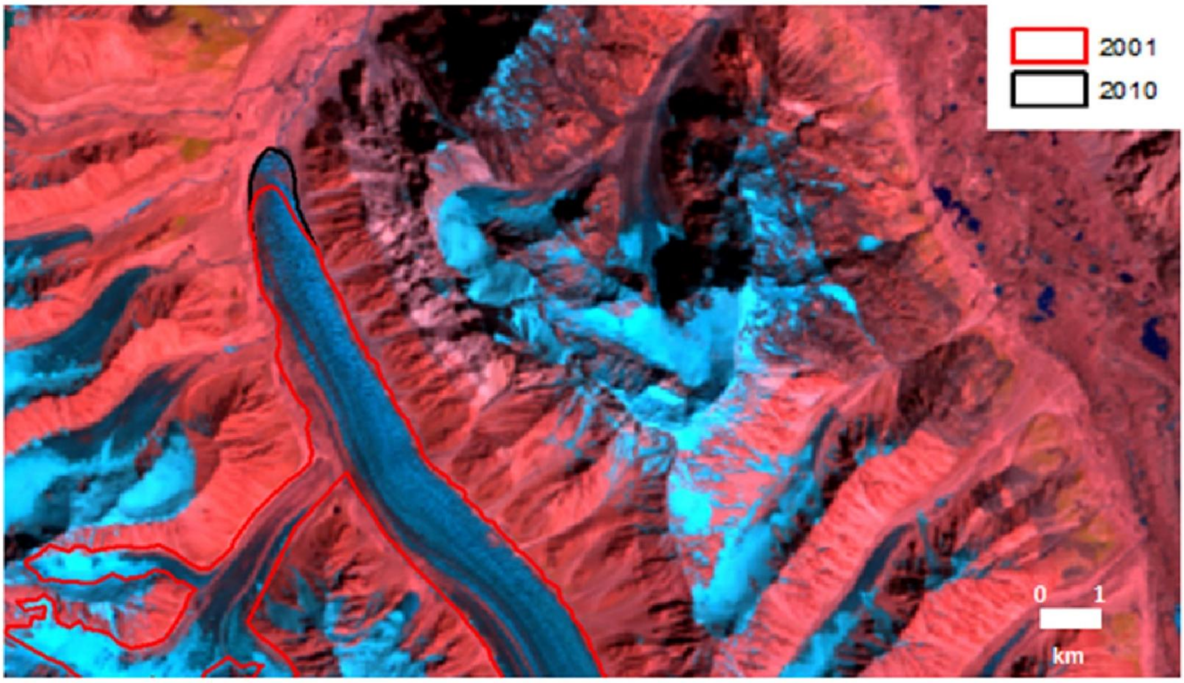

Exhibit 42 Example of an advancing glacier terminus near Braldu glacier from 2001-2010. See Exhibit 4 to see its location in the CKNP.

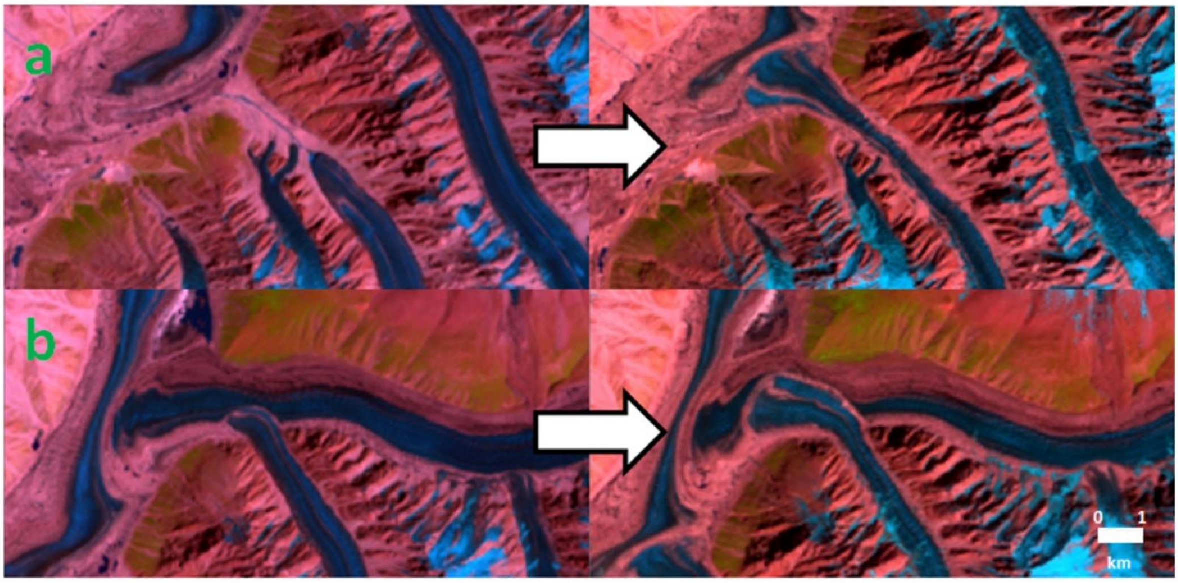

Exhibit 43 Comparison of Panmah's tributaries position in 2001 (left) and 2010 (right). See Exhibit 4 for the location in the CKNP.

In spite of the overall stable situation, when focusing upon those few glaciers witnessing surface change, noticeable variations are found (Exhibit 43 a, b). Especially glaciers in the 10 to 50 km2 size classes have shown appreciable advances (up to 489 m, with an average of 247 m for the whole period). We found and labeled 6 glaciers (Panmah and Braldu glaciers and some of their tributaries) as potentially surge type glaciers, also in accordance with Hewitt (2007), and Copland et al. (2011). Furthermore, looped moraines indicating possible past surge events were found on their surfaces (Copland et al., 2003). A most prominent example is given by Panmah's tributaries, some of which have experienced surges from 2001 and 2005

(Hewitt, 2007), now protruding far onto the main trunk of the Panmah glacier. Other glaciers of the area, such as Khurdopin, Virjerab (Gardelle et al., 2012), Liligo (Belò et al., 2008), and possibly Hispar (Copland et al., 2011), are in a quiescent phase. The rest of glacier expansion through recent years could be charged upon diffuse glacier advance activity, as reported by Scherler et al. (2011).

2.5.2 Debris-cover change during 2001-2010

Landsat images displayed that the total supraglacial-debris-coverage was 977 km2 ±138 km2 in 2001, and 1070 km2 ±194 km2 in 2010, about 20% of the total ice covered area. When considering only the ablation area, the percentage rose up to 31 %. The accuracy of the surface comparison is ±238 km2, then the change in the debris cover area of +92 km2 falls within the error range. In spite of this non-significant area change, debris cover increment can be appreciated by comparison of two FCC images upon some selected glaciers (Exhibit 44).

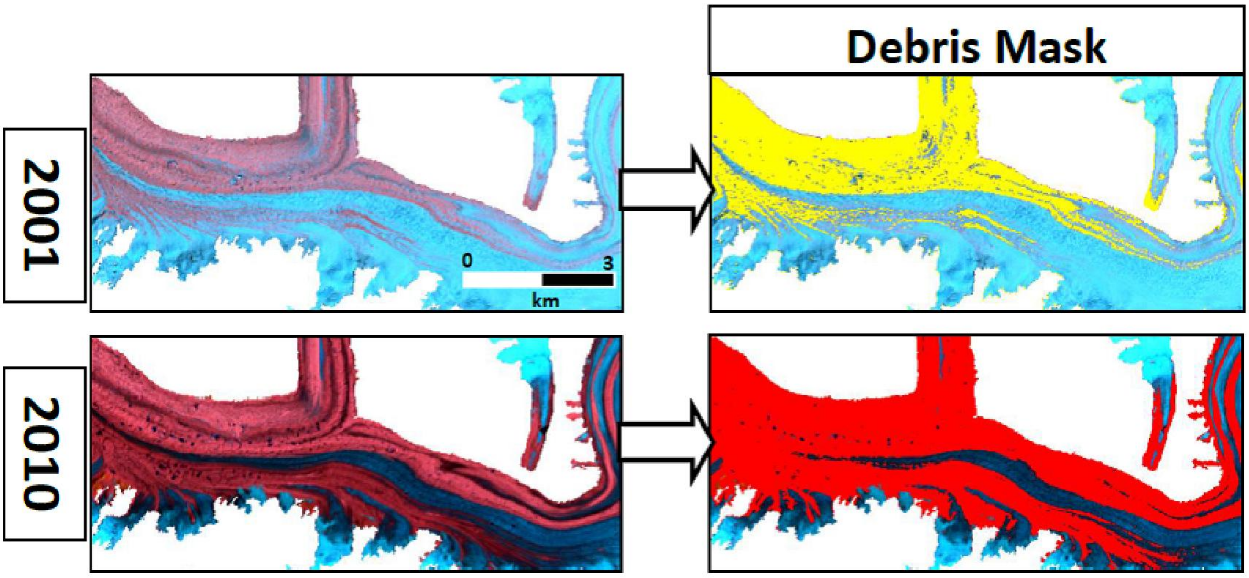

Exhibit 44 Supraglacial debris coverage change for 2001 (upper Exhibits) and for 2010 (lower Exhibits).

The maximum cover was found at 4300 m a.s.l., in the ablation zone. Supraglacial debris increase may likely be labeled as another cause of the stable conditions of the Karakoram glaciers. In fact supraglacial debris coverage, whenever thicker than a "critical thickness" (sensu Mattson et al., 1993), could reduce buried ice melting rates (Mihalcea et al., 2006; Hagg et al, 2008; Bocchiola et al., 2010; Sherler et al., 2011). Potential sources of debris cover may have been rocky avalanches due to steep slopes, glacier dynamics, wind action and other factors. In particular, hillslope-erosion rates usually increase with hillslope angle, so the flux of rocky debris to the glacier surfaces and therefore the formation of debris-covered glaciers are linked to steep (>25°) accumulation areas (Scherler et al., 2011), such as those present in the Karakoram range.

2.5.3 Snow cover variability

In Exhibit 45, we report average (2001-211) SCALS, or snow covered area in late Summer, as per altitude bins of 1000 m (i.e. 2000-3000 ma.s.l., etc.), refined into 500 m bins from 3000-6000 ma.s.l., where most of the snow dynamics likely occurs, and ELA is expected to dwell. We report within the radar plot snow cover areas as per aspect (8 bins of 45°), to illustrate variability of snow cover with slope orientation.

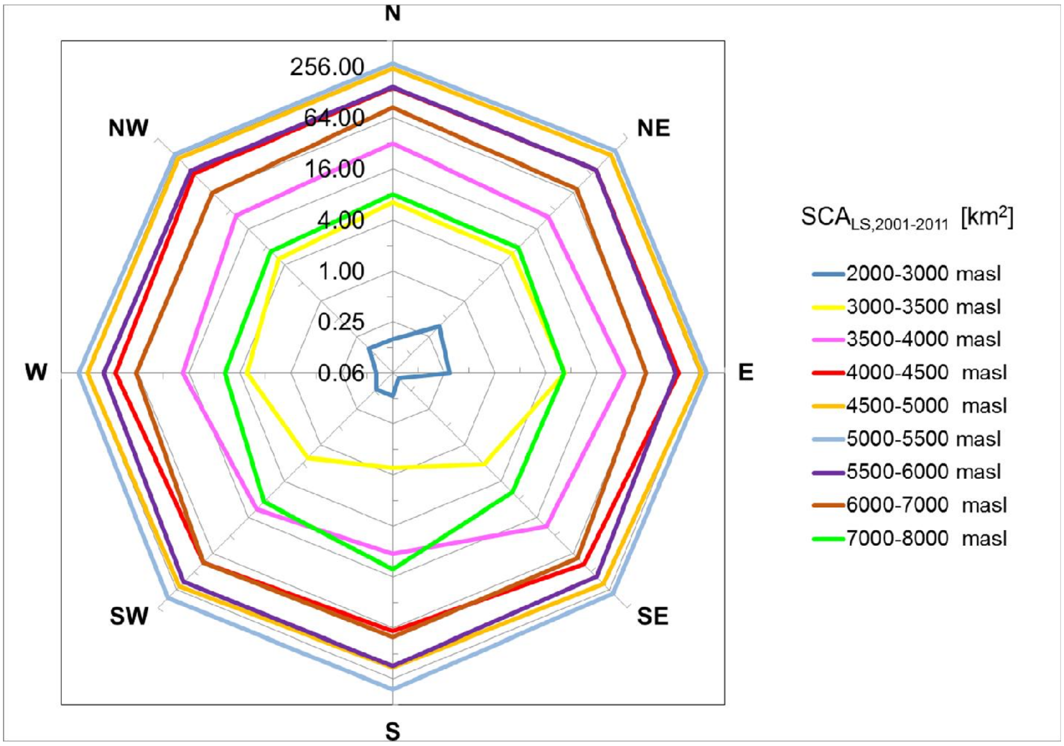

Exhibit 45 Average snow covered area in late Summer SCA_{LS} as per altitude bins, and aspect. Logarithmic scale (base 2) is used to enhance small snow covered areas at very low (and very high) altitudes.

From Exhibit 45, together with evidence of slightly smaller snow covered areas exposed towards South especially at the lowest altitudes, one gathers that considerable part of the snow cover area dwells between 4000 and 6000 m a.s.l., quite rapidly decreasing for lower and higher altitudes.

In Exhibit 46, we report altitude (bins) distribution of three different variables, namely i) average snow cover area in late Summer, with respect to the whole snow cover area in late Summer in the park (SCALS%), ii) average snow covered area in late Summer (SCALS*) with respect to greatest (Winter) observed snow cover area in that bin, and iii) ratio of greatest snow covered area in each bin to the maximum snow cover areas in the whole park (SCAMax%).

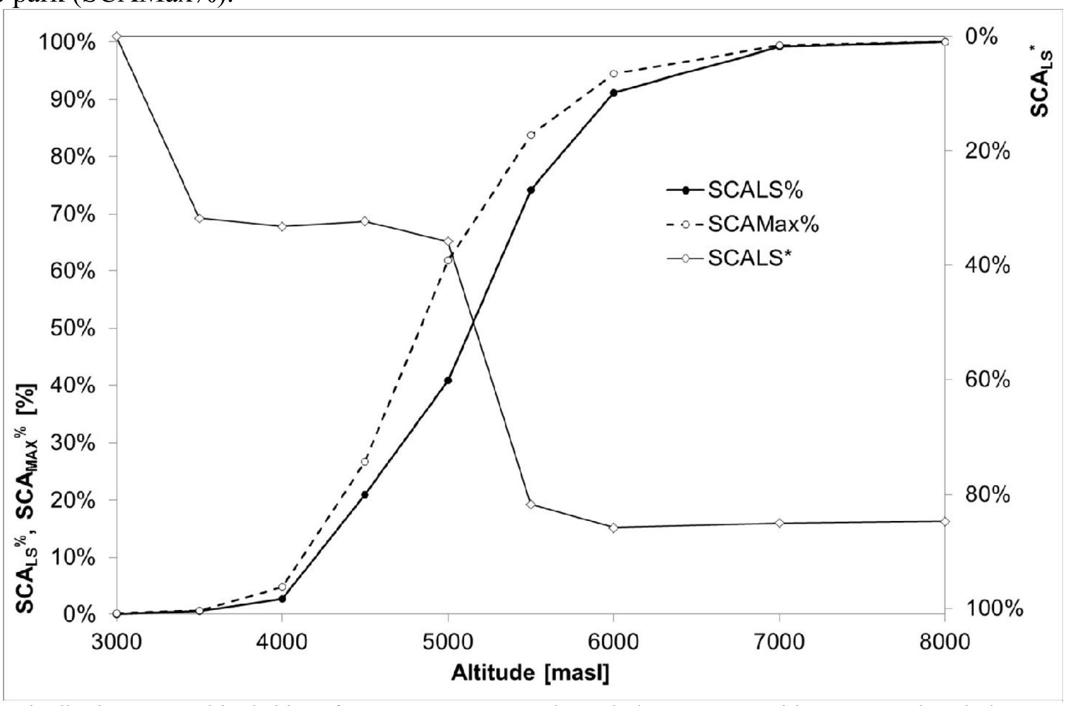

Exhibit 46 Distribution as per altitude bins of average snow covered area in late Summer with respect to the whole area $SCA_{LS}^{\%}$, of average snow covered area in late Summer SCA_{LS}^{*} with respect to greatest (maximum) snow covered area in that bin, and of the

greatest snow covered area in each bin with respect to the sum of maximum values of snow covered areas in the whole park $SCA_{Max}{}^{\%}$. Logarithmic scale (base 2) is used to enhance small snow covered areas at very low (and very high) altitudes.

From Exhibit 46, one sees that on average 88% of the snow covered area at Fall is contained between 4000 and 6000 ma.s.l. (SCALS%), thus demonstrating how snow dynamics is mostly played in this altitude bin, and that such range of altitude is utmost critical, also in view of potential changes of snow cover in response to climate change. From the shape of SCALS* curve one clearly sees how on average, above 5500 m a.s.l. or so and up to 8000 ma.s.l., snow cover at Fall is stably at 85% or so of the maximum seasonal value. Below this altitude, SCALS* decreases quickly. SCAMax% indicates the contribution to snow cover of each altitude belt during Winter time, i.e. when snow cover area reaches its largest value. The comparison of SCALS% against SCAMax% quantifies the relative importance of the loss of snow cover at the end of Summer in each belt, i.e. as quantified by SCALS*. One notices that the greatest cumulated loss of snow cover area (i.e. the vertical distance between SCALS% and SCAMax%) is reached towards an altitude of ca. 5000 ma.s.l. (ca. 20%), with decrease there above, meaning that areas above that altitude tend to contribute almost entirely to snow cover even after thaw. This is consistent with the pattern of SCALS*, displaying swift increase above between 5000 and 5500 mas.l.

Such circumstances may indicate that above 5500 m a.s.l. snow cover is substantially stable during the season, and one may assume that snow cover is permanent therein, whereas below such altitude more variable dynamic is expected, and snow cover may be considered less likely permanent. Such altitude may therefore be taken as a proxy for an average snowline for CKNP, just few hundred meters above the overall median glacier elevation calculated in the present study (5000 ma.s.l. ca.), and close to the ELA as estimated by other studies for our target area (Mayer et al., 2006; Mihalcea et al., 2008).

We then compared our estimated CKNP snow-cover against the results by Tahir et al. (2011), who studied snow variability of the close Hunza basin during 2001-2009, finding increasing snow cover area. We used here the same elevation belts as in their study (A, B, C, see Table 9). In Table 9 we report the rate of variation in time, or slope, of the snow coverage within each of the three belts A, B, C. In Table 9 Slope is the value of the rate of variation estimated using from linear regression analysis, expressed in km2 per year. Slope% is the rate of variation expressed as a percentage of the initial snow covered area (in 2001) per year. An increasing trend of snow cover is seen through time in all the elevation belts (see Exhibit 47).

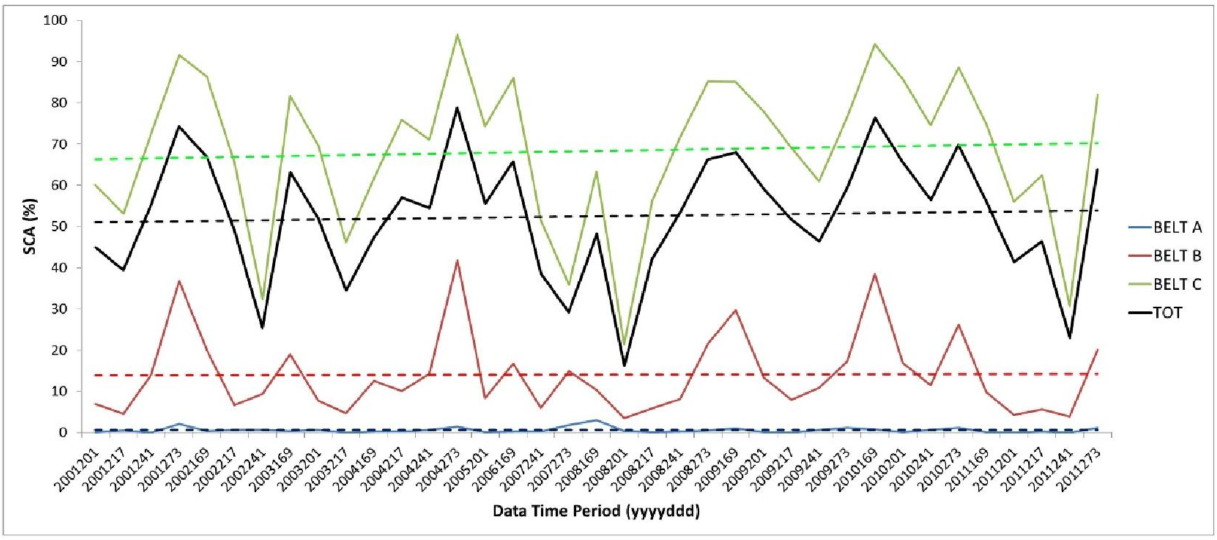

Exhibit 47 Snow cover distribution (SCA) in three different altitudinal zones of the CKNP for the May-September windows of 2000/2011 period. Data Time Period is given in years and Julian days.

In Belt A, a gain of +0.09 km2 yr−1 (or 2 % of snow cover area per year), was observed. In Belt B, snow cover area increased by +2.35 km2 yr−1, or +0.6 % yr−1. Belt C has increasing snow cover of +14.86 km2 yr−1, or +0.2 % yr−1. These results are qualitatively similar to those of Tahir et al. (2011), and seem to confirm a slight gain of snow covered area within the upper Karakoram recently, albeit again no conclusions can be drawn about the significance of such gain, in view of the short time series.

2.5.4 Climate trends

The results of the trend analysis of climate are shown in Table 14, and Exhibits 48-50, where the most significant trends highlighted are reported. The progressive MK test was carried out whenever both MK and LR tests showed non-stationarity, and the results are also reported in Table 7. Precipitation Pm demonstrates a substantial stationary behavior, i.e. no significant change is seen in the area. Concerning the number of wet days (Dw), increasing values are found in Gilgit (yearly, Y since 2001, JFM with no clear onset), i.e. there is a significant increase of the number of yearly (and Winter) precipitation events. In Astore significant increase of Dw is found in Summer months (JAS) via the LR test.

Table 14 Results of the climate trend analysis: a) results of the LR and MK analysis. For MK, p-val is displayed. The LR values are the linear regression coefficients (i.e. slope of the regression line, unity/year), LRp is corresponding to p-val. In bold significant p-val (α = 5%) are given. b) the beginning year and average values before and after the start for the trends derived from the progressive MK test are given. LT is the long term (1980-2009) average. c) correlation analysis of station mean climatic variables vs global temperature anomalies DTG and NAO index. The significant correlation (α = 5%) results are displayed in bold.

a) Station	Pm-Dw	P_Y	P_{JFM}	P_{AMJ}	P_{JAS}	P_{OND}	D_{wY}	D_{wJFM}	D_{wAMJ}	D_{wJAS}	D_{wOND}
Astore	MK	0.38	0.40	0.60	0.90	0.56	0.25	0.96	0.66	0.10	0.71
Astore	LR s	-2.22	-0.94	-0.39	0.00	-0.89	0.34	0.01	-0.01	**0.08**	0.03
Astore	LR p	0.43	0.55	0.84	1.00	0.49	0.22	0.71	0.87	**0.04**	0.27
Bunji	MK	0.90	0.42	0.99	0.99	0.84	0.84	0.38	0.38	0.68	0.79
Bunji	LR s	-0.32	0.29	-0.18	0.03	-0.47	-0.06	-0.01	-0.03	0.00	0.02
Bunji	LR p	0.82	0.49	0.84	0.96	0.39	0.81	0.85	0.44	0.94	0.28
Gilgit	MK	0.42	0.87	0.40	0.79	0.90	**0.00**	**0.00**	0.15	0.21	0.93
Gilgit	LR s	0.59	0.09	0.78	-0.07	-0.20	**0.87**	**0.11**	**0.09**	0.06	0.03
Gilgit	LR p	0.55	0.80	0.34	0.87	0.64	**0.00**	**0.00**	**0.04**	0.12	0.38
Station	Tmin-Tmax	T_Y	T_{JFM}	T_{AMJ}	T_{JAS}	T_{OND}	T_Y	T_{JFM}	T_{AMJ}	T_{JAS}	T_{OND}
Astore	MK	0.07	**0.05**	**0.04**	0.71	0.23	**0.01**	**0.01**	0.34	0.99	0.28
Astore	LR s	**0.03**	**0.05**	**0.06**	0.00	0.02	**0.04**	**0.08**	0.05	0.01	0.04
Astore	LR p	**0.02**	**0.05**	**0.01**	0.87	0.23	**0.01**	**0.00**	0.11	0.76	0.09
Bunji	MK	**0.01**	**0.00**	**0.03**	0.82	**0.02**	0.58	**0.01**	0.73	0.07	0.42
Bunji	LR s	**0.04**	**0.07**	**0.06**	-0.01	0.04	0.01	**0.06**	0.01	-0.03	0.02
Bunji	LR p	**0.00**	**0.00**	**0.01**	0.81	**0.04**	0.38	**0.01**	0.73	0.13	0.29
Gilgit	MK	0.16	0.42	0.76	**0.03**	0.49	**0.00**	**0.00**	0.33	0.93	**0.01**
Gilgit	LR s	-0.01	0.02	0.01	**-0.05**	-0.02	**0.05**	**0.09**	0.06	0.00	**0.07**
Gilgit	LR p	0.41	0.39	0.62	**0.02**	0.41	**0.00**	**0.00**	0.07	0.85	**0.00**
b) Station	Var.	Year st.	LT	Before	After	St.	Var.	Year st.	LT	Before	After
Astore	T_{minJFM}	2002	-4.4	-4.8	-3.7	Bunji	T_{minOND}	1997	5.1	4.9	5.5
Astore	T_{minAMJ}	1999	7.6	7.2	8.4	Bunji	T_{maxJFM}	1997	13.8	13.3	14.5
Astore	T_{maxY}	1998	15.7	15.3	16.2	Gilgit	D_{wY}	2001	39.3	33.6	53.4
Astore	T_{maxJFM}	2000	5.4	4.8	6.4	Gilgit	T_{minJAS}	1986	15.6	16.7	15.3
Bunji	T_{minY}	2003	10.9	10.7	11.7	Gilgit	T_{maxY}	1995	24.1	23.7	24.6
Bunji	T_{minJFM}	1997	3.5	3.1	4.1	Gilgit	T_{maxJFM}	1995	13.8	13	14.6
Bunji	T_{minAMJ}	2001	15.3	15	16.2	Gilgit	T_{maxOND}	1991	18.9	18.2	19.3
c)	Y	JFM	AMJ	JAS	OND	-	Y	JFM	AMJ	JAS	OND
DT_G/T_{min}	**0.21**	**0.25**	**0.35**	-0.16	0.19	NAO/D_w	**-0.32**	**-0.44**	**0.33**	**-0.33**	-0.10

DT_G/T_{max}	**0.55**	**0.41**	**0.24**	0.11	**0.33**	**NAO/T_{min}**	0.00	**-0.36**	**-0.26**	0.05	0.12
NAO/P_m	**-0.14**	0.10	0.17	**0.18**	**0.17**	**NAO/T_{max}**	**-0.21**	**-0.23**	**-0.22**	0.06	-0.05

The minimum temperature Tmin increases significantly in Astore for Winter and Spring (JFM, AMJ, since 1999-2002) and in Bunji for all periods except in Summer (Y , JFM, AMJ, OND, since 1997-2003). In Gilgit Tmin decreases significantly during Summer (JAS, since 1986). The maximum temperature Tmax increases significantly yearly, in Fall and Winter in Astore (Y since 1998, , JFM since 2000). Also in Gilgit significant Tmax increase is observed for most periods (Y, JFM, since 1995, OND, since 1991), while Bunji shows a significant Tmax increase only in Winter (JFM, since 1997).

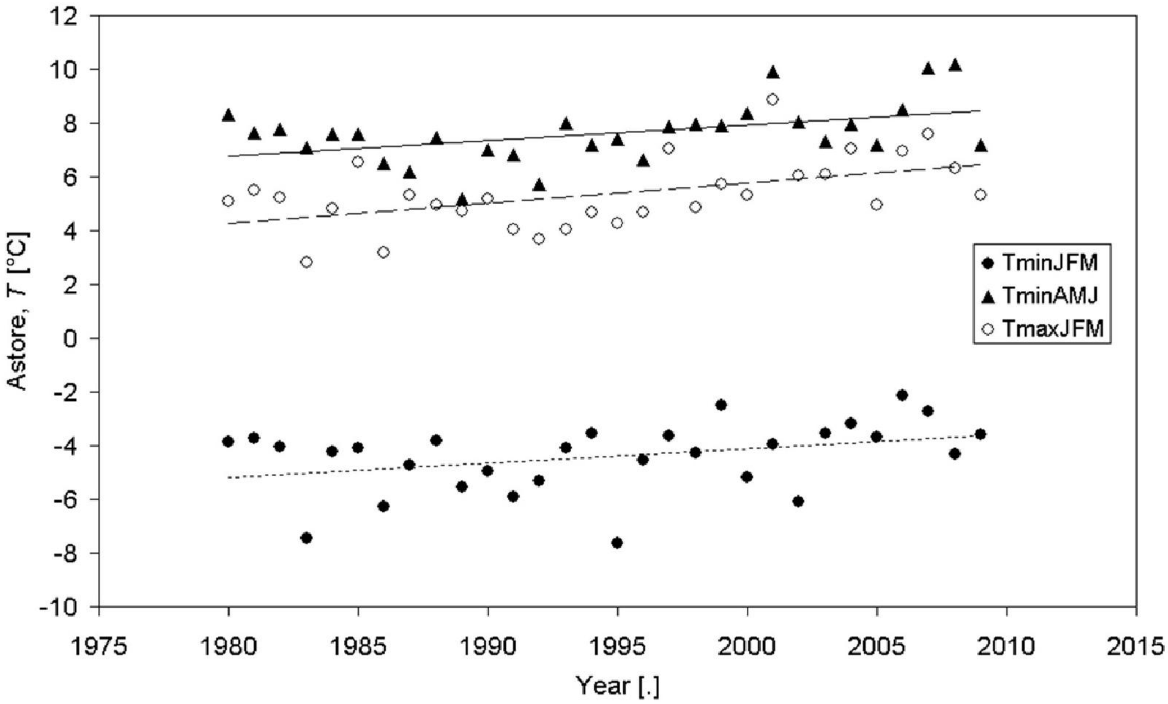

Exhibit 48 Seasonal minimum air temperatures (Winter: JFM, Spring: AMJ) and Winter maximum air temperatures for the station Astore, including their linear trends.

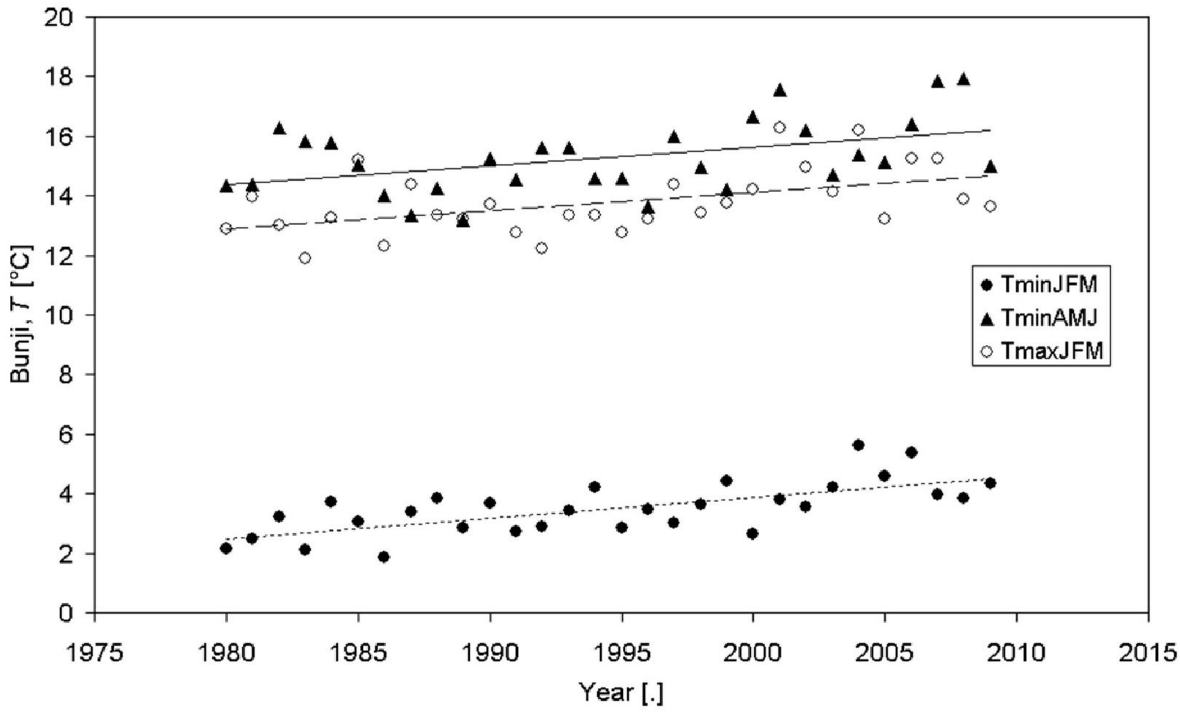

Exhibit 49 Seasonal minimum air temperatures (Winter: JFM, Spring: AMJ) and Winter maximum air temperatures for the station Bunji, including their linear trends.

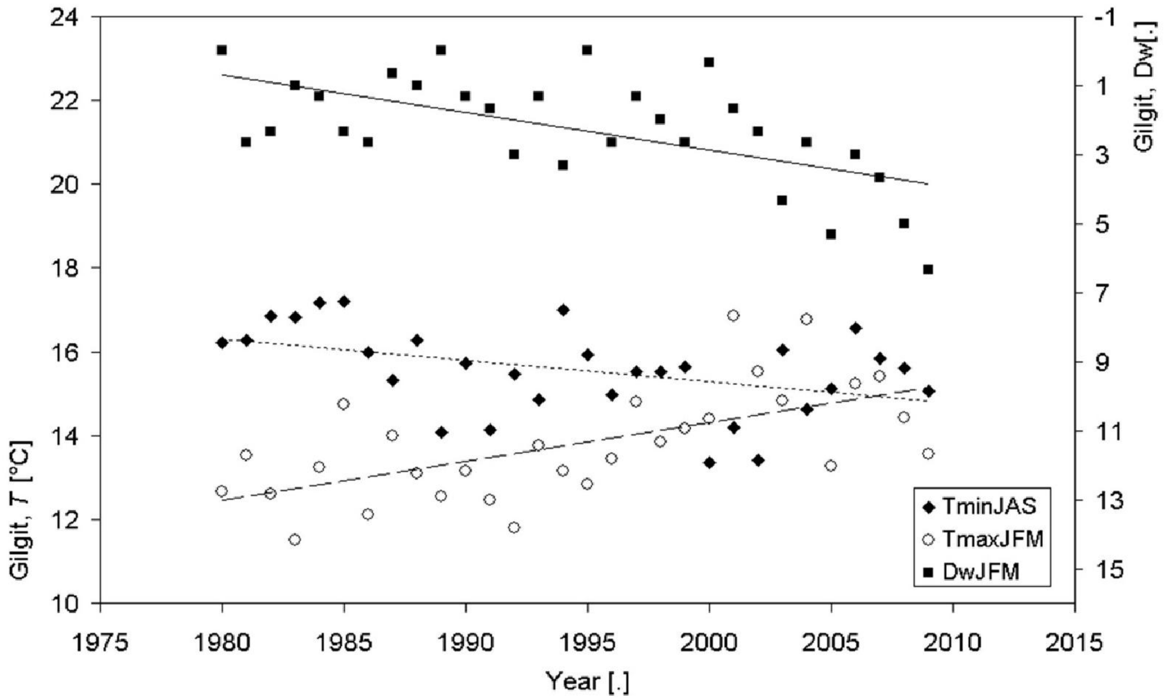

Exhibit 50. Summer minimum air temperatures (JAS) and Winter maximum air temperatures (JFM) for the station Gilgit, including their linear trends. In addition also the number of wet days D_w during Winter is displayed.

We evaluated the (linear) correlation between i) local temperatures and global thermal anomalies, and ii) the investigated weather variables and the NAO index. As a representative parameter of the region, the averaged values between the three stations have been used (Table 14). The minimum air temperature Tmin is significantly positively correlated with respect to DTG yearly, in Winter and Spring. The maximum air temperature Tmax is significantly positively correlated against DTG yearly, and seasonally, especially in

Fall and Winter. Concerning the NAO index, Pm shows a significant, albeit small correlation (negative vs. Y, and positive vs. JAS and OND). The duration of wet periods Dw is significantly shorter for higher NAO anomalies, unless during Spring. The minimum temperature Tmin is negatively correlated to NAO during Winter and Spring. Tmax is negatively correlated to NAO (Y , JFM, AMJ).

2.6 Discussion and conclusions

The main aim of this part of the research was to evaluate the recent changes of CKNP glaciers, given that they provide a not negligible water resource for the Park, and Pakistan as a whole. Moreover, we aimed at verifying if Karakoram anomaly may be detected also within this glacierized region of HKH and, if any, its magnitude and rate (Hewitt, 2005; Gardelle et al., 2012).

The CKNP glacier inventory we developed indicates a situation of stationarity. Our close watch on CKNP for the last decade confirmed the exceptional behavior of glaciers in the Karakoram. In facts, we analyzed a sample of more than 700 glaciers, and we found no significant area change between 2001 and 2010 (+27 km2 ± 42 km2). Understanding the reasons of such anomaly is a paramount important. Observations on meteorological data revealed that precipitation has been substantially constant during the last 30 years in our study area, and yet the number of wet days has increased, particularly in Winter. In a Park where most of the lands lay between 4000 and 5000 m a.s.l. this could result into an increased supply of fresh snow, and fresh snow can then be long-lasting here because of the favorable temperature gradient. In addition, analysis of thermal data from 1980 to 2009 revealed a significant decrease in minimum Summer temperatures at Gilgit, which may be considered as representative of climate within the park area, thus potentially contributing to snow and ice preservation.

Analysis of MODIS images during 2001-2010 confirmed that an increase of SCA has occurred in thaw season. Snow cover protects glaciers from melting by reflecting incoming solar radiation. We could place late Summer snowline around 5500 m a.s.l., which roughly corresponds to the average altitude of the largest glaciers here (i.e. > 50 km2). Whenever snow would be permanent at such critical elevations, ice ablation therein would decrease, so possibly contributing to Karakoram anomaly.

At lower altitudes, where snow is seldom present, and where ablation takes place (meaning more vulnerable conditions for glaciers), CKNP ice bodies are mostly covered by a thick layer of debris. In particular, supraglacial debris covers 31 % of the total ablation area, and its maximum coverage is found at an altitude of 4300 m a.s.l. (below the estimated snowline). This may have played an important role in ice preservation during Summer, as a thick debris layer may slow down melting rates (Mihalcea et al., 2006; Hagg et al., 2008; Bocchiola et al. 2010; Mayer et al., 2010; Sherler et al., 2011), as found out for several areas worldwide (Mattson et al., 1993).

These factors altogether may have pushed CKNP glacier mass balances towards positive net values. When focusing upon single glacier entities however, some variety is found. In facts, an in depth analysis revealed the presence of some potentially surge type glaciers in the study area. Surging may be statistically connected to various size-related variables, including perimeter and shape. Perimeter may increase the availability of avalanche-fed snow and debris material that may in turn affect the incidence of surging events (Barrand and Murray, 2006). In our case, those big glaciers representing most of the total icy coverage have complex shape (i.e. they are far from their equivalent circled shape), because of the many tributaries and the complex terrain. Areal changes here can then be caused not only by glacier expansion, but also by sudden advances, which most of the times do not translate into mass increase.

The stable superficial conditions we have found in CKNP glaciers agree, among others, with the results Gardelle et al. (2012; 2013), who found out a slight mass gain for glaciers in the same area for the same period. They estimated the Karakoram mass-balance into +0.10±0.19 myr-1 water equivalent.

Eventually, the present study dug into the situation of Karakoram glaciers, and in particular glaciers within CKNP covering more the 13000 km2, and brought to light new evidences of the existence of a Karakoram Anomaly. To gain insight concerning this anomaly more field data are required, especially to describe local glaciers changes, ablation and mass balances, and to evaluate magnitude and rate of snow accumulation. The lack of snow depth data at the highest altitudes, largely important for ice nourishing, may limit our understanding of glaciers' dynamics, and claims for further investigation in this sense.

3. Mountain Hydrology[3]

3.1 Mountain hydrology studies

3.1.1 Hydrological components of water resources in the CKNP

CKNP is a water rich area. Seasonal melting of snow and ice from the Karakorum provides plenty of water for drinking and irrigation, and for storage in reservoirs dowstream for the population of Pakistan. The mountain range of the Karakoram contains a large amount of glacier ice, and it is the third pole of our planet (Smiraglia et al., 2007; Kehrwald et al., 2008), delivering water for agriculture, drinking purposes and power production. There are estimates indicating that more than 50% of the water flowing in the Indus river, Pakistan, which originates from the Karakoram, is due to snow and glacier melt (Immerzeel et al., 2010). The hydrological regimes of Karakoram rivers and potential impact of climate change therein have been hitherto assessed in a number of contribution in the available scientific literature (Aizen et al., 2002; Hannah et al, 2005; Kaser et al., 2010; Bocchiola et al., 2011). The Karakoram stores a very relevant amount of water in its extensive glacier cover at higher altitudes (about 16,300 km2), but the lower reaches are very dry. Especially in the Central and Northern Karakoram, the lower elevations receive only occasional rainfall during summer and winter (Winiger et al., 2005). The state of the glaciers also plays an important role in future planning: shrinking glaciers may initially provide more melt water, but later their amount may reduced; on the other hand, growing glaciers store precipitation, reduce summer runoff, and can also generate local hazards. These differences could be caused by increases in precipitation since the 1960s (Archer and Fowler, 2004) and a simultaneous trend toward higher winter temperatures and lower summer temperatures (Fowler and Archer, 2005). As such, climate change represent a main source of risk for floods and for the food security of the populations living within the area of HKH. Despite the importance of this issue and the interest it has raised within the international scientific community, few studies were carried out assessing the impact of climate in this area. Particularly, it is important to evaluate the hydrological components of water resources regime, i.e. the origin of flowing available water, be it deriving from liquid precipitation (i.e. rainfall), snow melt, or ice melt. Here, we report the case study of the Shigar river closed at Shigar, nested within the CKNP, and providing a paradigmatic case for the area.

Using a properly tuned hydrological model, we investigate the seasonal hydrological fluxes, and the relative hydrological components, including water from ice and snow melt, and from liquid precipitation.

Then, we use projections from 3 different GCMs and three different RCPs as defined by IPCC to investigate potential modified hydrological cycle, and flood regime until 2100.

3.1.2 Hydrological modeling of the Shigar river

Introduction

To illustrate a case study of water resources assessment in the CKNP area, we developed a preliminary approach to modeling hydrological regime in a particular watershed (Shigar river at Shigar, ca. 7000 km2) nested within the park. We set up a minimal hydrological model, tuned against a short series of observed ground climatic data from a number of stations, in situ measured ablation, and remotely sensed snow covered areas. We then feed our model with locally adjusted future precipitation and temperature fields from one particular General Circulation Model (henceforth, GCM), namely the Community Climate System Model, version 3 (henceforth, CCSM3), available within the International Panel of Climate Change (IPCC) data base, using storyline A2, for the reference period 2050-2059. We adopt four different glaciers' cover scenarios, to test runoff sensitivity to decreasing size of glacierized areas. The projected flow duration curves, and some selected flow descriptors are evaluated. We then comment the modified snow cover, ice

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ablation regime and implications for water resources, displaying sensitivity to the chosen scenario. This preliminary case study illustrates the type of modeling approach that should be carried in the CKNP, by extension to the whole park area. The study area (Exhibit 51), is Shigar river closed at Shigar bridge, ca 7000 km2, nested within the upper Indus basin, and fed by seasonal melt from major glaciers. We tackled assessment of hydrology within this particular contributor to the Indus river because its whole catchment is laid within Pakistan, whereas a considerable part of the Indus catchment, the mountain chains of China and India before flowing therein, collecting then water from the CKNP park area. This makes data retrieval easier, and especially there is no need to make hypothesis about water coming from the Eastern area. This issue will require some consideration henceforth. The highest altitude here is reached by K2 mountain (8611 m asl) and the lower is at Shigar bridge at 2204 m asl, the average altitude is 4613 m asl and around the 35% of the area is above 5000 m asl. According to the Köppen-Geiger climate classification (Peel et al., 2007) this area falls in the BWK region, that displays dry climate with by little precipitation and a wide daily temperature range. The HKH area displays considerable vertical gradients. The Nanga Parbat massif forms a barrier to the Northward movement of monsoon storms, which intrudes little in Karakoram. In the HKH range there is extensive coverage of glaciers. In the Shigar basin the main ice body is the Baltoro, greater than 700 km2 in area. Thus, the hydrological regime is little influenced by monsoon and a major contribution results from snowmelt and glacier melt. Precipitation is concentrated in two main periods, Winter (JFM) and summer (JAS), i.e. Monsoon and Westerlies, the latter providing the dominant nourishment for the glacier systems of the HKH. Some studies indicates that these mountains gain a total annual rainfall between 200 mm and 500 mm, amounts that are generally derived from valley-based stations and less representative for the highest zones (e.g. Archer, 2003). High altitude snowfall seems to be neglected and is still rather unknown. Some estimates from accumulation pits above 4000 m asl range from 1000 mm to more than 3000 mm, depending on the site (Winiger et al., 2005). However, there is considerable uncertainty about the behavior of precipitation at high altitudes.

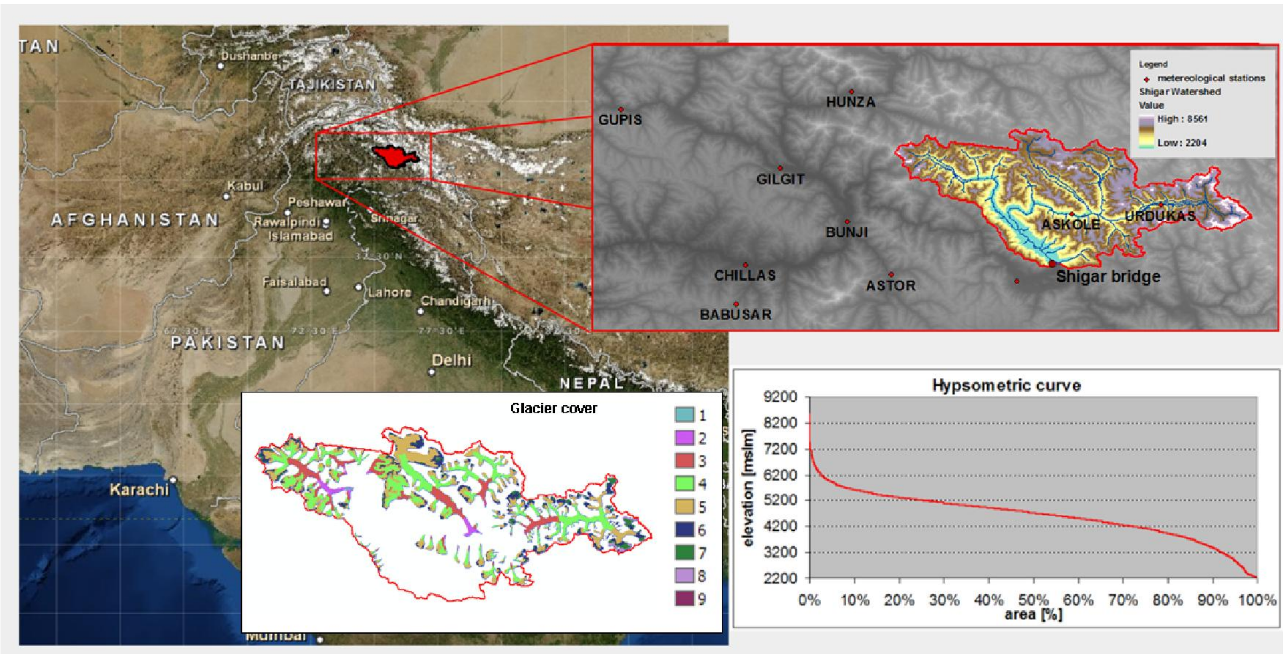


Exhibit 51 The study area: Shigar river basin in the HKH region. Red dots are the weather stations. Glaciers' cover reported in the 10 chosen altitude belts (no glacier cover in belt 10).

Data base

In the Shigar river catchment we had available data from two meteorological stations, property of the EVK2CNR committee: Askole (3015 m asl), and Urdukas (3926 m asl). For these stations there are available daily values of rainfall and mean air temperature for the period from 2005 until 2009, but with significant missing data periods, especially for the precipitation. These gaps are concentrated particularly in Winter, likely as precipitation falls under snow form, not measured at these stations. Out of the Shigar basin weather data are available, namely the monthly values of precipitation and temperature during 1980-2009, for 8 stations belonging to Pakistan meteorological department, PMD, all positioned below 2500 m asl. Monthly mean discharge averaged over the period from 1985 until 1997 are available. During this period there was an hydrometric station property of the water power development agency of Pakistan WAPDA at the Shigar bridge (2204 m asl), that is our control section (e.g. Archer, 2003). Weather data coverage is summarized in Table 15.

Table 15 Weather stations and measured variables during 2005-2008.

Station	Altitude [m asl]	Long [° E]	Lat [°N]	Variable	Resolution [.]
URDUKAS	3926	76.28611	35.72805	Temp, Precip	Daily
ASKOLE	3015	75.81527	35.68056	Temp, Precip	Daily
ASTOR	2168	74.86709	35.36341	Temp, Precip	Monthly
BABUSAR	2854	74.05287	35.20946	Temp, Precip	Monthly
BUNJI	1470	74.63503	35.6423	Temp, Precip	Monthly
CHILAS	1255	74.09936	35.41533	Temp, Precip	Monthly
GILGIT	1461	74.28351	35.92029	Temp, Precip	Monthly
GUPIS	2156	73.44538	36.23088	Temp, Precip	Monthly
HUNZA	2374	74.65969	36.32441	Temp, Precip	Monthly
SKARDU	2230	75.52631	35.32965	Temp, Precip	Monthly

We here used snow covered area SCA as derived from MODIS® images. Nowadays, SCA estimation from satellite data is widely adopted for water storage assessment in mountain areas, distributed modeling of snow cover and melting and hydrological and glaciological implications therein (e.g. Swamy and Brivio, 1996; Simpson et al., 1998; Cagnati et al., 2004; Hauser et al., 2005; Parajka and Blöschl, 2008; Georgievsky, 2009; Immerzeel et al., 2009). Unsupervised classification of SCA may be carried out based upon visible bands (RGB) and box type classification (Hall et al., 2003a, b; Hall et al., 2010, for estimation of SCA from MODIS® images), using digital number, DN > 200.

Also sub-pixel classification is used, e.g. by spectral unmixing.(e.g. Foppa et al., 2004), which still requires subjective choice of end-members (and more spectral bands for more end-members), while the main output is a percentage of in cell snow coverage, with no indication of spatial distribution of cells with snow. Here we used 40 images of SCA from MODIS during 2006-2008, taken from the product MODIS/Terra Maximum-Snow Cover 8-Day, L3 Global, at a 500 m resolution (MOD10A2, e.g. Hall et al., 2002). This contains Maximum SCA (yes/no) over an 8-day composing period. As no snow cover data were available within the catchment, as reported, we could not attempt either spatial estimation of snow cover (as e.g. in Bocchiola, 2010; Bocchiola and Groppelli, 2010), or investigation of snowfall properties in the area (e.g. Bocchiola and Rosso, 2007).

Weather data

To provide input data to our hydrological model for the purpose of testing its performance we proceed as follows. We use yearly total precipitation from the 8 PMD stations during 1980-2009 (overlapping the period of functioning of the WAPDA hydrometric station on the Shigar river, 1985-1997) to evaluate the presence and magnitude of altitude lapse rate of temperature and precipitation, and monthly lapse rates were used. Precipitation data show an increase from 1200 m asl to 3900 m asl. In the absence of further information we adopt a power law (Winiger et al., 2005), which we estimate from our precipitation data

$$P_y = 9 \cdot 10^{-6} z^{2.22},$$

with Py yearly amount of precipitation [mm] and z is altitude [m asl]. At high elevation this may lead to an overestimation of precipitation. However, this may have a little impact on the hydrologic balance, because with increasing altitude contributing area decreases significantly. We preliminarily evaluated the possible presence of an altitude lapse rate of precipitation by analyzing maps of average yearly precipitation as derived from TRMM satellite data during 1998-2009 (kindly provided by Dr. B. Bookhagen of UCSB, see Bookhagen and Burbank, 2006; 2010) for the Shigar basin area, but we could not detect any clear pattern (Exhibit 4.3). As a rough comparison, average precipitation in the area could be estimated in ca. 350 mmyear-1 by TRMM, whereas use of Eq. (1), tuned as reported using PMD data covering 1980-2009, provided an expected value of ca. 550 mmyear-1, i.e. with a difference of 35% or so. However, given the tremendous uncertainty in both techniques, such spread seems not unexpected.

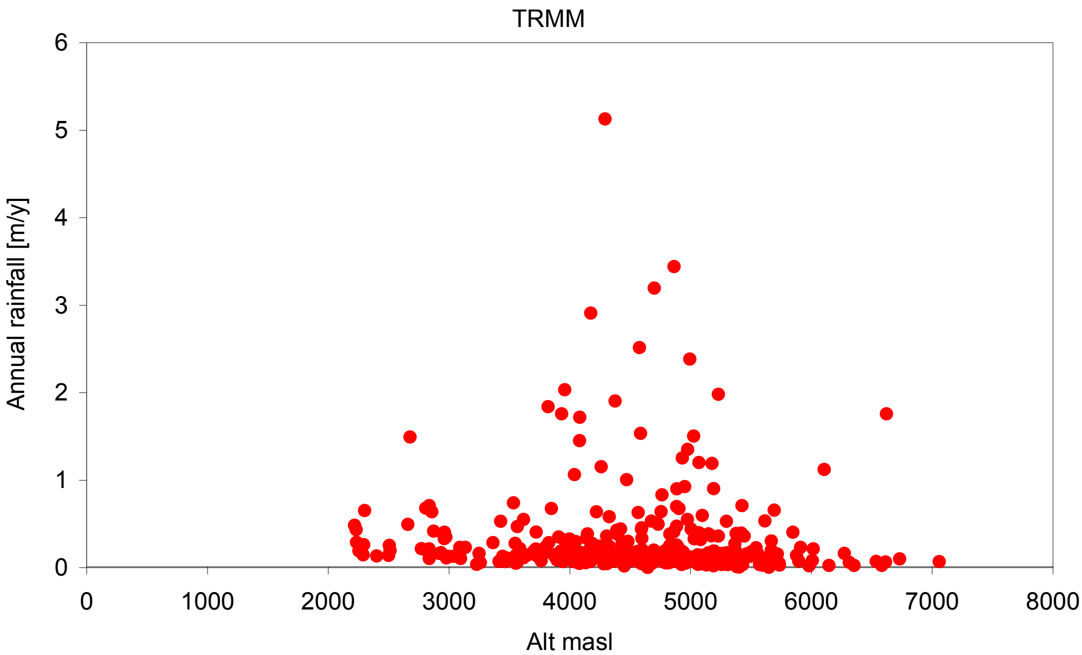


Exhibit 52 Average yearly precipitation as derived from TRMM satellite data during 1998-2009 (kindly provided by Dr. B. Bookhagen of UCSB, see Bookhagen and Burbank, 2006; 2010).

Using the daily precipitation data during 2005-2008 at the Askole station of EVK2CNR, most complete when compared against Urdukas, we then set up a disaggregation approach, which we use to disaggregate monthly precipitation from Astore station (most complete data base among the PMD stations). We use a random cascade approach (e.g. Groppelli et al., 2010; 2011), slightly modified to deal with monthly precipitation, namely

$$R_d = R_m Y_d = R_m B_d W_d$$
$$P(B_d = 0) = 1 - p_d$$
$$P(B_d = p_d^{-1}) = p_d$$
$$E[B_d] = p_d^{-1} p_d + 0(1 - p_d) = 1$$
$$W_d = e^{(w_d - \sigma_{wd}^2/2)}$$
$$E[W_d] = 1;\ w_d = N(0, \sigma_d^2)\quad ,$$

where Rm is monthly rainfall, Rd is daily rainfall, and Yd a daily cascade weight. Bd, pd, and σwd2 are model parameters, to be estimated from data, used to preserve intermittence, or correct sequence of dry and wet spells. The term Bd is a model generator (e.g. Over and Gupta, 1994). It gives the probability that the rain rate Rd for a given day is non zero, conditioned upon Rm being positive, and it is modeled here by a binomial distribution. The term Wd is a "strictly positive" generator. It is used to add a proper amount of variability to precipitation during spells labeled as wet. Model estimation (i.e. estimation of pd, and σwd2) is pursued monthly, based upon the 2005-2008 series at Askole. Then, in the hypothesis of similar statistic structure of precipitation between Askole and Astore we use the same approach to downscale monthly precipitation in Astore. So doing, we obtain a daily precipitation series at Astore, which we subsequently use for hydrological simulation during 1985-1997. Similarly, we use Askole daily temperature data, to disaggregate Astore monthly data, by random extraction of daily temperature according to a given (normal) distribution, estimated from data.

Snow and ice melt and SCA

Shigar watershed includes glaciers spread over a considerable, several of which displaying debris cover. Mihalcea et al. (2006) and Mayer et al. (2006) evaluate ice melt factors for both ice covered and ice free glacier based upon field ablation data from the Baltoro glacier, and Mayer et al. (2010) evaluated melt factors for Bagrot valley, and Hinarche glacier. Mihalcea et al. (2008) provided evaluation of debris cover thickness again upon Baltoro. We classified ice covered area using visible images, and compared our estimates glaciers' inventory from ICIMOD (Campbell, 2004) within the Shigar catchment. We obtained an ice covered area of ca. 2774 km2 vs 2240 km2 as from ICIMOD. We used debris cover extent and distribution as drawn from Baltoro glaciers to evaluate to evaluate melt factors therein. As a rough average value on the area we found a melt factor for ice DDi = 5.70.

Snow melt was tackled using degree day approach and melt factor. Among others, Singh et al. (2000) provide a review of plausible values for snow melt factors, including for glaciers in western Himalaya. Melt factors range from 1 mm°C-1day-1 to 14 mm°C-1day-1 or so. Snow cover data (and subsequent ablation) were not available here, so we tackled estimation of melt factors indirectly. We used our hydrological model to simulate snow cover at different altitudes for different values of the melt factors, during years 2005-2008, when weather data from EVK2CNR stations were available, and also MODIS SCA data could be retrieved. We then compared the estimated snow cover depth, or snow water equivalent SWE (including no snow) against SCA given by MODIS images for 2006-2008. Year 2005 was not considered, because no information about snowfall during the antecedent Fall was available to be used as a boundary conditions. We then estimated a best value for the snow melt factor, as the one providing the best correspondence in term of SCA variation, and snow depletion period.

The hydrological model

We used a semi-distributed altitude belts based model (Exhibit 53), able to reproduce deposition of snow and ablation of both ice and snow, evapotranspiration, recharge of groundwater reservoir, discharge formation and routing to the control section (Groppelli et al., 2011; Bocchiola et al., 2011). This simple model needs a few input data, i.e. a DEM, daily values of precipitation and temperature, information about soil use, vertical gradient of temperature and precipitation and some others parameters.

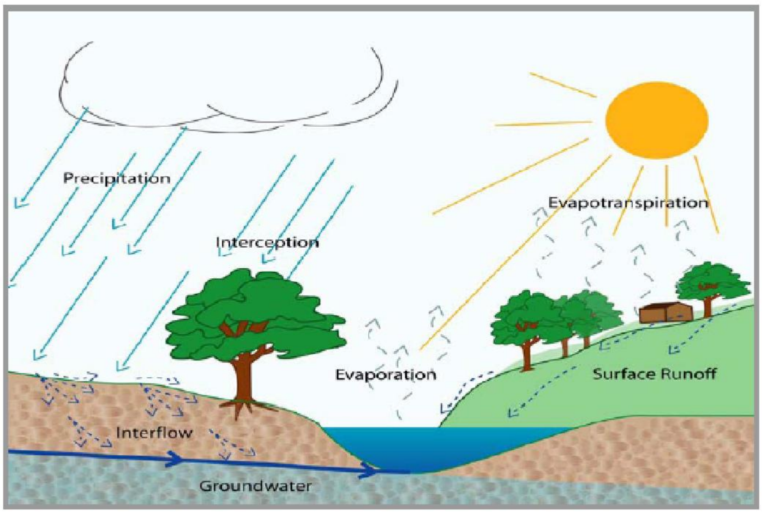


Exhibit 53 Scheme of main hydrological processes.

The model is a simplified version of model DHM, Distributed Hydrological Model (Wigmosta et al., 1994; Chen et al., 2005). In this model are considered two mechanism of flow formation: superficial and groundwater. The model is based on mass conservation equation and evaluates for each time step the variation of the soil water content in the ground layer. Soil water content S in two consecutive time steps (t, t+Δt), is

$$S^{t+\Delta t} = S^t + R + M_s + M_i - ET_{eff} - Q_g,$$

with R the liquid rain, Ms snowmelt, Mi glacial ablation, ETeff the effective evapotranspiration, and Qg groundwater discharge. Snowmelt Ms and glacial ablation Mi are estimated according to a degree day method

$$M_s = D_{Ds}(T - T_t),$$

$$M_i = D_{Di}(T - T_t),$$

with T daily mean temperature, DDs and DDi melt factors, evaluated as reported above, and Tt threshold temperature, Tt = 0 °C (Bocchiola et al., 2010). Degree day plus melt factor is a simple and parsimonious method for assessment of ablation and floods in mountain catchments, and it is used here accordingly (Singh et al., 2000; Hock, 2003; Simaityte et al., 2008). Ice melt occurs upon glacier covered area within each belt (Exhibit 4.5), after snow depletion is complete. The superficial flow Qs occurs only for saturated soil

$$\begin{aligned} Q_s &= S^{t+\Delta t} - S_{Max} \quad && if \; S^{t+\Delta t} > S_{Max} \\ Q_s &= 0 && if \; S^{t+\Delta t} \leq S_{Max} \end{aligned},$$

with SMax greatest potential soil storage [mm]. Potential evapotranspiration is calculated using Hargreaves equation, only requiring temperature data and monthly mean temperature excursion

$$ETP = 0.0023 S_0 \sqrt{DT_m}\,(T + 17.8),$$

in mmd-1, where S0 [mmd-1] is the evaporating power of solar radiation (depending upon Julian date and local coordinates), and DTm [°C] is the thermometric monthly mean excursion. Once potential evapotranspiration is known, effective evapotranspiration ETeff can be calculated. ETeff is made of effective evaporation from the ground Es and of effective transpiration from the vegetation Ts, both functions of ETP via two coefficients α and β, depending on the state of soil moisture (water content, given by S/SMax) and from the fraction of vegetated soil (fv) upon the surface of the basin (see e.g Chen et al., 2005)

$$Es = \alpha(\theta)\, ETP\, (1 - f_v)$$

$$Ts = \beta(\theta)\, ETP\, f_v,$$

with

$$\alpha(\theta) = 0.082\theta + 9.173\theta^2 - 9.815\theta^3$$

$$\begin{aligned} \beta(\theta) &= \frac{\theta - \theta_w}{\theta_1 - \theta_w} \quad && \text{if} \quad \theta > \theta_w \\ \beta(\theta) &= 0 && \text{if} \quad \theta \leq \theta_w \end{aligned},$$

Where θ_w is wilting point water content, while $\overline{\theta_1}$ is water content at field capacity. Actual evapotranspiration is then

$$ET_{eff} = Es + Ts.$$

Groundwater discharge is here simply expressed as a function of soil hydraulic conductivity and water content (see e.g. Chen et al., 2005)

$$Q_g = K\left(\frac{S}{S_{Max}}\right)^k,$$

with K saturated permeability and k power exponent. Equations (3-10) are solved using ten equally spaced elevation belts inside the basin. The flow discharges from the belts are routed to the outlet section through a semi-distributed flow routing algorithm. This algorithm is based upon the conceptual model of the instantaneous unit hydrograph, IUH (e.g. Rosso, 1984). For calculation of the in stream discharge we hypothesize two (parallel) systems (groundwater, overland) of linear reservoirs (in series) each one with a given number of reservoirs (ng and ns). Each of such reservoirs possesses a time constant (i.e. kg, ks). We assumed that for every belt the lag time grows proportionally to the altitude jump to the outlet section, until the greatest lag time (i.e. Tlag,g = ngkg for the groundwater system and Tlag,s = nsks for the overland system). So doing, each belt possesses different lag times (and the farther belts the greater lag times).

The hydrological model uses a daily series of precipitation and temperature from one representative station, here Askole, and the estimated vertical gradients to project those variables at each altitude belt. Topography is here represented by a DTM model, with 500 m spatial resolution, derived from ASTER (2006) mission, used to define altitude belts and local weather variables against altitude.

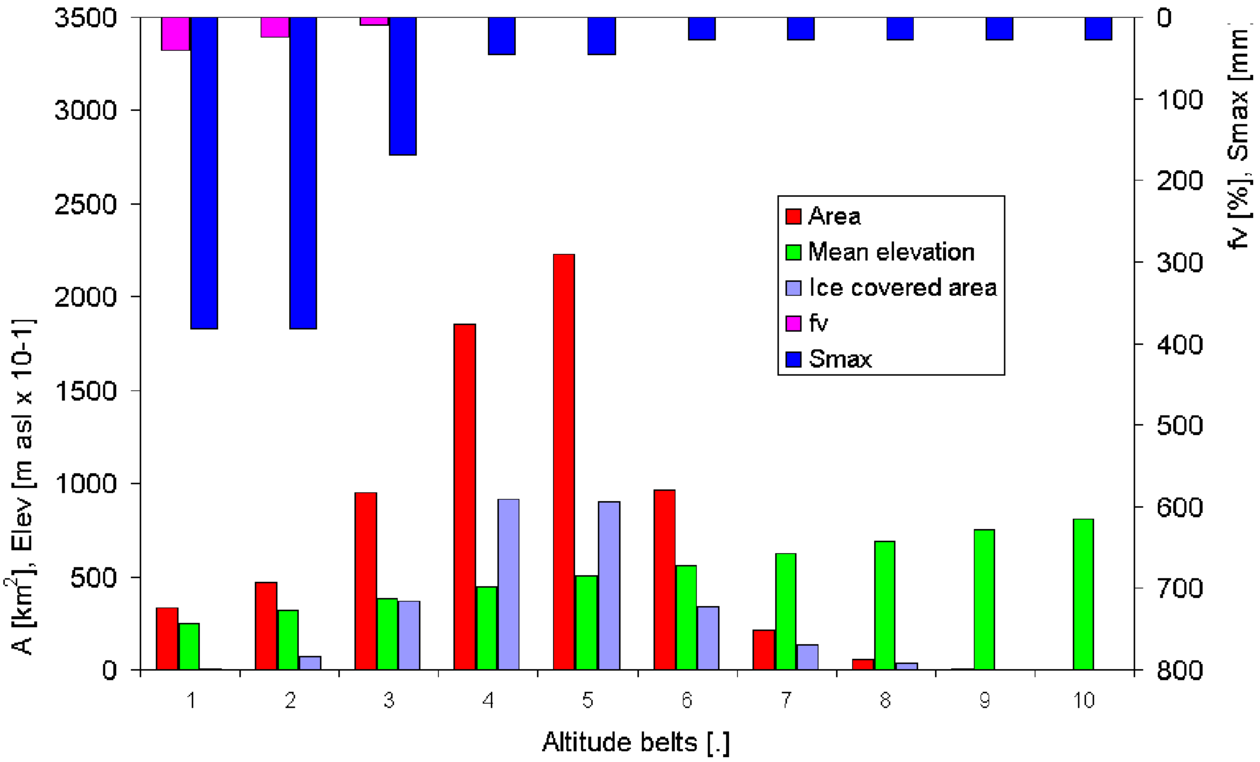


Exhibit 54 Main features of the hydrological model altitude belts.

Hydrological model calibration

As reported above, we synthetically simulated daily series of temperature and precipitation for 1985-1997 by disaggregation of monthly values. We feed these data to our model, to obtain daily estimates of in channel discharge at Shigar bridge. We subsequently evaluate monthly mean discharges, which we then average during 1985-1997. So doing, we can compare mean monthly simulated discharges against their observed counterparts. As reported, discharge under this form is only available to us. Whenever daily, or monthly discharges for the area would be made available to us, we could compare those path wise against model simulated discharges.

In Table 16 they are specified the parameters that were effectively used for the calibration, and those that were estimated on the basis of preliminary considerations and of the analysis of the available literature. Among the model parameters, the value of SMax is of considerable interest, since it drives the production of overland flow. If one compares this parameter to the parameter S of the method SCS-CN, which possesses the analogous meaning of maximum soil storage, it is possible to estimate in the first instance the value of SMax based upon that method. Analysis of the land cover of the area (mostly shallow soils, bare rock and ice) from satellite images (visible), plus the geological maps (on a paper support) allowed us to define reasonable CN values for each belt, thus making it possible to evaluate SMax.

The wilting point for the (scarce) vegetated areas $\theta w = 0.15$ was chosen based upon available references (Chen et al., 2005; Wang et al., 2009). The field capacity was set to $\theta l = 0.35$, using an average value for mixed grounds, according to studies on a wide range of soils (e.g. Ceres et al., 2009).

Often the number of reservoirs in the overland flow phase depends on the morphology of the basin, expressed e.g. through morphometric indexes (e.g. Rosso, 1984). However, an analysis of the values observed within several studies indicates an average value of ns = 3, which we use here. In analogy, the number of groundwater reservoirs may be linked to the topography, and we set ng = 3.

Results

From Exhibit 55, it is seen how the model fairly well represents monthly discharge as measured during 1985-1997, with Exhibit 56 displaying daily discharges at Shigar specifically during year 2012. From Exhibit 55, and 56 hydrological components of the Shigar river are clearly visible. Considerable stream flows start during June, peaking in July/August, with negligible flows already in November. Snow melt provides considerable contribution (up to 50%) to in stream discharge always but during Summer. Ice melts starts during Spring, and may reach a share of 805 or more during late Summer, then decreasing until December. Rainfall provides a considerable share of runoff during Winter and Spring. Globally, it is clear how Shigar river hydrological regime is regulated by snow and ice melt amount and timing.

The results shown here can be qualitatively extended to the whole CKNP area. In fact, Shigar river closed at Shigar cover an area of 6900 km2 ,with 2700 km2 of ice cover, i.e. 38% or so.

The CKNP park, embedding most of the Shiga river, covers an area of ca. 12000 km2, with ca. 4600 km2 covered in ice, again 38% or so (Minora et al., 2013). We may thus postulate that hydrology of the CKNP area is substantially depending upon snow and ice amount and timing of melt, and that our results concerning Shigar river may be preliminarily extended to the whole CKNP area.

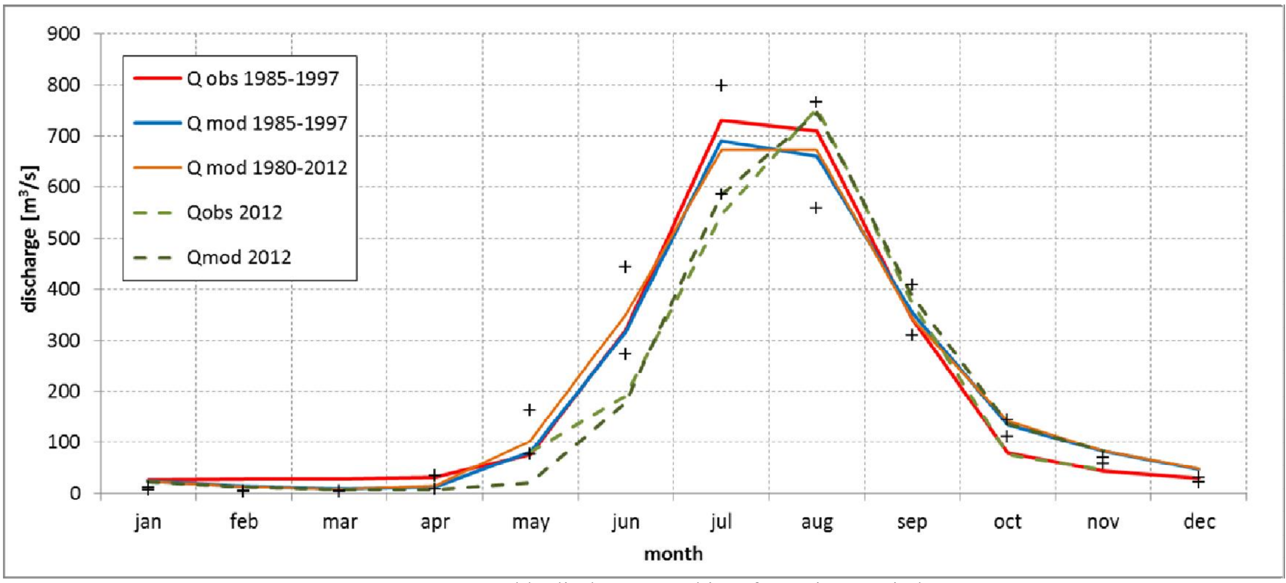


Exhibit 55 Monthly discharges at Shigar for various periods.

Table 16 Results of hydrological model calibration. Monthly discharges.

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	average
observed 1985-1997	26.07	27.76	28.55	31.81	76.47	319.42	729.21	710.09	343.53	78.71	44.13	29.05	**203.73**
model 1985-1997	24.05	13.43	8.72	12.78	81.27	316.22	690.03	659.95	355.54	134.27	82.60	46.61	**202.12**
model 1980-2012	24.07	13.23	8.49	14.60	102.16	350.68	672.78	672.71	341.39	142.38	83.61	47.24	**206.11**
observed Shigar 2012	-	-	-	-	80.98	190.63	544.93	753.20	373.54	76.36	45.00	-	**294.95**
model Shigar 2012	22.13	12.16	7.24	7.57	21.21	177.61	583.76	746.11	387.16	136.55	82.80	-	**305.03**

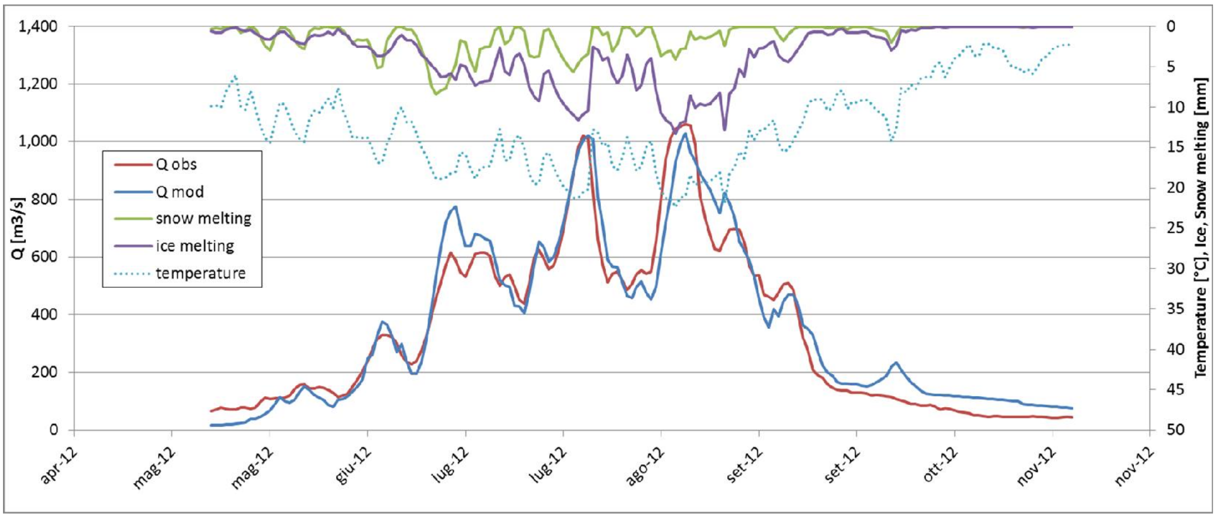


Exhibit 56 Daily discharges at Shigar during year 2012.

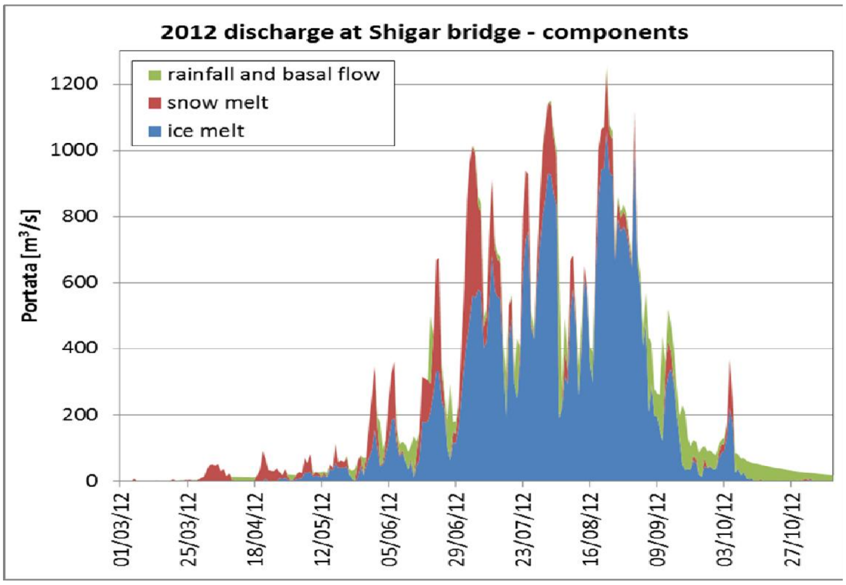


Exhibit 57 Estimated contribution of ice melt, snow melt and rainfall flows to daily discharges at Shigar, year 2012.

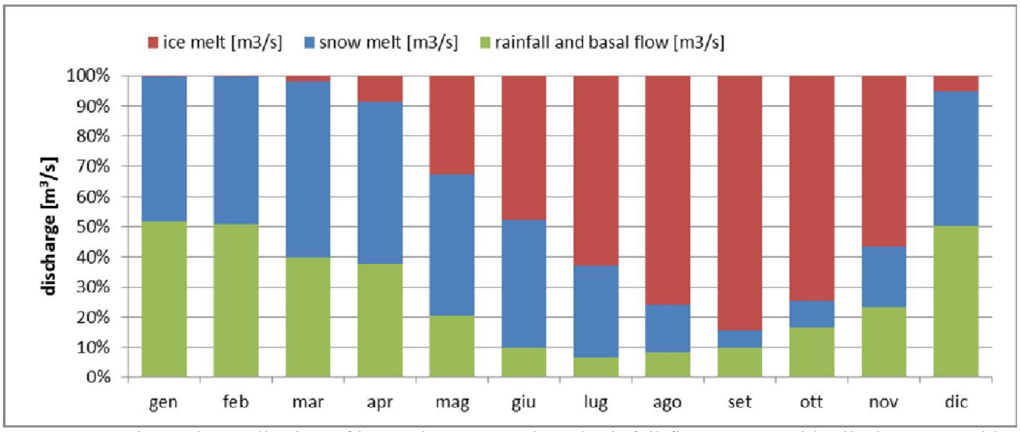


Exhibit 58 Average estimated contribution of ice melt, snow melt and rainfall flows to monthly discharges at Shigar, period.

3.1.3 Hydrological projections pending climate change

Introduction and methods

Water resources assessment exercise needs be carried under climate change scenarios. This requires use of the properly calibrated hydrological model, which will take a inputs future climate scenarios. This requires at least three types of information

i) Historical reference data base (at least 30 years backward): weather and possibly hydrometric data, including at least temperature, precipitation, discharge, should be available for thirty years backward or so. This is necessary to i) identify recent trends of weather and water resources, ii) benchmark outputs of control runs from GCMs models, and iii) project hydrological cycle under the what if hypothesis of future trends mirroring past ones, i.e the simplest hypothesis for climate projections.

ii) Data from GCMs: control runs, projections: General circulation models GCMs suggested by IPCC can be used to provide future climate scenarios. Ideally, one should choose those GCMs which provide the control runs (i.e. simulations of the past climate) closer to observed climate locally. Under the hypothesis that reasonable coincidence may remain valid in the future, GCMs projections under the IPCC storylines (or RCP, 2.6, 4.5, 8.5, etc..) can be used

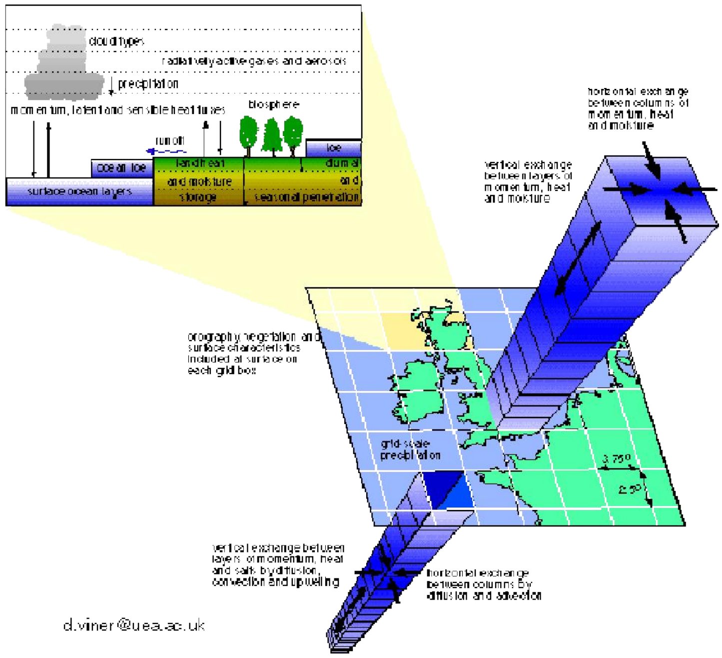


Exhibit 59 Scheme of GCM model grid and processes

iii) Locally tailored downscaling schemes: because GCM do not respect small scale climate variability, especially enhanced within mountainous area, locally tailored downscaling is required. This is especially true for precipitation, which exhibits high non linearity and non homogeneity in space and time.

To evaluate prospective hydrological cycle of the Shigar River, we downscaled three different GCM models' outputs of precipitation and temperature. A random cascade approach (e.g. Groppelli et al., 2011) is used to obtain ground precipitation at day i

$$R_i = R_{CCSM3,i} Y_i = R_{CCSM3,i} B_i W_i$$
$$P(B_i = 0) = 1 - p_i$$
$$P(B_i = p_i^{-1}) = p_i$$
$$E[B_i] = p_i^{-1} p_i + 0(1 - p_i) = 1$$
$$W_i = e^{(w_i - \sigma_{wi}^2/2)}$$
$$E[W_i] = 1;\ w_i = N(0, \sigma_i^2)$$

,

with RCCSM3,i projected CCSM3 precipitation at day i, and cascade model symbols having the same meaning as in Eq. (2). Again, model setup is carried out using data at Askole station during 2005-2008, and lapse rate to carry out altitude correction. Downscaling of temperature is also carried out using data at Askole station. We used in practice a monthly averaged DT approach and vertical lapse rate as deduced before to project temperature at each belt.

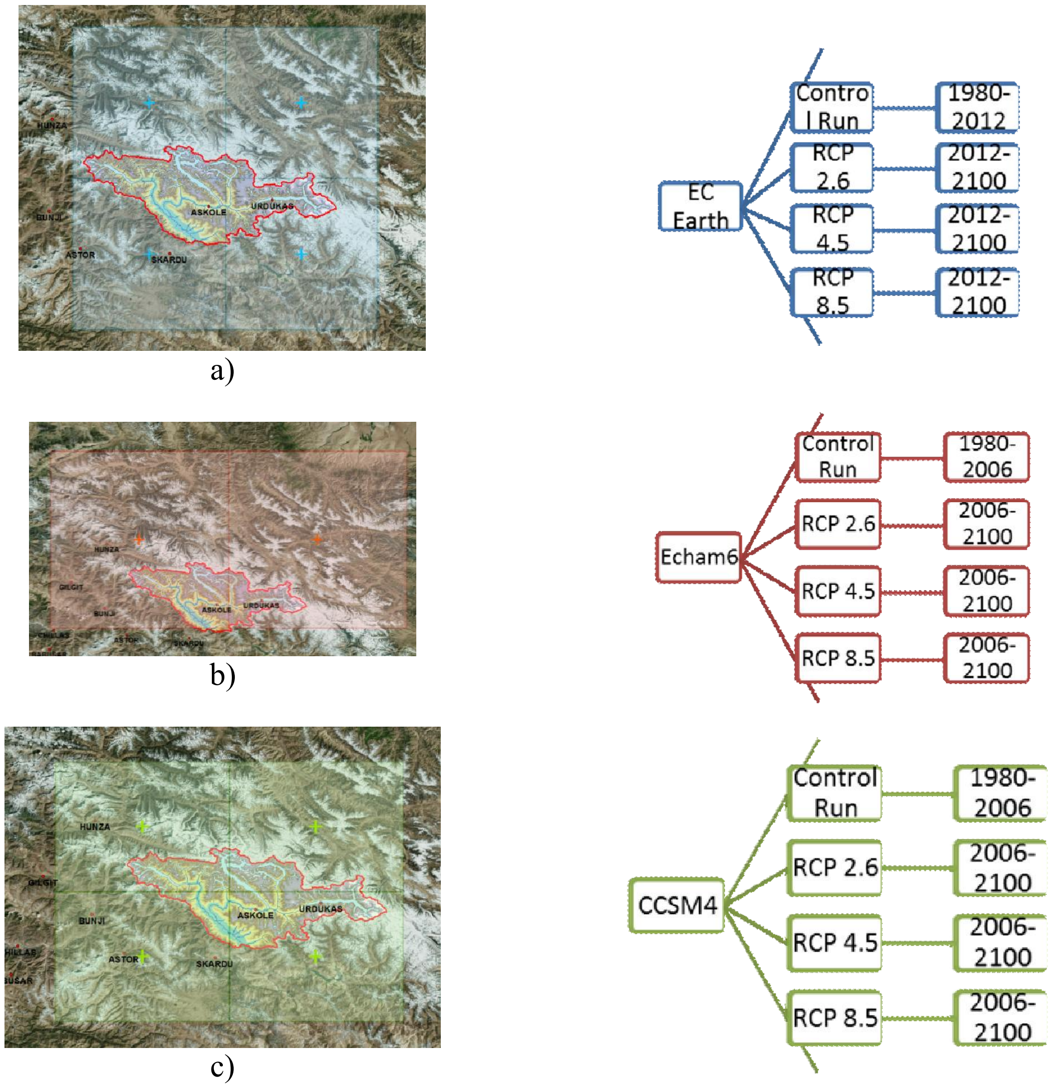
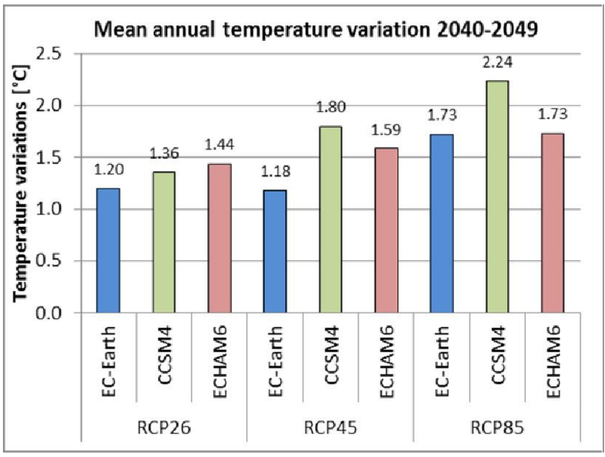


Exhibit 60 Adopted GCMs, ground footprint, and considered periods. a) EC-Earth model. b) ECHAM6 model, c) CCSM4 model.

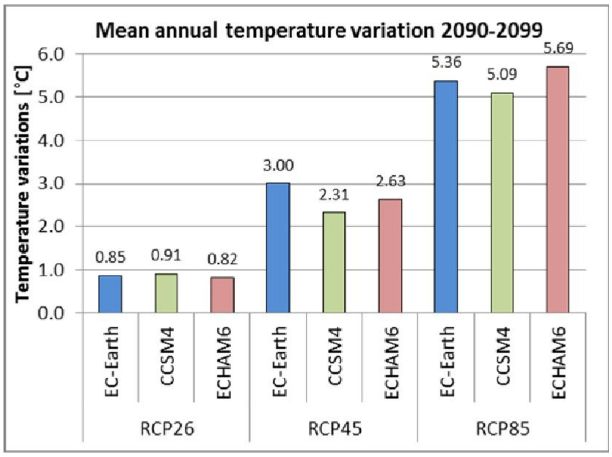
The adopted GCMs, all belonging to CMIP5 experiment, are reported in Exhibit 60.

Modified hydrological regime

In Exhibit 61 we report the mean annual variation (against 1980-2012) of temperature and precipitation as obtained from the chosen GCM models for two reference decades, 2040-2049 and 2090-2099, while in Table 17 and 18, the respective monthly values are reported.



a)



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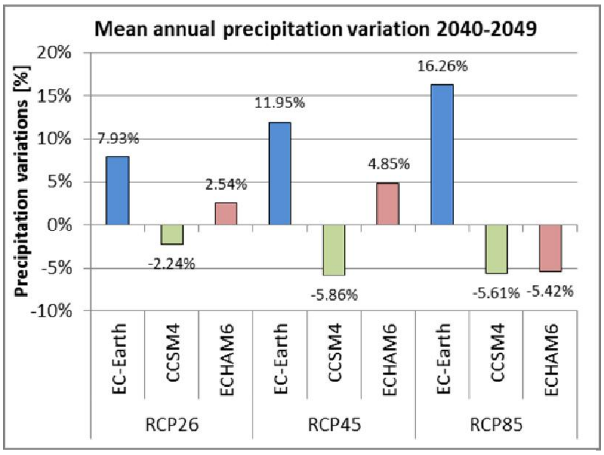

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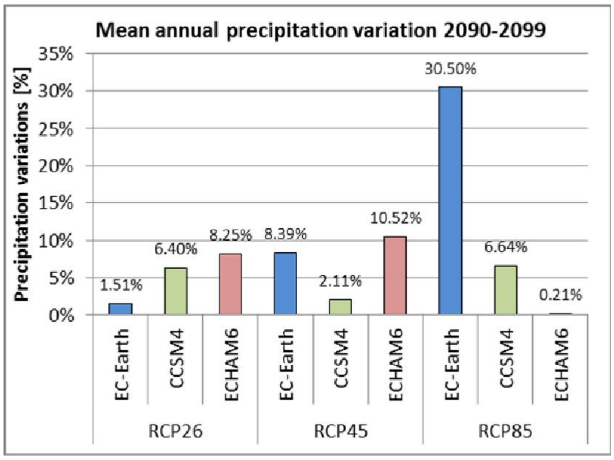


d)

Exhibit 61 Mean annual variation (*vs* 1980-2012) of temperature and precipitation for two reference decades. a) Temperature 2040-2049 b) Temperature 2090-2099, c) Precipitation 2040-2049. d) Precipitation 2090-2099.

While temperature always increase (up to +2.24 °C during 2040-2049, and to 5.69 during 2090-2099), precipitation may either increase or decrease (from -5.86% to + 16.26) at mid century. Increased precipitation is envisioned for the end of the century (up to 30.5%).

Table 17 Monthly temperature variation, 2040-2049, 2090-2099.

TEMPERATURE			jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2040-2049	RCP26	EC-Earth	1.32	1.00	0.50	1.42	1.27	-0.61	1.34	1.31	0.95	1.39	2.80	2.19
		CCSM4	1.28	0.10	-0.33	-0.21	0.50	0.72	1.71	1.73	2.72	2.97	2.83	2.13
		ECHAM6	1.52	0.61	1.38	1.40	0.82	1.19	2.18	1.06	1.66	1.74	2.17	1.44
	RCP45	EC-Earth	0.89	1.86	1.54	0.45	0.92	1.68	2.02	1.95	2.05	1.75	-0.41	-0.01
		CCSM4	2.28	0.37	0.97	0.30	1.29	0.86	1.55	2.08	2.59	3.68	3.06	2.37
		ECHAM6	0.51	1.31	1.74	1.89	1.21	1.23	2.42	1.92	1.79	2.99	1.52	0.50
	RCP85	EC-Earth	1.64	1.57	1.80	2.19	1.91	1.75	0.76	1.00	2.58	2.35	2.05	1.65
		CCSM4	2.31	1.10	0.62	0.85	2.31	1.53	2.05	2.76	3.59	3.93	2.90	2.73
		ECHAM6	0.96	0.87	1.36	1.75	0.92	1.39	2.28	1.78	2.90	2.76	2.10	1.71
2090-2099	RCP26	EC-Earth	1.57	0.67	1.06	-0.34	1.88	0.40	0.94	1.15	0.82	0.88	-0.47	2.04
		CCSM4	0.47	0.66	0.27	0.35	-0.15	-0.61	0.72	1.25	2.64	2.19	2.08	0.98
		ECHAM6	-0.13	0.58	1.27	1.46	0.67	0.29	1.55	0.78	0.79	1.51	0.87	0.15
	RCP45	EC-Earth	3.61	3.28	2.36	2.87	3.01	2.76	3.13	3.37	3.93	3.19	2.89	2.14
		CCSM4	2.57	2.04	1.55	0.86	1.22	1.30	2.18	2.73	3.68	4.12	2.67	2.72
		ECHAM6	3.20	1.91	3.04	2.22	1.52	2.12	3.22	2.38	3.06	2.93	2.92	3.00
	RCP85	EC-Earth	4.02	3.79	5.91	5.69	5.29	4.65	5.08	5.97	5.68	6.57	6.78	5.29
		CCSM4	4.62	4.43	2.96	3.61	4.64	3.66	5.14	5.69	6.76	8.39	5.46	5.57
		ECHAM6	5.78	4.91	5.15	5.05	4.54	6.06	6.69	5.46	5.78	6.15	6.46	6.12

Table 18 Monthly precipitation variation, 2040-2049, 2090-2099.

PRECIPITATION			jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2040-2049	RCP26	EC-Earth	13.4%	9.2%	22.4%	-10.6%	10.4%	23.5%	6.2%	16.0%	24.4%	-15.1%	5.0%	-20.7%
		CCSM4	-26.8%	14.8%	-31.9%	24.7%	-5.4%	-8.3%	2.8%	37.1%	-20.7%	-63.0%	75.7%	-14.0%
		ECHAM6	13.0%	-34.5%	25.8%	-12.8%	38.8%	0.4%	-6.2%	-5.0%	18.0%	-48.4%	-23.2%	22.0%
	RCP45	EC-Earth	10.8%	44.5%	4.9%	43.2%	-17.0%	-8.4%	14.5%	3.1%	-2.2%	50.5%	-27.6%	-4.4%
		CCSM4	54.9%	8.6%	-9.7%	22.3%	-23.9%	33.9%	-12.2%	-53.8%	-40.2%	-49.5%	-59.6%	-24.2%
		ECHAM6	10.3%	19.0%	-14.3%	3.1%	34.5%	-41.6%	-20.7%	16.0%	12.2%	-12.4%	-6.2%	33.8%
	RCP85	EC-Earth	17.0%	7.2%	-16.2%	46.8%	6.9%	11.7%	72.2%	2.2%	10.5%	34.8%	-40.8%	46.1%
		CCSM4	5.7%	14.2%	-28.5%	6.5%	-1.8%	51.2%	-21.4%	-17.0%	-22.3%	-30.1%	-35.9%	0.1%
		ECHAM6	-17.6%	-13.4%	-16.9%	-17.0%	26.0%	-29.3%	-8.5%	12.6%	-9.7%	19.2%	-27.4%	29.0%
2090-2099	RCP26	EC-Earth	8.0%	21.6%	-8.9%	23.0%	-45.5%	48.3%	-2.7%	10.3%	0.8%	21.0%	-31.8%	-14.2%
		CCSM4	36.1%	1.3%	-16.4%	55.6%	9.5%	-24.0%	1.2%	1.1%	-17.5%	-27.5%	-39.2%	11.2%
		ECHAM6	10.1%	-24.1%	17.6%	-14.6%	10.0%	-18.4%	6.5%	5.3%	2.0%	103.3%	-9.9%	64.4%
	RCP45	EC-Earth	-25.3%	28.1%	-18.0%	11.6%	15.5%	37.4%	22.9%	-10.8%	-17.0%	33.2%	-34.7%	76.6%
		CCSM4	5.8%	6.2%	0.2%	40.9%	-9.7%	-11.1%	-5.2%	-17.0%	-24.1%	-26.6%	-29.3%	15.0%
		ECHAM6	-32.5%	-0.5%	15.5%	24.5%	56.1%	-11.4%	1.9%	9.3%	-8.7%	-5.7%	-0.6%	4.1%
	RCP85	EC-Earth	36.8%	13.7%	70.0%	42.7%	9.0%	30.9%	39.1%	-27.9%	-11.5%	28.0%	-1.4%	93.2%
		CCSM4	-1.8%	-39.7%	-19.0%	27.0%	55.8%	102.8%	-30.9%	17.4%	-6.2%	-6.1%	-27.3%	8.5%
		ECHAM6	22.2%	-34.3%	-2.5%	-15.3%	24.2%	-2.0%	-10.6%	-1.6%	62.5%	48.9%	-85.7%	22.8%

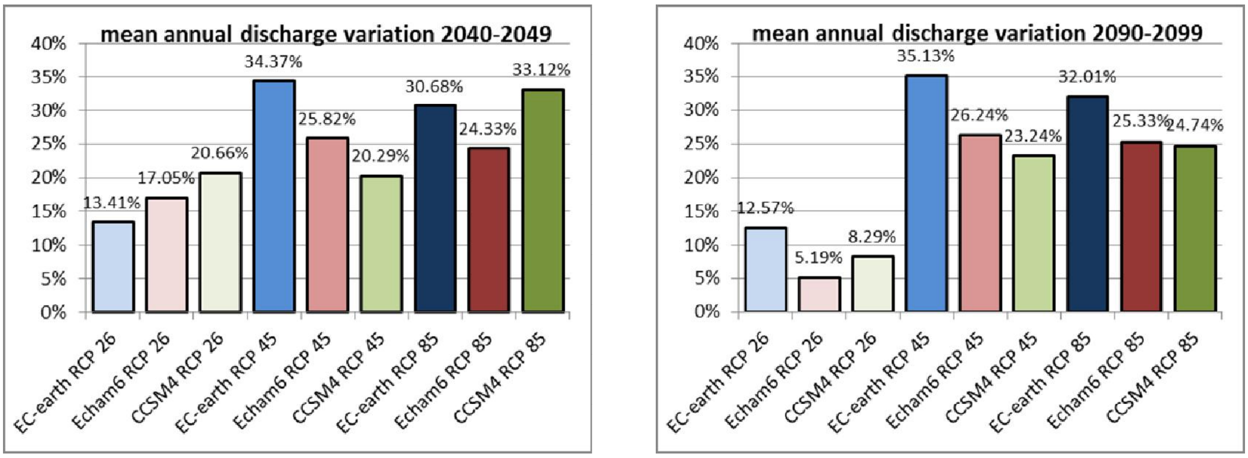
In Table 19 we report the corresponding hydrological simulation, i.e. the yearly average discharge, while in Exhibit 62 we report the expected changes (against 1980-2012) in average yearly projected discharge, 2040-2049, 2090-2099.

In Exhibit 63 it is reported the monthly mean discharge at Shigar river as projected by EC-Earth model for the three different RCP scenarios. In Exhibit 64 we report the monthly contribution of ice and snow melt at Shigar according to EC-Earth model.

Table 19 Average yearly projected discharge, 2040-2049, 2090-2099.

	Simulation	Mean discharge [m³/s]
1980-2012	Calibration 1980-2012	206.110
2040-2049	EC-earth RCP 26	233.744
	Echam6 RCP 26	241.251
	CCSM4 RCP 26	248.689
	EC-earth RCP 45	276.948
	Echam6 RCP 45	259.325
	CCSM4 RCP 45	247.926
	EC-earth RCP 85	269.352
	Echam6 RCP 85	256.256
	CCSM4 RCP 85	274.372

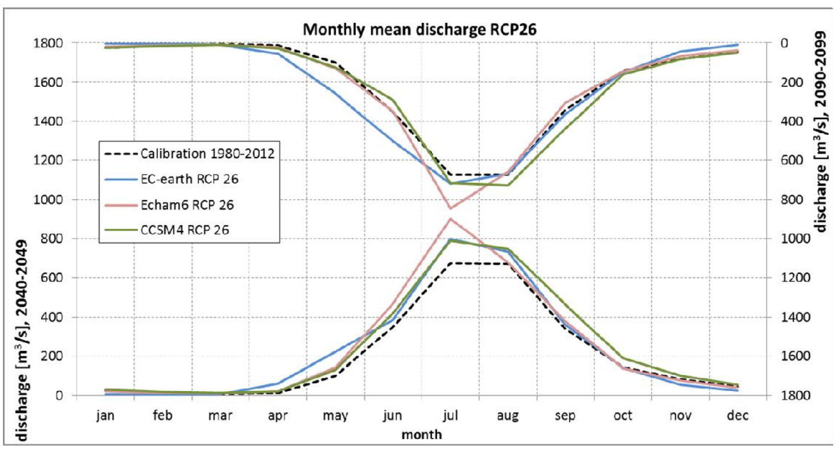
	Simulation	Mean discharge [m³/s]
1980-2012	Calibration 1980-2012	206.110
2090-2099	EC-earth RCP 26	232.0143
	Echam6 RCP 26	216.8158
	CCSM4 RCP 26	223.2081
	EC-earth RCP 45	278.5178
	Echam6 RCP 45	260.1996
	CCSM4 RCP 45	254.0167
	EC-earth RCP 85	272.096
	Echam6 RCP 85	258.3187
	CCSM4 RCP 85	257.1026



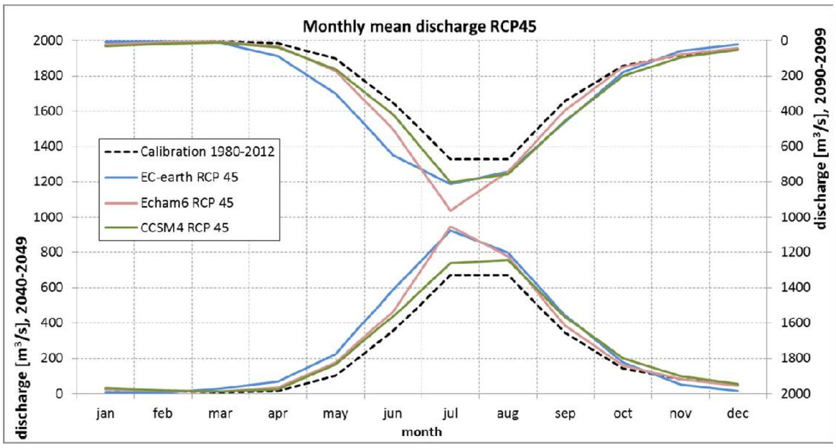
a) b)

Exhibit 62 Expected changes (against 1980-2012) in average yearly projected discharge, 2040-2049, 2090-2099.

Yearly discharges are projected to increase at mid century (up to +34.37%), but tend to stabilize at the end of the century (+35.13% max). Monthly discharge (Exhibit 63) is always larger than presently.



a)



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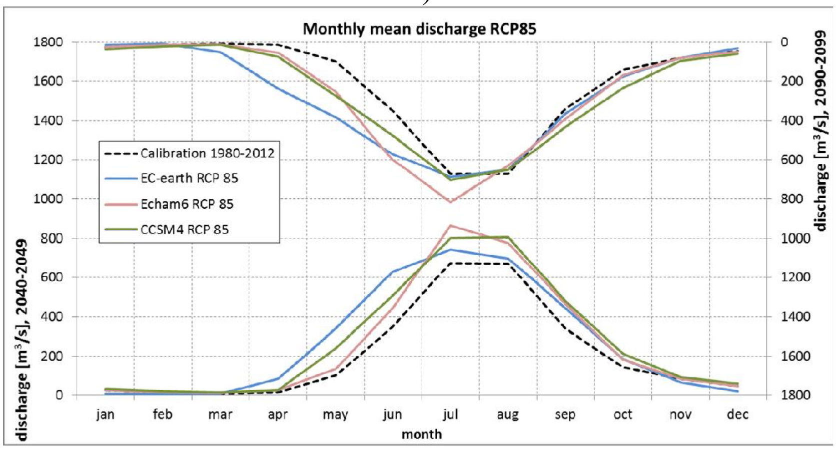
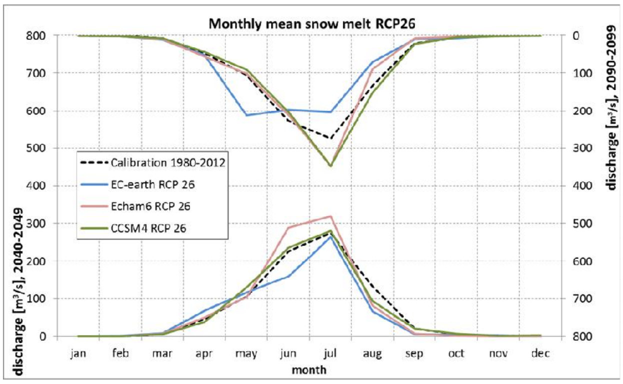
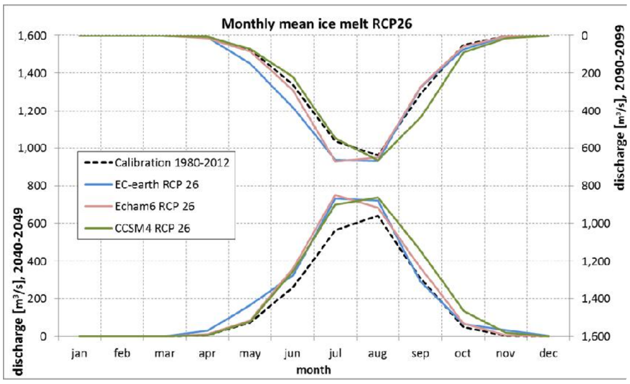


c)

Exhibit 63 Monthly projected discharge at Shigar, 2040-2049, 2090-2099. a) RCP 2.6. b) RCP 4.5. c) RCP 8.5



a)



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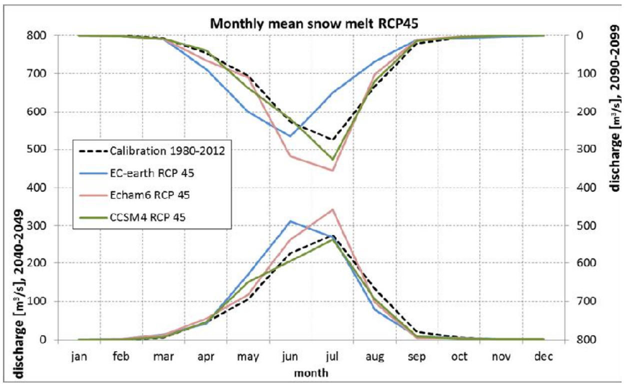

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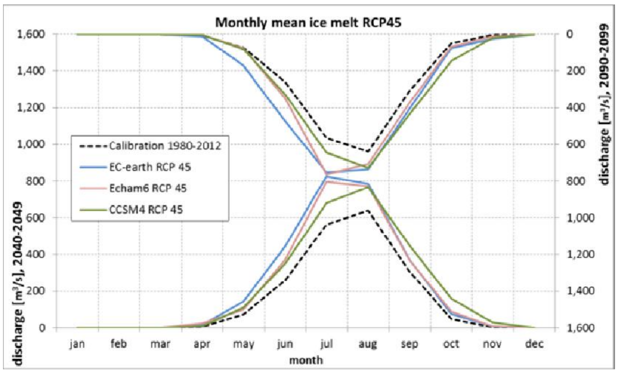

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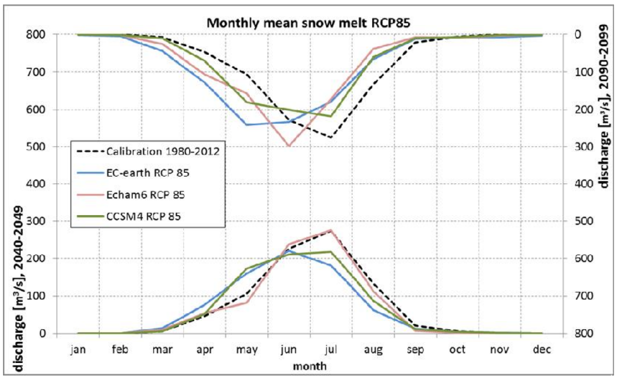

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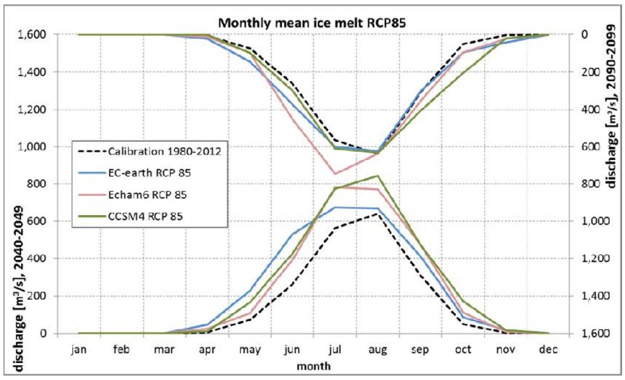
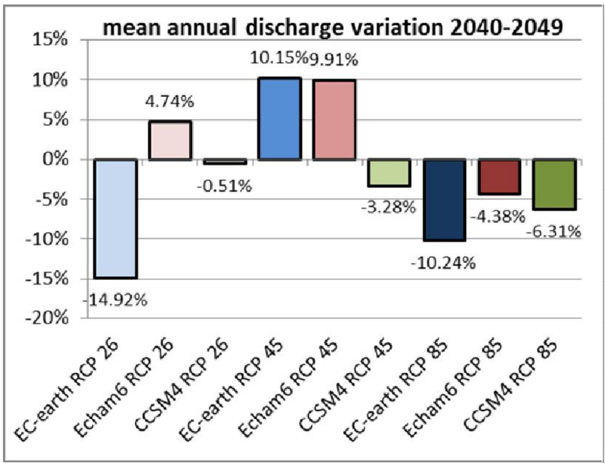
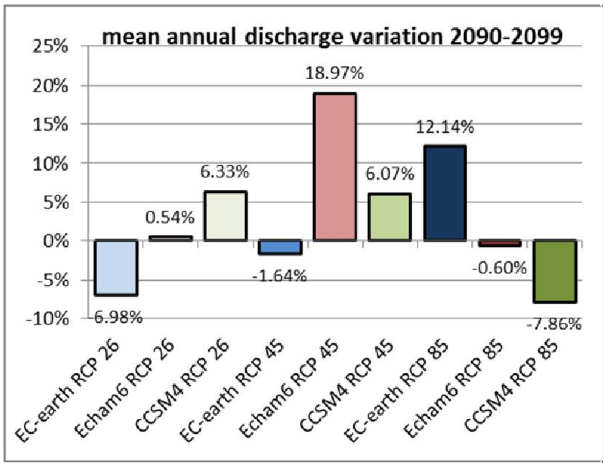


f)

Exhibit 64 Monthly contribution of ice and snow melt at Shigar according to EC-Earth model. a) Snow melt RCP 2.6. b) Snow melt RCP 4.5. c) Snow melt RCP 8.5. d) Ice melt RCP 2.6. e) Ice melt RCP 4.5. f) Ice melt RCP 8.5.



a)



b)

Exhibit 65 Expected changes (against 1980-2012) in average yearly projected contribution of snow melt to instream flows at Shigar. a) 2040-2049. b) 2090-2099.

Snow contribution is projected to either decrease or increase (-14.92 to +10.15 during 2040-2049, and -7.86 to +18.97 during 2090-2099), depending upon balance of precipitation and temperature.

Ice contribution to in stream discharge will be higher during half century (up to 51.68%) than at 2068-2100 (max 39.65%). Exhibit 66 displays duration curves (i.e. days of exceedance for a given discharge) of projected discharges at Shigar.

Exhibit 67 displays the estimated average thickness of ice as per altitude belts within the shigar river for years 2045 and 2095, provided by the hydrological model by using a simplified ice balance algorithm. Clearly, while at half century ice volume will be only slightly decreased, as a balance of ice melting and glaciers' feeding from snoe precipitation, towards the end of the century, ice volume will be considerably decreased, giving reason of the decreased contribution of ice melt to in stream fluxes, and of potentially decreased discharge with respect to half century, as shown in Exhibit 62.

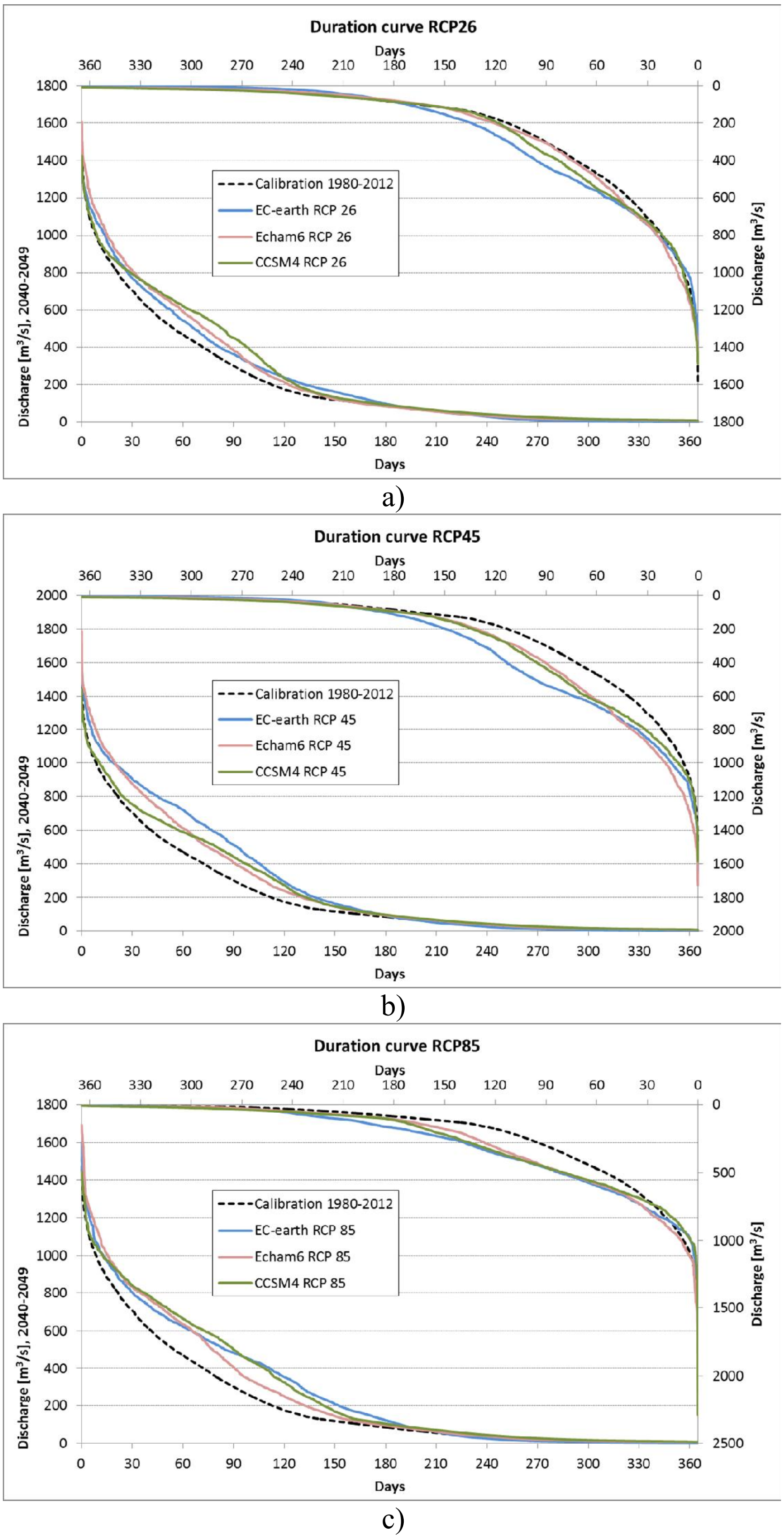
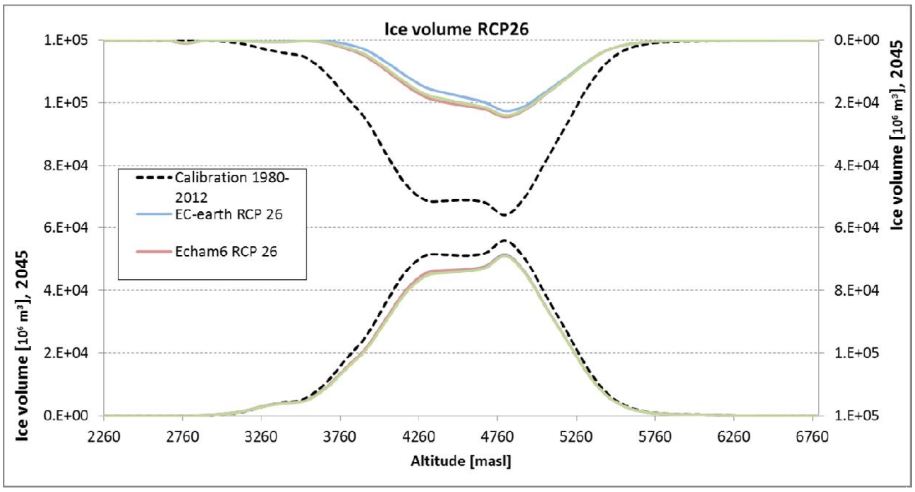
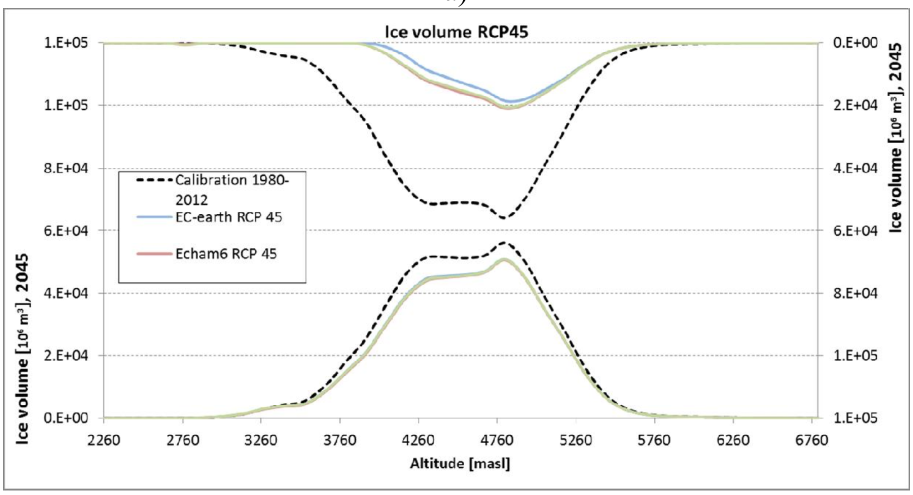


Exhibit 66 Duration curves of projected discharge at Shigar. a) RCP 2.6. b) RCP 4.5. c) RCP8.5. Left *y* axis 2040-2049. Right *y* axis 2090-2099.



a)



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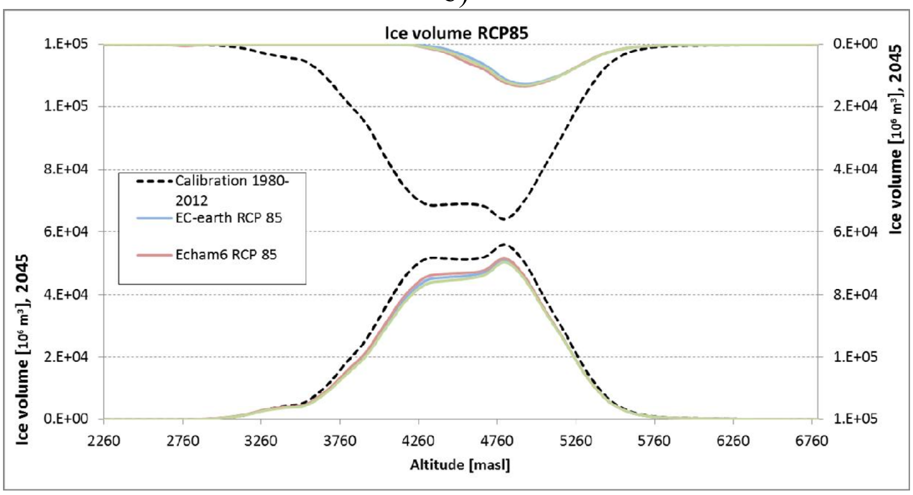


c)

Exhibit 67 Estimated ice volume as per altitude belts at year 2045 (left *y* axis) and at year 2095 (right *y* axis), against initial estimates during 1980-2012.

Modified flood regime

We evaluate here potential changes of flood regime under prospective climate change. We adopt annual flood series (AFS, e.g. Bocchiola et al., 2003; Bocchiola and Rosso, 2009) analysis based upon the simulations carried out using our hydrological model. For each year of the control run simulation (1980-2012) we extract the maximum value of (daily) flood discharge, so obtaining a sample of 33 yearly maxima. Based upon the theory of extreme values, we provide estimated return period for each value of the considered sample, and we fit an extreme value distribution (here, Generalized Extreme Value, GEV). Also, we estimate index flood value Qi, or expected value of maximum year flood, as

$$Q_{in} = E[Q_{AFS}] = \frac{1}{n}\sum_{j=1}^{n} Q_j ,$$

which provides the average magnitude of yearly flood peaks (Table 20). In Exhibit 68 find the so obtained distribution of extreme values, fitted according to a GEV distribution providing the flood peak discharge with return period T (years), as follows

$$Q(T) = Q_{in}\left\{\varepsilon + \frac{\alpha}{k}\left[1-\left(-\ln(1-1/T)\right)^{k}\right]\right\},$$

with ε, α and k GEV distribution parameters, empirically estimated from the data.

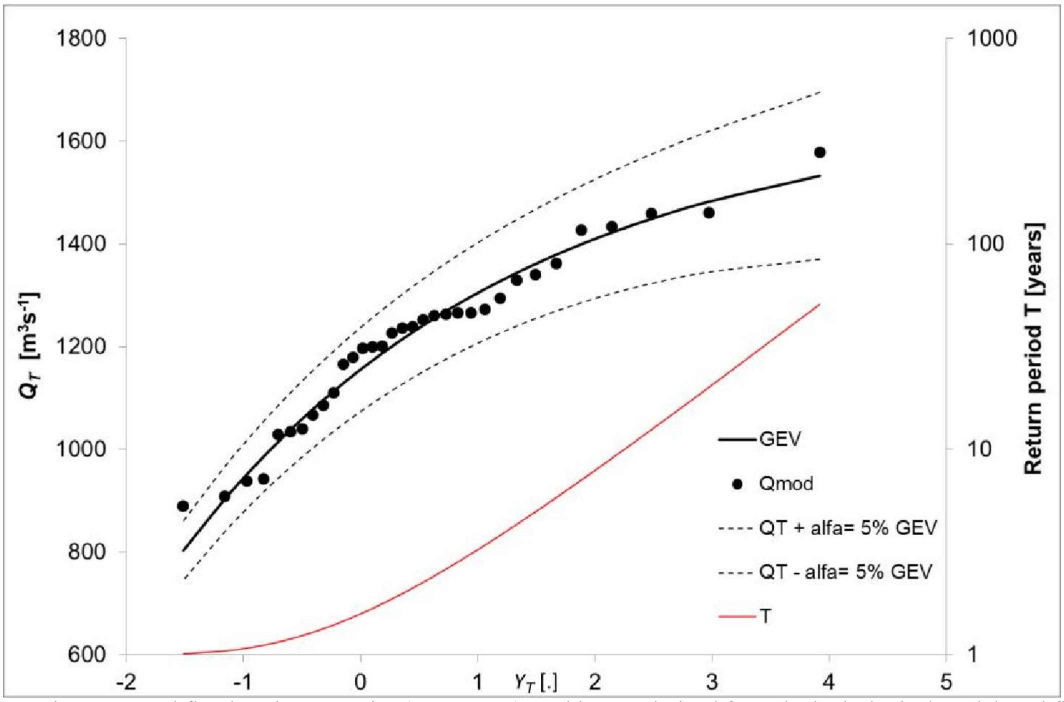


Exhibit 68 Maximum annual flood peak AFS series (1980-2012) at Shigar as derived from the hydrological model, and fitting using a GEV distribution.

Notice that such distribution is derived from peak flood values simulated using our hydrological model, so it should not be regarded as totally dependable. However, it provides a first order approximation of extreme flood distribution in the Shigar river, and can be used for comparison against flood regime under climate change scenarios.

In Exhibit 69 we report the estimated AFS values under climate change scenarios for 2024-2056, while in Exhibit 70 the AFS are reported as projected to 2068-2100. In Table 20 it is reported index flood Qin or mean value of maximum year flood.

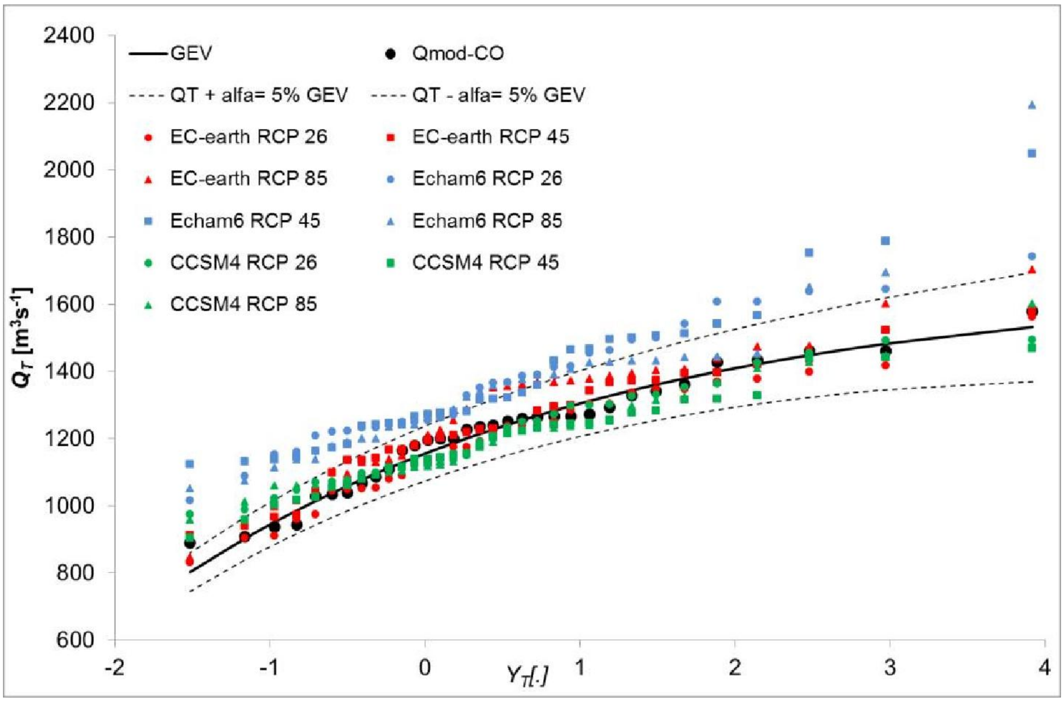


Exhibit 69 estimated AFS values for 2024-2056.

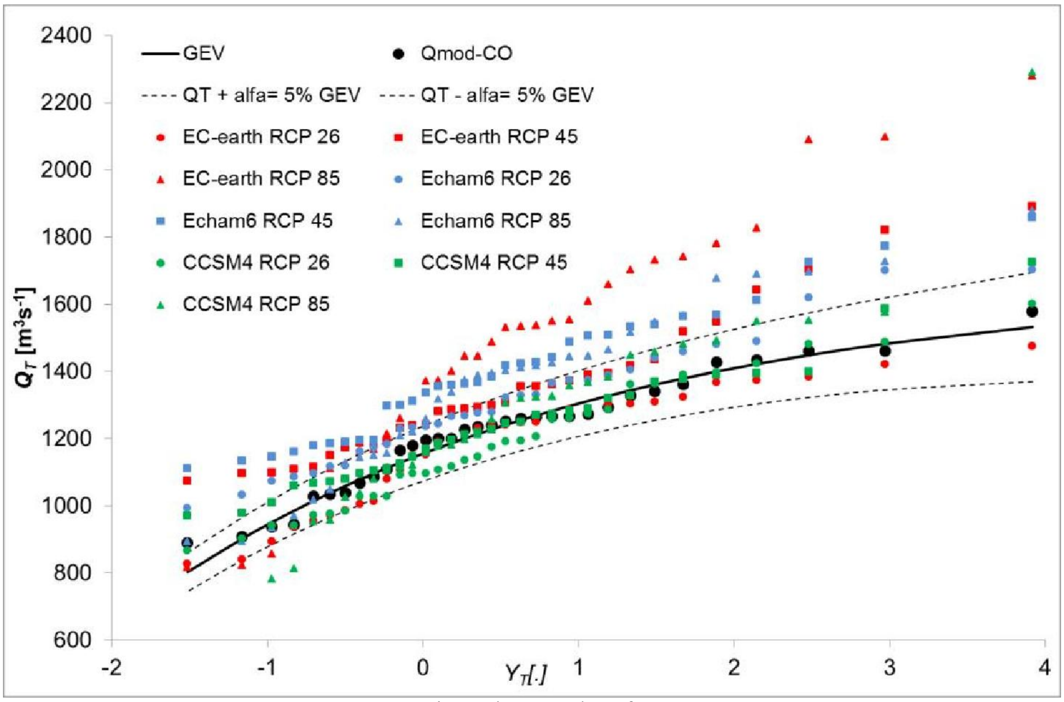


Exhibit 70 estimated AFS values for 2068-2100.

Table 20 Index flood value Q_i, expected value of maximum year flood, during control period and projected.

Q_{in} [m^{3}s^{-1}]	Period	EC-earth RCP 26	EC-earth RCP 45	EC-earth RCP 85	Echam6 RCP 26	Echam6 RCP 45	Echam6 RCP 85	CCSM4 RCP 26	CCSM4 RCP 45	CCSM4 RCP 85
CO	**2024/2056**	1186	1234	1268	1357	1368	1344	1208	1184	1198
1211	**2068/2100**	1177	1335	1440	1299	1393	1338	1176	1228	1230

From the comparison of Exhibit 69 and 70, one deduces that within the first half of the century flood peaks for assigned return period may remain unchanged, or significantly increase only according to ECHAM6 model, while towards the end of the century are more likely to increase.

3.1.4 Discussion

The results shown here for the Shigar river are paradigmatic for the CKNP, and provide some interesting insight into potential modification of hydrological regimes in the park under climate change as projected by the presently available IPCC models.

Future climate for the century in this area is projected to be warmer, and likely wetter, and ice bodies may be expected to start significant downwasting in the second half of the century.

As a result, a likely intensification of the hydrologicsl cycle will occur within the CKNP area. On the one hand, the hydrological regime of the CKNP will maintain its unimodal shape, driven by snow and especially ice melt, and monsoonal rainfall, thus providing acceptable water resources supply. On the other hand, larger floods will be likely to occur during the warm season.

Given that towards the end of the century glaciers will down waste considerably, it is to be assessed what the effect might be of a large loss of glacier volume, potentially occurring even after 2100.

Water management in the CKNP under the prospective situation as projected will therefore require increased attention to flood hazard assessment and flood emercengy planning and management.

Least downwasting of ice bodies is expected within the first half of the century, a trend possibly mirroring the peculiarity of the present “karakoram anomaly”. However, towards the end of the century, glaciers’ shrinkage is expected.

3.2 Water resources assessment

We report here suggestions for assessment of water resources in the CKNP, and their timing, based upon:

1) Installation of a hydrometric network;

2) Modeling of hydrological regime within the CKNP area. Given the utmost variable conditions of (natural) streams, there are no hydrological monitoring protocols that we know of, and measuring method has to be chosen depending upon ad hoc reasoning.

For the building of hydrological stations we propose here use of Eulerian methods (as we implemented for the two case studies catchments), that entail explicit assessment of flo geometry and velocity, rather than of simple volume as in non-Eulerian methods. Eulerian methods require measurement of:

• Flow velocity. Flow velocity is measured spot, and flow discharge is deduced from velocity and flow area $Q = V \cdot A$, and a stage-discharge curve is built.

• Flow depth. Flow depth is measured continuously, and flow discharge is estimated by way of stagedischarge curve.

A suitable (but not the only available) method for velocity measurements is Doppler flow meter flow tracker uses Doppler velocimetry to the measure fields of flow velocity in 3-D (XYZ), and estimate discharge through velocity/area (1 measure of speed at 0.6*h for h < 0.6 m, 2-3 points for h > 0.6 m, rules ISO-USGS).

The flow tracker is used with wading technique, and section geometry is calculated to allow extrapolation of the stage-discharge relationships, either by way of proper hydraulic (e.g. Manning) equations, or by polynomial interpolation.

Flow depth may be measured using a continuous monitoring device, such as a sonic gauge, or pressure transducer, depending upon the features of the measured stream. Some relevant traits may be highlighted for deployment of a hydro network, and some consideration can be drawn. Some main issues have to be verified in the realization of a hydrographical station to be inserted within a network, especially in this very high altitude region. Some of these issues can be thus schematized as follows, depending upon type of installed devices (i.e. sonic gauge or pressure transducer).

3) Easy accessibility of the interest sites, also considering the transport of material necessary to installation. The chosen sites may to coincide with the presence of roads near the river bed, and in particular in presence of narrow sections and bridges. Even when accessibility is given only by trails, accurate choice of the station site may be carried out so that they are more accessible. The necessary tools me be carried by porters during an expedition.

4) Instrumental functioning (e.g. intrinsic of the device, due to cold climate, and/or for suspension load, bed load). This is especially for pressure gauges, but applies also for sonic gauges, say if cables and other pieces are nearby the floodplains. The stations should be installed in a repaired as possible position, to decrease the chance of malfunctioning due to environmental conditions and hydraulic stressing, e.g. for high turbulence and solid load. However the stations will demand continuous monitoring, likely by CKNP staff, with regard to possible malfunctioning, but even for data downloading, etc.

5) Possible positioning in thalweg (i.e., at channel bottom, for pressure gauges). The pressure devices should be in the thalweg line, or lowest bed part, to avoid null reading of the sensor in presence of water. Positioning of the sensor in thalweg would however expose the sensor to current and solid load. So the device should be protected by use of hoses, either in plastic o metal, and shielded from the intrusion of sand and gravel.

6) Complicate installation by hanging, i.e. from bridges (sonic gauge). Mounting a sonic gauge may be complicated, due to the requie hanging frame. Also, presence of strong wind may hamper measurement by vibration or by moving the device. This needs be taken into account when planning installation.

7) Possible flow measurements by wading and/or tracer for bigger flow sections. Wading techniques are suitable for measurement of stream flows in mountain torrents of small size, or better with acceptable flow depth and velocity. The calibration of the stage-discharge equation is easier under these conditions. Use of tracer is suitable, but some knowledge of flow depth in the section is still necessary. For higher flows, as Shigar river here, cross section depth was taken, but flow velocity could only be established by use of float and stopwatch. In such case, more trials such be carried out, and surface velocity interpreted using hydraulic laws for flow velocity based upon logarithmic profiles.

8) Relative stability of morphologic conditions of the river bed, evolving in time, and modifying stage-discharge relationship. Flow measurements and section survey should be made at least yearly, at the onset of thaw season, to account for variation occurring during seasonal high flows. Ideally, for the most accessible sections, surveys should be done after each noticeable flood event. Also, because for high flows immersed devices (pressure gauges) may be damaged, maintenance is necessary therein.

9) Choice of a design discharge (i.e. for hydro-station dimensioning) for given frequency of occurrence. Ideally, a design flow discharge should be estimated whenever it is necessary to install a hydro-station, aimed to i) know the greatest flow conveyed in the section when it is naturally defined, ii) define the width of the section whenever artificial confinement would be necessary (e.g. by side walls). This could be done by way of critical flow design, pending the choice of a reference return period. Also, optimal design of the network may be dealt with further on, considering technical requirements, budget constrains, etc.

Concerning network building, i.e. (optimal) positioning of hydrometric stations, no unique solution is available. As a rule of thumb, one may consider at three targets, namely:

i) Installing a number of stations that allows monitoring all (or most) of the out-flowing streams from the target area (the CKNP here),

ii) Monitoring catchments of increasing size (i.e. basin order according e.g. to Horton-Strahler approach),

iii) Monitoring of especially interesting sections (e.g. glaciers here). However, the final choice is based upon subjective decision. Here, we propose, in Exhibit 57, and Table 40 a preliminary sketch for deployment of the network. The CKNP park is not a hydrologically closed area (i.e. the catchments therein do not join within the park). Because we imagine that all the hydro stations should dwell within the park's boundary, or at least reasonably close, we propose to install a number of stations which allows to measure water from the catchments out-flowing from the park at their outlet sections. This will allows assessment of water resources from the whole park area. Also, we suggest to monitor with special emphasis smaller catchments, at the outlet of some specially significant glaciers. Because most of water resources in the CKNP comes from glaciers, and ice bodies are very sensitive to climate warming, long term monitoring of such catchments seems utmost important. Shigar station, nearby the South border of the park, and Paiju station, at the front of Baltoro glacier, are also reported. We also indicate a highest and lowest priority, based upon catchment size and glaciers' presence, i.e. for expected amount of delivered water (the more water, the higher priority).

Albeit no real protocol is available for hydrological modeling, like for instance for meteorological data retrieval, it is possible to provide a sketch of the procedures and tools necessary for setting up a hydrological model of the area.

a) Hydrological model: this can be either lumped, semi-distributed or distributed, in order of complexity. Lumped models provide non spatially varying representation of hydrological processes, so they do not account for variations of climate in altitude, including temperature drift, etc. Semi-distributed (tipically, altitude belt based) models allow accounting for such variability, but not for fully distributed values. However, these models are normally computationally fast, and provide a good trade-off between representation of spatial variability, and short computational time. Fully distributed models give reason of full spatial variability (pending data availability), and are namely very complete tools. However, relatively high computational burden may be a liability, especially for large catchments (greater than 100 km2 or so). For the purpose of water resources assessment, daily simulation of stream flows is enough.

b) Stream flow data: these can be used for direct assessment of water resources, and for calibration/validation of the hydrological models. Notice that a semi-distributed or distributed hydrological model, once calibrated, can provide flow estimates for ungauged catchments interest, therefore increasing knowledge with respect to direct gauging.

c) SCA pictures: in mountain snow fed catchments, investigation of snow covered areas (SCA) by way of satellite data is utmost important. Indeed, use of SCA is widespread, as it provides a benchmark for snow cover dynamics simulation. Satellite SCA data at medium to moderate resolutions are now available easily at virtually no cost, and can be downloaded at least weekly (bundles) if not daily for the purpose of hydrological model calibration/validation.

d) Snow cover data: some information about snow cover depth and density is necessary for model setup. SCA pictures provide area coverage, but not absolute values. Also, snow depth data may provide indication of Winter accumulation, necessary for glaciers' feeding.

e) Ice cover data: glaciers' area cadastre is fundamental also for hydrological modeling, because the latter include ice melt and related discharge. Also, hydrological models can explicitly track ice cover in time, so that validation via ice area cover is necessary.

f) Ice melt data: seasonal melting of ice need be tracked for calibration of ice melt modules within hydrological models, and to track ice depth.

g) Weather data necessary, rainfall, temperature, radiation, evaporation, wind, air moisture: it is assumed that the CKNP will develop a meteorological network providing the necessary input data for the development of hydrological models. Minimal models, like the one developed by the author, and reported hereon, need only precipitation and temperatures. However, more sophisticated modeling requires more information.

h) Soil moisture data: information of soil moisture, say by way of time domain reflectometry TDR probes, may be used to infer soil storage, fundamental for hydrological modeling. Water resources assessment exercise may be also carried under climate change scenarios. This requires use of the properly calibrated hydrological model, which will take a inputs future climate scenarios. This requires at least three types of information.

i) Historical reference data base (at least 30 years backward): weather and possibly hydrometric data, including at least temperature, precipitation, discharge, should be available for thirty years backward or so. This is necessary to i) identify recent trends of weather and water resources, ii) benchmark outputs of control runs from GCMs models, and iii) project hydrological cycle under the what if hypothesis of future trends mirroring past ones, i.e the simplest hypothesis for climate projections.

j) Data from GCMs: control runs, projections: General circulation models GCMs suggested by IPCC can be used to provide future climate scenarios. Ideally, one should choose those GCMs which provide the control runs (i.e. simulations of the past climate) closer to observed climate locally. Under the hypothesis that reasonable coincidence may remain valid in the future, GCMs projections under the IPCC storylines (A1, A1B, A2, B1, B2, etc..) or RCPS under AR5 (RCP2.6, RCP4.5, RCP6.5, RCP8.5) can be used.

k) Locally tailored downscaling schemes: because GCM do not respect small scale climate variability, especially enhanced within mountainous area, locally tailored downscaling is required. This is especially true for precipitation, which exhibits high non linearity and non homogeneity in space and time.

Whenever real time flood forecasting would be of interest within the CKNP, some particular issues would need be faced. As a baseline, hydrological forecasting is based upon hydrological modeling carried out using real time weather data, or forecast of such data, which provides present (now-casting), or future (fore casting) flows. Depending upon combination of i) basin response time, and ii) lead time of forecast issuing, different approaches are needed. When lead time is smaller than response time, flood fore casting is carried out using hydrometric data and flood wave equations, so only hydrometric data are necessary. Conversely, with greater lead time than the response time, weather forecasting are needed. In the following we assume as a mere example that lead time is in the order of 12 hours.

l) Real time weather forecasting, rainfall, temperature: for small catchments, i.e. those with response time smaller than 12 hours or so, forecast of weather variables (at least temperature and rainfall) is necessary. Therefore, the CKNP should develop a system for assimilation of weather forecast in real time, and subsequent calculation of forecast discharges by way of the hydrological model

m) Real time hydrometric reading: use of implementing a real time hydrometric reading system may be twofold. For small catchment (in the sense explained above), it is necessary for real time hydrological model calibration. For bigger catchments, hydrometric data can be used to provide flood wave propagation via solution of flow routing equations, which needs either downstream or upstream boundary conditions.

n) Rainfall thresholds: flood alert may be issued by way of rainfall thresholds, i.e. calculation of values of precipitation during a given time window above which a flooding is probable. This can be done by i) analysis of historical flood events, ii) simulation using he hydrological model.

o) Online and/or offline model calibration schemes: the hydrological model to be used for flood forecast may be calibrated i) offline, i.e. based upon historical data, or ii) online, i.e. during the flood event. The second approach should provide better performance, but requires development of a proper online calibration tool, allowing update at fixed time intervals during forecast exercise. Water management based upon a quantitative framework requires a number of steps, summarized here. The underlying hypothesis is that some hydraulic structures (e.g. dams, impoundments, etc..) are present within the CKNP that can be managed to obtain an optimal water allocation.

p) Assessment of water demand/conveyance for multiple purposes (agriculture, cost of hydropower, flood warning: a quantitative assessment is necessary of the amount of water required for each and every type of use within the park. This should be carried out by the park authorities based upon interviews, historical consumption data, indirect estimation.

q) Multipurpose water management optimization tools: numerical models could be developed to simulate optimal allocation strategies, based upon the water demand as explained above, and knowledge o the available water management structures and regulations.

The issues sketched here constitute the backbone of a possible protocol for development of comprehensive water resources assessment within the CKNP. The study already presented displays application of some of the procedures that can be included into a preliminary proposed protocols for hydrological monitoring and modeling of water resources in the CKNP area. Clearly, within the park management plan, a choice of priority should be made to envision an order of priority and a time table of implementation of the several activities. This should be discussed with park authority, and stakeholders of the park. Further issues/requirements may arise in the discussion concerning management plan implementation.

Table 21 Proposed hydrometric network in the CKNP.

Sr. No	Name of River	Village	Length [km]	Area [km^2]	Average discharge [m^3s^{-1}]
1	Hisper + Hoper	Sumaiyar	98	1778	Unknown
2	?	Shimshal	76	1101	Unknown
3	Hushey	Kande	73	1040	Unknown
4	?	Shingshal	59	690	Unknown
5	Talley	Doghani	44	394	Unknown
6	Bagarot	Kothi	46	431	Unknown
7	?	Hurban	42	361	Unknown
8	Astak	Astak	36	271	Unknown
9	Tormik	Dasu	32	221	Unknown
10	Baltoro	Paiju	84	1331	≈30 (measur.+model)
11	Basha	Arandu	74	1049	Unknown
12	Hisper	Hisper	71	962	Unknown
13	Biafo	Biafo	66	845	Unknown
14	Shigar		201	6923	200 (measur.+model)

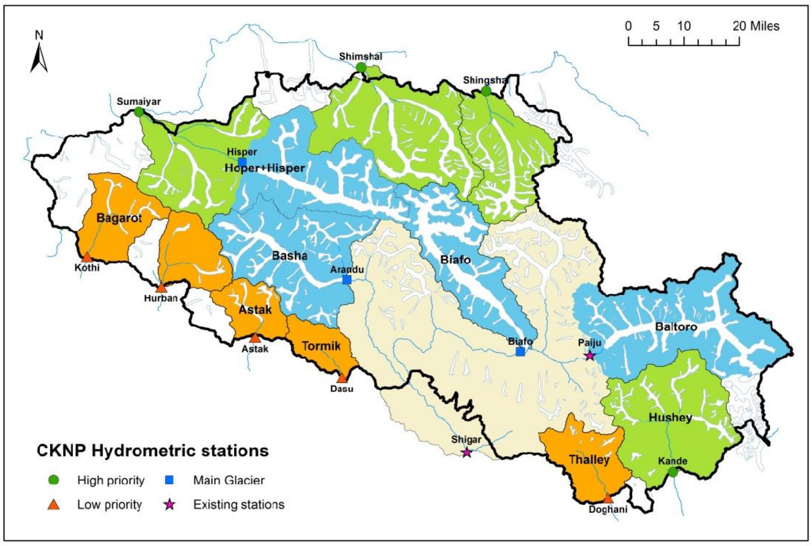


Exhibit 71 Location of hydro-stations proposed

3.3 Pasture modelling

3.3.1 Pasture in CKNP

Livestock farming plays an important role in the economy of CKNP, and in the region's food security due to its contribution to the production of milk, meat, farmyard manure, wool and draft (Hofmann et al., 1998; Hussain et al., 2010). In 2002 the animal population was estimated to exceed two million animals with a prevalence of poultry and goats (NASSD, 2002). Most of the households (80-90%) are reported to have adopted the transhumant system of animal husbandry. During the winter livestock are kept in the village, fed with hay and straw. In the Summer months the animals are taken up into the mountains to graze on the sub-alpine (2000-3000 m a.s.l.) and alpine pastures (above 3000 m a.s.l.). Goats, sheep and lactating animals are closed in pens every evening for milking and safety purposes, while non lactating cows, zomo, and other draught animals are left grazing freely. With the first snow falls they move back to the lower pasture and then to the village in late September/October. Because of small landholding and availability of water, pastures are generally overgrazed, especially the ones near water sources. Overgrazing reduces the productivity level and biodiversity of the land and accelerate erosion and degradation. It also reduces palatable plant leaf areas, which reduces interception of sunlight and plant growth, so that plants become weakened and are replaced by unpalatable species. Overgrazing affect adversely also livestock performance and body condition. It is therefore necessary to explore mechanisms to reduce livestock grazing pressure on pastures. For this purpose it is essential to understand the pasture productivity by estimating the potential and actual biomass accumulation. It would be therefore possible to evaluate bearing capacity of pastures, and in general which management practice can be adopted in the area.

3.3.2 Crop model

As a first step towards understanding coupled dynamics of pasture and grazing species, we propose here an approach to pasture modeling (Nana et al., 2014). Particularly, we simulate biomass production under current climate conditions. This should provide a basis to evaluate bearing capacity of the area, making as able to subsequently simulate interactions of pasture and livestock. The Politecnico di Milano unit has recently carried out some experiences of modeling crops and agricultural water consumption, e.g. in Italy (Bocchiola et al., 2013) by way of literature models, including Cropsyst (Stöckle et al., 2003), and has developed an ad hoc hydrologically based model to simulate pasture growing (Nana et al., 2013). This allows the simulation of pasture dynamics within each catchment of the CKNP. We here briefly illustrate the set of equations driving our vegetation growth model. This is a multi-crop, daily time step cropping system simulation model which simulates water and nutrients balance within soil, phenology, root and plat growth, biomass production and crop yield. Main drivers of Cropsyst are meteo variables, soil properties and land management practices such as irrigation and manure. Water balance is carried out by taking inputs of precipitation P and irrigation I, and provides as outputs soil storage ΔS, surface flow Q, sub-surface flows G, evapotranspiration ET (soil evaporation Es plus crop transpiration Tc) as

$$P+I=\Delta S+Q+G+ET$$

Crop phenology is described by way of degree-day method °C-d, i.e. by accumulation of daily temperatures (below a cutoff value), until a given amount. Biomass accumulation is also tracked by CropSyst. The least daily biomass growth amount is taken of two potential values. The first one is given by potential transpiration TP [Kg/m2/d]

$$B_{PT} = \frac{K_{BT} TP}{VPD}$$

with BPT biomass produced by potential transpiration [Kg/m2/d], VPD vapour pressure deficit [kPa] and KBT biomass-transpiration coefficient [kPa kg/m3], from literature. The second potential daily biomass growth is given by photo-synthetic active radiation PAR [Kg/m2/d]

$$B_{IPAR} = e_I IPAR$$

with eI radiation efficiency [kg/MJ], and IPAR total photo-synthetically active radiation as intercepted by the plant [MJ/m/g]. Every day potential biomass is taken as the least of the values by of Eq.(2) and Eq. (3). This is then converted into real biomass BT as

$$B_T = B_P T / TP$$

with T/TP real to potential transpiration. Real transpiration is a function of potential available water, PAW

$$PAW = \frac{\theta - \theta_w}{\theta_l - \theta_w}$$

with θ soil water content [O-l], θw wilting point, θl field capacity. Leaf area index (LAI) is half of leaf total area per surface unit. In CropSyst this is a function of biomass

$$LAI = \frac{SLA\, B_T}{1 + p\, B_T}$$

with SLA specific leaf area and p stem/leaf partition ratio. Yield Y [ton/ha] is the product of total biomass at maturity BTM times harvest index HI, in ideal conditions (no water stress), depending on crop type, and corrected for sensitivity to water stress during flowering and grain filling.

$$Y = B_{PM}\, HI.$$

In addition to the data requested from the hydrological model the vegetation tool needs information about the management practices (clipping, irrigation, …) and phenological data of the simulated species. This module is based upon the hypothesis of ideal chemical soil condition, which normally leads to an overestimation of biomass production. However, nutrient budget may be also implemented, to keep track of the effect of land's over exploitation.

Here, we report to case studies, illustrating the viability of the model for pasture growth assessment.

3.3.3 Case study: Askole

We analyzed alfalfa (Medicago sativa L.) production in Askole (2980 m a.s.l.) for the period 1990-2010. According to Pakistan Generalized soil map published by Soil Survey of Pakistan, we hypothesized a loam soil. The parameters regarding the phenology of the crop where taken within a literature range, and we hypothesized an irrigation of 250 mm during the growing season. The average dry matter production is 7.9 ton ha-1. We report here de dry matter of the simulation period.

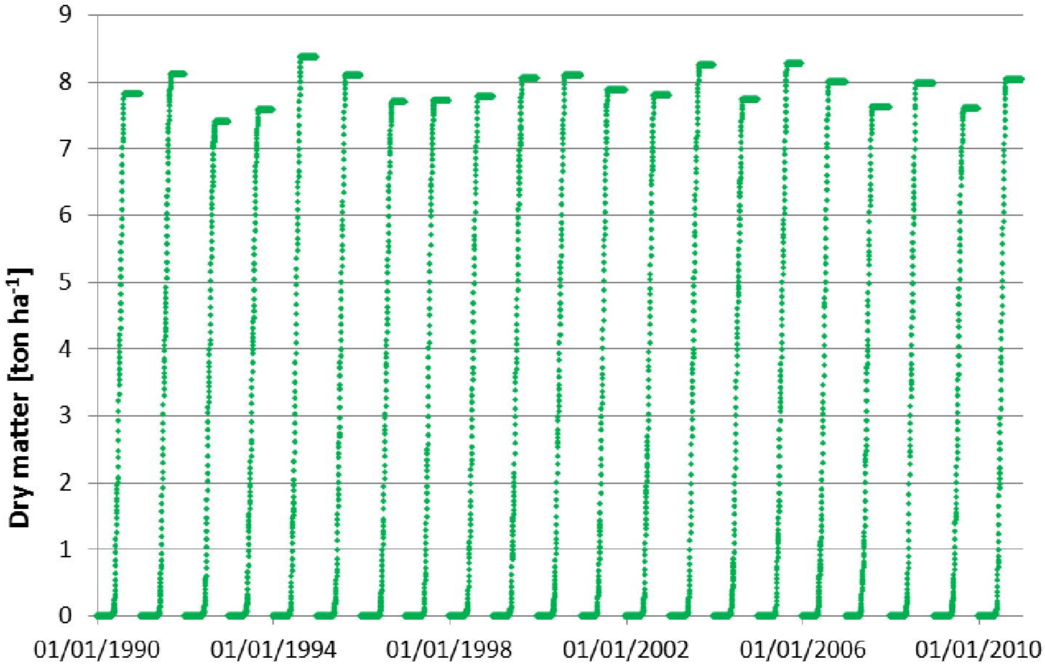


Exhibit 72 Simulation of alfalfa (*Medicago sativa L.*) growth in Askole (1990-2010).

We then hypothesized to cut the cultivar 3 times during the growing season, obtaining an average yield production of 19.9 ton ha-1 for the period 1994-1997. Here an example of dry matter production for the year 1997.

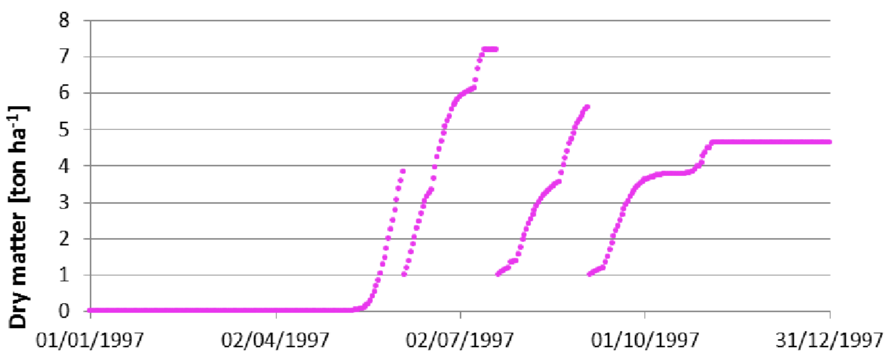


Exhibit 73 Simulation of alfalfa (*Medicago sativa L.*) growth in Askole using three cuts, year 1997.

We compared our results with those from a study of the FAO/UNDP Project PAK/86/027 on fodder crops production in the Northern Area of Pakistan (Dost, 1995). This study evaluated the green and dry matter yield of different Lucerne cultivars subjected up to 7 cuts per season in Chilas, Gilgit and Skardu, during the period 1994-1997. In Skardu, the closest location to Askole, the study reported an average yield of 20.38 ton ha-1, that is comparable to the yield simulated by the model. In the same location (Askole), and for the same period, we simulated pasture growth. Here, the dry matter production depends strongly upon precipitation, since here no irrigation is used. The following figure shows how dry matter (green in the figure) varies significantly during the period of the simulation.

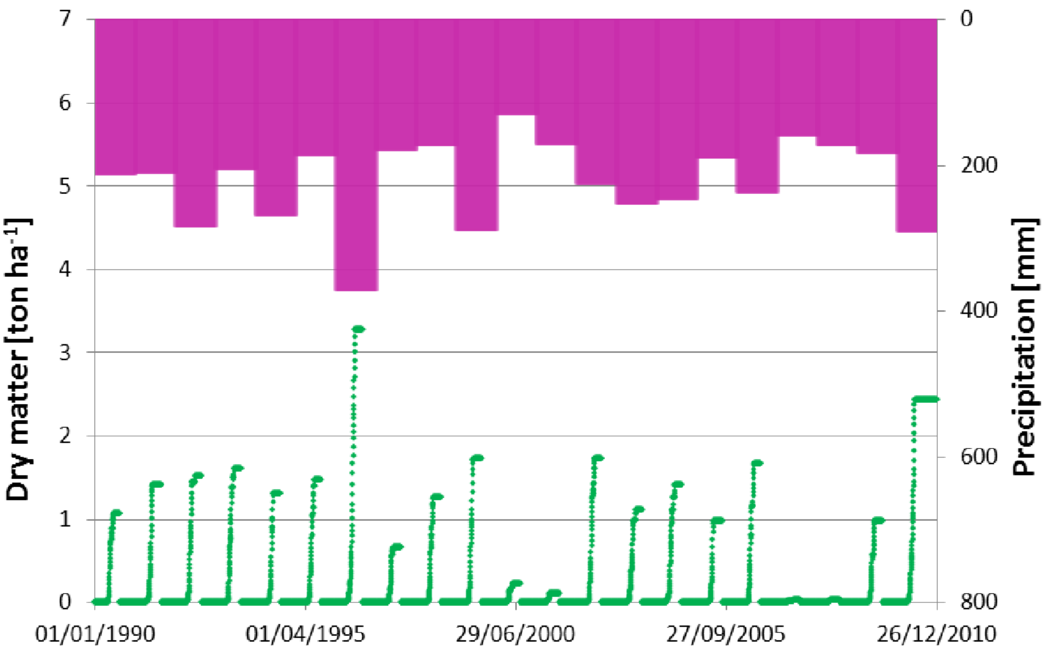


Exhibit 74 Simulation of pasture growth in Askole (1990-2010).

The average productivity is 1.24 tonha-1, with peaks during the rainiest years (1996, 2010) and very low growth during the driest ones. A study carried out from the IUCN-Pakistan in 2001 shows that the estimated potential productivity of pastures is 1.4 ton ha-1 for Gojal, 1.6 ton ha-1 for Astore and 1.20 ton ha-1 for Skardu. Actual surveys showed an effective productivity of 0.41 ton ha-1 for Gojal and Astore, and 0.24 ton ha-1 for Skardu. This degradation is mainly related to the heavy grazing pressure.

3.4 Conclusions

Under the umbrella of the SEED project a considerable amount of work as been carried out in the area of water resources assessment and management. Here, we have proposed a suite of tools, and methods, that may be adopted for water resources assessment, modeling, management, also under prospective climate change in the century. Also, a hydrologically based tool was developed to preliminary assess the productivity of some areas with pasture, for livery stock sustanaible herding. The model can mimic growth of several cropping species, including cereal (wheat, maize, rice, millet, etc..), and can be prospectively used for optimal cropping in the area. We suggest that in the near future, a number of actions are taken in the field of water resources, and pasture modeling, including. The installed hydrometric station are maintained, and the discharges therein estimated, and used for water resources assessment. The proposed hydro- network is installed. The developed hydrological model, and projections therein are used to model, and project forward water resources, also base upon new data, and to depic the stat eand fate the cryosphere in the park.

The pasture model is used to evaluate pasture productivity depending upon climate, and its future changes, and to model cereal growth in the Park area.

Eventually, a number of doors were pushed open during the project, and it seems imperative that further activities is carried out within the park in the fields of study highlighted here, in close cooperation between Pakistani and Italian authorities, and personnel. The authors hope such activities may be developed soon, and look forward to cooperate therein.

4. Water quality[4]

4.1 Introduction

Water is essential to the existence of all living organisms. Water resource requires a careful use to ensure sustainable populations grow and economic development. The correct management of aquatic resources is essential to obtain high quality water for domestic purposes and for the environment. Important linkages exist between ecosystems, domestic use of water, agricultural production, mining, forestry practices and water abstraction for industrial use. Industrial production, power generation, and human activities in general can alter the interplay between the various parts of the water cycle and lead to deterioration in the physical, chemical and biological properties of water that drive ecosystem functioning.

Some of the highest priorities for stakeholders are to understand and forecast potential changes in water quality and biological condition that may be caused by changes in major environmental drivers. Each major large-scale driver of change in environmental conditions may influence numerous water-quality stressors. The environmental drivers cited most frequently by the stakeholders included (1) climate change, (2) energy and natural resource development, (3) population growth and land-use change, (4) policies, regulations, and management practices, and (5) hydrologic modification and water reuse. Because of the multitude of ways that these drivers influence water quality, the approach to assessing all of them has a strong common element of systematic long-term monitoring of a diverse range of water-quality stressors and aquatic ecosystems.

There are a wide variety of individual water-quality stressors that will respond in different manners to changes in the environmental drivers, but the individual stressors identified as a high priority are chemical (e.g. nutrients, contaminants), or biological (e.g. pathogen) entities that can adversely affect: (i) the quality of water as a drinking water source or for other human uses, or (ii) aquatic ecosystems. Because individual stressors rarely act alone, a relevant task was to assess the relative importance of key individual stressors in the context of multiple drivers affecting water quality and aquatic ecosystems in different environmental settings.

In full harmony with priority issues and the general principles outlined by many international initiatives (e.g. UNEP, WHO, IUCN) the water management will be based on an ecosystem approach that complements with the current thinking on Integrated Water Resources Management. The principles that inspire this approach are equity (in the distribution of costs and benefits), efficiency (management promotes the most efficient use and reflects the full value of the resource, including market, ecosystem and socio-cultural values), sustainability (the water management regime is self-sustaining and readily adapts to changing conditions), legitimacy (water management institutions have a sound legal basis and their decisions and actions are seen as legitimate and fair by all stakeholders), accountability (policies, practice, roles and responsibilities have to be fair and legitimate uses of water resources and the different stakeholders are accountable for their actions), subsidiarity (decision-making authority is devolved to the lowest appropriate level along with the power and resources to make and implement these decisions), participatory (all stakeholders are given the opportunity to participate in water resources planning and management decision-making and to become involved in reducing water conflicts).

The logical approach of the Ecosystem Water Management is work at the catchment scale level since this is the geographic unit at which water resources are derived and ecosystems provide services, such as fresh water. To maintain goods and services, ecosystems need to be protected and wisely managed, which includes the need to allocate water to ecosystems such as forested slopes and downstream floodplain wetlands. Protection of goods and services also requires preventing the negative impacts of land-use change and anthropogenic activities (e.g. agriculture, industry, mining, urbanization) on water bodies.

[4] Authors: Andrea Lami, Michela Rogora, Gabriele Tartari (CNR ISE, Italy), Luigi Guidetti, Giacomo Archetti (Agenzia Regionale per la Protazione dell'Ambiente del Verbano-Cusio Ossola, Italy), Khalil Ahmad, Maisoor Nafees (KIU)

The ecosystem approach is expected to produce benefits to people, organisations, companies and societies. The following measures are part of an ecosystem approach to water management:

1) Combine water and land management in catchments and river basins by:

   a) Protecting critical mountain slopes, wetlands and forests to maintain springs and control soil erosion;

   b) Leaving enough water in rivers to maintain or restore downstream ecosystems and their benefits;

   c) Restoring ecosystems, springs and aquifers that are vital for water sources.

2) Address pollution problems by:

   a) Implementing basin-wide point-source pollution treatment and prevention plans;

   b) Developing financial, legal and institutional incentives for non-point source pollution prevention;

   c) Building capacity and technical support for demand-side water management.

3) Conserve aquatic biodiversity by:

   a) Maintaining or restoring migratory pathways of freshwater species through improved design or retrofitting of infrastructure;

   b) Integrating wetland protection and wise use into water resources and land use planning.

The geographic units for integrated resource management and decision-making are also receiving attention, with water catchments increasingly recognized as functional (and optimal) geographical areas that integrate a variety of environmental processes and human impacts on landscapes (Committee on Watershed Management, 1999). Using water catchments as a unit for integrated land-use assessment and management presents a number of methodological and technical challenges that exemplify many of the key issues involved in linking GIS with environmental models, and also in using linked GIS and environmental models for decision support (Aspinall and Pearson, 2000).

Glaciers, related streams and lakes represent the sources of freshwater for the CKNP ecosystems and communities. Linked to the rapidly growing demand (for energy, agriculture and human consumption) there is a necessity to improve water quality besides to reduce the sources of pollution; this for the needs of water supply for local communities but also for the fundamental relationship between water and the Park's ecosystems. To support the water management strategy for CKNP, a specific program to develop a water analysis and monitoring scheme is developed concerning the following activities:

   a. implementation of a laboratory for analysis of freshwater at KIU;

   b. development of a quality monitoring scheme for the CKNP from the quality assessment of water springs and reservoirs conducted in three valleys of Braldo, Basha and Shigar;

   c. enhancement of the capacity building at KIU and CKNP on water management also through the training of a PhD student of KIU;

d. organization of a Water Quality Network with the aim to establish common criteria to assess water quality among the different national and local organization and the CKNP management plan.

The research and monitoring activities performed in the framework of SEED will be linked together and will benefit of a parallel research activity on water bodies under the SHARE-PAPRIKA project, targeted to the understanding of the possible change in water resources as a consequence of climatic change. Research and monitoring activities concerning water quality are designed to achieve water resources conservation in relation to their use and to maintain as pristine as possible the wetlands biodiversity, providing solid estimations of species losses under reliable climate change and water use scenarios. Long term aims are to integrate freshwater ecosystems at a catchment scale and to focus on the key drivers of aquatic system change (nutrient enrichment, waste water discharge) and their interaction with global drivers (e.g. climate warming, ice cover duration) at different time scales. It's probable that future climate shifts, mainly in temperature, may induce more profound and strong variability in community composition. This will have a direct influence on the existing species and their tolerances, with losses of less tolerant and scarcer species and introductions of more lowland species.

Pakistan regulation for water quality

Although water is a federal concern in Pakistan, with the exception of national distribution of water through the Indus River System Authority (IRSA), the provinces mainly administer the water sector. There are several laws and regulations enacted to manage the water sector. This body of law and regulations generally provides the authority and powers to manage water sector but there is need to review it with a view to provide Integrated Water Resource Management (IWRM). The most significant laws and regulations are briefly described below. The Canal and Drainage Act of 1873 is the key legislation, which regulates the irrigation and drainage systems and has been adapted by various provinces. The Punjab Soil Reclamation Act of 1952 governed the preparation of drainage schemes and other drainage related works. The Act was later extended to cover the whole country. The Water and Power Development Authority was created at the Federal level in 1958 through the WAPDA Act. Its mandate was, and is, to undertake construction of large irrigation and drainage projects and construction and operation of large hydropower projects. The Authority is also responsible for generation, transmission and distribution of power in the country {except for Karachi where the Karachi Electric Supply Company (KESC) undertakes these works}. Both WAPDA and KESC are federal institutions under the control of Ministry of Water and Power. Recently WAPDA has decentralized power distribution through creation of subsidiary companies, which undertake power distribution and collect the revenues. In 1982 Water User Ordinances were promulgated to enable formation of Water User Associations (WUAs) for participation in water management at watercourse level. The WUAs made a good start by participating in improvement of more than 10,000 watercourses. In several cases WUAs contributed up to 55% of the cost of civil works for improvement of watercourses both in cash, kind and in the form of labour, but those generally became dormant once the improvement works were completed . In order to introduce institutional reforms in irrigation and drainage sector, the provinces enacted new Acts in 1997. These Acts provide the legal framework for establishment of Provincial Irrigation and Drainage Authorities (PIDAs), Area Water Boards (AWBs) and Farmers Organizations (FOs). The Pakistan Environmental Protection Ordinance (PEPO) was issued in 1983. It has been replaced with the Pakistan Environmental Protection Act, 1997. The Act is directed to provide a basic environmental policy and set up a management structure for pollution control. The National Environmental Quality Standards (NEQS), enacted in 1993, delineate allowable limits for 32 pollutants in effluents and industrial discharges along with other limits related to industrial and vehicular air emissions. Provincial EPAs/ EPD are responsible for monitoring and implementing the NEQS. Proper implementation and enforcement of the NEQS is poor due to lack of resources, equipment, and skilled staff as well as training and monitoring programmes.

After the formalization of the World Conservation Strategy in 1980, the Government of Pakistan developed a Pakistan water sector strategy in 2002 in which it is proposed a road map to meet the objectives of the National Water Policy for a sustainable and environmentally and economically sound water sector in Pakistan. The outcome are summarized in three documents:

1. The National Water Sector Profile (NWSP), which summarises and details all aspects of the Water availability and utilisation as they exist today. As such, it will become a standard source document for future water sector work.

2. The National Water Sector Strategy (NWSS). which identifies the key issues and objectives for the water sector and proposals for planning, development and management of water resources and their use in all water sub-sectors.

3. The Medium Term Investment Plan (MTIP), which identifies the key programmes and projects which should be undertaken up to 2011 which will make the initial contribution to achieve the objectives of the Strategy.

These documents cover the whole of the water sector, and all its sub-sectors such as: Water Resources Development, Urban Water Supply and Sanitation, Rural Water Supply and Sanitation, Industrial Water Supply and Pollution Control, Irrigation and Drainage, Hydropower, the Environment and Flood Protection.

These documents are also highlighted some of the institutional and management issues that affect the efficient achievement of the goals:

(i) Inadequate coordination between all water user organisations;

(ii) Difficulties in reaching consensus between the provinces on the issue of additional storage, retarding growth in water resources development;

(iii) Absence of an inter-ministerial, inter-provincial body to oversee water sector planning, development and management;

(iv) Changing administration under the Devolution Plan, and uncertainty in technical ability during the transition, especially in the domestic water supply and sanitation sub-sectors;

(v) Insufficient data base and information on water.

However, in these documents is not highlighted the crucial role of mountainous areas that are not only a reservoir of water, but they are fragile ecosystems be protected and preserved. Furthermore, the management of water resources in mountain areas poses specific problems that need to be addressed.

In Pakistan there are several potential contamination sources for drinking water. Bacteriological contamination in particular has been reported to be one of the most serious problems throughout the country in rural as well as urban areas (e.g. Kahlown et al., 2004; Sun-OK et al., 2001). Bacteriological contamination may occur due to leakage of pipes, pollution from sewerage pipes due to problem within the distribution system, intermittent water supply, and shallow water tables due to human activities. Chemicals deriving from industrial activities and agriculture (fertilizers, pesticides) may be a further source of water pollution in the country (Chandio, 1998; Din et al., 1997).

A report by the Government of Pakistan issued in 2008 includes finalized standards for quality drinking water in Pakistan stated in accordance with WHO criteria and guidelines (Government of Pakistan, Pakistan Environmental Protection Agency, 2008). Standards are provided for a list of bacterial, physical and chemical parameters (including organic and radioactive substances).

In this report we refer to these standards when discussing results of water analysis performed within the SEED project. In some northern areas of Pakistan fluoride was found in high amounts in runoff water consumed by the people. It can lead to the discoloration of teeth (dental fluorosis). Epidemiological evidence also shows that fluoride primarily affects the skeletal tissue (WHO, Guidelines for Drinking Water Quality, third edition, 2004). For these reasons strict monitoring of fluoride in drinking water is of great value in Pakistan and limit has been tightened than the WHO’s one i.e. less than or equal to 1.5 mg/l.

4.2 Study area

4.2.1 Water quality assessment

A conceptual approach for the water resources assessment has been developed and tested in the following valleys: Braldo, Basha, Nagar, Humza related to the SEED activities:

In the CKNP area the water input to different uses (agriculture and human) is typically a surface soring or even directly the water melting from glaciers or permafrost. Often the water is captured and stored in a tank and then distributed to the village by pipeline and public drinking fountain or tap. Therefore the sampling strategy decided was to sample the water at the source (tank) and at the lower point of distribution (tap). As an example, the sampling scheme adopted in the Askole village is shown in Exhibit 75.

Within the SEED project, it was established to perform an evaluation of the water quality of two Valleys in more details, Braldu and Basha. These Valleys have been selected because they are subject to different anthropogenic impact. The Braldu Valley is strongly affected by tourism, while the Basha Valley is mainly used by local community.

The surveys were performed in 2011, 2012 and 2013. A total of 65 sites were considered (Table 22). In some cases a repeated sampling was performed.

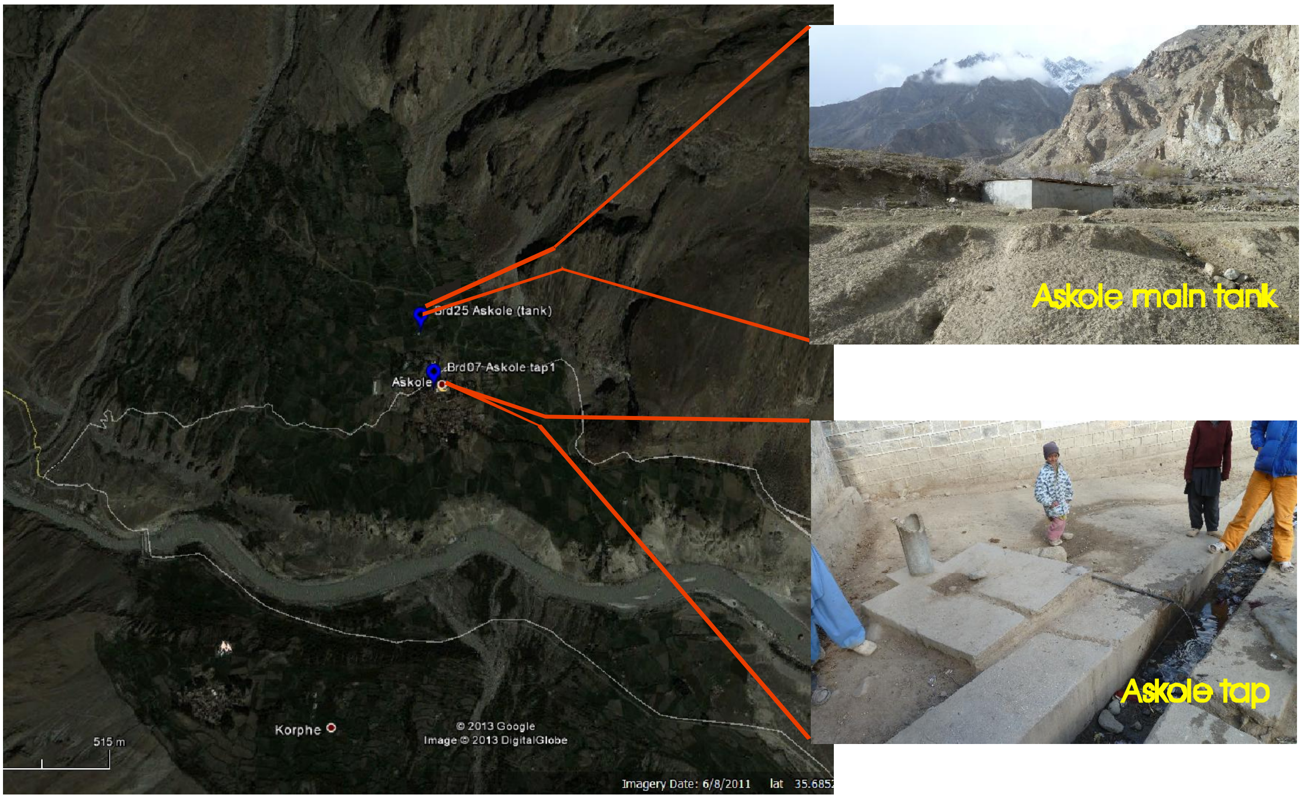


Exhibit 75 The sampling strategy for the Askole village

Table 22 Sampling sites considered in the three year period within the SEED project.

Site N.	Site	GPS coordinate UTM-WGS84	Elevation (m)	Valley
Brd01	Korophon	43S 582828 3949861	3075	Braldu
Brd02	Bardumal	43S 595751 3945907	3219	Braldu
Brd03	Paiju camp	43S 601884 3948733	3355	Braldu
Brd04	baltoro glacier's front	43S 604475 3949781	3400	Braldo
Brd05	Paiju bridge	43S 600338 3947650	3355	Braldo
Brd06	Golibital	43S 587235 3948402	3110	Braldu
Brd07	Askole tap	43S 573946 3949018	3057	Braldo
Brd08	Shigar bridge	43S 564906 3920024	2224	Braldo
Brd09	Khoburtse	43S 611107 3953210	3865	Braldu
Brd10	Urdukas	43S 616118 3954396	4050	Braldu
Brd11	Jula bridge	43S 587993 3951704	3124	Braldu
Brd12	Bardumal, Braldo river	43S 593961 3945658	3212	Braldu
Brd13	Jula camp	43S 588185 3950681	3169	Braldu
Brd14	Shigar restaurant	43S 565160 3920084	2208	Braldu
Brd15	Dasso	43S 546796 3952590	3065	Braldu
Brd16	Liligo	43S 608042 3951377	3720	Braldu
Brd17	Biafo bridge	43S 578977 3948256	2985	Braldu
Brd19	Lomar Spang, Tistong (tank)	43S 543786 3952221	2555	Braldu
Brd20	Tistong (tap1)	43S 543867 3951912	2438	Braldu
Brd21	Chukhil, Dassu	43S 546325 3953023	2479	Braldu
Brd22	Sarfloss, Dassu	43S 546291 3953113	2504	Braldu
Brd23	Glacier before Khoburtse	43S 610889 3952769	3799	Braldu
Brd24	Baltoro glacier's right	43S 604834 3950501	3783	Braldu
Brd25	Askole (tank)	43S 573912 3949176	3075	Braldu
Bsh01	Chumik Arindo	43S 530015 3968332	2874	Basha
Bsh02	Togi Arindo	43S 530194 3969027	2793	Basha
Bsh03	Khargan Arindo	43S 530220 3969391	2757	Basha
Bsh04	Bisil Bombari	43S 536744 3969997	2835	Basha
Bsh05	Bisil Skilkor	43S 535972 3970013	2720	Basha
Bsh06	Zill Shkong	43S 537033 3962438	2680	Basha
Bsh07	Zill Malong	43S 536692 3962035	2618	Basha
Bsh08	Seisko Shuaika	43S 538204 3963637	2794	Basha
Bsh09	Seisko Biarzing	43S 537561 3963539	2662	Basha
Bsh10	Chotrong Khonjing	43S 536812 3951322	2463	Basha
Bsh11	Tisal	43S 540102 3947051	2530	Basha
Bsh12	Tisal	43S 540709 3947413	2412	Basha
Bsh13	Starga Khor /thorgo)	43S 538705 3950735	2580	Basha
Bsh14	Tutsa Bein	43S 536296 3959605	2650	Basha
Bsh15	Bein (man source)	43S 536376 3959788	2645	Basha
Bsh16	Bein (lowest point)	43S 536088 3959687	2570	Basha
Bsh17	Dogoro Gone (tank)	43S 536417 3956852	2579	Basha
Bsh18	Dogoro Iul (tank)	43S 536611 3956887	2627	Basha
Bsh19	Dogoro Hango Tap 1	43S 536148 3957039	2524	Basha

Bsh20	Basha river(dogoro)	43S 535639 3956424	2465	Basha
Bsh21	Hamisil Tank	43S 536048 3952319	2533	Basha
Bsh22	Hamisil Tap	43S 536254 3952281	2508	Basha
Ngr01	Hoper Ratal tank	43 S 477953 4009019	2817	Humza - Nagar
Ngr02	Hoper Haklshel river	43 S 477871 4009422	2773	Humza - Nagar
Ngr03	Hoper Broshal tap	43 S 478481 4008854	2750	Humza - Nagar
Ngr04	Hoper Glacier	43 S 478514 4008853	2707	Humza - Nagar
Ngr05	Barbar Karimabad	43 S 470241 4020117	2451	Humza - Nagar
Ngr06	Ultar ghiacciaio	43 S 470504 4020570	2461	Humza - Nagar
Ngr07	Karimabad Village tap	43 S 470503 4020570	2385	Humza - Nagar
Ngr08	Aliabad Bultanabad Tank	43 S 464391 4017325		Humza - Nagar
Ngr09	Aliabad tap Bazar Market	43 S 465115 4017911		Humza - Nagar
Ngr10	Assalabad Nala Glacier	43 S 462265 4018751	2264	Humza - Nagar
Ngr11	Hassanabad Hunza sorgente	43 S 463889 4016962	2194	Humza - Nagar
Ngr12	Hassanabad Hunza tap	43 S 463939 4017002	2193	Humza - Nagar
Ngr13	Daltho Summyar sorgente	43 S 469147 4017671	2298	Humza - Nagar
Ngr14	Daltho Summyar tap lower	43 S 468344 4017560	2180	Humza - Nagar
Ngr15	Jut Gulman village (Nagar)	43 S 453726 4010330	2023	Humza - Nagar
Ngr16	Minnapin Rakaposhi lower tap	43 S 454052 4010610	1956	Humza - Nagar
Ngr17	Pissan Sholee	43 S 457223 4011265	2196	Humza - Nagar
Ngr18	Minnapin Ghiacciaio	43 S 457840 4011701	1991	Humza - Nagar
Ngr19	Minnapinn lower tap Deran Hotel	43 S 458648 4012036	2045	Humza - Nagar

4.3 Methods

In order to promote the efficient management of freshwater biodiversity and eventually inverse its decline, there is an urgent need to strengthen research activities on conservation, characterization, and development of biodiversity to provide solid estimations of species losses under plausible climatic change and water use scenario.

This SEED project activities aim at improving water quality in the CKNP region in two steps:

- an assessment (and tracking) of the situation and problem areas through the establishment of a water quality monitoring scheme and building of capacity to implement it in conjunction with water quality research;
- based on this assessment and on the analysis of the data, the identification and establishment of effective means to address water quality-related problems in the CKNP region.

To reach the above objectives, two major actions have been identified:

a) installation of the water quality laboratory at KIU campus

The first step was to identify the major parameters (chemical and biological) that have to be analyzed at the KIU Water Lab. The list of chemical variables is as follows:

Physico-Chemical: pH, conductivity, turbidity, total nitrogen, nitrate, nitrite, ammonium, reactive and total phosphorus;

Microbiological: Escherichia coli, Total bacteria at 22°C, Salmonella spp., Enterococchi

Under the supervision of the CNR Istituto per lo Studio degli Ecosistemi and in co-operation with ARPA-VCO, Omegna, chemical and microbiological analytical methods have been established following International Standard protocols. A description of the methods for chemical analysis in use at the CNR ISE chemical laboratory can be found at the web site http://www.idrolab.ise.cnr.it

After a visit to KIU to identify the proper room space and the already available instruments, it was decided that some civil work will be necessary to improve the room space that KIU have agreed to allocate for the Water Lab.

A list of necessary instrumentation was provided to expand and improve the analytical capacity. As well as it was organized a technical training period on the chemical and microbiological analysis, at CNR ISE and ARPA-VCO, in Italy, respectively, for a PhD student from KIU.

The following points were considered during the chemical training:

Laboratory practice and analytical techniques:

Lab organization and structure, reagent water quality for chemical determinations, technical and analytical balances, chemicals typology, reagent preparations, standards preparations and volumetric glassware quality, automatic and manual volumetric pipettes, collection and preservation of samples, basically instrumentation for the lab.

Water sampling methodology in lakes and rivers

Sampling pre-treatment and storage before the analysis (thermo stating, filtration)

Electrical conductibility and pH determination: instrument calibration and methodological approach.

UV-Visible spectrophotometric analysis (introduction: principles of UV-Visible spectrophotometer; how to choose the optical path (cuvette);check of the instrument functioning);

Ammonium determination (indophenol blue).

Phosphate spectrophotometric determination (molybdate).

Autoclave typical use for sample mineralization.

Total phosphorus spectrophotometric determination (molybdate) with autoclave mineralization at 120°C.

Total nitrogen spectrophotometric determination (220 nm) with autoclave mineralization at 120°C.

Nitrate spectrophotometric determination, direct determination at 220 nm and second derivative determination.

Nitrite spectrophotometric determination.

Linear regression used for method calibration with standards, statistical elaborations and critical evaluations of results from linear regression (Excel files).

Laboratory internal quality controls:

Blank control charts for the spectrophotometric determinations.

Repeatability control charts for different concentration levels.

Control charts organization in Excel files.

Detection limit (LOD) and quantification limit (LOQ) calculation.

Sample data base (Excel files)

Checking correctness of analysis by means of the ionic balance and the comparison of measured and calculated conductivity.

Laboratory external quality controls:

Certified reference material analysis.

Proficiency tests and method validation.

With respect to the microbiological training, the following points were examined:

Laboratory practice and analytical technique:

Lab organization and structure, reagent water quality for the microbiological evaluation of superficial water, drinking water and waste water, field sampling, preservation and storage of the samples, media for culture preparation and sterilization by autoclave, filtration, plate preparation, glassware preparation, good laboratory practice for assessment of biological risks.

Enzymatic confirmation test

Sampling pre-treatment and storage before the analysis (thermo stating, filtration)

Determination of total coliform plate counts and MPN technique

Determination Escherichia coli plate counts and MPN technique

Determination of total bacteria at 22°C

Determination Salmonella spp

Determination faecal Coliforms

Determination Enterocccii plate counts and MPN technique

Training supporting documentation (hard copy, pdf, Excel, Power point):

A detailed description (principle of the method, work flow chart) of all the analytical methods that have been considered during the training (pH, conductivity, ammonium, nitrite, nitrate and total nitrogen, phosphate and total phosphorus);

User Manual for the pHmeter e conductimeter which have been suggested to buy for the Water lab in KIU.

Mr Maisoor Ahmed Nafees has completed with success the training formation in water analysis scheduled with the SEED (Social, Economic and Environmental Development in the CKNP Region) project coordinated by Ev-K2-CNR, in collaboration with the Karakorum International University, and funded in the framework of the debt swap agreement between the Governments of Italy and Pakistan.

The training period at the CNR ISE chemical laboratory and at ARPA-VCO was carried out between 6th February and 22nd March 2012 and consisted of a full time frequency (8hr/day). The following staff was involved: Gabriele Tartari, Arianna Orrù, Paola Giacomotti, Chiara Manini from CNR-ISE and Giacomo Archetti from ARPA-VCO

In April 2013 an intensive training about laboratory analytical techniques was organized at the Water lab in Giligt for the local staff (Mr Imran) and for two CKNP game watchers for the sampling protocol.

With the implementation of the Water laboratory at KIU, it is also foreseen to establish a monitoring program in order to give the necessary quality assurance and quality control to the analysis performed by the laboratory. This activity will include a programme for testing the laboratory performance with inter-calibration exercise and exchange of samples with the reference Italian laboratory (CNR ISE).

b) water quality research and monitoring

Following the protocol established in SEED guaranteeing the non-contamination of the samples (Exhibit 76, and 77) in each station a volume of 1 litre of water has been taken. Each sample was accompanied by a descriptive form with additional information, to help with the interpretation of the results. The samples were then transferred to Italy and analysed in the hydrochemical laboratory of the CNR ISE of Verbania.

The chemical variables were determined with the methodologies in use at the laboratory and described in details at http://www.idrolab.ise.cnr.it: pH, conductivity, and alkalinity by potentiometric methods, major anions (sulphate, nitrate and chloride) and cations (calcium, magnesium, sodium and potassium) by ion chromatography, and total reactive phosphorus, ammonium, reactive silica and total nitrogen by spectrophotometry. The results of the analysis were subjected to analytical quality controls based on a comparison between the total concentrations of cations and anions and a comparison between measured and calculated conductivity on the basis of the concentrations of major ions.

A protocol was also established to collate all the data available for each site in term of meta-data (geographic position, description, photos) and data (physico-chemical, chemical, microbiological) in a specific form (Exhibit 78). A procedure to transfer these data to the SEED database was also established.

Following the sampling strategy describe above, some field work activity was realized in some selected valley (Braldu, Basha, Humza-Nagar) in order to verify the strategy and to collect reliable data for the water quality assessment

In 2011, in collaboration with the group of hydrologists and glaciologists, it was possible to organize a fieldwork expedition to collect samples along the valley of Shigar in two different periods: spring (March) and summer (July-August). The two periods were selected because they correspond to different flow regimes. Spring represents the low flow phase while summer the maximum flow in conjunction with the glaciers thawing. The list of sampling points with the main characteristics is shown in Table 22.

Materials needed for each sample:

- A bottle sterile 1000 ml necessary for the detection of Salmonella.
- A bottle of 500 ml sterile necessary for the detection of Total Coliforms, fecal coliforms and enterococci.
- portable-Bunsen burner
- Disposable gloves, bags, labels and pencil
- Thermometer
- GPS (check the reference system. Must be WGS84)
- Altimeter (if available)

Sampling procedure:

- To conduct (if possible) or make a closed valve sterilization using a portable-Bunsen summary of the end portions of the duct or the tap.
- Using a portable-Bunsen lit in close contact with the puncture completely fill the bottle avoiding as much as possible to let air bubbles inside, careful not to touch the sample or the stopper with your hands;
- Tighten the caps, label and store the bottles in a bag securely closed.
- Samples are stored in the dark or away from light or place them in the shipping container;
- compile the sample and returning the sampling point and the GPS coordinates and identification number of the used bottles;
- take some photos together from which you can see the condition of the sampling point, whether the surrounding snow or ice cover the surface.

Storage and shipment of samples

After collection, the samples should be kept in the dark and cool (in a refrigerator at about 2-8 °C, **do not freeze**) and sent to Italy where possible using a thermal container (Styrofoam box).

Materials needed for each sample:

- A bottle sterile 1000 ml necessary for the detection of Salmonella.
- A bottle of 500 ml sterile necessary for the detection of Total Coliforms, fecal coliforms and enterococci.
- portable Bunsen burner
- Disposable gloves, bags, labels and pencil
- Thermometer
- GPS (check the reference system. Must be WGS84)
- Altimeter (if available)

Sampling procedure:

- To conduct (if possible) or make a closed valve sterilization using a portable-Bunsen summary of the end portions of the duct or the tap.
- Using a portable-Bunsen lit in close contact with the puncture completely fill the bottle avoiding as much as possible to let air bubbles inside, careful not to touch the sample or the stopper with your hands;
- Tighten the caps, label and store the bottles in a bag securely closed.
- Samples are stored in the dark or away from light or place them in the shipping container;
- compile the sample and returning the sampling point and the GPS coordinates and identification number of the used bottles;
- take some photos together from which you can see the condition of the sampling point, whether the surrounding snow or ice cover the surface.

Storage and shipment of samples

After collection, the samples should be kept in the dark and cool (in a refrigerator at about 2-8 °C, **do not freeze**) and sent to Italy where possible using a thermal container (Styrofoam box).

Exhibit 76 Sampling protocol established in SEED

Social Economic Environmental Development

Water Survey Data Sheet

Site description

Site No: **Site ID*:** ____________________

GPS coordinate (UTM WGS84): N: ______________ E: ______________

Elevation (m a.s.l.): __________ from: ☐ GPS ☐ Map ☐ Altimeter

Site name: ____________________ Alternative name: ____________________

Administrative Units (province, village): ____________________

Type of water Superficial (river, stream)
Spring

Brief description of the area:

- type of vegetation (trees, grass): ____________________
- use of the area (cattle, fields): ____________________
- presence of animals: ____________________
- access to the water: ____________________
- presence of discharge pipe: ____________________

Picture (file name): ____________________

Sample data

Visual Monitoring - water appearance:

scum ______	orange to red ______	rotten egg ______
foam ______	yellowish ______	musky ______
muddy ______	black ______	other ______
clear ______	brown ______	none ______
tea ______	none ______	
milky ______		
colour sheen (oily) ______		
brownish ______		
other ______		

Sampling data:

d	d	m	m	y	y	y	y	Time

Water Temperature (° C) __________

Microbiological sample (bottle number): ____________________

Chemical samples (bottle number): ____________________

Assessment team members: ____________________

*Do not write here. This is reserved to the Water database manager

Exhibit 77 Sampling form to be filled in the filed by the operator and transferred to the lab with the samples seed Social Economic Environmental Development

Water resources monitoring
Summary information

Site Number: **Bsh02**
Site name: **TAQI ARINDO**
Alternative name:

U.T.M. WGS84 coordinates: Zone 43N, **530194, 3969027**
Elevation (m a.s.l.): 2793 from: X• GPS • Map • Altimeter
Administrative Units (province, village): **Arindo**

Type of water:	x	tap water		Spring		Superficial

Additional Information: tap water in front of private house
Notes: first tap on the pipe line
Brief description of the area:
type of vegetation (trees, grass): NO; site locate in the village
use of the area (cattle, fields): NO
presence of animals:yes, farmyard animals (poultry)
access to the water: open
presence of discharge pipe: NO
Picture (file name):

LEGENDA
Bsh02
Other points

Scale: printed graphic scale
Reference system: U.T.M. WGS84
Cartography: Google Earth (agg.2012)
Theme: Seed project (agg. 2012)

Relief date: 2012.06.09
Print date: 2012.08.02

Exhibit 78 SEED data form which summarizes the metadata for each site.

4.4 Synergies with other group

Since the water quantity and water quality issue are strongly interconnected a strong interaction n was developed with the Hydrologist group in order to identify the areas and the sampling sites to maximize the results from this kind of investigations.

However, the major interaction was with the KIU for the set up and planning of the water Laboratory analysis. Part of the instrumentation was already existent at KIU and was dedicated to the Lab, while the Italian group have invested a lot of energy in training KIU technician and PhD student as well as and game watcher from CKNP.

A relationship through the Water Committee was established with other Pakistani organization based in Gilgit such as AKPBSP, EPA, PCRWR.

4.5 Results

Despite the water quality is recognised as one of the major issue related to water resources management, generally reliable data and information are very scanty and limited to water quality for drinking purpose (e.g. faecal contamination). In addition very few data are available for the high altitude part of the Northern Area of the CKNP (Lodhi 2003; Shahid, A. and M.F. Joyia. 2003; Khalil, A. and S. Shah. 2007). Furthermore, these data are apparently contradictory since they are generally based on one sampling expedition and refer to a limited area, but at the same time the conclusions are often extended to the whole area. For example Lodhi (2003) concluded that most ot the water spring examined are suitable for human consumption, while Shahid, A., M. F. Joyia. (2003) and Khalil, A. and S. Shah (2007) reported the water from the Northern Areas as highly contaminated.

4.5.1 Water quality assessment - chemistry

From the general point of view, the sampled sites showed a very high chemical variability, especially as regards nutrient content. A summary statistic of the chemical characteristics of the considered samples is shown in Table 23. The sampling points showed first of all a varying solute content, from very dilute to highly mineralised water, as revealed by the conductivity values (from 60 to above 600 µS cm-1 at 20 °C). pH values were close or above the neutrality for most of the samples (mean values 8.04). Alkalinity, which represents the concentration of bicarbonate ions, varied between 0.5 and 3.3 meq L-1; however, values are quite high and typical of well buffered water (sensitive waters to acidification are those with alkalinity below 0.2 meq L-1). Turbidity proved to be quite high at some of the sites, reaching in some cases values above 500 FTU. The highest values affected glacier melting waters and were mainly attributable to suspended particles of inorganic materials.

Total nitrogen was normally quite low at the study sites (0.37 ± 0.36 mg N L-1 as mean value). The same holds for total organic carbon (TOC), which was around 1.0 mg C L-1 in most of the samples. The highest values of both total N and TOC (1.67 mg N L-1 and 14.2 mg C L-1, respectively) were measured at Urdukas in 2012, where a high level of total P (154 µg P L-1) was also detected. This situation was probably related to a local contamination (sampling was performed in proximity of the camp), but it was a transitory effect because the sampling performed at Urdukas in 2011 or in 2012 at other sites in the area did nor reveal any contamination.

As regards the various form of nitrogen, both concentrations of ammonium and nitrate were usually low, especially for ammonium (between 1 and 80 µg L-1). Nitrate levels were never found to be above the limits provided by the WHO and the Pakistan authority for dinking water quality. Organic nitrogen, which was calculated by difference form the concentration of total N and the inorganic forms, was absent in most samples (e.g. all the samples collected in the Humza-Nagar Valley) or between 10 and 300 µg N L-1 at the other sites (Braldu and Basha valley).

Table 23 Summary statistics of the chemical characteristics of water samples collected in the field trips of 2012 and 2013 (n = 62).

	pH	Cond. µS cm^{-1}	Alk. meq L^{-1}	Turb. FTU	N-NO3 µg L^{-1}	N-NH4 µg L^{-1}	Total N mg L^{-1}	Total P µg L^{-1}	TOC mg L^{-1}
Min	7.31	61	0.468	0.0	0	1	0.01	2	0.1
25 perc.	7.90	133	0.946	0.8	102	3	0.16	5	0.4
50 perc.	8.08	185	1.190	6.3	225	7	0.26	9	0.6
75 perc.	8.20	265	1.598	47.4	396	18	0.47	16	0.9
max	8.81	603	3.266	1032.4	1405	79	1.67	154	14.2
Mean	8.04	212	1.370	69.2	278	14	0.37	18	1.0
St. dev.	0.30	115	0.674	168.0	267	16	0.36	30	1.8

These data altogether demonstrated a good water quality in the study area, with very low nutrient levels. Total phosphorus, organic nitrogen and ammonium, which are usually indicators of contamination by pollution sources, both domestic or agricultural, were present in low concentrations in the majority of the samples. A very few examples of nutrient enrichment were found: for instance at Assalabad Nala Glacier and Korophon in 2013 higher concentrations of total P (above 100 µg P L-1) and TOC (2-3 mg C L-1) with respect to the rest of the sites were recorded. These samples were also characterised by high values of turbidity (> 500 FTU), suggesting the presence of particulate materials of both inorganic and organic origin.

All the samples representative of drinking water supply (tank or tap) proved to be of good quality as regards both the base chemical composition and the nutrient levels. The data collected in the three study areas are discussed in details in the following sections.

Basha valley

The location of the sampling points in the Basha Valley is shown in Exhibit 79. The sampling for chemical analyses in this area was performed partly in 2012 (10 sites) and partly in 2013 (5 sites). The results are shown in Exhibit 80.

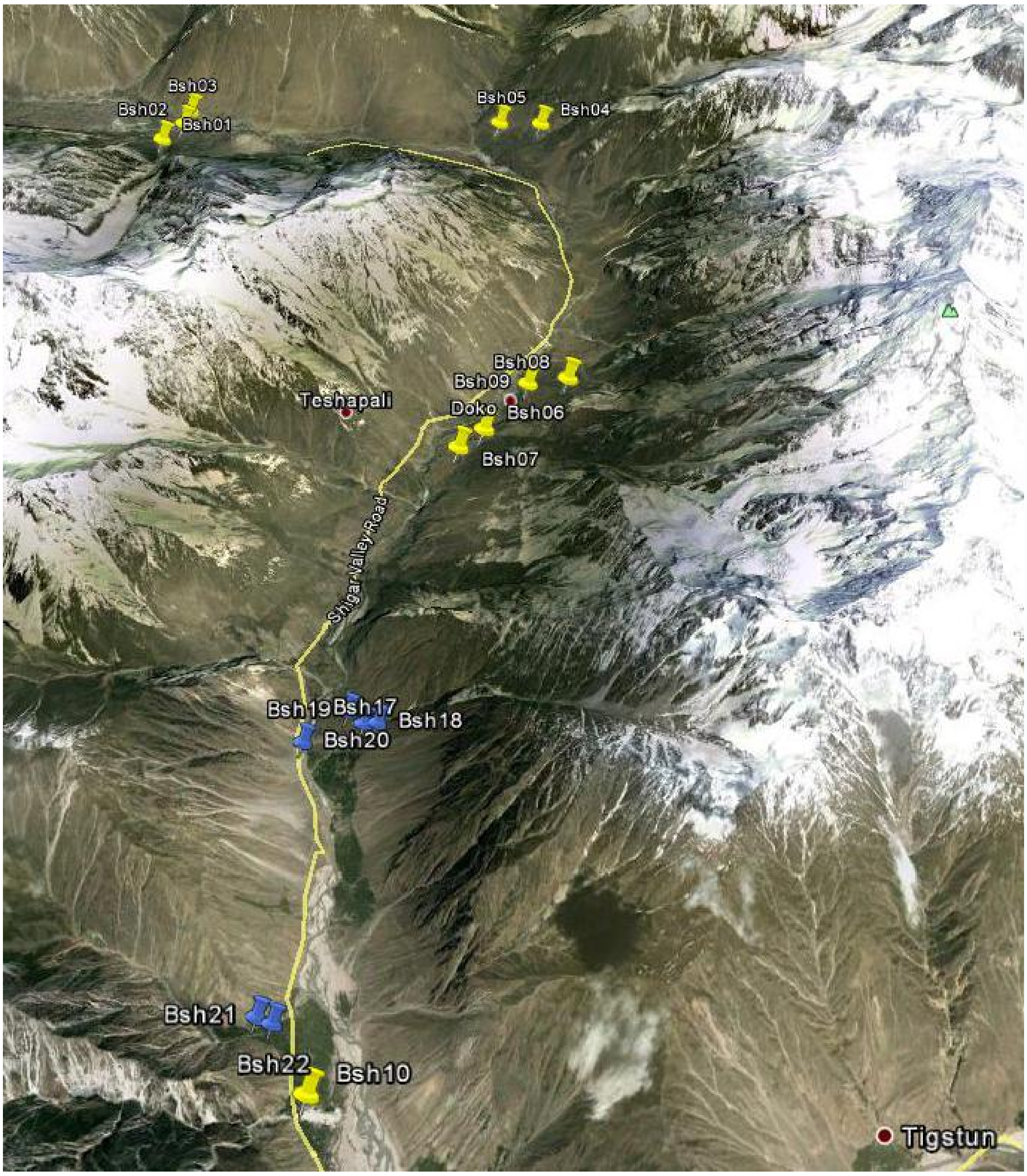


Exhibit 79 Sampling sites in the Basha Valley for chemical analysis (yellow: 2012; blue: 2013)

Code	Turb.	pH	Cond.	Alk	Cl	SO_4	NO_3	NH_4	Ca	Mg	Na	K	RP	TP	TN	Si	F	TOC
	FTU		µS cm⁻¹	meq l⁻¹	mg l⁻¹	mg l⁻¹	µg l⁻¹	µg l⁻¹	mg l⁻¹	mg l⁻¹	mg l⁻¹	mg l⁻¹	µg l⁻¹	µg l⁻¹	mg l⁻¹	mg l⁻¹	mg l⁻¹	mg l⁻¹
Bsh01	0.2	7.97	133	1.120	0.1	16.2	35	1	16.6	4.9	2.2	2.7	2	7	0.05	3.38	0.11	0.4
Bsh02	0.2	8.04	133	1.132	0.1	16.2	55	1	16.6	4.9	2.2	2.7	1	7	0.06	3.39	0.12	0.4
Bsh03	0.1	7.97	133	1.124	0.1	16.2	45	1	16.6	4.9	2.2	2.7	2	2	0.07	3.39	0.12	0.4
Bsh04	5.5	7.93	137	1.067	0.2	19.7	391	2	20.7	4.2	0.6	4.0	1	10	0.47	1.64	0.03	0.5
Bsh05	2.0	7.97	135	1.035	0.2	19.3	336	2	20.6	4.1	0.6	3.9	2	5	0.41	1.51	0.04	0.4
Bsh06	107.2	8.00	174	1.052	0.2	37.2	342	2	25.6	5.2	1.3	3.2	15	22	0.63	1.92	0.31	1.6
Bsh07	75.1	8.00	175	1.081	0.2	38.2	357	2	27.1	5.4	1.4	3.3	10	15	0.57	1.91	0.32	0.9
Bsh08	1.0	7.86	335	1.789	0.7	87.5	1405	1	63.0	8.8	2.0	10.5	14	23	1.64	3.40	0.18	1.0
Bsh09	0.7	8.08	399	1.800	0.7	87.5	1400	1	65.7	9.2	2.0	10.5	13	21	1.68	3.35	0.19	1.0
Bsh10	2.2	8.17	163	1.314	0.2	15.8	636	3	23.1	6.2	0.4	1.4	4	5	0.64	0.76	0.10	0.3
Bsh17	17.5	7.62	119	0.713	0.5	23.8	428	16	19.1	1.7	1.3	2.4	10	12	0.44	1.79	0.32	0.8
Bsh18	16.8	7.69	120	0.683	0.3	24.2	430	11	19.2	1.7	1.2	2.6	6	10	0.47	1.81	0.32	0.8
Bsh19	9.7	7.67	119	0.694	0.2	23.5	428	23	19.1	1.7	1.1	2.5	2	9	0.46	1.78	0.42	0.6
Bsh20	62.9	8.13	309	2.405	0.5	55.8	158	18	51.7	9.3	3.4	5.2	11	11	0.18	3.10	0.33	0.4
Bsh22	0.0	8.17	181	1.715	0.5	18.5	592	4	20.7	6.6	11.4	2.1	2	3	0.59	5.82	0.18	0.9

Exhibit 80 Results of the chemical analysis performed on the samples collected in the Basha Valley in 2012 and 2013

Data as a whole highlight the good chemical status of water resources in this area. Sites clustered in small groups according to their location. E.g. Sites Bsh01, 02 and 03 were very similar each other, indicating a common source of water. Similarly sites Bsh04, 05, 06 and 07 showed common chemical features. These groups of sites with similar water chemistry are mainly related to local characteristics of the watershed e.g. same lithology and soil cover. Sites Bsh08, 09 and 20 were characterised by higher concentrations of the major ions, particularly calcium and sulphate. Bsh08 and 09 also showed higher concentration of nitrogen (mainly nitrate) than the other sites. A contribution from groundwater at these latter sites may explain the higher solute content of water samples. Total phosphorus and TOC were low at most of the sites; slightly higher TP concentrations (above 20 µg P L-1) were measured at a few locations, but were not necessarily indicative of water pollution. Indeed concentrations of organic N, ammonium, total N and TOC were always low, thus confirming a general good water quality. Fluoride concentrations were also checked in all the samples, but values were in all cases far below the limit provided by the WHO (and the Standard values for Pakistan) for drinking water (1.5 mg L-1). It must be stressed that a correct evaluation of water quality, especially for human consumption, cannot be made on the basis of a single sampling. Repeated sampling and analysis must be done throughout the year, possibly in different hydrological condition.

Nagar-Humza Valley

The location of the sampling points in the Nagar and Humza Valleys is shown in Exhibit 81. The sampling for chemical analyses in this area was performed in 2013 and 19 sites in total were considered. The results are shown in Exhibit 82.

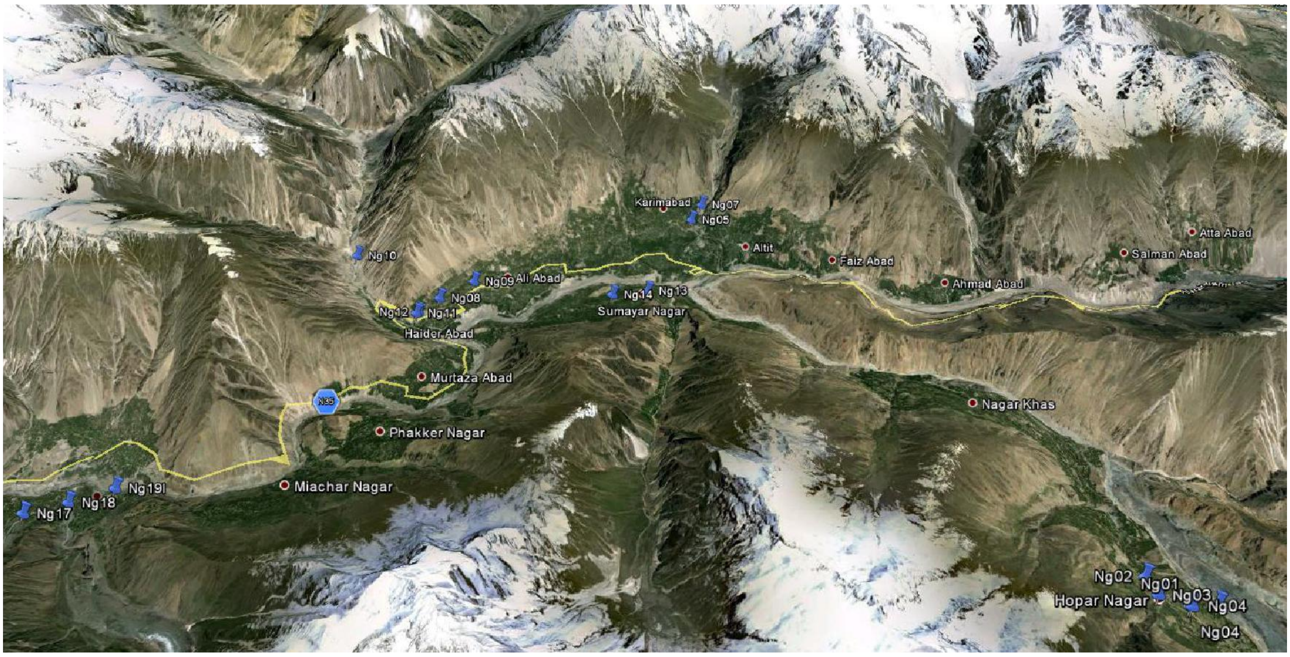


Exhibit 81 Sampling sites in the Nagar-Humza Valley considered for chemical analysis (sampling performed in 2013).

Code	Turb. FTU	pH	Cond. µS cm⁻¹	Alk meq l⁻¹	Cl mg l⁻¹	SO_4 mg l⁻¹	NO_3 µg l⁻¹	NH_4 µg l⁻¹	Ca mg l⁻¹	Mg mg l⁻¹	Na mg l⁻¹	K mg l⁻¹	RP µg l⁻¹	TP µg l⁻¹	TN mg l⁻¹	Si mg l⁻¹	F mg l⁻¹	TOC mg l⁻¹
Ng01	5.9	7.75	271	0.971	0.3	90.1	212	29	45.1	4.3	2.7	2.7	3	3	0.27	3.36	0.50	1.4
Ng02	10.2	7.36	233	0.800	0.8	74.7	367	37	37.4	3.8	2.1	3.1	41	47	0.74	3.07	0.47	1.3
Ng03	4.5	7.73	301	1.199	0.4	96.6	165	6	51.4	5.0	2.1	3.4	3	10	0.36	4.46	0.51	1.4
Ng04	148.2	8.61	118	0.826	0.2	22.7	17	25	17.2	3.5	0.3	2.0	11	16	0.03	0.33	0.02	1.1
Ng05	75.6	7.59	166	0.477	0.7	63.6	229	38	26.9	2.2	1.9	7.9	30	50	0.23	2.34	0.13	1.4
Ng06	96.4	7.64	194	0.488	0.8	66.5	298	41	28.0	2.3	1.9	8.3	35	54	0.23	2.52	0.13	1.4
Ng07	7.6	7.59	237	0.637	0.8	92.0	225	17	36.0	2.8	2.8	10.1	13	12	0.23	2.34	0.16	1.4
Ng08	4.3	8.10	286	1.515	0.6	69.0	167	8	39.1	7.8	2.2	5.3	5	10	0.18	3.32	0.12	1.5
Ng09	3.4	8.12	289	1.409	1.3	68.9	153	7	36.9	7.7	2.3	5.3	3	9	0.15	3.32	0.12	1.7
Ng10	>500	8.22	204	1.250	0.8	48.5	149	79	30.7	4.4	2.5	7.6	58	141	0.19	2.24	0.28	2.3
Ng11	0.6	8.14	250	1.555	0.6	59.9	99	12	37.6	8.8	1.9	5.1	5	7	0.08	3.58	0.12	1.3
Ng12	0.4	8.12	260	1.515	1.0	59.7	110	7	37.7	8.7	2.0	5.1	3	8	0.09	3.58	0.11	1.2
Ng13	0.0	8.02	241	1.377	0.6	58.7	308	4	38.1	7.2	2.2	2.4	1	4	0.23	3.30	0.32	1.5
Ng14	0.6	8.00	240	1.380	0.4	57.9	263	5	35.8	7.1	2.0	2.3	2	5	0.19	3.19	0.79	1.4
Ng15	0.2	8.29	207	2.071	0.4	15.5	571	6	29.4	10.0	1.8	4.4	1	2	0.53	1.56	0.02	1.3
Ng16	2.4	8.24	191	1.999	0.5	13.6	537	5	26.5	7.2	1.4	3.9	1	2	0.51	1.40	0.01	1.3
Ng17	0.4	8.19	316	3.266	0.9	27.9	199	4	22.2	27.0	5.9	4.9	1	5	0.13	2.38	0.02	1.5
Ng18	212.7	8.22	163	1.554	0.3	16.5	262	27	22.0	8.9	1.3	2.1	18	40	0.28	1.08	0.01	1.4
Ng19	0.2	8.23	314	3.260	0.5	28.1	225	4	20.6	25.4	5.9	4.7	1	12	0.17	3.01	0.01	1.4

Exhibit 82 Results of the chemical analysis performed on the samples collected in the Nagar-Humza Valley in 2013.

As for the Basha Valley, also for this area a general good quality of water emerged from the analyses. At the majority of the sites, water showed low levels of phosphorus and nitrogen compounds, as well as of TOC.

High values of turbidity and of nutrient content, including TOC, were found at one point (Ng10); quite high values of total phosphorus and nitrogen compounds were found also at Ng05 and 06, and partly at Ng18 (but TOC levels were low, below 1.0 mg C L-1). In order to assess the presence of pollution sources (e.g. sewage) it would be necessary to monitor these sampling stations on a regular basis.

These results, as those collected in the other study areas, have to be considered as very preliminary and no definitive conclusion could be drawn. It is strongly recommended that a monitoring scheme is foreseen for each site or area. Samples must be collected at least during the different water regimes that characterize each water courses.

Braldu Valley

Water samples in the Braldu Valley were collected in different field surveys (2011, 2012 and 2013). Furthermore in 2011 two sampling campaigns were performed in this area, a first one in April and a second one in July. Some of the sites in this valley were subject to a repeated sampling, so that a rough evaluation of the seasonal and interannual variability can be done. The activity in this area was performed in strict cooperation with the PAPRIKA project and the research units involved in it. The location of the study sites sis shown in Exhibit 83.

Results of the chemical analysis performed on the samples collected in 2012 and 2013 are shown in Exhibit 84. One sample results are reported for each site. Repeated samples, together with the previously collected data (April and July 2011) are discussed in details in the section about seasonal and interannual variability.

As already noticed above, a sample with striking chemical characteristics was collected in Urdukas (Brd10) in 2012; it was affected by anomalous level of both phosphorus and nitrogen compounds, and by a very high TOC content. These features indicate a possible contamination by organic substances. The sample was collected in proximity of a camp, so that it could be that sewage may have contaminated the water just before the sampling. However, the data collected at this site the year before did not indicate any contamination, so that the situation found in 2012 could be just an example of temporary pollution due to a localized source.

A few sites in the Braldu Valley also showed higher concentrations of fluoride (> 1.5 mg L-1) with respect to the rest of the samples: Brd03 (Paju), Brd20 (Tistong – tap water) and Brd24 (Baltoro glacier). Because these values are above the WHO and Pakistan authority suggested limit for drinking water, a regular check of the fluoride levels at these sites should be performed.

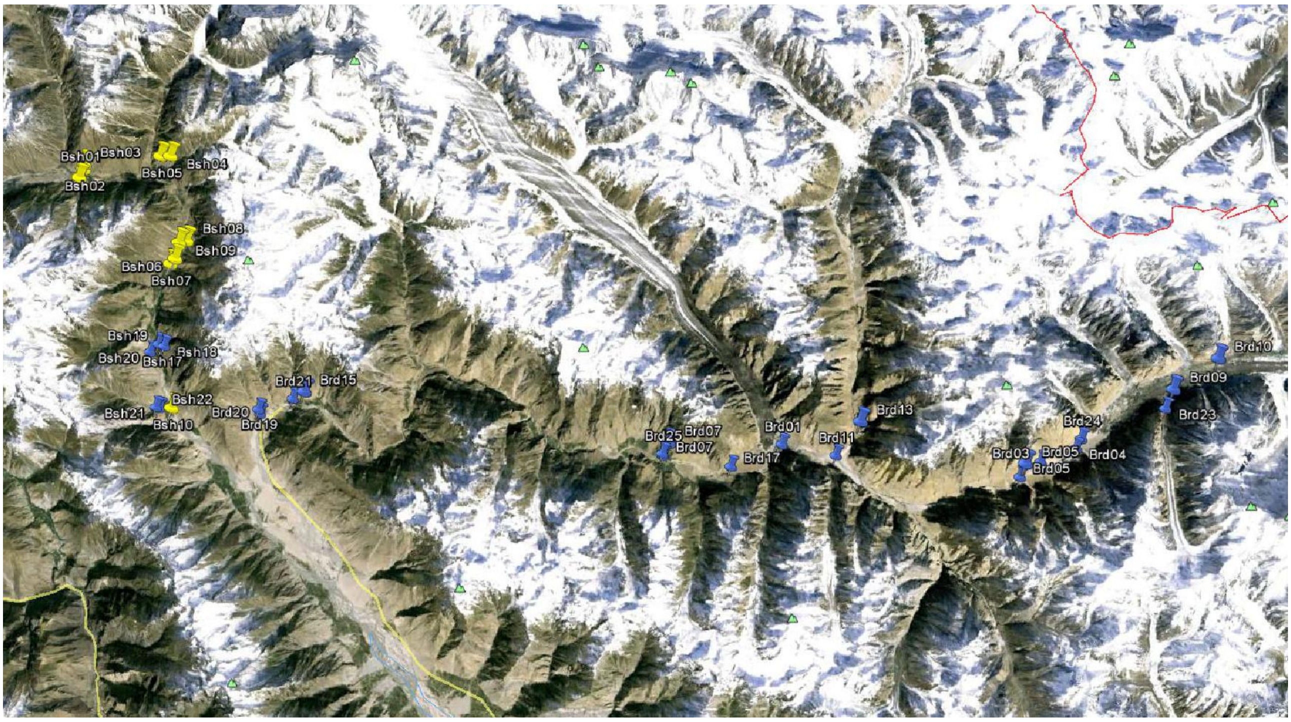


Exhibit 83 Sampling sites in the Braldu Valley (in blue) considered for chemical analysis (sampling performed in 2012 and 2013).

Code	Turb. FTU	pH	Cond. µS cm-1	Alk meq l-1	Cl mg l-1	SO_4 mg l-1	NO_3 µg l-1	NH_4 µg l-1	Ca mg l-1	Mg mg l-1	Na mg l-1	K mg l-1	RP µg l-1	TP µg l-1	TN mg l-1	Si mg l-1	F mg l-1	TOC mg l-1
Brd01	294.1	8.57	90	0.782	0.1	9.0	60	5	15.7	1.5	0.3	2.9	14	15	0.24	0.88	0.07	1.4
Brd03	1.3	7.84	328	2.998	1.0	38.4	0	3	55.8	8.9	12.0	1.9	6	10	0.13	8.58	1.71	1.9
Brd04	2.8	8.35	134	1.241	0.5	11.5	37	37	16.9	4.8	5.2	2.8	13	20	0.23	2.20	0.31	0.1
Brd05	623.6	8.60	61	0.753	0.2	6.2	106	6	12.6	1.9	1.5	2.6	7	9	0.20	1.23	0.18	1.0
Brd07	0.8	8.33	591	2.726	1.2	208. 4	213	7	71.8	35.8	4.9	18.0	3	3	0.40	5.81	0.38	0.1
Brd08	377.1	8.15	184	1.421	0.4	28.3	205	3	28.7	4.9	2.3	4.0	5	7	0.28	1.81	0.17	0.9
Brd09	1.3	7.67	61	0.468	0.4	6.2	260	2	9.9	1.5	0.7	0.7	2	2	0.45	0.85	0.12	1.7
Brd10	12.1	7.31	105	0.837	2.6	2.3	619	7	16.4	3.5	2.1	2.3	116	154	1.67	1.81	0.07	14.2
Brd11	325.2	8.13	103	0.884	0.3	11.0	149	2	16.3	2.1	2.3	2.0	4	11	0.43	1.53	0.21	0.7
Brd13	25.7	8.01	239	1.612	0.4	49.4	443	5	44.4	6.7	0.8	3.1	9	13	0.69	1.80	0.06	2.2
Brd14	12.5	8.17	238	1.648	0.4	47.1	576	7	33.9	10.4	1.8	2.2	11	25	0.76	1.50	0.04	0.6
Brd15	19.9	7.77	137	0.576	0.2	36.2	467	15	23.0	1.9	1.3	1.9	4	5	0.68	1.42	0.24	0.2
Brd16	107.8	8.08	114	1.181	0.6	3.0	418	6	20.0	3.4	0.8	1.3	3	3	0.65	1.19	0.21	3.2
Brd17	1032 4	8.81	92	0.777	0.1	10.7	52	3	13.3	2.4	1.0	3.7	6	6	0.37	1.38	0.09	2.1
Brd19	2.2	7.88	258	1.120	0.4	75.6	405	10	40.6	4.0	4.8	2.9	4	7	0.45	3.32	0.80	0.9
Brd20	6.1	7.95	269	1.177	0.4	80.2	422	10	43.0	4.5	4.9	3.0	8	6	0.45	3.48	1.83	0.8
Brd21	16.6	7.88	243	0.978	0.2	77.6	230	15	40.8	3.1	2.6	2.9	1	6	0.26	2.47	0.34	0.5
Brd23	19.9	7.94	90	0.650	0.1	12.6	100	23	13.2	1.5	1.0	2.8	5	9	0.17	2.27	0.28	0.1
Brd24	38.2	8.25	150	1.092	0.5	25.4	85	28	18.8	5.6	3.8	3.5	6	15	0.11	2.35	1.75	0.1
Brd25	0.1	8.24	603	2.397	1.2	217. 5	308	3	75.9	34.5	4.7	17.7	2	4	0.26	5.92	0.48	0.4

Exhibit 84 Results of the chemical analysis performed on the samples collected in the Braldu Valley in 2012 and 2013.

4.5.2 Seasonal and interannual variability

As indicated above, for a limited number of sites, located in the Braldu Valley, it was possible to perform a repeated sampling. This allowed a broad evaluation of the seasonal and interannual variability of water chemical characteristics. For instance, a few sampling points were considered both in April and July of 2011, as representative of the main flow conditions existing in the area. The comparison of the results from the two different water regimes clearly showed the impact of melting water on water chemistry. In particular the following points could be highlighted:

- a decrease in the concentrations of all solutes can be observed in the second period, due to the dilution effect related to the increased supply of melting water; as regards the different forms of nitrogen, generally low values are observed, typical of remote areas. There are exceptions, however, as the station Askole (in April) and two sampling points (Khoburtse, Urdukas). It can be seen that organic nitrogen is dominant, except in some cases (Askole and Korophon, but only in the first sampling) in which nitrate prevails. In these latter cases, the measured concentrations of nitrate are similar to those normally found in high altitude alpine lakes subject to high atmospheric inputs of nitrogen (Rogora et al., 2008). In total 8 samples were collected in the spring sampling, located along an altitudinal and latitudinal gradient. The results show an increase of solute content from the highest sites (Baltoro) to the sites located in the lowest part of the Valley. This can be partly related to a progressive increase of weathering products proceeding downwards, but also to the fact that more water is available in the upper part of the catchment, providing an enhanced dilution of the major ions.

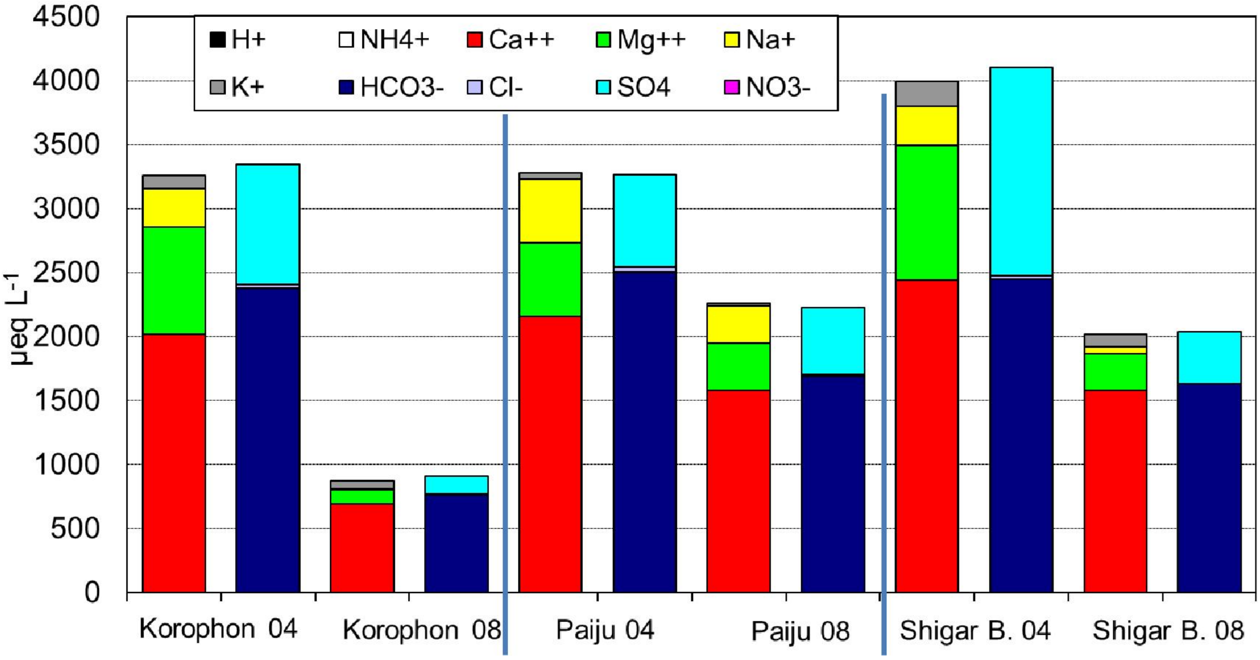


Exhibit 85 Comparison of the ionic composition of waters in April and August in three different stations along the Braldu Valley

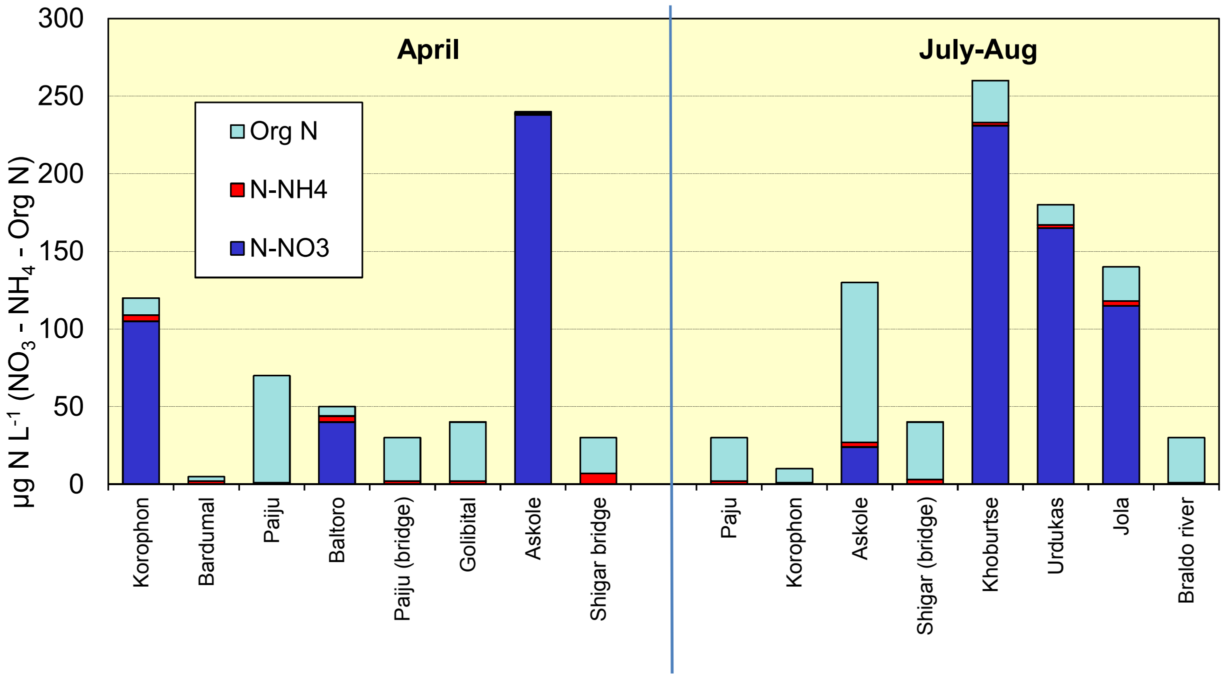


Exhibit 86 Concentrations of the major forms of nitrogen measured in the two campaigns of 2011.

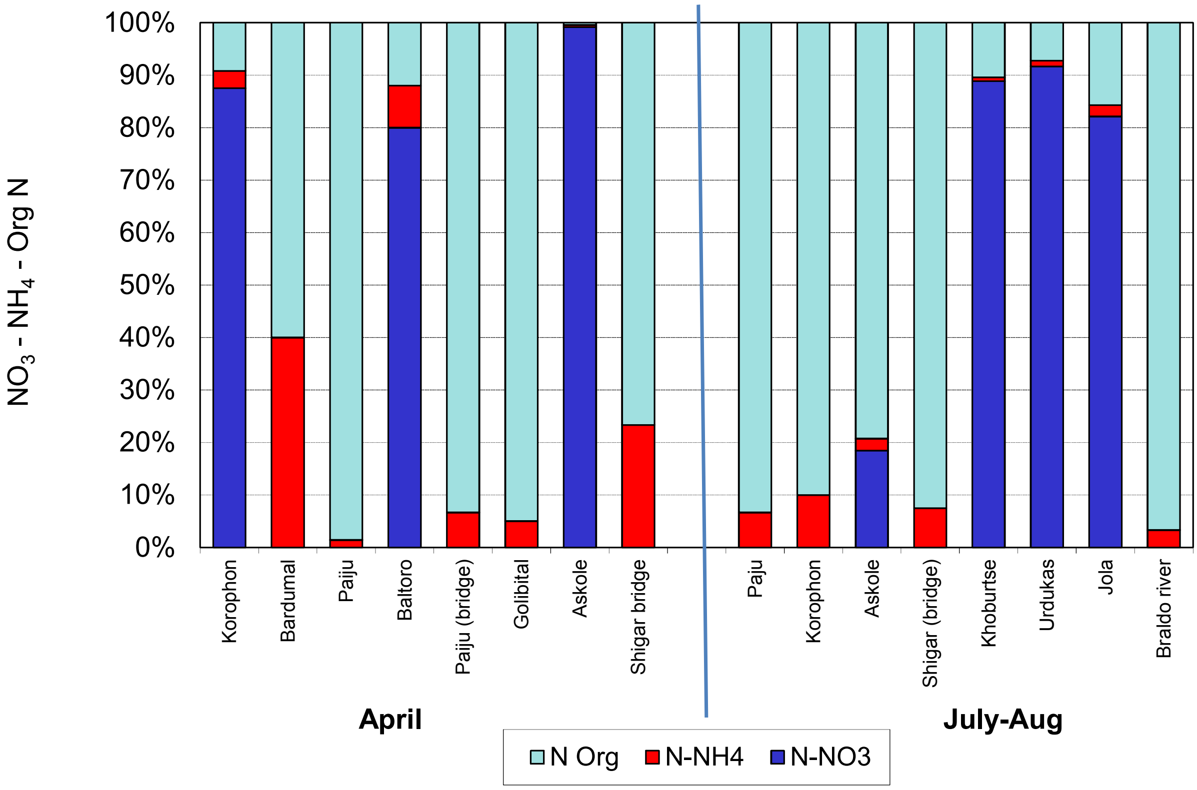


Exhibit 87 Per cent contribution of the different forms of nitrogen to the total nitrogen content of water samples in the two campaigns of 2011.

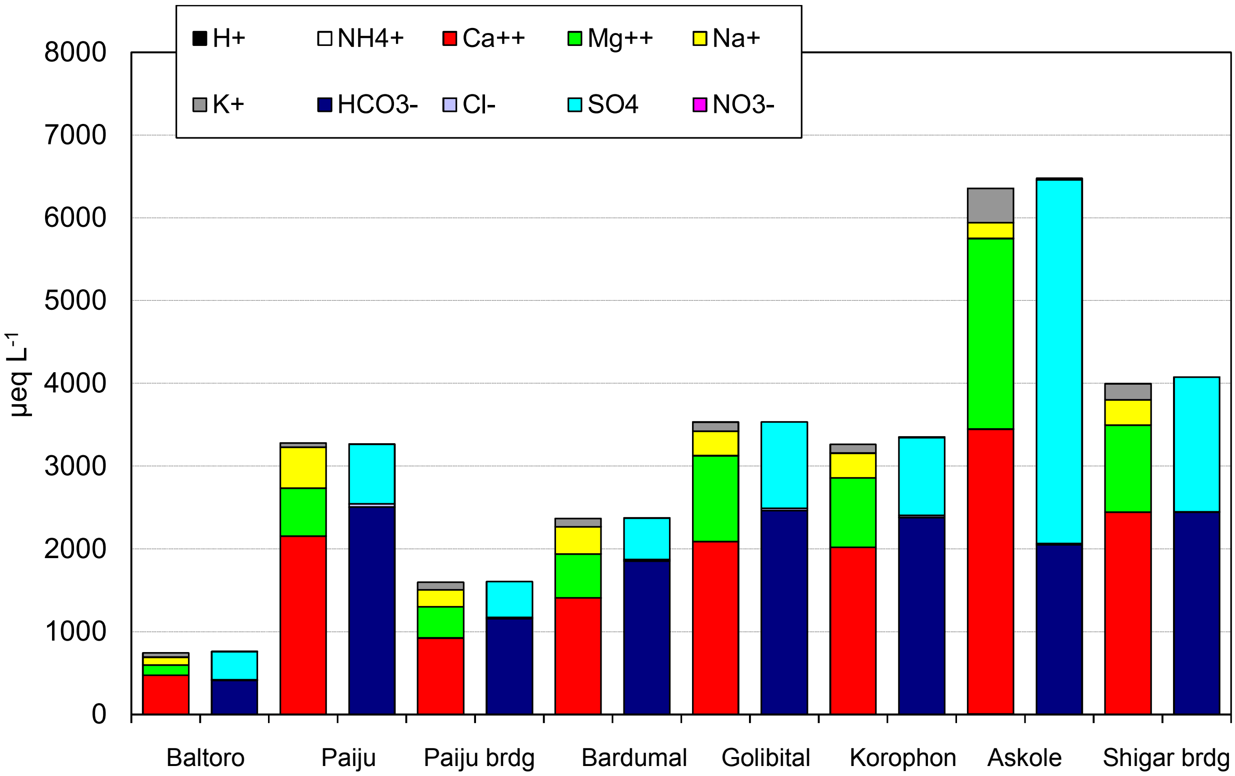


Exhibit 88 Ionic balance of the samples collected in April 2011. For each station, the left histogram represents the concentrations of cations, the right one the concentrations of anions.

4.5.3 Microbiological contamination

Here below (Table 24) are reported the results from the microbiological test performed in the case study valley of Braldo, Basha and Humza-Nagar.

Table 24 Microbiological results of the analysis performed in the three different valleys: Barlu, Basha e Humza-Nagar) within the SEED project.

Site code	Site name	Sampling date	E. Coli	Faecal streptococci	Salmonella spp.		Cont batt
			x100ml	x100ml	1 L	5 L	x100ml
BRD01	Korophon	01/06/2012	<1	<1	ass	n.d.	
BRD03	Paiju	31/05/2012	<1	110	ass	n.d.	
BRD04	Baltoro	30/05/2012					
BRD05	Paiju bridge	31/05/2012					
BRD07	Akole	02/06/2012	<1	<1	ass	n.d.	
BRD08	Shigar bridge	02/06/2012					
BRD09	Khoburtse	29/05/2012	<1	330	ass	n.d.	
BRD10	Urdukas	28/05/2012	<1	340	ass	n.d.	
BRD11	Jula bridge	01/06/2012	<1	31	ass	n.d.	
BRD13	Jula camp	01/06/2012					
BRD14	Shigar restaurant	02/06/2012	4	4	ass	n.d.	
BRD15	Dasso	02/06/2012	1	34	ass	n.d.	
BRD16	Liligo	29/05/2012	<1	8	ass	n.d.	

BRD17	Biafo bridge	01/06/2012					
BSH01	Chumik Arindo	09/06/2012	< 1	7	ass	n.d.	
BSH02	Togi Arindo	09/06/2012	< 1	< 1	ass	n.d.	
BSH03	Khargan Arindo	09/06/2012	6	3	ass	n.d.	
BSH04	Bisil Bombari	10/06/2012	< 1	< 1	ass	n.d.	
BSH05	Bisil Skilkor	10/06/2012	< 1	4	ass	n.d.	
BSH06	Zill Shkong	10/06/2012	< 1	13	ass	n.d.	
BSH07	Zill Malong	10/06/2012	2	38	ass	n.d.	
BSH08	Seisko Shuaika	10/06/2012	< 1	14	ass	n.d.	
BSH09	Seisko Biarzing	10/06/2012	2	10	ass	n.d.	
BSH10	Chotrong Khonjing	11/06/2012	6	4	ass	n.d.	
NGR01	Hoper Ratal	15/04/13	0	3	n.d	n.d	238
NGR02	Hoper Hakalshel	15/04/13	11	21	n.d	n.d	202
NGR03	Hoper Broshal low	15/04/13	4	0	n.d	n.d	226
NGR04	Hoper glacier	16/04/13	0	< 1	n.d	n.d	540
NGR05	Karimabad Barbar	16/04/13	65	33	n.d	n.d	157
NGR06	Karimabad Ultar	16/04/13	0	5	n.d	n.d	200
NGR07	Karimabad Village	16/04/13	0	1	n.d	n.d	53
NGR08	Aliabad (Sultanabad) Bultanabad	17/04/13	0	27	n.d	n.d	419
NGR09	Aliabad lower Bazar market	17/04/13	1	41	n.d	n.d	301
NGR10	Assalabad Nala Glacier	17/04/13	2	1	n.d	n.d	121
NGR11	Village Hassan Abad Hunza	17/04/13	0	2	n.d	n.d	145
NGR12	Village Hassan Abad Lower	17/04/13	0	< 1	n.d	n.d	125
NGR13	Daltho Summyar	18/04/13	0	< 1	n.d	n.d	136
NGR14	Daltho Summyar lower	18/04/13	1	3	n.d	n.d	102
NGR15	Gulmat Village (Jut)	19/04/13	1	1	n.d	n.d	133
NGR16	Minnapin Rakaposhi	20/04/13	5	< 1	n.d	n.d	107
NGR17	Sholee Pissan	19/04/13	0	2	n.d	n.d	99
NGR18	Minnapin glacier lower	19/04/13	0	< 1	n.d	n.d	19
NGR19	Minnapin lower Deran hotel	19/04/13	0	< 1	n.d	n.d	21

It have to be clearly stated that all the sites was sampled only one time so this results have to be interpret with caution and cannot be considered conclusive. However clearly emerge that most of the site sampled have quite good water quality at least under the microbiological aspects. Respect to the general situation there are clearly notable exception that highlight a faecal contamination of water, e.g. Aliabd Market (NGR09), Karimabad Barbar (NGR05), Hoper Hakalshel (NGR02), Hoper Broshal low (NGR03),Minnapin Rakaposhi (NGR16), Khargan Arindo (BSH03). For this site clearly there an urgent need to improve the sanitation water treatment.

Form the survey done the most evident lack is the protection of the sources from possible contamination from animals or people. Frequently the thank are feed by an open air channel, the thank often are not covered or are easily accessible to anyone. A better situation is usually observed for the water distribution from the thank to the village. In this case the water is transported in plastic pipe to the public tap.

4.6 Water management hints

Despite the water quality is recognised as one of the major issue related to water resources management, generally reliable data and information are very scanty and limited to water quality for drinking purpose (e.g. faecal contamination). In addition very few data are available for the high altitude part of the Northern Area that are part of the CKNP area. Within SEED project it was established to perform an evaluation of two Valley as test case to evaluate the condition of the water quality. The Valley (Basha and Braldu) have been selected because they have different anthropogenic impact. Braldu is strongly affected by tourism, while Basha is mainly used by local community.

Under the SEED project, several campaigns have been carried out to assess the quality of water in the CKNP area. During the last water quality campaign, the water has been tested also at village level, and the water samples have been analyzed at the KIU water lab that has been established within the activities of SEED and with the support of Cariplo Foundation.

The surveys were performed in 2011, 2012 and 2013. A total of 65 site have been sampled at once time and in some casa it was possible to repeat the sampling in some of the sites.

Compared with to the National Standards for Drinking Water Quality (NSDWQ), the water examined up to know resulted to be of good quality. However, considering that each site have been examined only once and that there are remarkable exceptions, there is a need to further extend in time and space the monitoring system of the water quality developed and described in the previous chapters. The monitoring is based on a Laboratory based in Gilgit at KIU operated by local staff and specialized in water analysis and a trained group of game watcher from CKNP for collecting the sample in cooperation and under the supervision of the Water Lab staff.

The monitoring protocol developed for collecting and analysing the samples revealed to be appropriate and feasible even in the extremely difficult operative condition due to remoteness of many sites considered. Clearly there are improvement that could be achieved with a better cooperation with local organization operating in the Gilgit-Baltistan dealing with water quality issue.

The major treats for the water quality are related to its high turbidity due to glacial origin and the low protection of both the input channel and the thank itself from possible faecal contamination. In few cases the analysis highlighted a relatively high value in fluoride so this element should be included in future monitoring.

The first priority management indication is the improvement of the protection of the source. First of all by substituting the open channel input pipe with plastic pipe and the implementation of sand filter to reduce the turbidity as the one here below describe:

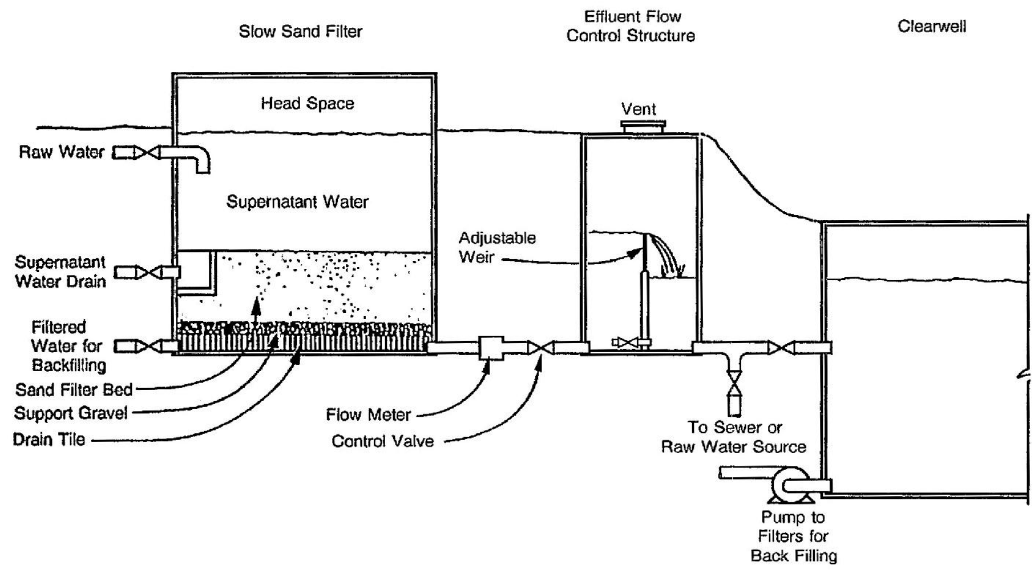


Exhibit 89 A schematic representation of the sand filter to reduce turbidity (http://en.wikipedia.org/wiki/File:Slow_sand_filter_EPA.jpg).

WHO guideline indicated as the most effective means of securing drinking water safety to establish a Water safety plans (WSPs, Bartram 2009). A comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from catchment to consumer.

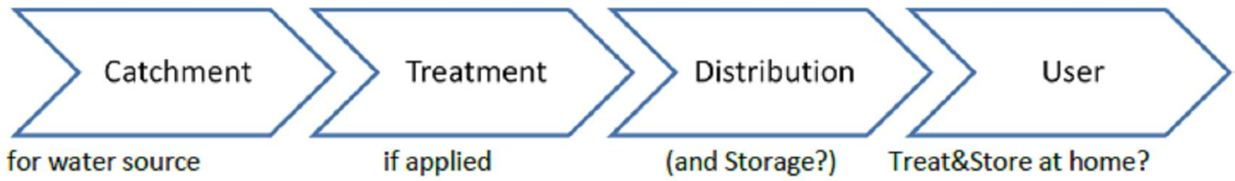


Exhibit 90 Water supply phases

Water safety plans consist of three main components:

1. A system assessment: to determine whether the water supply scheme can deliver water that is safe to drink by respecting the water quality standards of the country and of WHO.
2. Operational monitoring of an appropriate nature and frequency at an appropriate point in the water supply chain is defined for each control measure identified and implemented from the system assessment to ensure that any deviation from the required performance is rapidly detected
3. Management arrangements and communication including details of the system assessment, operational monitoring and validation monitoring together with a description of the actions to be taken in normal operation and incident conditions when there is, or there is a risk of, non-compliance with a standard or target value or failure to meet an operational control, or there is a potential risk to human health.

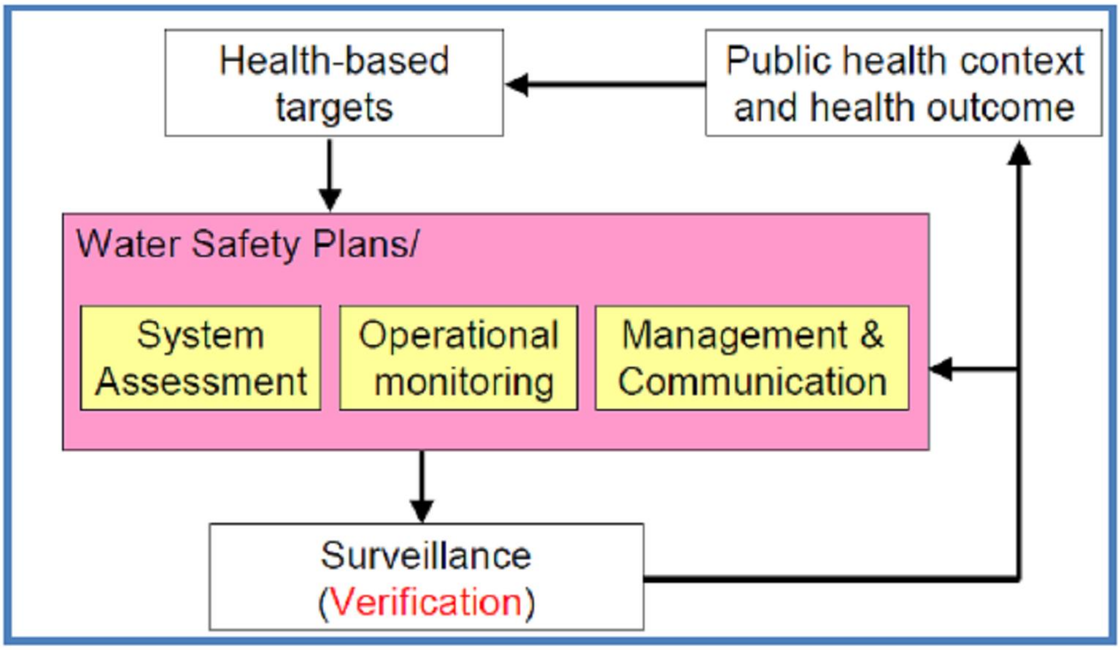


Exhibit 91 Framework for the development of a WSP

In this context it is strongly recommended to maintain and eventually expand the surveillance of the sources within the CKNP following the procedure and protocol tested in the field during the SEED project.

5. Forest Management[5]

5.1 Introduction

One of the key rule to assure the long term conservation of the activities promoted by the SEED project, is to explain to the local communities the existing situation for every task deriving from the studies and the related management actions proposed for the CKNP and adjoining valleys, to support the ecosystem and human activities.

Consequently the research has been organized into three main areas of investigation:

- The first relate to the spatial quantification of resources availability and involved the development of a land cover map of the Park area and an assessment of Park's forests in terms of above ground biomass and current annual increment. This was achieved using satellite images and field plots.
- The second investigation included activities aimed at assessing local communities' livelihood options with a specific focus on forest resources. We organized focus groups in 24 villages of 9 valleys with the double objective of collecting information and stimulate discussion about management plan issues.
- Finally, to increase locals' capacity in forest management related activities, two reforestation initiatives, which included all steps from seeds collection to seeding and seedlings protection from browsing, were organized. In this chapter, the management prescription for CKNP will be summarized. Most of those activities were implemented in collaboration with CKNP directorate, CKNP game watchers of local valleys and partially with the involvement of KIU PhD student.

5.2 Inventory of the forest ecosystems of the CKNP (types)

The whole work has been done in collaboration with Professor Maria Teresa Melis of University of Cagliari.

The methodological approach implemented involves the construction of a database on the land cover (with particular emphasis on forest cover) and land use. Successively, the results obtained have been used to assess the forest Above Ground Biomass (FOREST BIOMASS) and increment. This objective has been achieved by processing data from the analysis of remotely sensed images and field-acquired data. The data from different sources contribute to create a knowledge system that can be used in the different stages of management of the Park: in the programming phase when they are the basis for knowledge of the environment dynamics and of the distribution of resources and during subsequent monitoring activities. In this way, it becomes mandatory to follow a replicable methodology in time and in space based on data calibrated to the ground.

The classification schema utilized in land use mapping includes the main components of the landscape:

- Vegetation features: forest, herbaceous cover, crops
- Mineral features: water, rock and soil
- Human component: villages, roads and other artifacts.

In this project the implementation of a land cover/ land use classification is focused on these goals:

- distribution of forest resources and human activities

[5] Authors: Tommaso Anfodillo, Efrem Ferrari (University of Padova, Italy)

– evaluation of the resources in quantitative terms (extent)

These objectives meet the general focus of the management of the natural resource in the park. In particular, the distribution and extent of forests inside Central Karakoram National Park is of uttermost importance since no data about forest typology, forest extent and biomass were previously available.

A comprehensive and synoptic overview of the Park vegetation distribution, has been considered a priority for the management and future monitoring of the Park. This study aimed at: i) define vegetation landcover classes, meaningful for the Park management, ii) evaluate best methodology to obtain a spatial reliable vegetation map of the entire CKNP, iii) describe the essential land cover characteristics of the park area. Moreover, the map will serve as a basis for the development of above ground biomass and increment assessment, two key parameters to achieve sustainable forest management. Essential characteristic of the output were: i) clarity and easiness of the defined classes (i.e. to be understood and used by local communities and meaningful for managing the Park), ii) simple and robust methodology (i.e. to be easily replicable in future monitoring of vegetation cover change), iii) to form the basis for above ground biomass and increment assessment and, above all, iv) economically and temporally cost-effective.

5.2.1 Methods

Following this rational, and considering the difficulties related to vegetation mapping in steep mountain areas (Dorren et al., 2003; Gartzia et al., 2013; Hantson and Chuvieco, 2011; Vanonckelen et al., 2013), we performed a combined classification involving the use of vegetation index (NDVI), ancillary data (Dem) and supervised classification implemented through a Decision Tree. This classification was based on Landsat images, due to their large and long lasting dataset freely available and on field collected training datasets. In particular, one was used to calibrate satellite derived indices and one to evaluate the accuracy of final classification. Both datasets were collected on ground in various CKNP valleys in the period between April 2011 and May 2013 (the former, composed by 117 points collected in 8 valleys, the second, specific for validation, composed by 334 ground control points gathered in 10 valleys).

5.2.2 Results

The number of classes and their definitions is a trade-off between the need to precisely assess ecosystems distribution inside the Park borders and the limits imposed by the satellite images classification procedure. Additionally, being the land-cover mapping an important management tool for Park staff, clarity and reduced redundancy are essential characteristic. Therefore, 8 classes have been developed, enough general to encompass a wide variety of similar environments and enough different each other to simplify their recognition and maximize their management usefulness. The classes are: Bare soil, scattered vegetation, sparse trees, open forest, closed forest, grassland, agriculture and snow-ice.

Table 25 Land cover classes identified for the Central Karakorum National Park, their definition and the main species present.

Class	Definition	Main Species
Bare soil	Nude soil, bare rock, debris covered by isolated plants	*Capparis, Ephedra, Cardus*
Scattered vegetation	Scattered and fragmented *chamaephytes* vegetation.	*Artemisia, Juniperus*
Sparse trees	Tall shrubs or single trees. C.c. < 10% and height < 5 m.	*Juniperus, Rosa, Artemisia*
Open forest	Partially forested. 10% < C.c. < 50%. 5m < mean height < 15m	*Juniperus, Pinus, Picea, Salix*
Close forest	Dense forests. C.c. > 50 %. Mean height > 15m	*Jun., Picea, Pinus, Betula, Salix*
Agriculture	Fields/orchards/plantations/villages.	*Populus, Salix,* crops
Grassland	Dense grassland & meadows	*Carex, Poa*
Snow & Ice	Snow covered land/ice	

The accuracy of the classification adopted resulted in acceptable level of accuracies (80.24%) and kappa statistic (0.7691). Open forest resulted the class with the lowest producer's and user's accuracies (0.7) following the difficulties of satellite images to detect small differences in tree cover. The land cover map developed for the Central Karakorum National Park revealed important information regarding vegetation distribution inside the study area. Grasslands cover the 11% (1350 km2) of the total surface (11862 km2), followed by scattered vegetation (7.9%) and sparse vegetation (4.2%). Open and close forests represent the 2.6% and 2% respectively (310 and 230 km2), while agriculture the 1.2%. Un-vegetated surfaces are the large majority, 70.6%, with 16.3% of the area being bare rock and 54.3% covered by snow or ice. Large differences are evident between the different valleys, both in grassland and forest cover.

Table 26 Land cover (in % of total valley area) for the different valley and total valley surface (in ha). (AG: agriculture, GR: grassland, SV: scattered vegetation, SP: sparse vegetation, OF: Open forest, CF: Close forest, SN: Snow and Ice, BR: bare rock).

Valley	AG	GR	SV	SP	OF	CF	SN	BR	TOT
Astak	0.7	14.5	5.5	3.7	5.7	4.5	45.5	19.9	26948.64
Bagrote	3.0	16.3	8.6	8.0	7.8	9.1	28.1	19.1	43245.7
Baltoro	0.0	1.6	5.2	0.1	0.0	0.0	78.7	14.5	170940.5
Basha	1.7	14.2	6.4	5.8	4.0	2.0	46.3	19.5	166826.7
Biafo	0.0	4.9	3.6	0.4	0.2	0.1	74.6	16.2	82837.37
Braldu	2.0	16.8	14.8	10.0	3.5	1.6	37.7	13.7	106888.1
Danyore	1.0	15.3	9.5	8.8	8.1	8.8	32.9	15.6	11609.64
Dumordo	0.0	5.4	6.2	0.9	0.2	0.0	74.2	13.1	84726.04
Haramosh	2.1	19.1	6.7	6.7	6.8	12.9	29.5	16.1	48623.05
HIsper	0.1	6.3	7.3	1.9	0.5	0.1	62.6	21.1	130567.4
Hoper	1.9	10.4	6.7	5.4	2.9	1.7	47.9	23.0	42585.02
Hushey	0.4	10.8	8.6	3.7	1.2	0.1	64.2	11.0	103918.8
Jutal/Jaglot	0.9	12.2	12.7	9.6	7.7	6.4	32.6	17.9	10168.2
Kharku	0.0	28.3	24.1	1.2	0.1	0.0	38.3	8.0	4987.26
Minapin	8.8	10.6	9.9	9.9	5.7	5.0	24.8	25.4	37383.84
Shengus	0.2	20.3	8.8	5.2	6.7	4.4	44.1	10.3	13390.11
Shigar	0.1	23.7	15.1	5.1	2.3	1.4	34.8	17.5	38884.37
Thalley	2.6	24.4	12.6	6.3	4.6	0.5	42.5	6.5	39524.31
Tormik	3.2	36.1	5.5	6.5	7.6	4.4	24.8	11.8	22099.41

In general, surface covered by vegetation is lower in the valleys lying north of the main Karakorum ridge. In example , Hispar valley, located in the Northern area of the Park, have 16% of the total valley area covered by vegetation (7.35% scattered vegetation, 6% grassland, 0.64% for open and close forest) while in Haramosh valley, located in the more humid south-west area just south of the Karakorum ridge, vegetation cover is 52% (19% grasslands, 13% close forest, 6.8% open forests, 6.7% for both scattered and sparse vegetation).

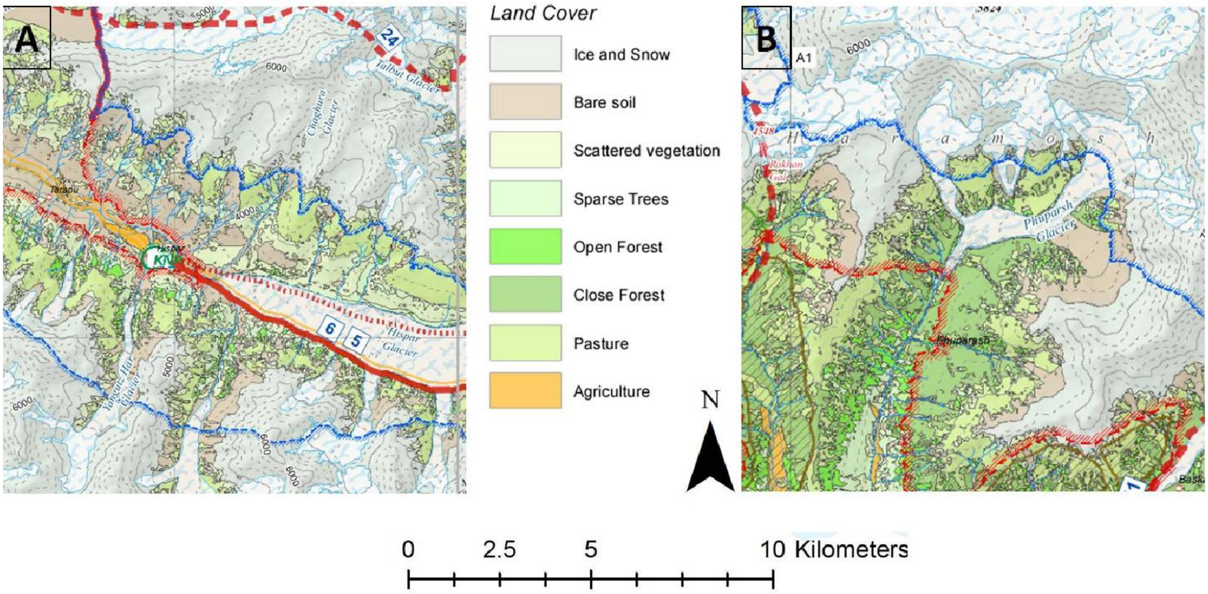


Exhibit 92 Example of land cover map for A) Hispar valley (North of Karakorum main ridge) and B) Haramosh valley (South West of Karakorum main ridge). The two valleys are separated by less than 10 km large mountain ridge, however, their land cover appear very different.

We additionally evaluated how the three main forest types (Junipers, Conifers and High altitude Broadleaves) in the Open and Close Forest classes are distributed within Park valleys (Table 26) and along altitudinal and exposition gradients (Exhibits 93-94). Conifer forests are relatively abundant in the Western valley, south of the main Karakorum ridge around the Rakaposhi massif. Haramosh (26.9%), Danyore (20.9%) and Bagrote (14.9%) are the richest valley in terms of conifer forests (Picea smithiana and Pinus wallichiana). On the contrary, in Baltoro/Dumordo/Hushey and Kharku valley, located in the Eastern area, conifers are absent. Broadleaves species distributions show similar trends even if less pronounced: Haramosh (18.7%) and Minapin (16.8%) are the valley with the highest proportion compared to Baltoro/Hushey (2.6%) and Thalley (2.4%) having the lowest. Even if less abundant, both Betula utilis and Salix spp are diffuse in all the CKNP valleys.

Table 27 Species composition (in percentage of total open and close forest class) in the different CKNP valleys.

Valley	Broadleaves	Conifers	Junipers
Astak	13.8	5.7	80.5
Bagrote	11.1	14.9	74.1
Baltoro	0.5	0.0	99.5
Basha	13.0	4.9	82.1
Biafo	11.5	5.1	83.3
Braldu	11.2	5.3	83.5
Danyore	11.2	20.9	67.9
Dumordo	2.4	0.1	97.5
Haramosh	18.7	26.9	54.4
HIsper	5.1	3.1	91.8
Hoper	8.9	5.7	85.3
Hushey	2.6	0.1	97.3
Jutal/Jaglot	10.5	12.8	76.7
Kharku	6.4	0.0	93.6
Minapin	16.8	11.9	71.3
Shengus	10.9	11.6	77.5

Valley	Broadleaves	Conifers	Junipers
Shigar	6.1	8.8	85.1
Thalley	2.4	4.5	93.0
Tormik	15.1	7.2	77.6

Regarding altitudinal and aspect distribution, the results of the analyses highlight the different ecological needs of each species: birch and other high altitude broadleaves are mainly located on North and North East exposed slopes, in a narrow altitudinal range (3300-3900 m a.s.l.).

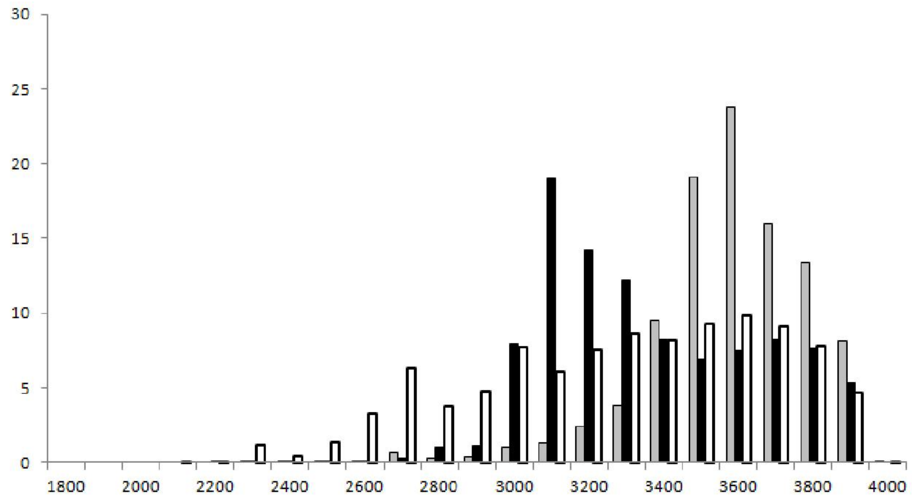


Exhibit 93 Altitudinal distribution (m a.s.l.) for the main forest types (relative percentage). Full black bars: conifers, grey bars: broadleaves, white bars: Junipers).

Conifers, are widespread on North and West slopes in between 3000 and 3900 m a.s.l.. Junipers are less influenced by slope orientation and similarly, show the highest plasticity, with a very broad altitudinal range (2800 m a.s.l. – 3900 m a.s.l.).

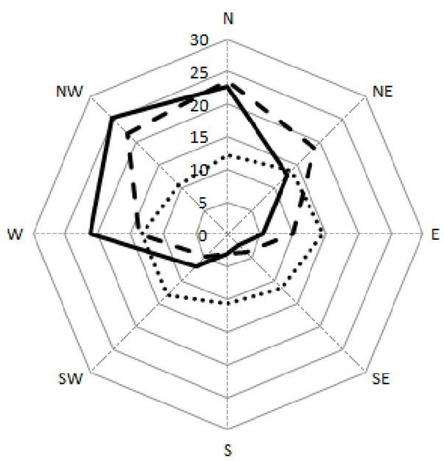


Exhibit 94 Topographic distribution (relative percentage) for the main forest types. Full line: conifers, broken line: broadleaves, dotted: Junipers).

5.2.3 Conclusion

The vegetation map produced provides the Park managers with valuable data to develop management guidelines. The results clearly suggest that rather than general indications valid for the whole Park, valley based management approach should be promoted. The establishment of plantations, often recommended by many governmental and non-governmental organizations, as a measure to reduce pressure on natural forests, shall be prioritized according to per valley forest availability, starting from those who revealed a chronic lack/degradation of wood resources. The distribution of natural forest trees, additionally, suggests to carefully plan reforestation and enriching seeding according to the elevation and exposition revealed in this study.

5.3 Inventory of the forest ecosystems of the CKNP (biomass and increment)

The whole work has been done in collaboration with Professor Maria Teresa Melis of University of Cagliari.

From a simplistic and strictly management oriented point of view, sustainable forest management can be summarized as the need to ensure that, over a certain area and in a defined time frame, wood felling are not overtopping forest yield (Davis et al., 2001; Irland, 2010). This, together with rational management practices, would ensure the long-term retention of forest stock, without further reductions in the total amount of wood. In Pakistan northern mountain ranges, however, lack of forest inventories (Gohar, 2002) make the precise assessment of forest biomass and current annual increment particularly difficult. We aimed at gather information about the basic parameters needed to define appropriate management guidelines and to prioritize interventions in the most forest deficient CKNP areas.

5.3.1 Methods

Field plot data (DBH, increment) and allometric equations were used to assess plots forest biomass.

Those were related, through regression models, to Landsat images derived spectral values. After best model selection and validation, we predicted forest biomass values in un-sampled locations. Subsequently, plot current annual increment was related to plot forest biomass through regression and this relation was used to estimate the total current annual increment of village's forests.

5.3.2 Results

In the 60 survey plots, we measured DBH of 2424 trees, mainly Junipers spp. (55%), Picea smithiana (38%), Betula utilis (6.8%) and Pinus wallichiana (6.6%). Average DBH, maximum DBH and maximum height are summarized in Table 28.

Table 28 Maximum (Max) and average (Avg) DBH and maximum height (Max) for study areas species.

	DBH (cm)		**H (m)**
	Max	Avg	Max
Betula utilis	75	18	21.2
Juniperus	87	13	17
Picea smithiana	117.5	22.6	43
Pinus wallichiana	87.5	22.7	30

Pinus wallichiana and Picea smithiana are the tree species reaching the greatest size both for DBH and height. High average DBH of sampled trees denotes a common lack of regeneration in those stands. This is probably consequence of the heavy livestock browsing pressure, particularly meaningful considering that Picea smithiana is the only shade-tolerant specie which therefore should have a lower mean DBH compared to the others (Schickhoff, 1998). Through allometric equations we estimated the forest biomass of each tree and consequently of each of the 58 plots. Out of a total of 482 Mg, 283 Mg are from Picea smithiana, 101 Mg from Junipers, 57 Mg Pinus wallichiana, and 41 Mg from Broadleaves. Plot forest biomass ranged from 0.4 Mgha-1 to 343 Mgha-1 with a mean of 83.9 Mgha-1. As expected, however, the frequency distribution of plots forest biomass reveals generally low levels of biomass: 55% of the plots have less than 40 Mgha-1 while only 30% have more than 100 Mgha-1. Those data are in line with previous research findings from studies conducted in CKNP forests (Akbar et al., 2010; Akbar et al., 2011; Hussain et al., 2013) as well as from FAO national statistic which estimate an average growing stock of 47.5 Mgha-1 for Pakistan.From the 393 increment cores collected, we assessed the annual percentage increment per tree species. Junipers have the highest mean increment (3.5%), followed by Pinus wallichiana (2.25%), Picea smithiana (2.2%) and Betula (1.1%). It's important noting the high dependency of these values on the diameter class of the trees from which are measured.

The model used to spatialize the biomass data was composed by NDVI and PCA due to higher fitting to the data. Predictor variables PCA1, PCA3…PCA7 were not significant (p-value>0.05) in the preliminary models and thus were eliminated. The final model, with an adjusted R2=0.799, was significant according to the analyses of variance (F stat: 114.5, p-value:<2.2 e-16). Trough t-test we evaluate the distribution of the average squared residuals which did not differs significantly from 0 (p-value>0.1).

Table 29 Regression model developed for the FOREST BIOMASS -Landsat spectral values/indices relation.

Biomass f (NDVI, PCA)	log(biomass)=4.6349+3.7979*log(NDVI)-9.1773*(PCA2)	ADJ R^2: 0.799

Normality of residuals was tested through Shapiro Test (W=0.9712, p-value=0.1821) while heteroskedasticity was tested with Breusch-Pagan test (BP=8.3, p-value=0.01). The results obtained confirm the ability of NDVI to be used as a proxy of vegetation biomass in dry regions with a reduced tree cover/canopy density. In such areas, stand biomass is directly related to tree cover and NDVI is a powerful index for discerning those vegetation, and therefore forest biomass gradients.

Table 30: Forest biomass (Mg) values and current annual increment (Mgyr-1) in the CKNP valleys.

Valley	Veg. Area (km^2)	Tot biomass (Mg)	TOT increment ($Mgyr^{-1}$)	bioma /Km^2 ($Mgkm^{-2}$)
Astak	37.5	147255	971.2	3924.8
Bagrote	107.6	434216	2923.4	4033.9
Baltoro	2.1	287	3.4	138.9
Basha	196.5	417418	2865.7	2123.9
Biafo	5.6	8902	63.8	1594.0
Braldu	160.9	229810	1616.5	1428.6
Danyore	29.9	133206	852.7	4460.6
Dumordo	8.7	2069	21.7	237.7
Haramosh	128.5	1005445	6064.7	7827.5
HIsper	33.2	20168	165.4	607.6
Hoper	42.7	72062	533.1	1686.6
Hushey	52.7	22112	196.3	420.0
Jutal/Jaglot	24.1	81642	541.6	3390.0
Kharku	0.7	179	1.6	270.5
Minapin	77.3	234092	1577.6	3029.7
Shengus	21.9	75064	494.9	3421.7
Shigar	34.1	59788	435.6	1755.5
Thalley	44.9	30675	246.8	682.9
Tormik	41.0	139833	902.3	3411.1

Over an area of 11861 km2, we estimated a total biomass of 3114222 Mg of which 90% from close forests, 8% from open forests and 1.8% from sparse trees vegetation classes. The total current annual increment is estimated to be 20478 Mgyr-1 (0.67% of forest biomass). For comparison, we assessed the average forest biomass of forested areas (according to FAO standards) which equals to 55.6 Mg/ha, just slightly above Pakistan average growing stock of 47.5 Mg/ha estimated by FAO (2010). Forest biomass is not equally distributed among the valleys, but show an highly variable distribution, as expected by previous land-cover studies. South-west valleys as Haramosh (32% of total CKNP biomass), Bagrote (14%) and Basha (13%), indeed, represent almost half of total CKNP biomass while eastern valleys, on the contrary, reveal lows levels of biomass. A similar pattern is observed in the increment availability: the largest increment is clustered in few valleys (28% of total in Haramosh, 16% in Basha, 13% in Bagrote) while eastern valleys show relatively low levels of total increment, with the only exception of Braldu (in which high altitude broadleaves forests are quite abundant).

5.3.3 Conclusion

CKNP faces a high risk of forest degradation. This is mostly consequence of increased firewood demand and mismanagement. Unsustainable forest management leads to further degradation of forests, which affect their ability to deliver products and services to dependent local communities. In an area characterize by rough topography and unstable geology, this means also increased soil erosion, slope instability, as well as reduced carbon sequestration and threat for biodiversity. A co-management between communities and Forest Department shall be prioritized, as a basis to increase local awareness and capabilities in forest management.

5.4 Local communities' livelihood in the Central Karakorum National Park

Degradation of ecosystems and loss of biodiversity in mountain areas has led to the creation of numerous protected areas in developing countries and specific prescriptions aimed at the conservation of their natural heritage were established (Leverington et al., 2010). Often, the conventional management strategies applied involved top-down approaches, such as "fences and fines" system, for which prohibition in access or use is a precondition for preservation of the natural capital (Masozera et al., 2006). Those, however, led to widespread conflicts between authorities and local communities, particularly evident where the latter are dependent on natural resources for their subsistence (Maikhuri et al., 2000; Wells et al., 1992). A paradigm shift towards decentralization and devolution has been promoted to counteract and mitigate those negative effects: the responsibility for protection has been gradually held back to communities, paving the way for what today is commonly called Community Based Management (CBM) (Fisher, 1999). In CBM, communities are the target for assessing natural resource uses, problems, trends and opportunities. By incorporating them in the management system, their experiences, values and capacity are preserved, resulting in higher level of acceptance and sense of ownership both positively correlated with natural resource conservation (Ellis and Porter-Bolland, 2008; Sam and Shepherd, 2011). An in depth analysis of the quantity and value of wood and non-wood forest products and services, as well as a verification of the wood fuel efficiency of the traditional structures and of the local sustainable natural resources use techniques and practices was performed to allow a better evaluation of local needs.

5.4.1 Methods

The 24 focus groups, one per each village, were organized in collaboration with the CKNP game-watchers (Exhibit 95). The main objective was to gather information about livelihood opportunities and natural resource uses in the different CKNP villages. Additionally, it was a precious opportunity to inform locals about CKNP management plan and main forest management guidelines. The presence of at least one representative from each community, in the form of nambardar (chairman of local community organization) has been strongly encouraged. A specific questionnaire was developed to gather information about the uses of forest resources and was translated in Urdu/Shinaa/Baltì or Burushaski according to local community linguistic preferences.

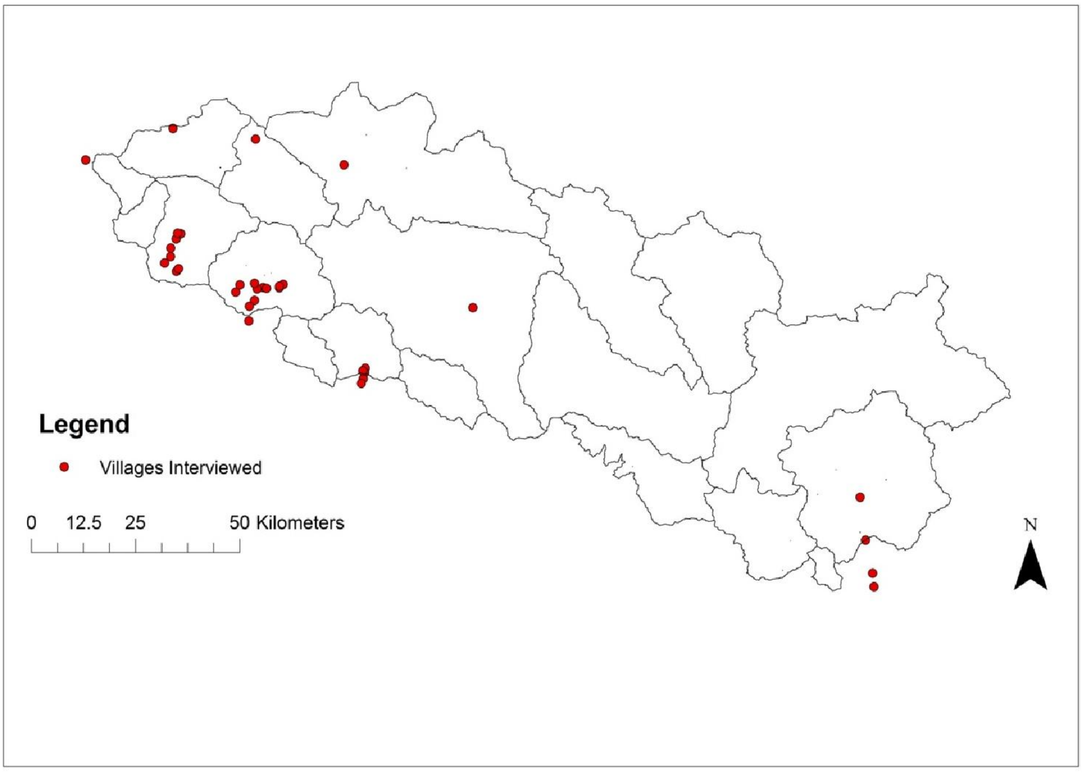


Exhibit 95 Location of the villages where focus groups were conducted.

5.4.2 Results

The communities living around CKNP are heavily dependent on natural resources located inside and around the park boundary. The livelihoods opportunities are strongly tied with the availability of resources, the location of the villages (i.e. altitude), climate, availability of water and easiness of road connections. Comprehensively, all community but one (Minapin Nagar) are mainly relying on goods (output) produced from local activity (input): i.e. food (agriculture), fruits (orchards), dairy and meat (livestock), timber (forest), non-wood forest products (forest). Mining, as tourism, are important natural assets only for few villages and not all the household are usually involved in such activities. Thus, benefit sharing is not equally distributed.

The livelihood in the research area is a typically mountainous livelihood scheme in which livestock, agriculture and horticulture, and forest harvesting and non-wood forest products collection are fundamental activities performed at different times of the year in a cycle, along altitudinal gradients. The timing of the cycle is decided by the climate of the area and might vary from village to village and in between valleys. Here we will define the main steps, similar through all the study area. During springs, the fields are ploughed and grains are sowed. Consequently, household's livestock is moved out of villages to the lower pastures, free of snow, to protect cultivated areas from animal browsing. As the season advance, livestock is gradually moved at higher elevation to the summer pasture (July-August) above the timberline (4500 m a.s.l.). In the mean time, crops are grown and finally harvested. Therefore, livestock can gradually returns to lower pastures and to stables at village levels (November). There, they will stay during all winter (November – March) until successive spring, feeding on the crop residuals and hay collected during summer stored and dried by the households. From summer to early autumn, orchards production is collected and dried, eventually being sold to the nearest city market. In the villages where productivity is higher (lower elevation), fruits is an important component of the households economic portfolio.

During summer and autumn months, firewood and timber, where available, are harvested from local forests and used for construction or as firewood reserve for the following winter. In few valley timber and more rarely firewood is illegally sold to the market.

The overall livelihood scheme is constant over the study area, although timing and relative importance of each output may vary according to village location. The main difference is the availability of forest resources (Exhibits 96 and 97), almost absent in the eastern valleys of CKNP.

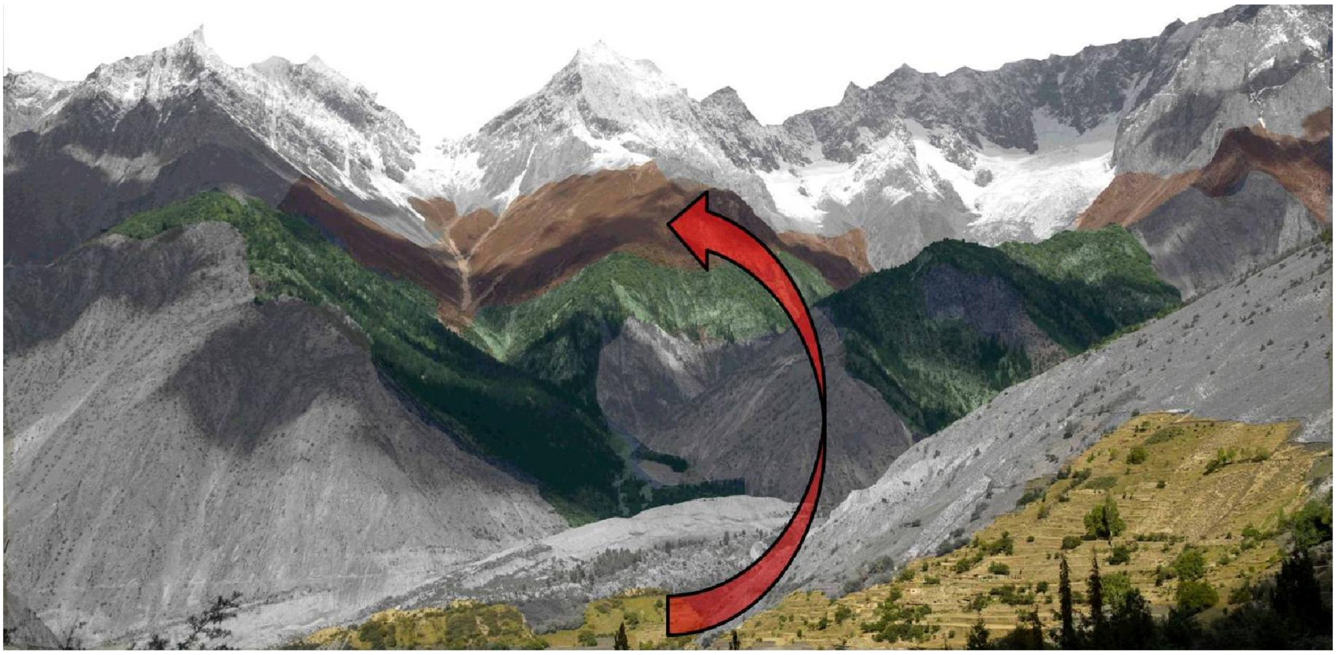


Exhibit 96 Combined mountain – agriculture in Western CKNP valleys: fields, yellow shaded, forest, green shaded and pasture, red shaded are all major component of the subsistence livelihood of local communities. Livestock is gradually moved from spring to early autumn months out of villages gradually up to summer pastures, located well-above the treeline (4000 m a.s.l.).

Exhibit 97 Combined mountain – agriculture in Eastern CKNP valleys: fields, yellow shaded, and pasture, red shaded. Note the absence of forest areas.

5.4.3 Land Tenure

Houses, arable lands and livestock are property of each households while pastures, forests and irrigation systems (fundamental as rain-fed agriculture is not possible due to aridity) are collectively managed at village or households level.

5.4.4 Agriculture

In the research area, agriculture is forcedly restricted to irrigated terraces, due to extreme slope steepness and summer aridity. Predominant crops are grains as wheat, barley and buckwheat. Additional crops as legumes are seldom grown as catch crop while potatoes are the main cash crop. Those productions hardly met household yearly needs and often a large amount of the yearly income is spent on purchasing additional requirements from the market. This is especially true for high altitude villages (above 2500 m a.s.l.) located in the single cropping zone while lower villages, located in the double cropping zone, usually are able to satisfy their own requirements. Most of crop derivates are dried and stocked during the good season and used as winter fodder for livestock. For those cultivations, manure from household's livestock is the main fertilizer.

5.4.5 Orchards

Household living in villages located at lower elevation (below 2500 m a.s.l.) maintain a great variety of fruit trees as apricot, walnut, apple, cherry and pears. Most of the fruits are simply collected and dried on house roof. Then, villages located in proximity of market city as Gilgit or Skardu and with sufficiently good road connection sell them directly there. This is an important asset as productivity and quality is relatively high. Orchards leaves are collected in the autumn months and used as additional fodder for livestock. Similarly, all pruning residuals are used as firewood. For lower altitude villages, where quality and productivity are higher, orchards can constitute both an important revenue and a large source of firewood.

5.4.6 Agro-forestry

Poplars (Populus spp.) and willows (Salix spp.) are the predominant plantation grown around fields and villages. Poplars can be successfully grown in villages up to 3000 m a.s.l. however, as growing rate decrease sharply with elevation, they are more diffuse at lower elevation where they assume an important role in timber production. Similarly to orchards, pruning residuals and leaves are used as firewood and fodder respectively. Poplar became relatively abundant in the last 20 years following large scale supporting campaign by NGOs. No coppice plantation system is used specifically for firewood production. To protect fields from livestock browsing during early spring, when animals are not yet moved to higher elevation pastures, linear hedge of Russian olives (Seabuckthorn, Hippophae spp.) are common. Those are seldom used as firewood, especially in drier areas.

5.4.7 Livestock

Goats, sheep, cattle, yak and crossbreed of cow and yak are common all over the study area. Goat and sheep share in total household livestock are particularly large in lower altitude villages, whereas cows, yaks, and crossbreed, tend to be more common in higher altitude villages, probably as a consequence of larger and more fertile grasslands (Tab. 4). While goat, sheep and cows are grazing in managed pastures, yaks are free roamers: during summer in high altitude pastures (> 4500 m a.s.l.) as well as in winter (around forest or in intermediate pastures (3500 m a.s.l.)). The amount of livestock is variable from village to village, according to pasture size and fertility, and among household within a village. However, through all the study area, livestock represent the most valuable asset for households, thanks to relatively high prices of selling animals in the market and the good value of the dairy products (mainly butter). Just to mention, one goat average price is between 10 and 15.000 Rps (between 70 and 100 €[6]). Moreover, animals can be readily sell in case of economic shortages.

The alpine pastures constitute a key resource for households, which organize the grazing mainly according to two schemes:

1. The household leave most of its animals to a shepherd, which will have the responsibility to move the animals in the different pastures until autumn months (Nov).The shepherd keeps all the dairy products as a payment or exchange the 50% for a certain amount of grains (usually 1 kg of butter equals to 5 kg of grains). In this case, few huts are usually available in the largest pastures.
2. Each family moves his own livestock during the spring and summer months to the upper pastures. In villages where amount of animals is not very large, several families might join together their livestock, each keeping them for one/two weeks. Usually several huts are located in pasture zones.

Rather than a single upward movement to summer pastures, the grazing is organized in a cycle where each single intermediate pasture is used for several weeks both on the upward and downward movement to/from summer higher pastures (Exhibit 98). Regulation in the grazing-land uses are mainly adopted at village level, through a specific commission. Those decides the timing at which livestock should be moved out of the village and the use rights of all the village pastures.

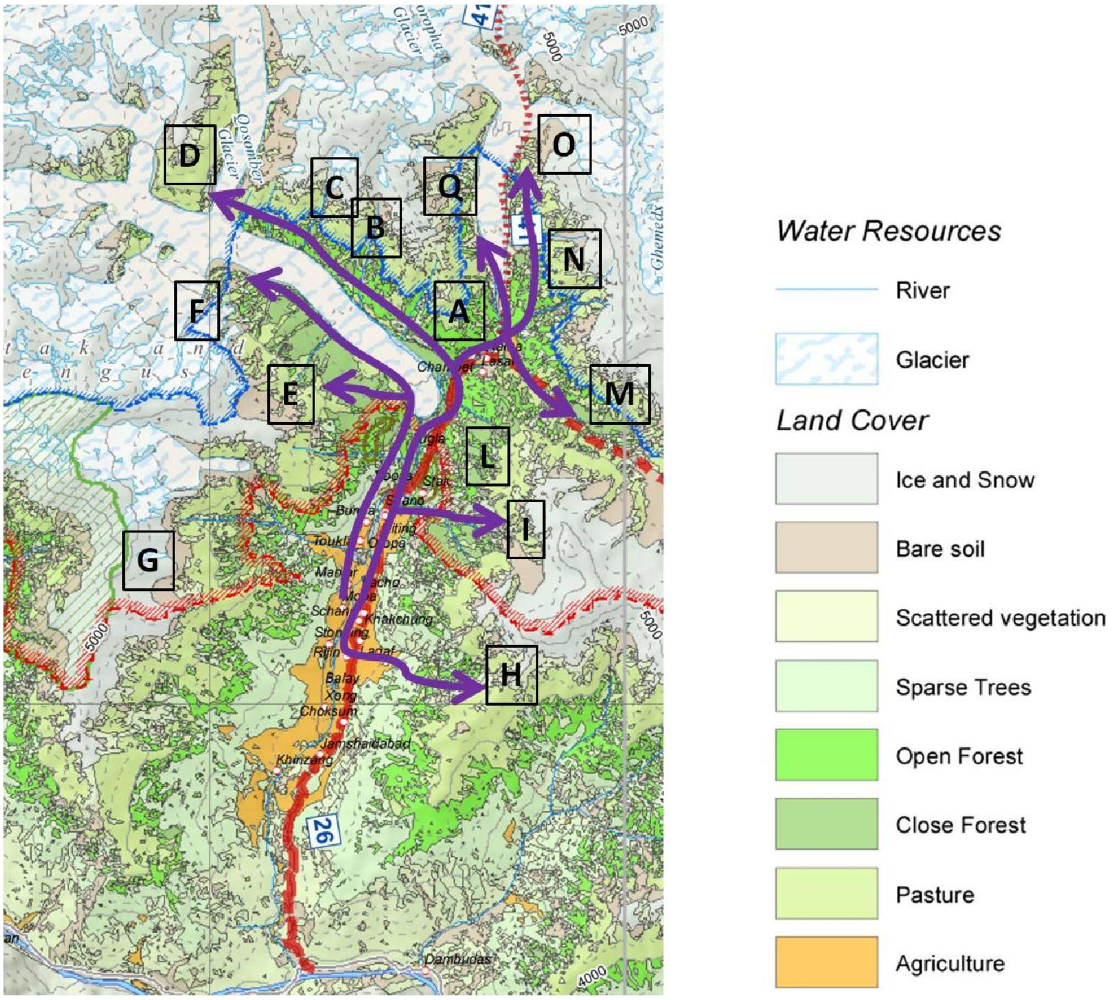


Exhibit 98 Pastures of Astak valley and movement of livestock during the season: A) Chambet (April/May->Sept/Oct), B) Morpholuma (June/August), C) Seralpa (June-August), D) Chaspolo (August); E) Kutja (May/September), F) Schango Luma (June/August); G) Tuglamo (June/August); H) Servogir (July/August); I) Matumbur (July/August); L) Lassar (June/August); M) Lahamosh (June/August); N) Drumaso (June/August) O) Hlarzing (July/August), Q) Liglidlmo (June/August).

[6] Considering January 2014 exchange rate (1 € = 144 Pakistan Rupees).

5.4.8 Forests

Forests are essential for providing grazing ground for the livestock, for covering the firewood necessities (heating and cooking) and for the supplement of timber for construction. Additionally, non-wood forest products as mushrooms (morels) and other plants are widely collected for personal use as well as, in some cases, for selling. From an economical point of view, communities which can entirely rely on self-collection of forest products (timber and especially firewood), even if it is a time consuming activity, save large amounts of money. The different forest conditions among the Gilgit and Skardu district have historically brought some differences in forest use: the forest of Skardu district are mainly used for communities subsistence due to the lack of high-value timber, while the richest forest in the south-eastern sector of Gilgit district have been (and in some cases are still) illegally felled for selling timber in the local markets (Ali et al., 2005; Ali et al., 2006).

A large majority of the communities, realized that most of forest are under pressure, have tried with different degrees of success to limit their exploitation through the creation of specific forest committees. Those in some areas have been successful in reducing the forest degradation (as in Bagrote and Khaltaro) while in other areas like Haramosh and Jaglot Gor were unable to effectively tackle deforestation and corruption which today are still very common.

Timber

Most of the high value timber (mainly Pine and Spruce) is located in the southern valleys of Gilgit district. Consequently, villages with little access to high forests or located in forest scarce areas, organized private/common poplar plantations for obtaining construction wood and firewood is the only product harvested from natural forests. In those realities accessibility to the forest has not been regulated or restricted yet and average annual timber wood needs per household, obtained from the plantation, has been estimated to be 500 Mg per household per year.

On the contrary, in forest rich villages timber harvesting is usually regulated and represent an important share in total household livelihood revenues. All the timber harvested in those valleys shall be considered illegal, as local laws allow the cutting of trees only if previously marked and signed by forest officials. However, in practice, this is hardly happening and locals decide by themselves where and how much to cut. Usually a commission is setting a certain amount (in n° of logs) harvestable for each household. It is important noting that use rights are maintained even by households now residing in nearby villages/cities. Those are allowed to cut the same amount of local residents. The usual amount harvestable is around 100/200 logs per household per year. From a large tree, locals usually obtain around 50 logs. The value of a large tree harvested, divided into logs and transported to the nearest city (Gilgit or Skardu), can vary between 100.000 Rps (Picea) and 125.000 (Pinus). It is evident, therefore, the high importance that forest harvesting represent in the livelihood of forest-rich communities.

Firewood

Firewood is by far the most important wood products harvested from CKNP forests, covering more than 75% of the total forest utilization, as organic carbon is used for heating and cooking and not feasible alternative are found at the moment (Exhibit 99). This is a consequence both of the cold climate and the high cost of purchasing firewood from local markets (700 Rps per 40 kg in Skardu7). The preferred firewood is Juniperus, a very common but slow growing species, followed by shrubs, Artemisia roots, dung and riparian vegetation (as Seabuckthorn) all important component of household fuel portfolio. Additionally, fruit trees pruning residuals are often being used and their relative importance increases in those villages where orchards, being an important income source, are diffuse. Only Minapin Nagar, thanks to its location along Karakorum Highway and the higher revenues related to other economic sources, shifted to gas/LPG cooking systems. In most of the villages there is no restriction/indication on firewood harvestable amounts and locations, but there are exceptions like Hushey village (where a ban has been imposed on some degraded

7 Equals to 5€ per 40 kg transport included (Skardu). In Astak, firewood is sold locally at 2€ per 40 kg.

forests close to the village) or few location in Astak valley. What is usually put in practice is a ban on selling of firewood to nearby villages or cities, at the moment heavily regulated in most villages. Considering wood consumptions, the amount of firewood yearly used obviously decreases from the higher villages (apr. 4000 kg/household/year) to the lower one (2000 kg/household/year). Similarly the share of firewood collected from natural forests decreases from 100% for the villages in proximity of forested areas (higher altitude) to almost 0 of the ones far away from them or located the valleys with scarce forest resources. These villages are mainly using dry livestock dung or orchards residuals to overcome their firewood needs.

Non-wood Forest product

Few non-wood forest product assume an economical significance for local communities. In particular, morels mushroom represent the most important one. Collected in spruce and pine forests from late spring until early autumn, they are dried and sold in Skardu or Gilgit market city. The average price for a kg of good quality dry mushroom can reach 11000/12000 Rps. No large scale processing or drying facility is available and usually only few households (mainly shepherd or young people) is actively searching for them during most of the season.

Valley	Village	N° HH.	Alt.	Agriculture	Orchards*	Livestock G	S	C	Y	Livestock products*	Pasture organization	NWFP *
Astak	Astak I	600	2500	double	Apr	15	10	4	1	Meat, butter	Shepherd	
	Astak II	700	2450	double	Apr	15	10	4	1	Meat, butter	Shepherd	Morel
Sagrote	[illegible]	250	2610	-	Wal	-	-	-	-	-	Shepherd	
	[illegible]	250	2636	single	Wal	10	2	2	-	Meat, butter	Shepherd	Morel
	[illegible]	100	2415	single	-	15	10	4	-	Meat, butter	Shepherd	Morel
	[illegible]	250	2353	double	Apr	15	10	5	-	-	Shepherd	
	[illegible]	140	2156	double	Apr, Wal, App, Cher	10	10	4	-	-	Shepherd	Morel
	[illegible]	150	2231	double	Apr, Wal, App, pear	5	10	3	-	-	Shepherd	Morel
	[illegible]	100	2137	double	Apr, Wal, App, Cher	10	2	2	-	-	Shepherd	
	[illegible]	150	2850	-	Wal	-	-	-	-	-	Shepherd	
Basha	[illegible]	200	2716	single	-	30	20	15	30	Meat, butter, wool	Family	
Haramosh	[illegible]	200	2636	double	Apr	50	20	15	-	-	Family	
	[illegible]	200	1846	double	Apr, Cher	30	10	5	-	-	Family	Morel
	[illegible]	250	1475	double	-	5	1	1	-	-	Family	
	[illegible]	45	2044	single	-	40	10	10	-	Meat, butter, wool	Family	Morel
	[illegible]	250	2601	single	-	50	30	5	30	Meat, butter, wool	Shepherd	Morel
Hushey	[illegible]	300	3075	single	-	30	20	5	10	Meat, butter, wool	Family	
	[illegible]	75	2620	double	Apr, Wal	15	10	2	1	-	Family	
	[illegible]	300	2642	double	Apr, Wal	10	10	1	1	-	Family	
	[illegible]	200	2877	single	Wal	15	10	5	5	Meat, butter	Family	
Minapin	[illegible]	140	2025	double	Wal, Apr, Cher	2	3	1	-	-	Shepherd	Morel
Jaglot	[illegible]	150	1950	double	Apr, Cher	15	5	1	-	-	Shepherd	Morel
Hopar	[illegible]	600	2700	double	Wal, Apr, App, pear	20	33	3	1	Meat, butter	Shepherd	
Hispar	[illegible]	200	3003	single	-	20	10	2	5	Butter, wool	Shepherd	

Exhibit 99 Livelihood strategies in the 24 villages surveyed. n° HH: Number of Household, Alt: Altitude (m a.s.l.), Agriculture: double/single cropping zone, Orchards: only fruits sold to market have been highlighted (Apr: Apricot, Wal: walnut, App: apple, Cher: Cherry, Pear), Livestock: n° of animals per HH (G: goat, S: sheep, C: cow and crossbreed, Y: yak); Livestock product: only products sold to market are highlighted; Pasture organization: how is, at village level, organized the grazing of livestock; NWFP: only products sold to market are highlighted.

Valley	Village	Population	Avg HH firewood (MgHH^{-1}yr^{-1})	% forest	Avg timber (Mgyr^{-1})	Avg firewood (Mgyr^{-1})	Tot (Mgyr^{-1})	CAI (Mgyr^{-1})	Difference (Mgyr^{-1})
Astok	*Astak E*	600	2.5	85%	40	1275	1315	498	-817
	Astak O	700	2.5	70%	40	1225	1265	473	-792
Bagrote	*Bilchar*	250	2	100%	6	500	506	265	-241
	Bulchi	250	4	100%	20	1000	1020	474	-546
	Chirah	100	4	100%	6	400	406	1494	-192
	Farfoo	250	4	100%	20	1000	1020		
	Hopey	140	2.4	75%	8	252	260		
	Datuchi	150	3.75	65%	2	366	368	176	-192
	Sinoker	130	3.2	40%	2	166	168	134	-35
	Taysote	150	2	100%	4	300	304	376	72
Basha	*Arandu*	100	3	100%	20	300	320	1481	1161
Haramosh	*Barchi*	200	2.5	100%	1500	500	2000	678	-1322
	Dassu	300	2.5	100%	600	750	1350	1268	-82
	Hanuchal	250	1.5	100%	187.5	375	562	447	-115
	Jutial	45	2	100%	1012.5	90	1103	1654	552
	Khaltaro	150	3	100%	10	450	460	2015	1555
Hushey	*Hushey*	300	3.5	50%	0	525	525	123	-402
	Marzigond	75	1.5	10%	0	11	11	6	-5
	Tailo	300	1.5	2%	0	9	9	1	-8
	Kande	200	3	40%	0	240	240	73	-167
Minapin	*Minapin*	140	6.5	20%	10	14	24	511	487
Jaglot	*Jaglot*	150	2.5	100%	100	375	475	542	67
Hopar	*Hopar*	600	1.6	60%	0	576	576	533	-43
Hispar	*Hispar*	200	4	100%	0	800	800	165	-635

Exhibit 100 Village's population (N° of Household), average firewood needs per Household (Avg HH firewood, MgHH-1yr-1), percentage of firewood collected from natural forest (% forest), total average timber (Avg Timber, Mgyr-1) and firewood (Avg firewood Mgyr-1) needs per village and grand total wood needs (Tot, Mgyr-1), village's forest current annual increment (CAI, MGyr-1) and difference between total CAI and needs (Difference, Mgyr-1, negative values when needs are higher than CAI).

5.4.9 Conclusion

Local communities living in the Central Karakorum National Park valleys are heavily dependent on natural resources and their livelihoods were traditionally shaped over a fragile equilibrium with natural resources availability. Increase in population and change in traditional living conditions, have recently modify this equilibrium which today seems to be lost, as their use of natural resources have probably reached, in many areas, an unsustainable rate. According to the results of forest inventory and local community survey, natural forests at the moment do not have always the potential to support the local's needs. 16 out of 22 villages have unsustainable harvesting rate. In most cases this is consequence of the scarce growth of local forest resources and the high firewood demands of the local communities. Generalizing for the whole study area, it seems to be important to encourage out-of-forest firewood plantation diffusion, through highly productive and easy to maintain short rotation coppice systems. Those interventions shall be prioritize in the villages located in the eastern CKNP where CAI is usually very low and at low elevation villages, where with sufficient watering, production capabilities are higher. Incentives in the adoption of improved cooking stove, whereas possible and accepted by locals, should be encouraged instead in high altitude villages. Timber harvesting shall be managed according to sound silvicultural principles as target diameter, planning of harvesting in time and space, specie-specific treatments for both Pinus and Picea respectful of the different ecologic needs of those two species. Specifically, the possibilities to control or limit their exploitation rate for forest products and their use of grazing lands is limited if no alternative measures are being provided. However, the diffuse mismanagement and the limited knowledge in restoring degraded ecosystem leave space for mitigation measures which might partially counteract the predominant trend. Working in collaboration with the community, acknowledging first their problems and solving them with a capacity building perspective, are to be considered the only feasible options for reducing the degradation processes.

5.5 Capacity building and management plan guidelines

Pakistan is a country which has very little level of participation of local communities in forest management (Shahbaz et al., 2011). Here, forest department is in charge of taking forest related decisions at all levels (planning, monitoring, harvesting, etc) and direct involvement of locals is uncommon (Shahbaz et al., 2007). Communities are being viewed as the source of deforestation and forest degradation rather than an important stakeholder that, with proper involvement, can improve forests conservation and management. If this belief is partially congruent with the observations made in Central Karakorum National Park, the current strict regulations applied to the forest sector did not halt or reduce the deforestation rate anywhere in the country (FAO, 2012).

The top-down, centralized governance system, typical of former British colonies is one of the main reasons behind those unsuccessful attempts, despite large founding and efforts both from the Government and NGOs sectors (Ali and Benjaminsen, 2004; Ali and Nyborg, 2010; Knudsen, 2011).

Contrary to other former colonial countries of South-Asia, as India, Nepal or Bhutan, where participatory forest management is a reality since the 1980s, in Northern Pakistan little improvement towards a less rigid governance system has been made (Rasul and Karki, 2007).

Generally, participation of communities in forest management is considered at three levels (Ostrom, 1990; Rasul and Karki, 2007):

- participation in the programming phase,
- participation in the decision making process and
- participation in the protection/management of forests.

Through the activities implemented in the CKNP during the research, it was our aim to develop awareness about forest importance and to increase communities' participation at all three levels. However, the strong rigidity in the local institutions, especially when dealing about forest management in protected areas, heavily limited our "space of manoeuvre".

This chapter describe the main measures which have been implemented during the last three years to increase locals' participation in forest management.

Specifically, the first subchapter relates to the capacity building measures aimed at providing skills in reforestation activities among locals and CKNP personnel. Those have been undertaken in 2 valleys.

The last subchapter, contains the management plan guidelines developed after the consultative process with local communities: in this phase, communities' participation to the decision making process was proactive and positive, but to involve them directly in the management a proper legislative framework, of rights and duties, is needed. Regarding this issue, recently, a progress towards a more flexible and comprehensive approach to forest management in protected areas, through a relaxation of existing rules and regulation, gives hope for future's improvement.

This is not to mention that participatory processes are a long and continuous work, which cannot be completed in a short/medium time span of only three years. Results, therefore, are still at their preliminary phase. Indeed, the size of the Park, economic and time constraints has forced us to limit the mitigation actions at just two valleys. However, the involvement of locals and their positive attitude, makes it an important example which we hope might benefit the development of a provincial-based change in governance system.

5.5.1 Capacity building and mitigation measures

In the Central Karakorum National Park there is large need of forest restoration activities. The few example carried out by the provincial forest department, indeed, had often scarce success since planting materials, species and site selections were poor. Additionally lack of involvement of locals resulted in little acceptance and sense of ownership. This lead to heavy browsing of seedlings by livestock (due to uncontrolled grazing, as in Jaglot valley), destruction by land-owners (as in Haramosh), low survival rate of seedlings.

Seeds and seedlings, additionally, are not produced or grown locally and the great climatic and environmental variability of Pakistan, makes the use of non-local planting materials subjected to a high risk of mortality. Indeed, local seed-banks of forest species are not available and, therefore, to promote reforestation initiatives, seeds must be collected in loci to conserve species genetic variability and adaptability.

Therefore we considered important for the Park to develop skills and knowledge about all the steps necessary to start reforestation using local plants species.

We selected two case study valleys (Bagrote and Astak) where, in collaboration with local representatives, we identified two reforestation areas. In both cases, this was not a straight forward, single meeting decision, but was rather the results of a decision process with local communities where areas of high degradation were identified and mapped and the most favorable site were selected, bearing in mind the results of land cover mapping and species altitudinal and exposition distribution.

The focus of those reforestation activities mainly related to two aspects:

- to evaluate best timing and simplest methodologies for conifers cones collection and storing.
- to evaluate best practiced and techniques for seeding and fencing.

The first reforestation area, located in Bagrote valley, was seeded with Pinus wallichiana seeds in Autumn 2012 by the Bagrote local community organization following winter seeding technical guidelines. The reforestation area was visited in late Spring 2013 and revealed good levels of seedlings germinability (>75%) and survival.

The second reforestation, undertaken in Astak valley (Skardu district), was seeded instead with, Picea smithiana seeds, collected independently by the local community during autumn 2012. were seeded in Spring 2013.

A reference guide book was produced to be delivered and shared among CKNP officers and other relevant stakeholders.

5.5.2 Management plan guidelines

The following management indications aim at setting the basis for participatory and sustainable forest management in the Central Karakoram National Park. This is a long lasting and continuous process, where technical skills, community awareness and training of civil society, forest department and park rangers are all necessary ingredients for the delivery of an effective and successful plan. The management plan guidelines can be seen as the conclusion of this thesis work. Three years are not a sufficient amount of time to develop an effective and comprehensive Sustainable Forest Management for the CKNP. However, precious progressions towards its implementation have been made. All those guidelines have been discussed and decided through a consultative process with the representative of each local communities. The time-frame for the adoption of those guidelines through the Park area have been estimated in 5 years. Simultaneously, a

Forest management indication 1 – Constitute forest committees at valley level and community based forest management

In the valleys where they have not been already constituted, CKNP should promote the establishment of forest committees at valley level. The forest committees should become the reference party for the CKNP forest management on the territory, organizing the different actions planned (i.e. reforestation, plantation, etc.) and monitoring the forest threats & degradation drivers. Forest committees, moreover, are the pillars of community based forest management, in which, as the word is suggesting, communities are independently managing their forests with additional assistance by the Forest Department or the CKNP staff.

Additionally forest committees together with CKNP staff should:

Estimate local communities' wood necessities and harvesting areas: precisely, using the questionnaire which has been developed by EV-K2-CNR and University of Padua and locating harvesting areas on the maps developed for the CKNP. A team, composed by the local forest committee members and local CKNP staff will organize open interviews with elders of each village, or, in larger valleys, with a representative sample. This will be a precious occasion also to raise awareness about forest resources conservation and importance.

Report about drivers of forest degradation inside the CKNP buffer area: for each valley a report should clarify if, and in that case, which are the most important factors affecting deforestation and forest degradation (illegal harvesting, firewood necessities, timber harvesting, lack of management guidelines, etc.).

For the SW valleys, where Pinus wallichiana (Kail – Tangshin) or Picea smithiana (Spruce – Katwul – Stak) forests are present: forest committee should be in charge for the collection of cones from those two species. [2.5 kg of Pinus wallichiana (Kail – Tangshin) seeds and/or 1 kg of Picea smithiana (Spruce – Katwul – Stak) seeds - depending on species presence in local forests - would be sufficient to guarantee assisted artificial regeneration in harvested areas (see forest management indication 3).]

Forest management indication 2 –Sustainable Forest Management Plan per valley level (SFMP)

Each forest committee shall prepare a simple Sustainable Forest Management Plan at valley level. This document should include a brief description of the following topics:

- Harvesting area: locate, on a valley map, the areas used by each community to harvest firewood and, eventually, timber.
- Estimation of local community wood necessities: through questionnaire (see management indication 1), the annual wood consumption of local people should be estimated per village (or groups of villages) level.
- Highlight degraded areas: eventually locate on a map the forest areas heavily degraded and the motivation (if possible).
- Regulation already in practice: describe if some regulation have already been set (e.g. limitation on access, ban on harvesting etc) and for which area are valid.
- Forest prescription: in the document all the prescriptions which the forest committee has established should be clearly stated.

The sustainable forest management plan shall be approved, at least, by the forest committee and the CKNP.

Forest management indication 3 – Timber harvesting in mountain dry temperate forest.

According to University of Padua, inside CKNP buffer area some forests is eligible for organized timber harvesting. Those are stands which are classified as “closed forest” of Pinus wallichiana (Kail, Himalayan Blue Pine) and/or Picea smithiana (Katwul, Morinda spruce).

Similarly to what is performed in Europe and North America, harvesting of green trees should be allowed if degradation status is limited (but first a change in Northern Area current forest legislation is needed).

The specific management prescriptions will be defined in the sustainable forest management plan (SFMP).

General guidelines, set by forest committee, should include:

- To adopt a “target diameter” management prescription, for which only the trees which reach or exceed a certain diameter (60/ 80 cm – 23/30 inch, depending on specific site and fertility) can be cut while all the trees smaller than this threshold should be left to grow. These management guidelines (that shall be defined in detail) ensure a correct diameter composition of the forest stands.
- Define the entire forest area eligible for felling and locate it on a map.
- Divide this area into parcel, with an average size of 50 hectares (120 acres) and easily identifiable and understandable borders (ridge, rivers, roads, etc.). Around 10 parcels shall be identified.
- Each year, harvest timber (and eventually firewood) only from a certain parcel, selecting the trees to be cut with the target diameter system: an average cutting cycle of 10 years shall be allowed.
- The area interested by the felling should be left to natural regeneration with additional assisted artificial regeneration (if necessary) provided by the above mentioned seed harvesting (see Forest management indication 1).
- Avoid grazing, as much as possible, in regeneration areas eventually by building fence with thorny shrubs (i.e. sea-buckthorns) to prevent goat and sheep feeding on young seedlings. In any case, a collaboration with shepherds should be promoted in order to avoid unattended grazing.
- Support a complete utilization of the wood residuals following tree harvesting (e.g. branches, stump,...) also for firewood purposes.

Forest management indication 4 – Firewood collection

Firewood collection, being an essential practice for the community living around the CKNP borders, cannot be limited if alternative energy resources are not found. Moreover, in the short-term-future we do not foresee any feasible possibility for a significant reduction of firewood needs of local communities. Nevertheless, actions raising local communities awareness about the (often) unsustainable long term effects of the current firewood collection practices should be implemented.

Most of firewood necessities are actually met using a wide array of different forest resources according to village location: Juniperus is the most common harvested species, followed by riparian vegetation and other minor shrubs (like Artemisia) in drier and more continental valleys (NE CKNP).

In principle, even the firewood collection activity should be included in the SFMP, with simple prescriptions discussed and approved by the forest committee, local community and CKNP (e.g. reduce collection in heavily degraded areas for a certain time period).

Management indication for firewood collection, which might be considered by the forest committees include:

- Juniperus trees: we recommend to do not harvest complete individuals but rather cut single branches. Juniperus trees, indeed, show a rather strong resilience and are able to sprout new branches the following years.

- Regarding riparian vegetation: for coppice plants like sea-buckthorns or willows we suggest to cut single basal shoots from each plant to preserve its root system. Doing so new shoots can re-grow rapidly producing new biomass to be harvested.
- Shrubs: for coppice plants we suggest to partially cut the basal shoots trying to avoid, if possible, the cutting of whole individuals. In these cases, local knowledge and traditional management system should be emphasized and taken into consideration.

Forest management indication 5 – Firewood plantation

In those areas were firewood from local forests is hardly sufficient to cover the needs of local communities, or where forest degradation have depleted above ground biomass to extremely low amounts, specific actions should be implemented to increase wood availability from non-forest areas. Plantation of trees (poplar, willow, sea buckthorn) to be managed as coppices for the production of firewood, therefore, should be promoted as an effective tool to reduce the pressure on natural forests. Those activities shall be directed particularly to those valleys where forest cover is naturally scarce.

Forest management indication 6 - Training forests

Inside the buffer areas, training forest could be promoted for each valley (if supported by local communities). The objective of training forest is to train local park rangers and members of the forest committees in different forest management practices. Different types of cuttings can be adopted and effect on forest regeneration monitored, in time. Those would be ideal areas also for evaluating the regeneration capabilities of forests in time. One training forest shall be identified for each most common forest typology present in the valley

5.6 Formative training and capacity building

During all the seven missions organized in the Central Karakorum National Park by our team, strong relationship were developed both with CKNP game-watchers (through field visits) and local communities (focus groups and reforestation activities). Additionally, during the first year (2011) one KIU forest phd student joined our team during all field missions. Unfortunately, he quit the phd program at the end of 2011, and there was no replacement. Two seminar for phd student were organized in November 2011 and June 2012 at the KIU University.

6. Evidence-based contribution to development of conservation oriented livestock and pasture management in the Central Karakorum National Park[8]

Two main courses of action have characterized our contribution to design an evidence-based livestock policy concept for its discussion and inclusion in the CKNP Management Plan.A first course was devoted to Livestock Health, with the ultimate goal tooperatively answer to the following two main questions:

1. are Livestock Health issues of any interest for an administration (CKNP) whose core mission is the Conservation of a unique natural heritage?
2. if yes, which are the priorities and which sustainable policy can be suggestedwith the limits of the due attention to existing budgetary constraints?

A second course of action was rather focused on the impact of Livestock on natural resources (namely primary productivity) within the CKNP Buffer Zone. In this case, the main questions before us were:

3. how can we cheaply measure the Livestock impact at the Park scale?
4. how can resource managers at CKNP similarly cheaply monitor the dynamics of the Livestock impact within short and medium time scales?

In fact, there is close relation between both courses of action, as resourcedeterioration (if any) has obvious cause/effect links with livestock number, management and ultimately health. Resource deterioration and poor livestock health have the potential, in turn, to mirror on fitness and population size of related sympatric wildlife, namely valuable free-ranging ruminants, becoming a matter of concern for their conservation then a typical issue deserving interest by the chief administration of a protected area of remarkable national and international reputation.In this interim report we will try to concisely inform stakeholders about all actions carried out within both courses and illustrate the available results with a special focus on findings which we deem of immediate relevance to development of a Livestock Policy in the CKNP.

Regarding the livestock/pasture management, a new field mission is planned in spring 2015, focused on:

- development of another vaccination and mass treatment campaigns on livestock, with improvement of training for local supporting personnel;
- epidemiological survey of small domestic ruminants in new CKNP areas;
- definition of an insurance scheme for yearly vaccination and anti-parasitic treatment of small domestic ruminants in the CKNP area;
- development of guidelines for livestock/pasture management good practices.

The results of these activities will be integrated with the previous results, with the aim to support the amendment process of the CKNP Management Plan.

6.1 Interview survey of local communities

6.1.1 Main Objectives

1. Collecting first-hand information on animal health and inter-species relationships at the livestock/wildlife interface, with special focus on sheep and goats;

[8] Authors: Luca Rossi (University of Torino)

2. Assessing awareness of selected communities on sanitary risks related to livestock/wildlife cohabitation.

6.1.2 Material and Methods

An ad hoc interview form was developed, including a total of 19 questions. All were YES/NO or Multiple Choice Questions. Fields were present for additional notes and explanations. All forms were filled by the chairman and a single operator of the Livestock Health sub-Project (LHsP), with the support of local translators usually represented by personnel of the CKNP. Interviewed people were farmers with special experience in sheep and goat husbandry and management; candidates were suggested by notables of local communities.During interviews (each one lasting between 15 and 30 min), all efforts were done by interviewers and translators to avoid any kinds of misinterpretation. With a single exception (in Hushey, Ghanche), a single interview was obtained per community, with the contribution of 2-4 experts.

Exhibit 101: Interviewing in proximity of a broq in Thallay, Ghanche

6.1.3 Results

Overall, 14 forms were filled in 11 communities (namely Hushey, Kanday, Dalter, Thallay, Tormik, Haramosh, Skanderabad, Nilt, Minapin, Miacher, Hoper), involving 35contributor experts.

Amongst main causes of year round mortality in sheep and goats, “Diseases”was ranked first in 6 communities and second in 5. The second most important cause was “Predation” (ranking first in 5 communities), followed by “Winter Starvation” and “Casualties”.

The main predator were “Stray Dogs” (namely in communities along the Karakoram Highway), followed by “Wolf” and “Snow Leopard”.

In the preceding three years, mortality due to diseases in SRwas mainly:

i. in form of separate individual casesas opposite to outbreaks or a combination of both (10 communities);
ii. affecting both lambs/kids and adult individuals (6 communities);
iii. observed in spring (7 communities) followed by winter;

Observed pathologies were mainly involving the skin, feet and mouth/lips (as signaled in 10 mainly communities), followed by the respiratory system (9), eyes (8), digestive system and body condition (6 communities each).

Wild Caprines (Asian ibex and/or Flare-horned Markhor) grazing not simultaneously on pastures that domestic flocks were actually grazing or had recently grazed were reported in 8 communities, more frequently during summer (7). Wild Caprines grazing simultaneously with domestic flock were reported “several times in the same year” in 6 communities, though “only occasionally” in other two. Prevailing minimum distance between interacting livestock and wildlife was <10 m (6). A nice snapshot showing a male markhor and a female domestic goat at the distance of approximately two meters was shown to an interviewer by personnel of CKNP based in Haramosh. Putative Asian ibex x domestic goat hybrids were signaled by experts in 3 communities.

Wild Caprines with signs suggesting disease were never observed in 6 communities. In the remaining 5, suspected conditions (all in Asian ibex) were winter starvation, dystocial parturition (a single case) and a single all age outbreak characterized by mouth involvement (at least 10 ibex affected, in Hushey).

Most communities (10) answered NO when asked “Do you think that wildlife may transmit severe diseases to your flocks”, though the opposite was deemed more likely (6 YES and 5 NO). However, only two communities perceived that cross transmission of diseases between wildlife and livestock is currently a problem. Out of 4 communities involved in Trophy Hunting programs, two answered YES and two NO.

Five of 11 communities happened to have their flocks vaccinated (undetermined diseases) or mass treated (usually against parasites) at least once in the last three years (usually, partial campaigns supported by WWF or The Snow Leopard Trust). All communities answered YES when asked “Would you be favorable to vaccination or mass treatment to improve health and productivity of your flock?”. Seven communities suggested spring as the most appropriate season to vaccinate or mass treat their flocks, followed by winter and autumn.

Most interviewed experts were owing binoculars (in 8 communities).

No shepherd dogs (or any other owned dog) are used in the interviewed communities. However, as anticipated stray dogs are abundant (and problematic) in communities along the Karakoram Highway.

6.1.4 Discussion and “Take home messages”:

Based on results of the present interview survey, a representative sample of CKNP communities perceives diseases as the main cause of year round mortality in Small Domestic Ruminant (hereafter SDR), superior to kills by stray dogs and large sylvatic predators. This result was somewhat unexpected.

Contributors had clearly no specific education in livestock health, nevertheless we may infer from interviews that mortality is mainly due to endemic diseases affecting SDR of all ages. Outbreaks with high mortality rates, eventually involving several flocks in a limited time interval, are apparently less frequent than suggested by the general epidemiological situation in the Country.Therelatively low outbreak risk is consistent with the limited import of live animals (eg, replacement rams and bucks) in the CKNP valleys, reported by interviewed animal health operators(see 1.B, pg.9). Remarkably, the prevailing endogamic attitude of local SR farmersis favorable prerequisite for sustainable preventative actions in the animal health domain.

The higher incidence of disease related mortality in (early) spring may be reasonably associated to predisposing factors, namely the poor condition at the end of winter; but it may also derive from increased contact rates between flocks which were previously confined in their winter shelters, resulting in enhanced spreading opportunities for a range of transmissible pathogens.

Description of main symptoms of disease in affected SR points towards a range of pathologies which are “classic” in extensive farming systems worldwide, eg:

i. skin: sarcoptic and psoroptic mange;
ii. feet: footrot;
iii. mouth/lips: contagious ecthyma (Orf);
iv. respiratory system: bacterial and parasitic pneumonias;
v. eyes: infectious kerato-conjunctivitis (by Mycoplasma).

Hence, feedback by interviewed farmers seems to confirm that the bulk of disease related mortality in CKNP communities is represented by “traditional” endemic diseases. Nevertheless,selected symptoms or combinations of symptoms may also fit diseases of major concern in Veterinary Public Health, such as FMD (Foot & Mouth Disease), Sheep Pox, Goat Pox, PPR (Peste des petit ruminants) and CCPP (Contagious CaprinePleuropneumonia).These diseases are cross transmissible to zoologically related wild Caprines, and outbreaks with severe demographic consequences have been reported in the Asian continent, including Pakistan.

Answers dealing with spatial relationships between SR and wild Caprines support the view that close interactions between these actors occurin most communities.They are often perceived as common events (“several times in the same year”). Interactions at very short distance (<10m) seem also common and, apparently, even direct (sexual) contact may occur on occasion, leading to hybridization. Under these circumstances, all kinds of known pathogens may be potentially cross transmitted, including those characterized by poor environmental survival.

Despite favorable prerequisites for cross transmission of diseases between investigated livestock and wildlife, no more than a single outbreak with no major demographic consequences in affected ibex (putatively FMD or Contagious Ecthyma) was mentioned by contributors.Though we cannot exclude that inconsistencies with the fore mentioned background may derive from incomplete awareness of interviewed experts, we feel prone to accept that no major outbreaks (eg, as visible and demographically impacting as sarcoptic mange amongst Blue Sheep in nearby Shimshal Valley, Khunjerab National Park) occurred in CKNP wildlife during recent years. In fact, similar feed-back was independently received by local veterinary officials (see 1.B, pg. 9), CKNP personnel and a considerable amount of other people involved in animal husbandry and trophy hunting in the area. It may be hypothesized (though it needs evidence-based confirmation) that wild Caprines in CKNP are frequently exposed to a range of endemic pathogens of livestock, which in turn may booster substantial herd immunity under natural conditions.

Given the very limited number of disease outbreaks recorded in wild Caprines, it is not surprising that local communities are only partially aware that “flocks may transmit severe diseases to wildlife”.

Finally, it is interesting to register that local communities have no preconception against livestock vaccination and/or mass treatment campaigns, not even the communities lacking previous experience. Spring time is suggested as the most appropriate season to vaccinate or mass treat SR, possibly because spring is the season with the highest incidence of disease related mortality.

Exhibit 102: Meeting the local community in Kanday, Ghanche

6.2 Interview survey of local animal health professionals

6.2.1 Main objectives

1. Collecting first-hand information on livestock population size and trends;
2. Collecting first-hand information on diseases affecting livestock (with special focus on sheep and goats) and related wildlife;
3. Discussing with local animal health experts about implementation of livestock vaccination/mass treatment schemes in communities within CKNP.

6.2.2 Material and Methods

No specific interview form was developed. Interviews were carried out in english by the chairman of the Livestock Health sub-Project (LHsP). Interviewed people were Official Veterinarians and Livestock Assistants belonging to the Department of Livestock and Dairy Development, Gilgit-Baltistan, and two practitioners contracted by KIU (Prof. Naqvi). Interview meetings were organized in towns/villages of the four districts of GB in which CKNP territory is included (Hunza-Nagar, Gilgit, Skardu, Ghanche).Each meetings involved 1-4 experts. A considerable amount of notes were taken during interviews, and report/data were kindly offered by the Official Veterinarians when available.

6.2.3 Results

Overall, 7meetings were held, namely in Gilgit, Minapin, Skardu (two), Khaplu(two) and Hushey, involving 19 contributor experts.

Information was obtained on the organization of veterinary public services in GB, which includes structures with different complexity and staff, from Hospitals (4 in Hunza-Nagar, 2 in Gilgit, one in Ghanche)to Dispensaries (19 in HN, 24 in Gilgit, 16 in Skardu, 16 in Ghanche)and finally First Aid Posts. In total, there are 4OfficialVeterinarians enrolled- all of them DVMs - supported by 54 Livestock Assistants with a one yeareducation in Animal Health. Extension workers with baseline education are also available in several communities in support of Official Veterinarians and Livestock Assistants.Official Veterinarians mainly operate at the Hospitals and surroundings, whereas activity in Dispensaries is mainly run by Livestock Assistants, under the supervision of Official Veterinarians. In communities within CKNP there are one Hospital (Minapin) and 12 Dispensaries.

Livestock

Based on contributions, the value of live production animals was estimated as follows (€/unit):

- ✓ Sheep: 60-100
- ✓ Goat: 150-250 (highest price for lactating goats)
- ✓ Cattle: 300-600 (up to 1200)
- ✓ Yak:up to 1500

Quite lower prices may be paid for animals to slaughter (30 €/sheep, 80 €/goat).

The value of meat was estimated as follows (PKR/kg):

- ✓ Sheep: 500
- ✓ Goat: 500
- ✓ Cattle: 280-300
- ✓ Yak: 280-300

Main production from local dairy cattle is butter, whereas dairy goats are raised for butter and raw milk intended to drink.Mixed cow/goat butter is also produced. Cow milk is usually reconstituted from powder, whose origin is external to GB: powder milk is quite expensive (600 PKR/kg).

There is still large use of cattle and cattle x yak hybrids (zomo) for packing and agricultural work (eg, ploughing).

Local goats usually raise one kid, and sheep also raise one lamb (sometimes two, if given additional feeding in form of concentrates). Births are seasonally concentrated (in winter-early spring). Weaning occurs at the age of 2-3 months. High survival of kids and lambs is reported (suggesting adaptation of local breeds to harsh environmental conditions).

Livestock census is updated on occasion of vaccination campaigns that Official Veterinarians carry out to circumscribe foci of epidemic diseases Census data relative to CKNP area communities were kindly provided us by Official Veterinarians of the Districts of Ghanche, Skardu and Hunza-Nagar, and integrated with livestock data provided by selected communities interviewed in Gilgit District (see Annex 2, in the Final Report). All census data are reasonably updated (never collected before 2010).

Based on interviewed experts, SR have greatly reduced in number compared with 3-4 decades ago. Decrease in SR number was more obvious in communities enjoying easier connections with towns (eg, along the Karakoram Highway), conversely it was less spectacular in remote villages. In a shorter time interval (last decade) different trends were signaled, namely a slight increase in communities with increasing human population and very high unemployment rates, and further decrease in richer communities (eg, in Hushey). As opposite, the number of cattle has maintained steady or increasing in all Districts. Amongst factors contributing to diminished pastoralism are the availability of alternative (and more remunerative) job opportunities for adults, and the increasing demand of schooling for kids and teenagers, once the typical manpower destined by households to livestock guarding and care. Interviewed experts confirmed that, in several communities within CKNP, SR flocks are now in charge of specialized shepherds during the transhumance to high summer pastures, while SR care from autumn to spring is still managed at the household level.

Overgrazing by livestock is not felt as a problem in the high summer pastures, where – reportedly – cattle and ST are usually grazed separately. However, overgrazing may occur when, for some reasons, cattle and SR are grazed together. As opposite, conservation of hay and fodder is felt as a fundamental issue, since it mirror on livestock condition and the associated resilience to a range of endemic pathologies.

Diseases

Most frequent pathologies in cattle are parturition related pathologies (uterus prolapse, dystochia, milk fever), mastitis, haemorragic septicemia (by Pasteurella multocida) and clostridioses (blackleg, blackquarter, anthrax).

In SR, sarcoptic and psoroptic mange (in goats and sheep, respectively) are well known conditions. Other frequent pathologies in SR are rumen foreign bodies, mastitis, pneumonias, endoparasitism by liver flukes and gastrointestinal nematodes, and skin diseases by lice, Hypoderma or traumatic myasis agents. Reportedly, diarrheas (nutritional in origin or caused by a range of infectious and parasitic agents) are relatively less frequent.

Outbreak diseases are observed in SR, namely FMD, Goat Pox, Sheep Pox, PPR (Peste des Petits Ruminants), CCPP (Contagious CaprinePleuropneumonia) and Enterotoxaemias. Diagnosis of outbreak diseases is mostly clinically and epidemiologically based (eg, whether occurring in goats, or sheep and goats simultaneously). Recent Pox outbreaks 50-60% morbidity. Ruminants affected by FMD are treated symptomatically with local traditional medicines.Recognized risk factors for the occurrence of outbreak diseases in local SR are the transit of large flocks destined to feed the Army troops based in the conflict zone with India, west of the Actual Ground Position Line (AGPL), and the purchase of live sheep and goats from villages at lower altitude. Nevertheless, interviewed experts agree that import of SR from other communities (or markets) is not common practice and that endogamy is still the prevailing attitude.

“Classic” zoonotic infections of livestock such as Brucellosis (BRC) and Tuberculosis (TB) are apparently rare. An interviewed physician operating in Shigar Valley on behalf of SEED Project added that beef tapeworm (Taenia saginata) is prevalent in the area, while he was not aware of any case of human hydatidosis. Rabies is apparently absent in the CKNP communities, though increasing stray dog population along the Karakoram Highway is an obvious risk factor deserving attention.

Though no major sanitary problems occurred in CKNP at the livestock/wildlife interface, the Veterinarian in charge at the Minapin Hospital (Hunza-Nagar District) referred that 4 sick markhors (two males and two females, age 1-2 years) had been hand captured by officials of the GB Wildlife Dept. Three were affected by ocular pathology (putatively infectious kerato-conjunctivitis) and one had Pox-like cutaneous lesions (putatively Goat Pox). In 2013, FMD was detected in a female ibex found dead around Hushey, while compatible FMD signs (lameness, painful feeding) were concurrently observed in other ibex from the same zone. The veterinarian in charge at the Skardu Veterinary Hospital referred of a supposedly mangy ibex observed in proximity of Satpara Lake, on the way to Deosai National Park. Rumors of mange in ibex around Hushey were also referred, though there was no official confirmation of the diagnosis. During interviews we were made aware of a recent outbreak in proximity of ChitralGol National Park, in which 45 markhors were found dead possibly because of FMD (http://www.dawn.com/news/712249/foot-and-mouth-disease-endangers-markhors-in-chitral-game-reserve). Robust cases of mange were reported us in foxes in CKNP (Thallay, Hushey) and in a snow leopard in proximity of Skardu (http://tribune.com.pk/story/125991/captured-snow-leopard-dies-in-custody/).

Vaccination and mass treatment campaigns

As anticipated, vaccination campaigns of livestock carried out by Official Veterinarians are implemented with the sole scope to circumscribe ongoing outbreaks. Logistic and budget difficulties while implementing such emergency vaccinations have been referred.

Preventive vaccination campaigns (for the sake of clarity, those carried out to anticipate outbreaks) are not common practice in the CKNP area. Only recently, NGOs like WWF-Pakistan and the Snow Leopard Trust have sponsored focal vaccination or mass treatment campaigns against Goat and Sheep Pox, PPR and mange (eg, in Hushey, Kanday and Hoper). As referred, compliance by communities was quite variable (from 30 to approximately 100%) as well as the competence and commitment of the operators. On occasion, the purchased amount of vaccines/antiparasitic drugs was insufficient.

Vaccines approved for use in SR in Pakistan are either of local or international patent (the latter are usually 2-3 fold more expensive). Vaccines against FMD and Poxinfection are deemed robust and effective, while some of the experts questioned on the efficacy and stability of the vaccines currently available against PPR. When vaccines are needed, a two weeks-one month interval must be foreseen before delivery by the producer companies. Injectable ivermectin (IVM) formulations to control mange are similarly well known and easily accessible in drug stores located in towns and main villages across GB, though they are deemed expensive.

Cost/vaccinated head of currently available PPR vaccines is comprised between 5 and 8 PKR, while vaccines against Sheep and Goat Pox are cheeper (< 2 PKR).

According to an interviewed experts, 7 working days would be necessary to vaccinate 3000 SR with a door-to-door approach. The suggested composition of the “vaccination team” is 3-4 people, namely one Official Veterinarian or Livestock Assistant and 2-3 extension workers. Based on recent experience in Hushey (a WWF funded campaign), a second expert indicated 9-10 working days to vaccinate the same amount of SR, and suggested an ideal team of 6 people. A third interviewed Official Veterinarian affirmed that one thousand SR can be vaccinated in one day, provided full compliance is assured by the host community.

Discussion and “Take home messages”:

Interviews with experts focused on (though were not only devoted to) pastoralism and the health of sheep, goats and wild sympatric ruminants. The underlying concept of this particular choice is that cross-transmission of pathogens at the livestock/wildlife interface is facilitated by zoological proximity, which is obviously much greater within the subfamily Caprinae than between Caprinae and Bovinae (like cattle, yak and their hybrids). FMD is the only significant exception to the fore mentioned “rule”.

Information reported under the heading Livestock (see above) can be summarized as follows:

- ✓ the market value of live SR is still quite high compared with the cost of living in GB;
- ✓ the market value of the SR meat is also high compared with alternatives (eg, beef and poultry)
- ✓ expectedly, local SR breeds appearwell adapted to harsh environmental conditions,and able to cope with malnutrition related to poor winter diet;
- ✓ despite all the above, SR are in negative population trend due to profound (maybe irreversible) socio-economic changes, which mainly impact on previously widespread availability of cheap juvenile manpower.

Prevalent pathologies are endemic and “classic”amongst extensively raised livestock worldwide, with the exception of sarcoptic and psoroptic mange which are prophylactically controlled, and were eventually eradicated, in most developed Countries and regions.

However, outbreak diseases (mostly of infectious origin) are also not rare in livestock raised in the CKNP communities, and all interviewed experts were able to mention personal involvement in the control of recent foci of highly contagious FMD, Sheep and Goat Pox and PPR. Reportedly, outbreaks were most frequently prompted by contact with livestock originating from outside the CKNP communities.

Interviewed professionals were not feeling that major sanitary problems had occurred in CKNP following the cross transmission of pathogens from livestock reservoirs. Nevertheless, they were aware of disease episodes (some small outbreak included) occurred in wild Caprinae in the CKNP or elsewhere in GB. Under the circumstances (a huge zone, relatively low wildlife densities and a limited number of animal health professionals),information that we managed to collect is evidence that a range of transmissible diseases may already spills from infected livestock over valuable (eventually naïve) wildlife. While it is commendable that such information simply exists, it is recommended that greater support be offered to Official Veterinarians and Livestock Assistants, to improve their diagnostic skillsand be motivated, in future, to make all efforts to preserve precious biological samples (of domestic and wild origin) and forward them to reference laboratories for sound etiological diagnosis.

In a conservation perspective, livestock diseases are mainly relevant as threats and limiting factors for sympatric wildlife. Accordingly, measures to reduce infectious contacts at the livestock/wildlife interface should be part of a comprehensive Management Plan in all Conservation Areas were livestock is allowed to use pastures which are also home of zoologically related wildlife. Amongst such measures are vaccination and mass treatment campaigns against pathogens representing major threats to wildlife. Based on interviews, diseases which seems to deserve special attention are mange (which may be controlled in the domestic reservoir by means of mass treatments with effective anti-parasitic drugs), PPR, FMD, Sheep and Goat Pox and CCPP. While no CCPP vaccine is allowed in Pakistan for use in goats, vaccines are officially registered in the Country for use in SR against the remaining three diseases.Interviewed experts informed that prophylactic vaccination and mass treatment campaigns have been recently carried out in selected CKNP communities by conservation oriented NGOs. These preliminary trials, though perfectible in terms of organization and compliance by communities, suggest that the time is ripe for such innovative approach.

Based on current organization of public veterinary services in GB, it is certain that future vaccination (and mass treatment) programs to be implemented in the frame of SEED Project might benefit from the existing network of Official Veterinarians, Livestock Assistants and extension workers in charge of the Department of Livestock and Dairy Development. It is reasonable to assume that, due to the low number of Official Veterinarians, Livestock Assistants will be the natural candidate leaders of local vaccination teams.

Cost of vaccines and injectable anti-parasitic drug for mange control is relatively cheap for international standards, and may be compatible with co-financing of yearly vaccination and mass treatment schemesby local communities.

Finally, different opinions were collected on composition of the “optimal” vaccination team, and the number of SR that such team may vaccinate on a daily basis with a the desirable “door-to-door” approach.

6.3 Epidemiological survey of small domestic ruminants in selected communities of the CKNP area

6.3.1 Main objectives

1. Investigating the prevalence of transmissible agents which may severely affect wild Caprinae following spill-over from the domestic reservoirs;
2. Clinically reveal other transmissible diseases of livestock which may be cross-transmitted to wild Caprinae.

6.3.2 Material and Methods

We investigated for the presence of:

- ✓ antibodies directed against the nucleoprotein of the Peste des Petits Ruminants (PPR) virus;
- ✓ DNA of Mycoplasma conjunctivae, the agent of Infectious Keratoconjunctivitis (IKC);
- ✓ DNA of Mycoplasma capricolumsubsp.capripneumoniae(Mccp), the agent of Contagious CaprinePleuropneumonia (CCPP).

Samples were collected from sheep and goats belonging to villagers of Hushey, Kanday, Skanderabad, Minapin, Nilt, Hoper and Hisper. Four sampling sessions were held in March/April 2013, September 2013, March/April 2014, September 2014.

For the PPR survey, samples were represented by air dried blood deposited on filter papers (4-5 drops/filter paper; a filter paper/individual). For the diagnosis of M. conjunctivae and M.

capricolumsubsp.capripneumoniae infections, samples were ocular and nasal swabs respectively. All samples were maintained at room temperature until analyzed.

Sampled animals were filed by village, sex, age, lactation status, Body Condition Score (BCS), Anemia Score (based on the internationally recognized FAMACHA System) and eventual clinical signs.

Antibodies directed against the nucleoprotein of the Peste des Petits Ruminants (PPR) viruswere searched by means of a solid competitive screening ELISA, available in form of commercial kit (ID Screen® PPR Competition, ID.vet Innovative Diagnostics, France). The test uses technology developed by a FAO reference laboratory (CIRAD-EMVT, Montpellier, France). According to the manufacturer's instructions, samples presenting a competition percentage less than or equal to 50% were considered positive, samples greater than 50% and less or equal to 60% were considered doubtful, and samples greater than 60% were considered negative.

DNA of M. conjunctivae and M. capricolumsubsp.capripneumoniae were processed by PCR according to Motha et al. (2003) and Woubit et al. (2004) respectively.

The clinical trial was mainly carried out in parallel with blood and swab sampling. Additional caseload was spontaneously presented by villagers.

Exhibit 103: Eye swabbing an asymptomatic lamb for presence of m. conjunctivae

6.3.3 Results

Overall, 288 blood samples (136 from sheep and 152 from goats) were analyzed. Antibodies against the nucleoprotein of the PPR virus were revealed in 18 sheep (12.3%) and 20 goats (13.2%)(Table 31). Seroreactors originated from three communities, namely Skanderabad (two goats), Kanday (10 sheep and 9 goats) and Hushey (8 sheep and 9 goats).

The high seroprevalence found in 2013 in Kanday and Husheywas associated with a vaccination campaign by the Public Veterinary Services, reportedly carried out 2-3 years before. Remarkably, no seroreactors were found in additional blood samples (N=78) obtained from juvenile individuals (48 kids/lambs and 30 yearlings) raised in the same communities.

Table 31: Prevalence (%) of antibodies against peste des petit ruminants virus (ppr) in 146 sheep and 152 goats sampled in six communities of the cknp area. legenda: (*) only individuals aged below 18 months

Community	Sheep					Goats				
	N	Pos	Dou	Neg	Prev	N	Pos	Dou	Neg	Prev

Skanderabad	12	0	0	12	0.0	23	2	0	0	8.7
Nilt	10	0	0	10	0.0	9	0	1	8	0.0
Minapin	28	0	0	28	0.0	24	0	0	24	0.0
Hisper	10	0	0	10	0.0	10	0	0	10	0.0
Kanday_2013	26	10	0	16	38.5	25	9	1	15	36.0
Kanday_2014*	14	0	0	14	0.0	10	0	0	9	0.0
Hushey_2013	10	8	0	2	80.0	13	9	0	4	69.2
Hushey_2014*	26	0	0	26	0.0	28	0	0	0	0.0
Total	**136**	**18**	**0**	**118**	**12.3**	**152**	**20**	**2**	**130**	**13,2**

In total, 43 of 337 ocular swabs (12.8%) tested positive for M. conjunctivae. Amplified products from two of the generic PCR-positive samples (one from a sheep and one from a goat) were subjected to gene sequence analysis and were 99% homologous with the M. conjunctivae isolate HRC/583 deposited at the GenBank database.

Prevalence of M. conjunctivae infection was significantly higher in sheep than in goats (20,1 vs 8,9%; P<.001). Only minor village related differences were observed (Table 32).

Table 32: Prevalence of *m.conjunctivae* infection in 179 sheep and 158 goats sampled in six communities of the cknp area.

Community	Sheep			Goat			Total		
	n	Pos	prev	n	pos	Prev	n	pos	Prev
Kanday	69	13	18,8	44	2	4,5	113	8	7,1
Hushey	50	10	20,0	53	6	11,3	103	16	15,5
Minapin	15	4	26,7	2	0	0,0	17	4	23,5
Hoper	10	3	30,0	22	5	22,7	32	8	25,0
Hisper	9	1	11,1	23	0	0,0	32	1	3,1
Skanderabad	26	5	19,2	14	1	7,1	40	6	15,0
Total	**179**	**36**	**20,1**	**158**	**14**	**8,9**	**337**	**43**	**12,8**

Analyses for presence of M. capricolumsubsp.capripneumoniaeDNA are in progress.

The clinical survey, implying handling of approximately 550 SR and additional 180 cattle in seven communities, revealed occurrence of the following diseases/conditions:

Disease/condition	Species	Cases observed (1 or 2-5 or >5)	Community
Malnutrition	Goat	>5	All investigated communities
Anaemia	Goat	>5	All investigated communities
Cough + Nasal discharge	Goat	>5	All investigated communities
Infectious Keratoconjunctivitis	Goat	>5	All investigated communities
Severe lice infestation	Goat	>5	All investigated communities
Sarcoptic Mange	Goat	Doubtful cases only (no confirmation in skin scrapings from 6ind.)	Skanderabad, Minapin, Kanday, Hoper
Contagious Ecthyma (Orf)	Goat	2-5	Skanderabad, Hushey, Kanday
Ringworm	Goat	2-5	Skanderabad
Goat Pox	Goat	1	Hoper

Malnutrition	Sheep	>5	All investigated communities
Anaemia	Sheep	>5	All investigated communities
Cough + Nasal discharge	Sheep	>5	All investigated communities
Infectious Keratoconjunctivitis	Sheep	>5	All investigated communities
Psoroptic Mange	Sheep	>5	Minapin, Hushey
Ringworm	Sheep	1	Skanderabad
Ovine Epididymitis	Sheep	1 (*Brucellaovis*)	Hoper
Malnutrition	Cattle	>5	All investigated communities
Anaemia	Cattle	>5	All investigated communities
Ringworm	Cattle	>5	All investigated communities
Sarcoptic Mange	Cattle	2-5	Skanderabad
Dermatophilosis	Cattle	1	Nilt
Besnoitiosis	Cattle	1	Skanderabad
Papillomatosis	Cattle	1	Nilt
Podoflemmatitis	Cattle	1	Minapin


Contagious Ecthyma (Orf), Hushey


Infectious Keratoconjunctivitis, Kanday


Goat Pox, Hoper

6.3.4 Discussion and "Take home messages"

The present epidemiological surveycompletes and enrich the information collected with interview based surveys (see previous chapters, 1.A and 1.B) and the year round analysis of the official register of the Veterinary Hospital, Skardu (1.C).While a limited part of analyses are still pending (namely those dealing with prevalence of the CCPP agent), available results already permit to advance in the identification of priorities for the sustainable management of animal health at the livestock/wildlife interface.

Main result of the PPR serosurvey is that PPR is not permanently circulating in SR having access to pastures within CKNP. As shown in Table 31:

i. in Hunza-Nagar district, only two positives were found in a single low altitude community along the Karakhoram Highway;
ii. in Ghanche district, a first sampling campaign in 2013 (when the majority of sampled sheep and goats were adults) initially generated alarming results though, during a second visit, it became clear that a vaccination campaign against PPR had been carried 2-3 years before in Hushey and (partially) in Kanday. In 2014, additional sampling on young sheep and goats (aged between 6 and 18 months), in which no seroreactors were found, provided evidence that PPR virus is not endemically present amongst local SR. Hence, it is reasonable to assume that high prevalence of specific antibodies that we revealed in 2013 was the result of previous vaccination.

From an operative perspective, we may infer that – in default of acquired immunity induced by mass preventive vaccination – the accidental (though realistic) introduction of the PPR virus with imported sheep or goats (either healthy carriers, pauci-symptomatic individuals or individuals in incubation phase) would result in severe outbreaks. In turn, these outbreaks would imply a significant risk of spill-over to susceptible (and seemingly naïve) wild Caprinae, as already occurred in Sindh ibex (Capra aegagrusblythi) in SW Pakistan (Abubakar et al., 2011).It is reasonable to assume that the risk would be higher in areas (eg, Community Controlled Hunting Areas) where the population size of wild Caprinae is increasing, and where livestock/wildlife contacts are all but rare events, as suggested by results of interview based surveys.

In passing, the PPR survey demonstrated the feasibility ofthe use of filter papers as support for sampled blood, thus by-passing the constraints related to adequate preservation of serum samples in remote mountain areas.

M. conjunctivae, the agent of IKK in domestic and wild Caprinae, was found in 12.8% of 337 swab samples analyzed, and in all investigated communities. As expected, DNA of M. conjunctivae was found both in healthy carriers and in individuals showing clinical symptoms compatible with IKK (ocular discharge, conjunctivitis, keratitis). However, other symptomatic individuals (5 of 9) tested PCR-negative, suggesting (maybe, beyond the need to improve the PCR sensitivity) that other agents are involved in ocular pathology in the area. In our opinion, this would deserve future in-depth analysis.

Results suggest that:

i. as opposite to PPR virus, M. conjunctivae is clearly endemic amongst SR in the CKNP area;
ii. IKK is commonly observed pathology in local SDR (see also Table 3);
iii. current epidemiological background in CKNP is favorable to spill-over of M. conjunctivae from the domestic reservoirs to susceptible wild Caprinae. The statement is justified by the prevalence of the agent amongst SDM, and the existing opportunities of close contact between domestic and wild Caprinae (see mainly 1.A), permitting direct or flies-mediated cross transmission of this environmentally liable agent. Things being as they are, referred sightings and rumors of free-ranging wild Caprinae affected by "ocular disease" conditions – referred on occasion of interview surveys - appear reliable.

In an evolving scenario, where wild Caprinaein positive demographic trend will likely structure in increasingly larger social groups (which, in turn,are conducive to efficient intraspecific transmission of environmentally liable pathogens like M. conjunctivae), it may be foreseen that IKK cases and outbreaks in wild Caprinae will become increasingly more frequent. Awareness should be raised amongst stakeholders (eg, Park wardens and local communities) to permit monitoring of this prospectively emerging problem amongst valuable CKNP wildlife.

As regards the clinical survey, we deem it worth stressing the following:

i. widespread malnutrition in all livestock species, in late winter as well as late summer (for details, see Final Report in prep.), is evidence that resources are insufficient.In the circumstances, resource competition with sympatric wild Caprinaemay exist, and deserve fine-tuned investigation priority;
ii. widespread (chronic) anemia may be associated with malnutrition and a range of parasitic agents, favored by diminished resilience of malnourished hosts .Amongst them, Haemonchus contortus ("the barbers's pole worm) has the potential to cause outbreaks in wild Caprinae, as observed in Europe (Lavin et al., 1997). H. contortus has been recently indicated as an emerging threat for the endangered Kashmir markhor, in Chitral (http://www.dawn.com/news/1078047). H. contortus infectionmay be controlled by the strategic or tactic use of several antiparasitic drugs, some of them also acting efficiently against mange mites. The presence or absence of H. contortus in the CKNP area can be easily demonstrated by means of a limited number of necropsies in slaughtered sheep and goat ;
iii. sarcoptic mange (by Sarcoptes scabiei) is a recognized threat to the conservation of several species of wild Caprinae. In our survey, in contrast with interviewed experts, we could not confirm the endemic (or at least the common) occurrence of sarcoptic mange in SDR in the investigated CKNP communities. Caution is essential, since a larger sample of sheep and goats (and the corresponding skin scrapings) should be examined for solid conclusions. However, sarcoptic mange is prevalent in SDR across Pakistanand the bordering nations, and transmission from the domestic reservoir to wild Caprinae (namely Blue sheep) has been reported in nearby Shimshal Valley, Kunjerab NP (Dagleish et al., 2007). Accordingly, sarcoptic mange should remain a priority disease to control in SDR ranging within CKNP;
iv. pathologies of the respiratory tract are highly prevalent. Sound knowledge of the etiological agents involved (eg, by necropsies and noninvasive nasal swabbing) would be extremely useful to target control measures against pathogens which may be cross-transmitted to sympatric wildlife, causing deadly outbreaks as recently occurred in markhors in Tajikistan (Ostrowsky et al., 2011).

6.4 Vaccination trials in selected communities of the CKNP area

6.4.1 Main objectives

1. Testing the feasibility of mass vaccination/treatment campaigns of Small Domestic Ruminants, to be sustainably managed at the community level;
2. Developing a contextualized (conservation oriented) scheme for the mass vaccination and treatment of Small Domestic Ruminants.

6.4.2 Material and Methods

The first trials were carried out in March/April 2014, while other trials are scheduled in late winter 2015.

Four communities (Hushey, Kanday, Skanderabad, Hoper) were involved following previous contacts and their official consent, while a community (Hisper) was involved at short notice (three days) due to contingent reasons. Finallythe efficiency, reliability and strong motivation of alocal vaccination team permitted to involve other two communities (Minapin and Miacher) at very short notice.

The general scheme of work was as follows:

a) Meeting with major representatives of the visited community, during which the collaborating experts (on behalf of Ev-K2-CNR and CKNP) illustrate the concept and vision underlying the offered mass vaccination/treatment program;
b) Recruitment of local volunteers, with priority for Livestock Assistants (if present) and the local CKNP wardens;
c) Training phase of one-two local vaccination teams (3-5 people each), during which experts actively participate in vaccination work;
d) Operational phase, during which the local team autonomously run the mass vaccination/treatment program, while experts only supervise their work.

It was the task of Ev-K2-CNR, in collaboration with experts, to provide all necessary material, namely:

- ✓ Freeze dried attenuated vaccineagainst PPR (Pestevac®JOVAC- Jordan Bio-Industries Center; vials of 100 doses);
- ✓ 100cc sterile saline vials for vaccine reconstitution;
- ✓ Antiparasitic drugs (different multi-dose formulations of injectable ivermectin);
- ✓ 2.5 cc plastic syringes;
- ✓ 10 cc plastic syringes;
- ✓ 16-18G x 15 mm stainless steel veterinary needles;
- ✓ Sharps containers;
- ✓ Rubbish containers;
- ✓ Vaccination/treatment record forms;
- ✓ Didactic material (eg, a teeth eruption scheme)
- ✓ Emergency drugs.

During the Training phase, enrolled teams were instructed how to:

- ✓ Professionally and safely handle target animals;
- ✓ Estimate the age by teeth eruption (to be able to apply a different vaccination/treatment protocol to young individuals < 2 years old);
- ✓ Dissolve the freeze dried pellet vaccine with the sterile diluent, to reconstitute a multi-dose vaccine vial;
- ✓ Adjust the dose of the anti-parasitic drug to the species and size category (kid/lamb,yearling, adult female, adult male) of the animal to inject;
- ✓ Inject animals subcutaneously;
- ✓ Safely handle needles during recommended substitutions (one needle/household)
- ✓ Properly fill the vaccination/treatment record forms.

The treatment protocol included:

- ✓ door to door work (which may be more accurate and professional);
- ✓ the sc injection of all available sheep with 1% ivermectinsolution at the approximate dose of 200 mcg/kg or 0.2 ml/10 kg;
- ✓ the sc injection of all available goats with 1% ivermectinsolution at the approximate dose of 400 mcg/kg or 0.4 ml/10 kg;
- ✓ the sc injection of all available sheep and goats aged between 3 and 20 months (two-tooth) with the anti-PPR vaccine.

Performance of local teams during theirTraining Phase was carefully evaluated by collaborating experts (Prof. P. Lanfranchi, University of Milano, Italy; Dr. D. Gauthier, Laboratoire Departemental d'Analyses Veterinaires des HautesAlpes, France; Dr. S. Rossi, Office National de la Chasse et de la Faune Sauvage, France, in addition to the Project Coordinator, Prof. L. Rossi). Based on outcome, teams were either admitted to the Operational Phase, or given additional training, or eventually dismissed. Additional on-site meetings were jointly held to evaluate the entire work carried out in each community.

Exhibit 104: Maintaining the cold chain during transport of vaccines

Exhibit 105: The limited volume of freeze dried vaccine vials

6.4.3 Results

In total, 4211 sheep and 3788 goats received the anti-PPR vaccine and/or the anti-parasitic treatment.

Several vaccination teams were trained, usually including the local Livestock Assistant, the local CKNP warden/s and two-three extension workers or other volunteers (occasionally an Official Veterinarian or a second CKNP warden, if available). Remarkably, a ladies team was assembled and trained in Hoper, as initially suggested by local community.

Exhibit 106: Ladies on training, Hoper

Performance of the teams varied in a wide range (Table 33), from weak (no autonomydespite additional training,no shift to any Operational Phase) to excellent (full autonomy and high efficiency).

Table 33: Performance of the vaccination teams during the training and the operational phase of their activity, as per joint evaluation of the collaborating experts.

TEAM ID	COMMUNITY	TRAINING PHASE	OPERATIONAL PHASE
1	Hushey	EXCE	EXCE
2	Hushey	EXCE	EXCE
3	Kanday	ADEQ	ADEQ
4	Skanderabad	WEAK	NA
5	Skanderabad	WEAK	NA
6	Minapin/Miacher	EXCE	EXCE
7	Hisper	ADEQ	EXCE
8	Hisper	EXCE	EXCE
9	Hoper	ADEQ	WEAK
10	Hoper	EXCE	ADEQ

LEGENDA:

Training Phase:
EXCE = half day training sufficient for reliability on all tasks, immediate shift to the Operational Phase
ADEQ = half day training not sufficient for reliability on all tasks, conditional shift to the Operational Phase
WEAK = two training sessions still not sufficient for reliability on some tasks, or team not available for a second training session. No shift to the Operational Phase
Operational Phase:
EXCE = efficient work in full autonomy
ADEQ = efficient team, still limited inaccuracies in age determination and compilation of treatment/vaccination forms
WEAK = team inadequate to operate in autonomy, or not available two training sessions still not sufficient for reliability on some tasks, or team not available for a second training session. No shift to the Operational Phase
NA " Not applicable

Best results were not necessarily obtained in those communities which, months in advance, had guaranteed their consent to implementation of the program. Successful performance of enrolled teams mainly depended from good selection of the team members by the communities (sufficient literacy is by no means a favorable parameter), individual motivation especially in the case of Livestock Assistants, and positive leadership dynamics within teams. In general, performance of CKNP wardens was good to excellent, and superior to other volunteers. It is worth stressing that, in spring 2013, CKNP wardens had received specific education on Livestock and Wildlife Health, including field demonstrations by the Project Coordinator. Worst results were obtained where other activities were interfering, and/or the leadership within the communitywas (or appeared to as) weak. In those cases, either team members were inaccurately enrolled, or they were available for only limited time (eg, for the Training Phase though not for the Operational Phase in autonomy).

Where the whole program could be completed (as in Hushey, Kanday and Hisper), it became clear that a tight-knit team can treat and vaccinate (with the requested door to door approach) from 65 up to 90 SDR/hour (Table 5). The difference will mostly depend on the distribution of animal shelters (hence the distance to reach them) and the average size of flocks to be treated/vaccinated (lower time/head is requested when operating on large flocks).

Table 34: Number of sheep and goats injected during the mass treatment/vaccination trials carried out in march-april 2014, and time worked by the different teams.

COMMUNITY	INJECTED SHEEP	INJECTED GOATS	WORKING TIME (ALL TEAMS INVOLVED)	INJECTED ANIMALS/HOUR
Hoper	502	126	12	52.3
Hisper	562	558	17	65.9
Skanderabad	246	542	12	71.2
Minapin/Miacher	1438	1001	31	78.7
Hushey	712	598	20	65.5
Kanday	751	963	19	90.2
TOTAL	**4211**	**3788**	**111**	**72.1**

6.4.4 Discussion and "Take home messages"

Results of the first mass treatment/vaccination trials are encouraging. They demonstrate that the training of teams able to autonomously perform local scale vaccination/treatment programs is realistic goal. Remarkably, teams trained in Hushey, Kanday and Hisper were able to vaccinate/treat well above the 90% of local SDR.

In parallel, unsatisfactory team performance in other communities (eg, Skanderabad and Hoper) suggest that awareness and education work is still necessary at the community level to raise compliance by livestock owners and permit selection of motivated team members.

A significant role within teams was played by CKNP wardens, who distinguished themselves for skills in fieldwork organization and data recording, amongst others. It goes without saying that the "image" of CKNP will derive great benefit from the active participation of its personnel to vaccination campaigns with visible fall-out on livestock health.

Based on data in Table 5, it may be calculated that a single motivated team, working for 7 hours a day, may treat/vaccinate between 450 and 630 SDR (average 540). Hereafter, this values will be our unit of measure to calculate cost and timing of the vaccination/treatment campaigns to promote and organize within CKNP. Interviewed experts had referred values between 300 and 1000.

A problem faced by most teams was the limited compliance by livestock owners, who were not always willing to keep their flock in the shelter, waiting for operators to come. It is our opinion that anticipating treatment/vaccination campaigns of one-two months (eg, in February/March, according to the altitude) would significantly reduce the drawback.

6.5 Monitoring overgrazing

An improvement in the management of pastures and rangelands is necessary. The first step in the management of livestock in an area like CKNP, is the evaluation of the primary productivity of the pastures. In other word it is necessary to estimate the biomass availability and distribution. The production of accurate and precise map of vegetation will be important for a sustainable management of pastures and rangelands. This will be important for: increase the quality of livestock management, reduce the impact on the ecosystem and on the wildlife, reduce the soil erosion, increase the productivity.

An effective way to produce vegetation maps for large areas in remote region, is the use of satellite images. The Landsat project in particolar allow to use high quality multispectral images with no charges at all.

Vegetation indices derived from remotely sensed data have long been proposed as a source of information for predicting green biomass levels. Numerous studies have found significant relationships between vegetation indices and green biomass (Pearson et al., 1976; Bedard and LaPointe, 1987; Hardisky et al., 1984; Deering and Haas, 1980), while others have reported little or no association (Waller et al., 1981; Anderson and Hanson, 1992). The results of these studies indicate that vegetation indices do respond to varying levels of green biomass.

However, our ability to predict mathematical coefficients that describe the relationship is confounded by factors such as changing sun angle, albedo, foliar cover, atmospheric haze, shadow, plant condition, and standing dead biomass (Richardson and Everitt, 1992; Jasinski, 1990; Holben, 1986; Bedard and La-Pointe, 1987; Waller et al., 1981; Hardisky et al., 1984; Anderson and Hanson, 1992).

Different kind of vegetation index derived form satellite images have been created such as (VI) have to be used as the RVI (ratio), DVI (differnce) and NDVI (normalized difference) (Anderson et al., 1993).

Biomass estimation in arid and semiarid environment (as the CKNP area) is more difficult (Anderson et al., 1993) and specific vegetation index have been created (SAVI – Soil Adjusted Vegetation Index).

6.5.1 Development and validation of NDVI index based on local vegetation condition in CKNP area

Main Objectives

The first important step in overgrazing monitoring is the evaluation of the resources available for livestock. In remote areas usually is very difficult to obtain accurate maps of land cover characteristics. Nowadays there are large possibilities to obtain information about the earth, using the remote sensing technologies. Main objective of this action was to evaluate if it was possible to obtain accurate and precise information on the distribution of vegetation in the CKNP area using freearchive of satellite images. In particular we wanted to: i) evaluate the availability of good quality Landsat images (from Landsat 8 archive) for the CKNP area; ii) use and validate the efficacy of vegetation indexes such as the Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI), in predicting pasture distribution in CKNP area.

Material and Methods

The vegetation analysis in the study area have been carried out using a step by step protocol and in particular: i) Landsat images acquisition, ii) homogenization of the images and calculation of vegetation indexes (NDVI and SAVI),

Landsat images acquisition.

We used Landsat 8 images, freely available on the NASA repository glovis.usgs.gov. Landsat 8 images are particularly useful for our purposesbecause of their high geometric (30 meters), spectral (multispectral images with 11 spectral bands) and temporal (one image of the same area every 15 days) resolution. We downloaded images of the 148/35 and 148/36 quadrants (identify with path and row ID) of the period April 2013-September 2014. We selected and collected only images with proper quality (low cloud coverage)

Homogenization of images and calculation of vegetation indexes (NDVI and SAVI)

Images have been processed using software GIS QGIS 2.0. In order to normalize the images collected in different period of the year we converted the DN (Digital Number) values of the band 4 and 5 of each raster in TOAref (Top of Atmosphere Reflectance) values. TOAref was calculated using the following formula TOAref=Mp*Qcal+Ap ; whereMp=band's reflectance multiple value , Ap= band's reflectance added value , Qcal= raster value). With these homogenized rasters(bands 4 and 5) we calculatedNDVI index (Normalized Difference Vegetation Index - with the following formula – > (TOArefB5 - TOArefB4) / (TOArefB5 +

TOArefB4)) and SAVI index (Soil Adjusted Vegetation Index - with the following formula ->(TOArefB5 - TOArefB4) / (TOArefB5 + TOArefB4 + L) * (1 + L) with $0<L<1$ based on the soil aridity).

NDVI and SAVI are vegetation index that can be derived from multispectral remote sensing images and are directly correlated with presence and density of vegetation.

NDVI is calculated from the visible red (band 4) and near-infrared (band 5) light reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Calculations of NDVI for a pixel results in a number that ranges from minus one (-1) to plus one (+1). A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of vegetation. Negative values indicates the presence of water.

SAVI index is very similar to NDVI but it is used to better evaluate vegetation density and distribution in arid and semi arid areas (so in our opinion could be very useful in CKNP area).

To exclude from the final map all the possible errors in NDVI / SAVI calculation, due to cloud coverage, we used the quality Landsat band called BQA to exclude all the pixels with erroneous values (that is pixel covered by cloud cover). For this quality check we exclude all the pixel with BQA values in the range [1-28,672].

Results.

The Landsat archive interrogation produce 28 good quality Landsat images, in the period 25/04/2013 - 19/09/2014. We evaluate the images in three different squares:29, 35 and 36. Image quality ranges from a minimum of 5.61% to a maximum of 62.55% of CC (Cloud Cover) value. The mean CC value in the datasets used was 30.61%. In table 1 all the images used with ID number, the acquisition date and their CC value are provided.

Table 35: Landsat 8 images used: id number, acquisition date, cc values are provided

ID	WRS_ROW	DATA	CLOUDS %
115	35	25/04/2013	54.11
131	35	11/05/2013	58.34
147	35	27/05/2013	54.94
163	35	12/06/2013	43.86
179	35	28/06/2013	50.86
179	36	28/06/2013	57.16
195	35	14/07/2013	10.26
195	36	14/07/2013	7.52
211	35	30/07/2013	5.61
211	36	30/07/2013	19.31
227	35	15/08/2013	70.83
243	35	31/08/2013	62.55
243	36	31/08/2013	34.67
252	29	09/09/2013	4.83
259	35	13/09/2013	42.19
307	35	03/11/2013	12.46
307	36	03/11/2013	10.54
323	35	19/11/2013	40.33
339	36	05/12/2013	28.27
86	35	27/03/2014	60.72
86	36	27/03/2014	49.74
118	35	28/04/2014	11.49
159	29	08/06/2014	4.83
166	35	15/06/2014	8.84
182	35	01/07/2014	22.64
230	35	18/08/2014	17.65
239	29	27/08/2014	4.01
262	35	19/09/2014	8.49

The best quality images were available in July (mean CC value 13.1%) while the worst quality images were available in March (CC = 55.2%), April (CC = 42.1%) and May (CC = 56.6%). This great differences in images quality were probably due to different climatic conditions in the study area along the year. In conclusion the best period for images acquisition in CKNP area is the summer season.

Example of good quality Landsat images are provided in figure 107. The lack of cloud cover allows to obtain accurate and precise information about the earth surface.

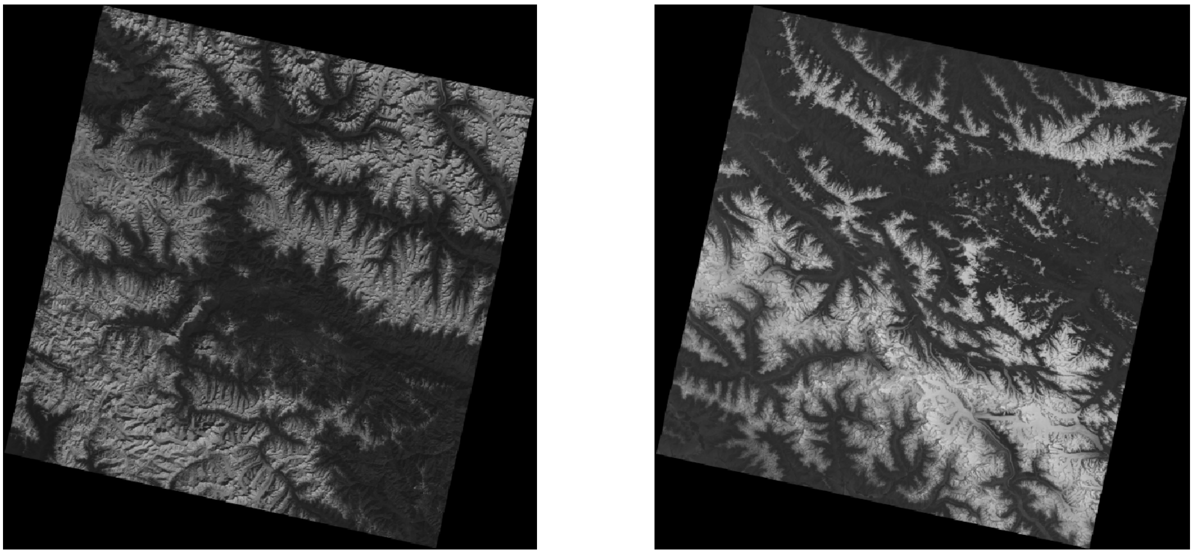


Exhibit 107: Landsat 8 images related to quadrants 148/35 and 148/36. Cloud cover <10% for both the images.

Figure 35.

Two example of NDVI index maps are provided in figure 108 and 109. Figure 108 provides an example of good quality image taken in July, with low Cloud Cover (CC = 7.5%). In figure 109 (taken at the end of August) is represented a low quality image, with large Cloud Cover (CC = 62.6%). As you can see, the first image provide useful information about vegetation distribution while the second one is completely useless.

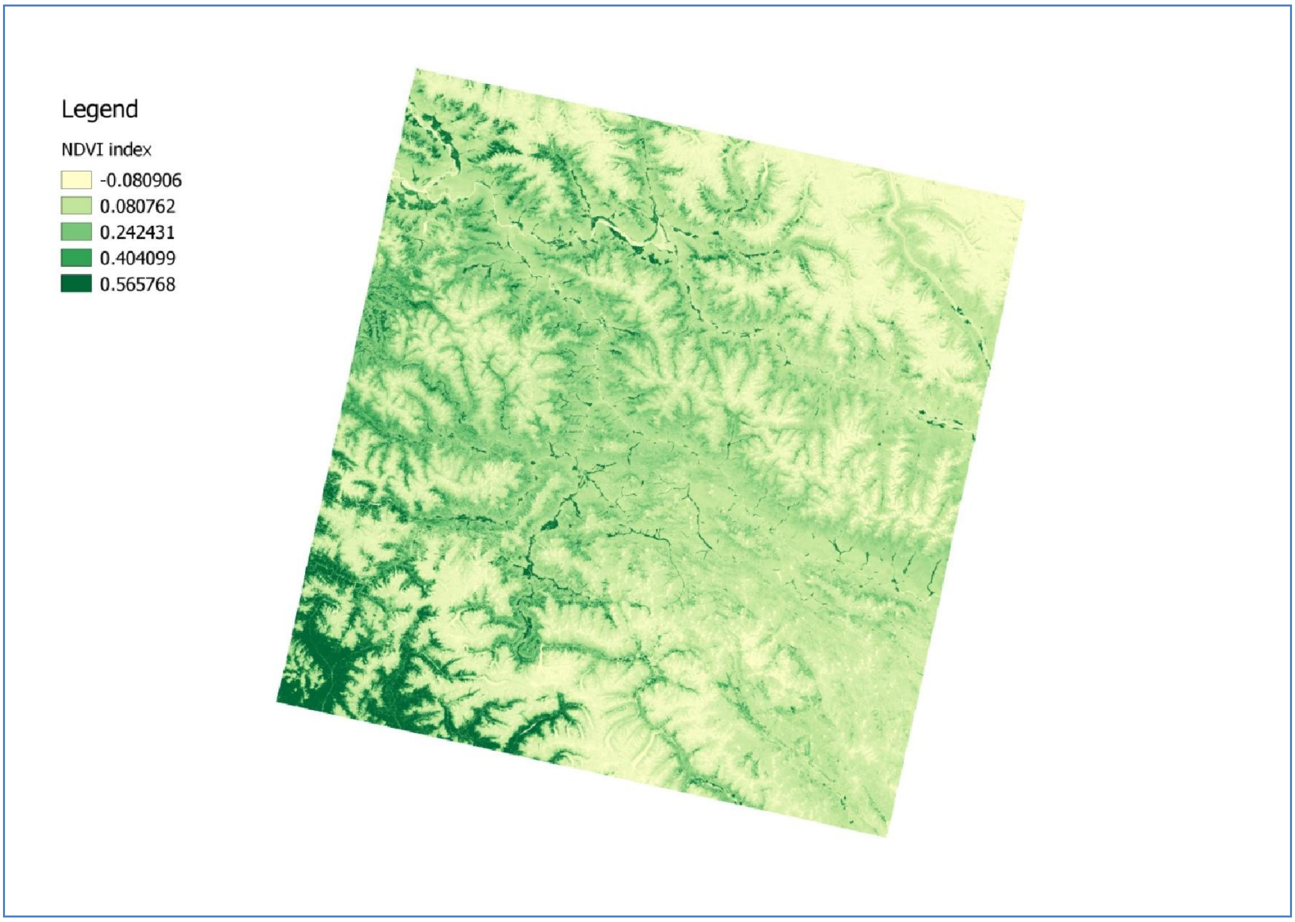


Exhibit 108: Landsat 8 NDVI index derived from a good quality image (acquisition date 14/07/2013) with CC = 7.5%.

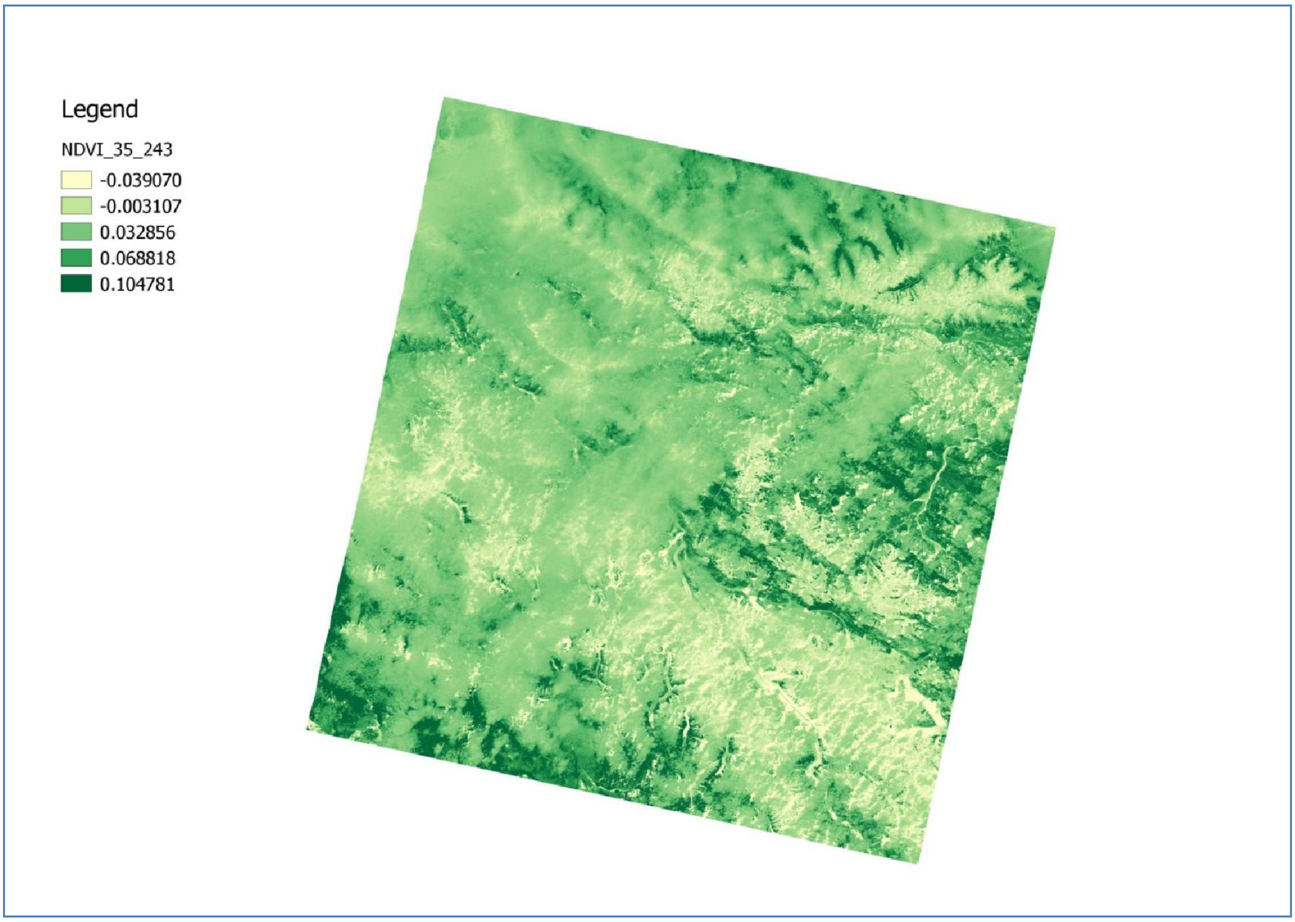


Exhibit 109: Landsat 8 NDVI index derived from a bad quality image (acquisition date - 31/08/2013) with CC = 62.6%.

Discussion and "Take home messages"

This first action implemented give us some important information.

First of all the Landsat 8 archive had proved to be a very useful and powerful tool to investigate the environmental characteristics of an area. Landsat 8 images are very accurate and precise datasets to derive vegetation characteristics. In particular the high geometric resolution (30 meters till to 15 meters) and the short revisitation period (15 days between two consecutive images of the same areas) allow to use these images for medium resolution environmental surveys.

Nevertheless there are several issues related to the use of remote sensing images. First of all it is very important to normalized the images in order to compare satellite photographs taken in different period. During the validation process we provided a first important results: a quick user friendly protocol to process the images.

Another problems related to the use of Landsat images is the presence of cloud that provide "dirty" images, not useful for scientific and practical analysis. The first part of our work, even in this case give very good results, as we identify the best period of the year to acquire useful Landsat images (period with the highest probability to download high quality images); moreover we develop a protocol to perfectly "clean" even images with cloud coverage and make them usable.

The most important results of this action was to provide useful tools for the management and remote sensing monitoring of the CKNP area through the use of freely available environmental datasets.

6.5.2 Satellite derived map of pastures available in the CKNP area

Main Objectives

Objective of this part of the work was the validation of the NDVI/SAVI maps created in the previous action. The validation was done with the collection and evaluation of Ground Control Points (GCP) in the field during two different mission in the CKNP area. Due to the particular climatic condition of the CKNP area, the vegetation index derived from remote sensing images have to be validated. The main objective of the validation is to calculate a cut off value to discriminate the vegetated and not vegetated areas, but even to discriminate between different type of land cover.

Material and Methods.

The validation of the vegetation map was done with the following steps: 1) collection of GCPs; 2) validation of vegetation maps and calculation of cut-off indexes.

Collection of GCPs

The collection of GCP was done in the Hushe and Khande valleys (3050mt; 35° 10′ 0″ N, 76° 20′ 0″ E) - Ghangche district, during two different field mission. We selected and localized Ground control points (GCPs) using gps equipment(GPS modelloEtrex Venture – Garmin) with an accuracy of +/- 5 meters. Each GCP have been classified in classes and subclasses of Land cover (table 2) to evaluate the vegetation index of each land cover type (using both NDVI and SAVI index).

Table 36: Classes and subclasses of vegetation land cover type used to classify the GCPs. Subclasses were used to underline the small differences in vegetation index of the same land cover type.

Classes	Subclasses
Bush	Mountain moorland; Sparse bush; Bushes; Moraine with vegetation.
Conifer	Sparse Conifer; Conifer;
Broadleaf	Sparse Broad-leaved; Broad-leaved; Mixed sparse vegetation; Mixed dense forest;
Brock	
Cultivation	**Fields/agriculture**
No vegetation	Glacier; Moraine
Pastures	Pasture; Exausted pasture; Pasture with 25% rocks; Pasture with 50% rocks; Pasture with 75% rocks

Validation of vegetation index

Using the GCPsand crossing them with the previously created vegetation rasters, we evaluated the range of vegetation indexes for each land cover class. This information allowed to quantify the discriminating capacity of NDVI / SAVI indexes to identify areas with/without vegetation and the confidence intervals of the estimations.

Results

Data collection

646 Ground control points (GCPs) were collected in the period 2013-2014 during two different field mission. GCPs have been selected in order to be representative of all the categories of land cover in the study area. They were grouped in 7 land cover categories. In table 1 the percentage of GCP of the different land cover classes is provided. The most represented land cover class was the "Bush" with 34.25% of the GCPs, followed by the "Pastures". The less represented land cover class was the "Cultivation" one with only 0.69% of the points.

Table 37: Percentage of GCPs falling in the different Land cover classes.

Land cover type	%
Bush	34.25
Brock	2.24
Cultivation	0.69
Conifer	10.84
Broadleaf	7.40
No vegetation	22.20
Pastures	22.37
Totale GCP	100

The distribution of the GCP in the study area is represented in figure 110-114. The points are overlapped to vegetation maps of different quality.

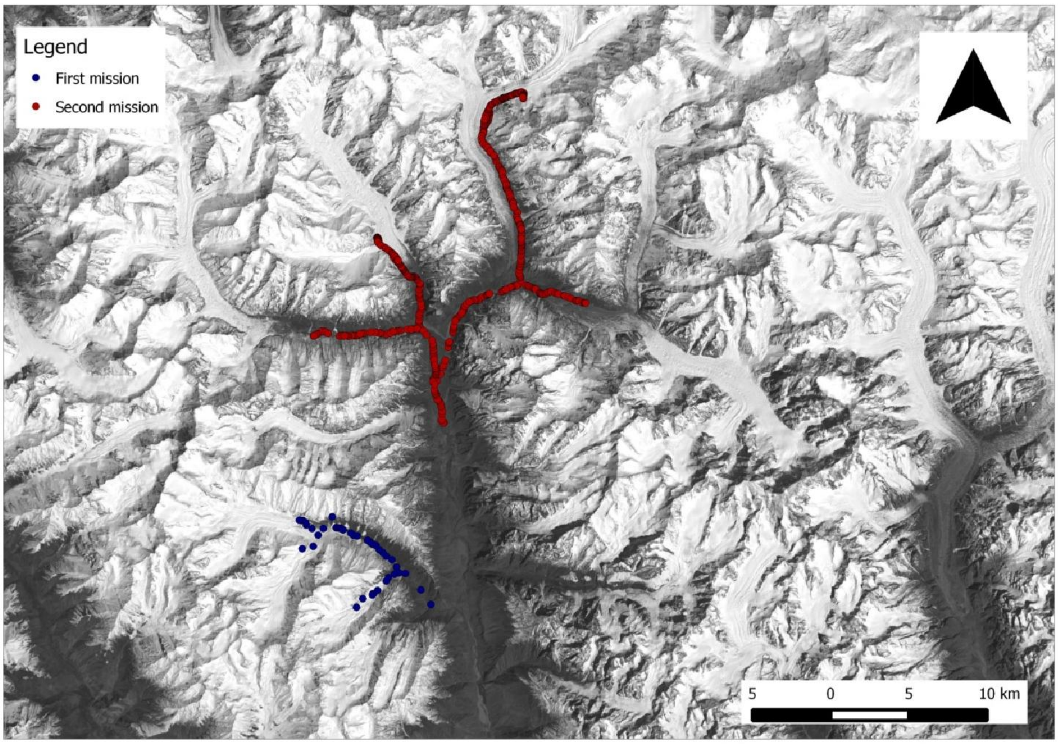


Exhibit 110: GCP collected during the first (blue pointS) and second (red points) mission. Points are drawn on a vegetationmaps of 25 April 2013

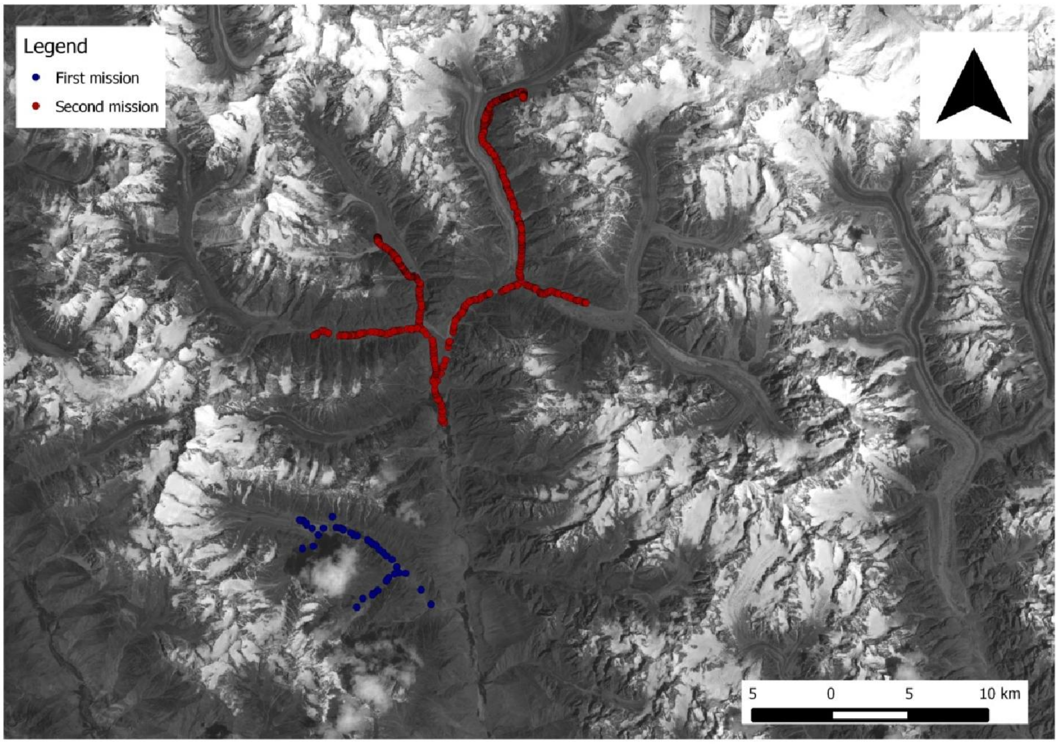


Exhibit 111: GCP collected during the first (blue pointS) and second (red points) mission. Points are drawn on a vegetationmaps of 15 July 2013

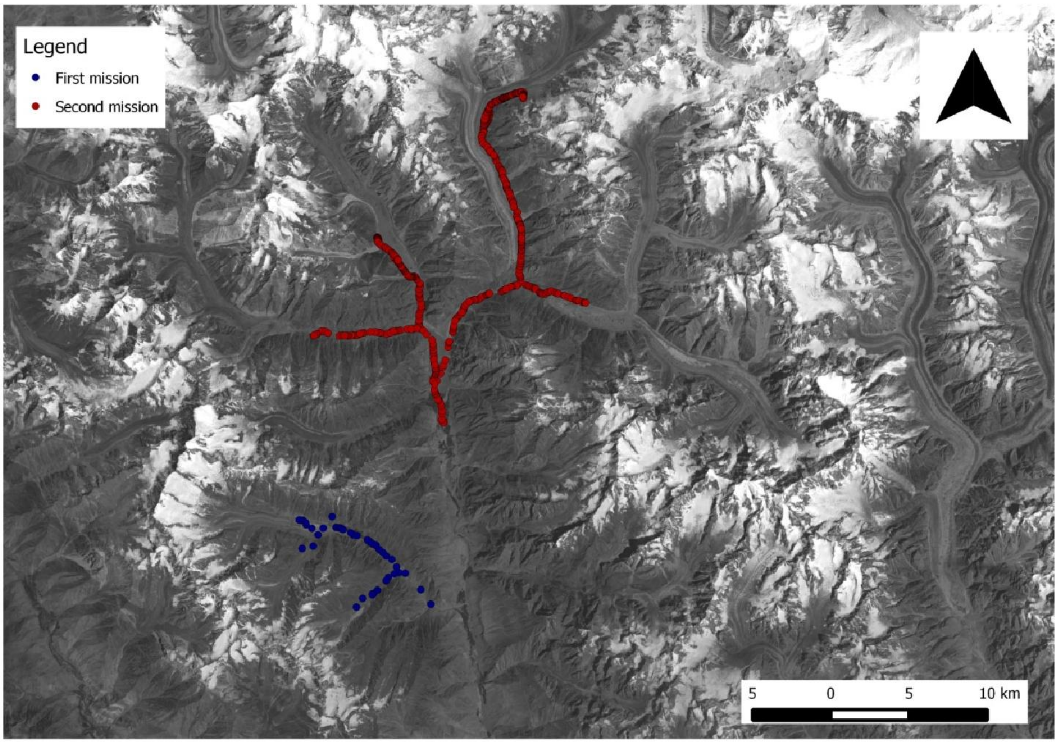


Exhibit 112: GCP collected during the first (blue pointS) and second (red points) mission. Points are drawn on a vegetationmaps of 30 July 2013

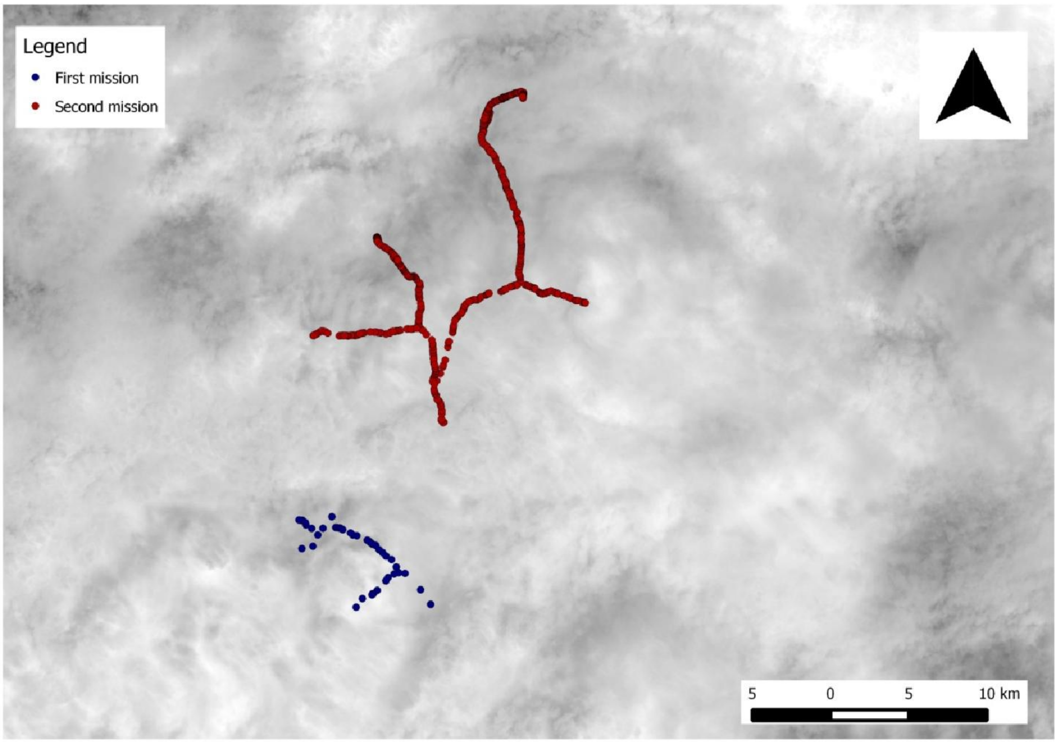


Exhibit 113: GCP collected during the first (blue pointS) and second (red points) mission. Points are drawn on a vegetation maps of 15 August 2013.

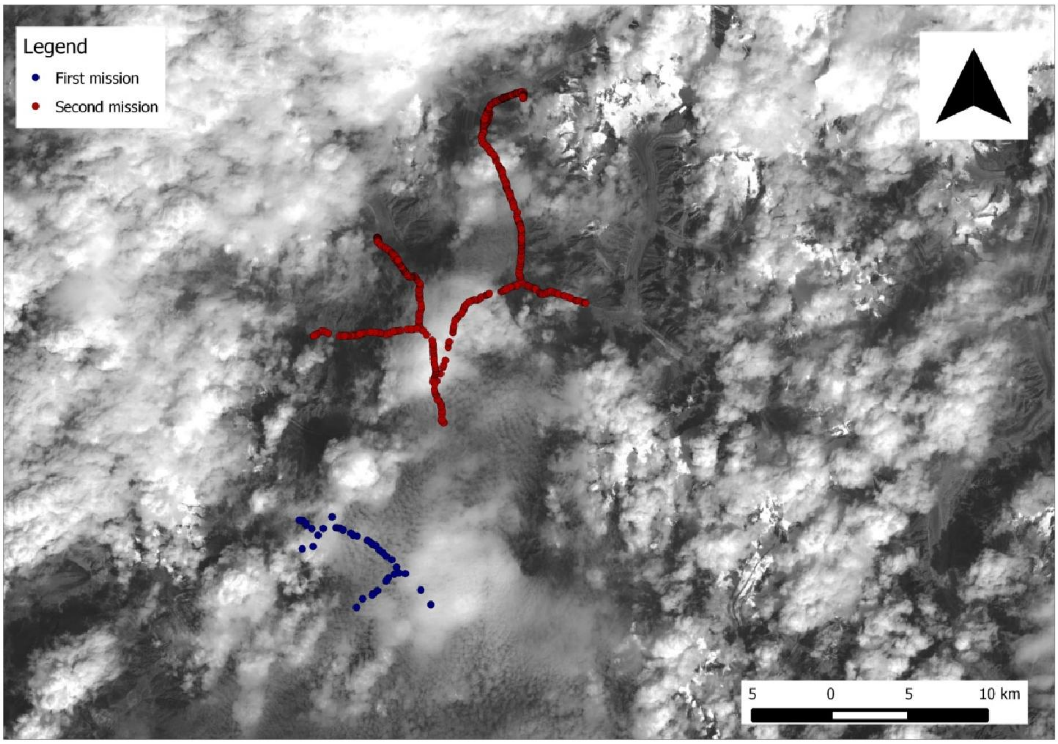


Exhibit 114: GCP collected during the first (blue points) and second (red points) mission. Points are drawn on a vegetation maps of 31 August 2013.

NDVI index values

Using the collected GCPs we evaluated the NDVI index for each land cover class. The mean NDVI value for the 7 land classes, measured along the whole study period is reported in table 4.

As expected, the “Cultivation” class shows the highest NDVI value (mean value 0.477), followed by the "Broadleaf" (mean value 0.234) and by the “Brock” (mean value 0.220). The “Pasture” show a mean NDVI value of 0.133. The vegetation peak was reached in July.

Table 38: Mean NDVI values for the different land cover classes along the study period

	27/3	28/4	15/6	28/6	01/7	14/7	30/7	18/8	31/8	13/9	19/9	03/11	Total
Bush	0.014	0.059	0.163	0.173	0.211	0.240	0.231	0.196	0.157	0.016	0.186	0.074	**0.143**
Brock	0.025	0.116	0.236	0.240	0.268	0.301	0.282	0.273	0.270		0.249	0.158	**0.220**
Cultivation		0.114	0.586	0.510	0.686	0.704	0.692	0.578			0.269	0.153	**0.477**
Conifer	0.041	0.176	0.224	0.171	0.242	0.256	0.257	0.261	0.147		0.256	0.161	**0.199**
Broadleaf	0.031	0.141	0.254	0.254	0.299	0.321	0.320	0.286	0.275		0.274	0.125	**0.234**
No veg	0.010	0.031	0.045	-0.003	0.067	0.068	0.071	0.061	0.035	0.010	0.030	-0.063	**0.030**
Pasture	0.029	0.061	0.165	0.123	0.199	0.220	0.213	0.172	0.122	0.013	0.185	0.091	**0.133**

To evaluate if the NDVI index could discriminate among different land cover classes an One Way Anova test was used. The results of the Anova test for the different date is reported in table 40. A statistically significant difference in NDVI values was reported.

Table 39: NDVI differences among the different Land cover classes. Anova value and significant level for each date (*** means a p value <0.001; ** means a p value < 0.01)

	27/3	28/4	15/6	28/6	01/7	14/7	30/7	18/8	31/8	13/9	19/9	03/11
Anovavalue	5.333	17.86	88.41	39.19	70.76	81.06	77.48	57.03	25.24	6.301	56.27	24.19
p-value	***	***	***	***	***	***	***	***	***	**	***	***

Anova test evaluate only the presence of a general difference among different classes. To evaluate the presence of significant difference, for each date,between pairs of single Land cover classes a Tukey post-hoc test was performed. The Tukey test highlighted the existence of significant differences of the NDVI value for the single pairs of Land cover class. As example, the results of Tukey post hoc test for the date 30 July 2014 is reported below (Test used: Multiple Comparisons of Means: Tukey Contrasts) (table 41). The only not significant comparison are those among brock and other land cover types. In other word these results stated that the analysis of NDVI index could discriminate the land cover class, starting from a remote sensing derived vegetation map.

Table 40: Tukey multiple comparison test for the single land cover classes. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 (Adjusted p values reported -- single-step method)

	Estimate	Std. Error	t value	Pr(>|t|)	p value
brock-bush	0.05074	0.02596	1.954	0.40042	
cultivation-bush	0.46124	0.04580	10.071	<0.001	***
conifer-bush	0.02535	0.01312	1.932	0.41422	
broadleaf-bush	0.08916	0.01526	5.844	<0.001	***
no vegetation-bush	0.15979	0.01085	-14.730	<0.001	***
pasture-bush	0.01850	0.01024	-1.808	0.49803	
cultivation-brock	0.41050	0.05185	7.917	<0.001	***
conifer-brock	0.02539	0.02762	-0.919	0.96254	
broadleaf-brock	0.03843	0.02870	1.339	0.80559	
no vegetation-brock	0.21053	0.02662	-7.908	<0.001	***
pasture-brock	0.06924	0.02638	-2.625	0.09953	
conifer-cultivation	0.43589	0.04676	-9.322	<0.001	***

	Estimate	Std. Error	t value	Pr(>|t|)	p value
broadleaf-cultivation	0.37207	0.04740	-7.849	<0.001	***
no vegetation-cultivation	0.62102	0.04617	-13.450	<0.001	***
pasture-cultivation	0.47974	0.04603	-10.421	<0.001	***
broadleaf-conifer	0.06381	0.01794	3.558	0.00567	**
no vegetation-conifer	0.18514	0.01438	-12.878	<0.001	***
pasture-conifer	0.04385	0.01392	-3.150	0.02239	*
no vegetation-broadleaf	0.24895	0.01635	-15.225	<0.001	***
pasture-broadleaf	0.10767	0.01595	-6.749	<0.001	***
pasture-no vegetation	0.14128	0.01181	11.966	<0.001	***

To better display the differences in NDVI values among the land cover classes,a boxplot graph was used (figure 115).

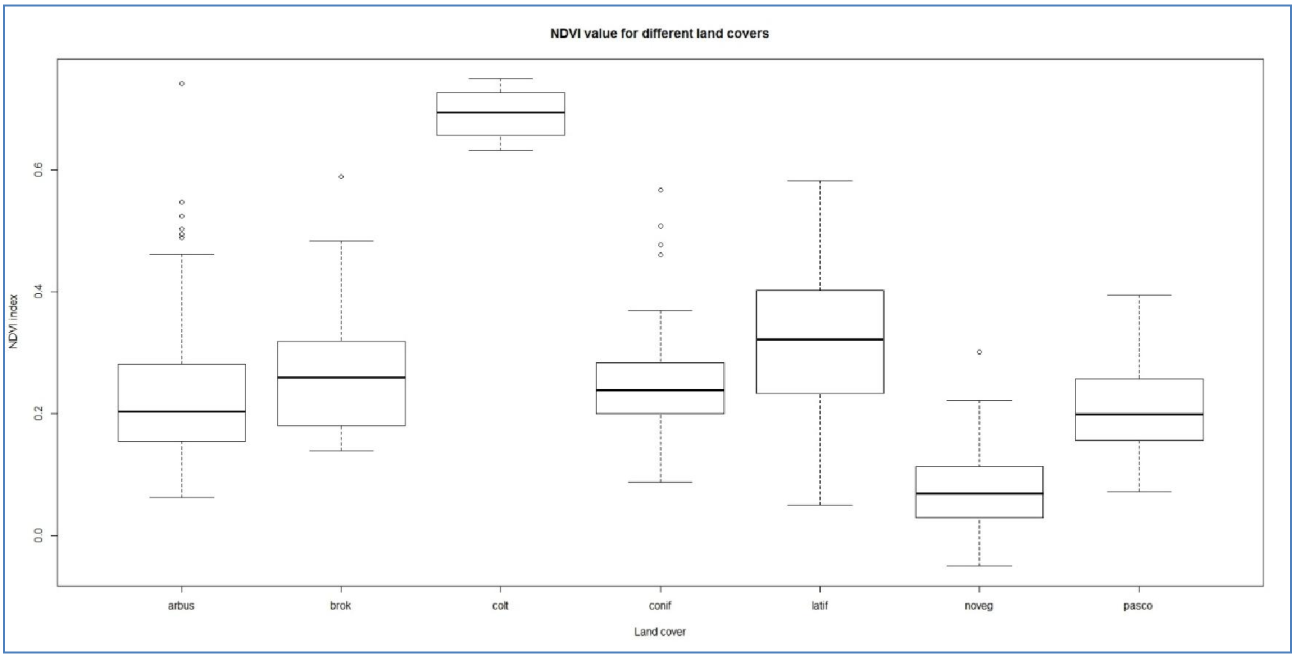


Exhibit 115: Boxplot of NDVI values divided for Land cover classes. NDVI data refer to vegetation index derived for the 30 July 2013

All the analysis point out that in the NDVI index range [0.20 – 0.30] we have the highest probability to find the pastures areas in a vegetation map derived from a satellite images. In general the vegetated area are represented by NDVI index higher than 0.07.

SAVI index values

The same analysis done for NDVI index were repeated for the SAVI one.

Even in this case an evolution of the SAVI index occur along the study period with the peak in July (table 42).

Even in this case the "Cultivation" shows the highest index value, followed by the "Broadleaf" and the "Brock". All the SAVI values are lower than the one calculated with the NDVI index.

Table 41: Mean SAVI values for the different land cover classes along the study period

	27/3	28/4	15/6	28/6	1/7	14/7	30/7	18/8	31/8	13/9	19/9	3/11	Total
Bush	0.011	0.020	0.093	0.090	0.123	0.137	0.130	0.100	0.065	0.014	0.090	0.038	0.076
Brock	0.021	0.061	0.139	0.104	0.161	0.179	0.166	0.146	0.135		0.123	0.064	0.118
Cultivation		0.065	0.359	0.215	0.457	0.471	0.459	0.374			0.147	0.065	0.290
Conifer	0.034	0.093	0.128	0.077	0.140	0.144	0.142	0.135	0.074		0.119	0.066	0.105
Broadleaf	0.028	0.073	0.140	0.144	0.167	0.177	0.174	0.140	0.129		0.126	0.053	0.123
No veg	0.011	0.016	0.028	0.004	0.044	0.043	0.044	0.033	0.015	0.008	0.020	-0.010	0.021
Pasture	0.028	0.015	0.093	0.056	0.114	0.124	0.121	0.077	0.056	0.012	0.088	0.041	0.069

The Anova test (table 8), the Tukey multiple comparison test (table 44) and the boxplot (figure 116) show the same results seen for the NDVI: a high level of accuracy of this index in discriminating the presence of vegetation and in identifying the different land cover classes.

Table 42: SAVI differences among the different Land cover classes. Anova value and significant level for each date (*** means a p value <0.001; ** means a p value < 0.01)

	27/3	28/4	15/6	28/6	01/7	14/7	30/7	18/8	31/8	13/9	19/9	03/11
Anovavalue	3.748	14.67	95.81	23.54	78.76	86.96	82.26	52.08	21.09	6.242	56.07	34.15
p-value	**	***	***	***	***	***	***	***	***	**	***	***

Table 43: Tukey multiple comparison test. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 (Adjusted p values reported -- single-step method)

	Estimate	Std. Error	t value	Pr(>|t|)	p
brock-bush	0.035591	0.014636	2.432	0.1589	
cultivation-bush	0.328934	0.025816	12.741	<0.001	***
conifer-bush	0.012002	0.007394	1.623	0.6263	
broadleaf-bush	0.043144	0.008600	5.016	<0.001	***
no vegetation-bush	-0.086507	0.006115	-14.147	<0.001	***
pasture-bush	-0.009781	0.005770	-1.695	0.5764	
cultivation-brock	0.293343	0.029228	10.036	<0.001	***
conifer-brock	-0.023589	0.015572	-1.515	0.6987	
broadleaf-brock	0.007553	0.016180	0.467	0.9990	
no vegetation-brock	-0.122097	0.015007	-8.136	<0.001	***
pasture-brock	-0.045372	0.014870	-3.051	0.0309	*
conifer-cultivation	-0.316932	0.026358	-12.024	<0.001	***
broadleaf-cultivation	-0.285790	0.026722	-10.695	<0.001	***
no vegetation-cultivation	-0.415441	0.026028	-15.961	<0.001	***
pasture-cultivation	-0.338715	0.025950	-13.053	<0.001	***
broadleaf-conifer	0.031142	0.010112	3.080	0.0281	*
no vegetation-conifer	-0.098508	0.008104	-12.156	<0.001	***
pasture-conifer	-0.021783	0.007847	-2.776	0.0675	.
no vegetation-broadleaf	-0.129650	0.009218	-14.065	<0.001	***
pasture-broadleaf	-0.052925	0.008993	-5.885	<0.001	***
pasture-no vegetation	0.076725	0.006656	11.528	<0.001	***

The boxplot of SAVI value, related to Landsat image dated 30 July 2013, is reported in figure 116.

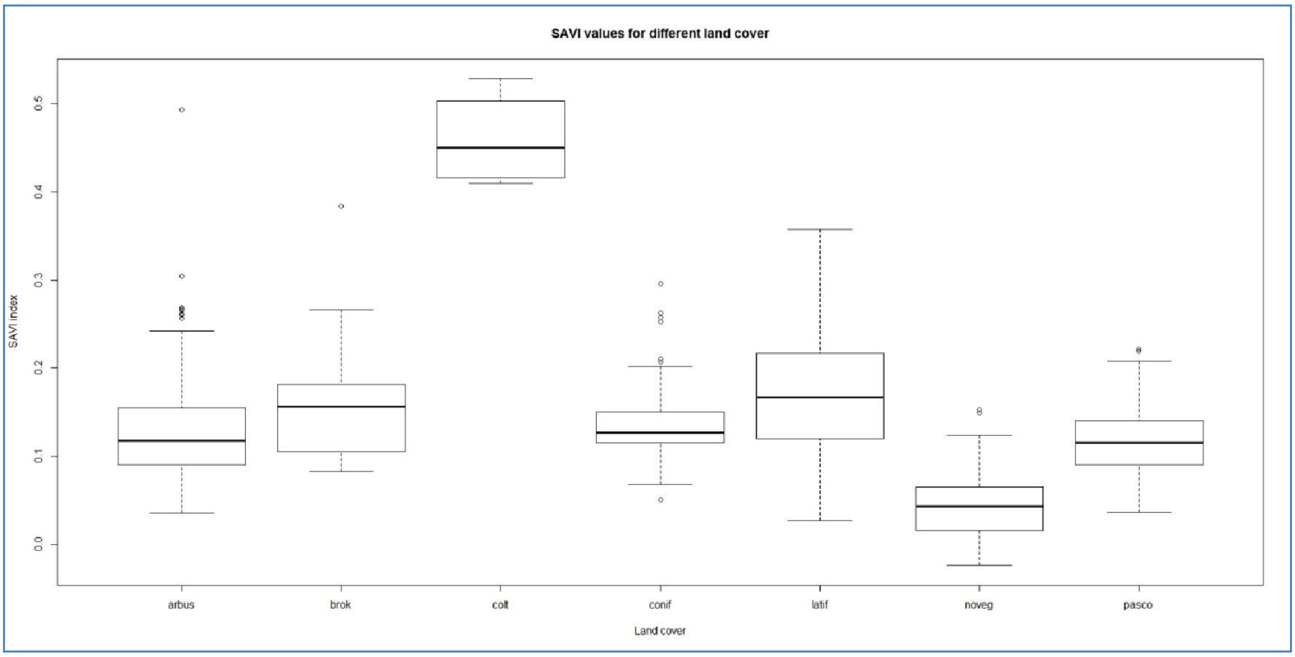


Exhibit 116: Boxplot of SAVI values divided for Land cover classes. SAVI data refer to vegetation index derived for the 30 July 2013

The SAVI index value that better identify vegetated areas is in the range [0.12 – 0.18].

Pastures validated map.

Applying the validated NDVI index to a vegetation map for the month of July (month with vegetation peak and with the best quality in terms of CC percentage) we derived a validated map of pasture for a sample area close to our sampling points. (figures 117 - 119). This map is very useful to understand the resource available in these valleys in terms of vegetation (pastures in particular).

The sample area we used had an extension of 3,310 kmq (figure 117). The extension of vegetated area (NDVI index > 0.07) is 243.17 kmq (figure 118) and the extension of pasture area (NDVI index in the range 0.20 - 0.30) is 95.85 kmq (figure 119).In other word the vegetated patchesare the 7.35% and the pasture areas are the 2.89% of our study area (39.42% of all the vegetated areas).

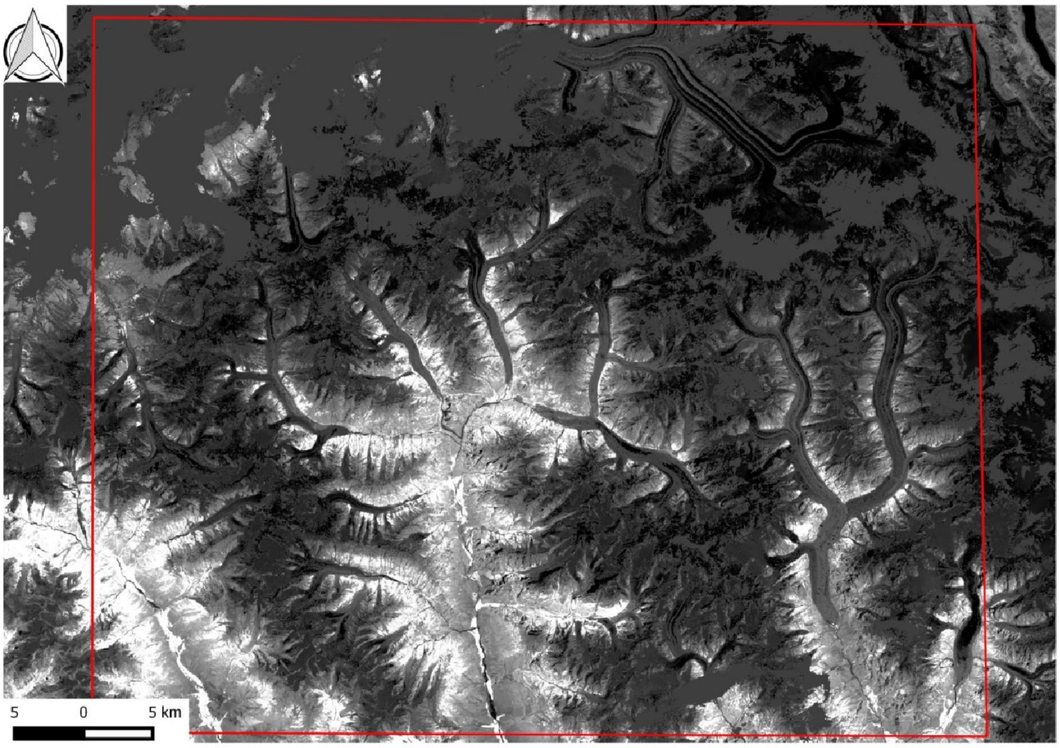


Exhibit 117: Validated map. In red the sample area used for the simulation analysis.

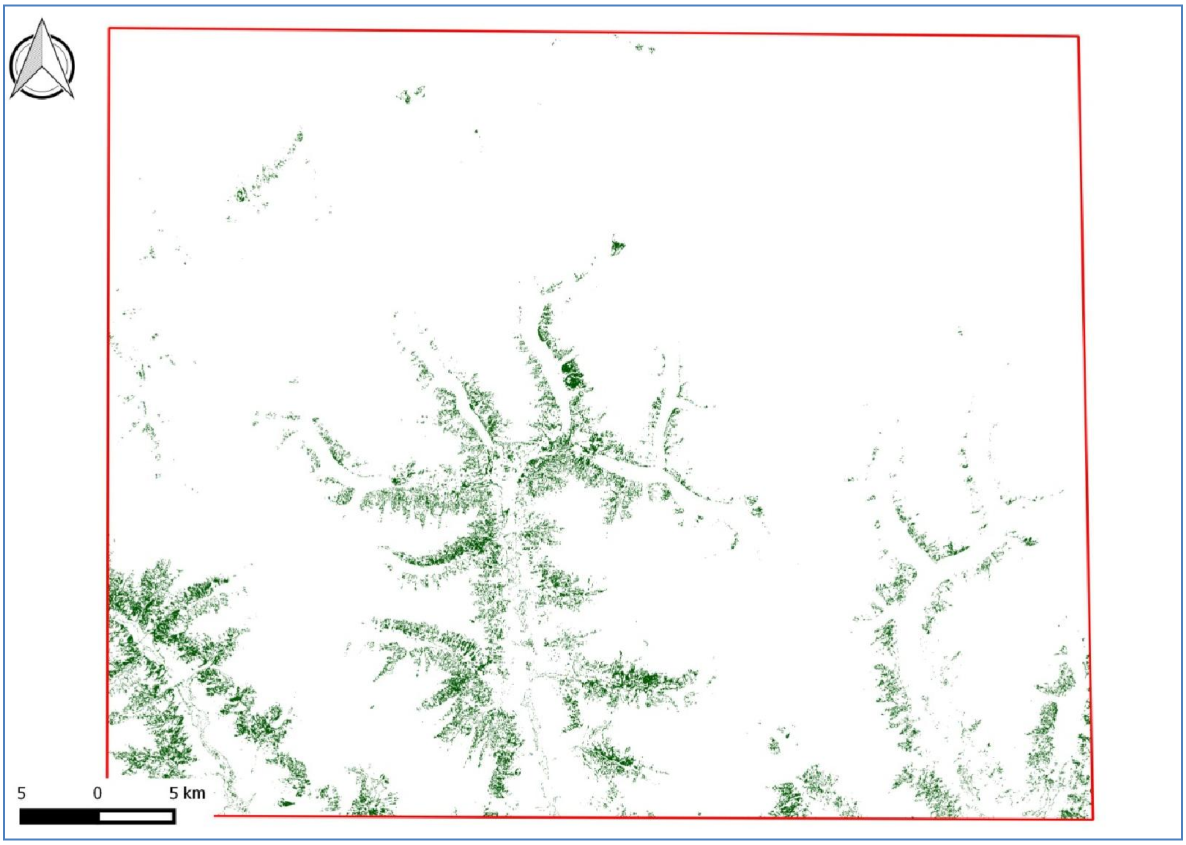


Exhibit 118: Validated map. In red the sample area used for the simulation analysis. In dark green the vegetatedareas.

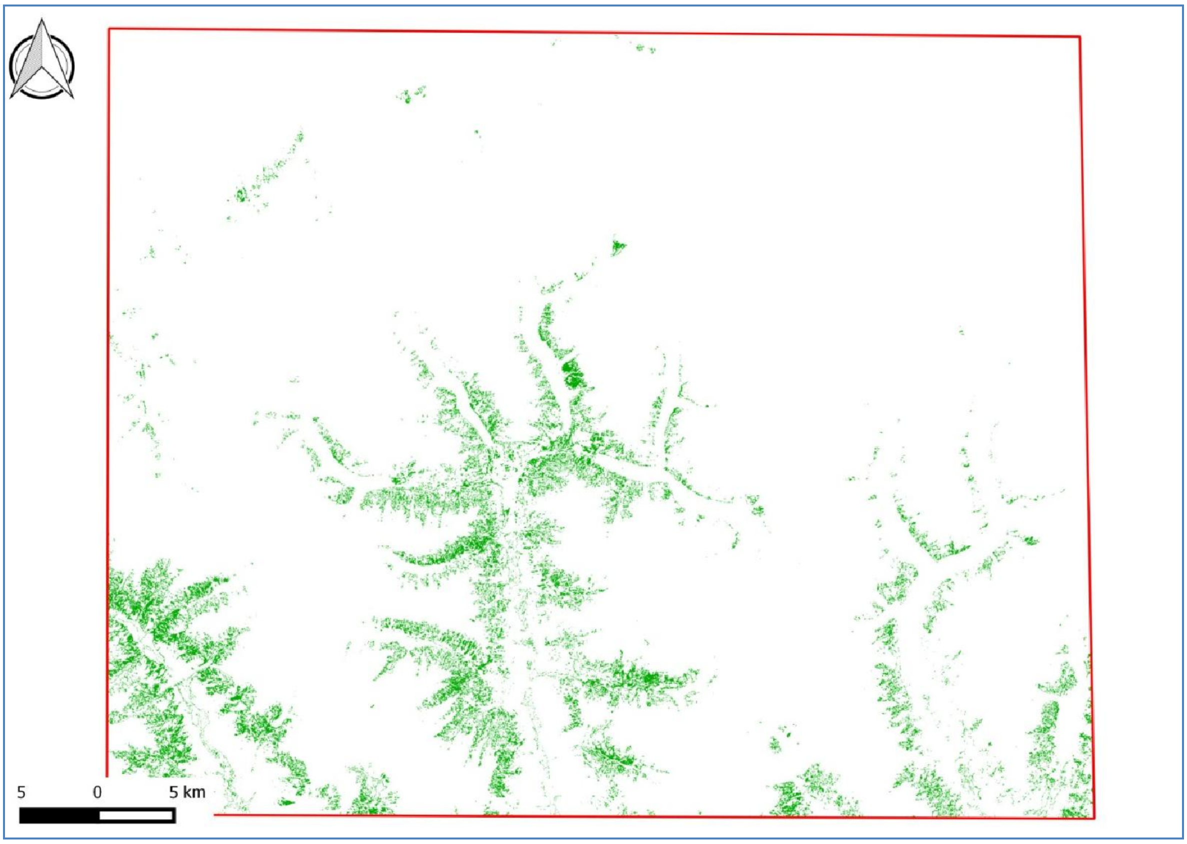


Exhibit 119: Validated map. In red the sample area used for the simulation analysis. In dark green the vegetated areas.

Discussion and "Take home messages"

The two field mission carried out for the collection of GCPs gave very useful results.

The validation of the vegetation index demonstrated that both NDVI and SAVI are useful to discriminate the different land cover classes. In other word it is possible not only to discriminate between vegetated and not vegetated areas but even to recognize, with a good level of accuracy, the extension and distribution of the pastures in our sample area.

This result is very useful to evaluate the resource availability for livestock in CKNP area. Only 2.89% of the whole area seems to present the spectral characteristics of pasture areas. This is due from one side to the climatic condition of the area but it is probably due even to a uncorrect management of livestock with a high degree of overgrazing in the few "good" area. Our resource availability assessment could be an important starting point to change livestock management in CKNP area.

6.5.3 Satellite based dynamic assessment of vegetation / overgrazing in the CKNP area

Main Objectives

The main objective of this last action was to evaluate the vegetation dynamic in CKNP area using a temporal series of satellite images. For this reason we select and use only high quality images, normalized them and evaluated the trend of vegetation dynamic from March to November.

Material and Methods

The calculation of NDVI and SAVI index was done using the same protocol proposed in the previous action (see chapter 2B section Material and methods)

Results

NDVI dynamic

Very interesting information derived from the analysis of NDVI values trends along the study period. Each Land cover class presents a typical evolution of the NDVI values from March to November. In the following figures the NDVI index variation along the study period is represented (figures 120 - 127)

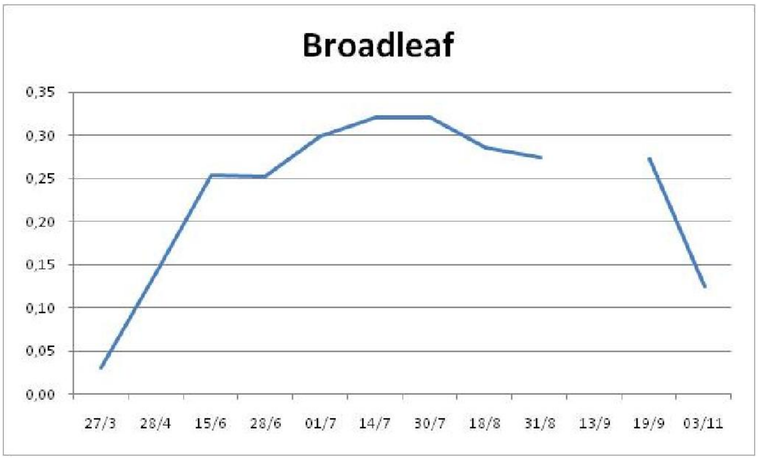


Exhibit 120: NDVI value variation from March to November for the Land cover class "Broadleaf"

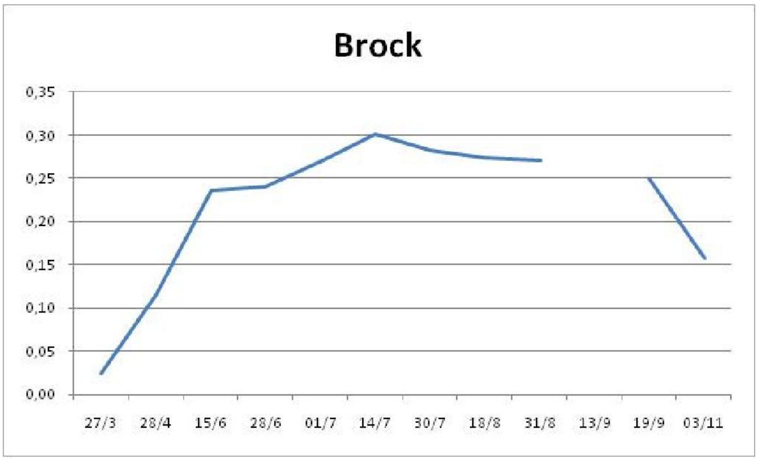


Exhibit 121: NDVI value variation from March to November for the Land cover class "Brock"

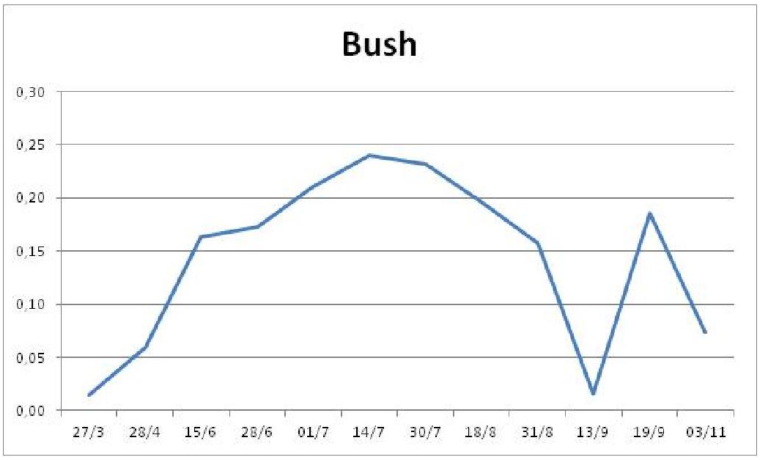


Exhibit 122: NDVI value variation from March to November for the Land cover class “Bush”

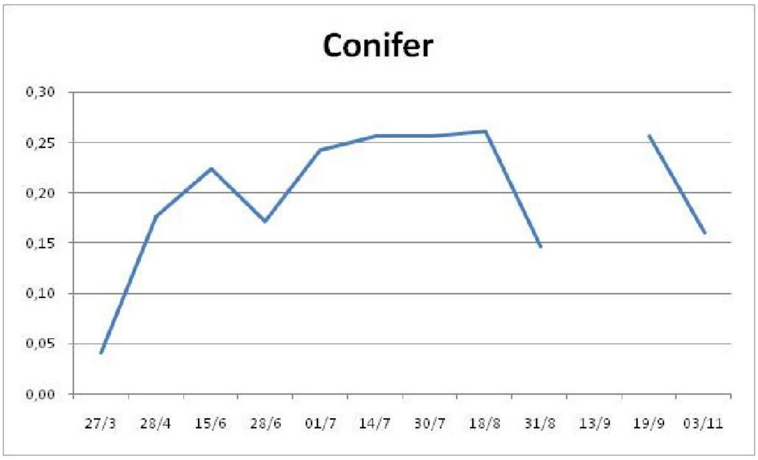


Exhibit 123: NDVI value variation from March to November for the Land cover class “Conifer”

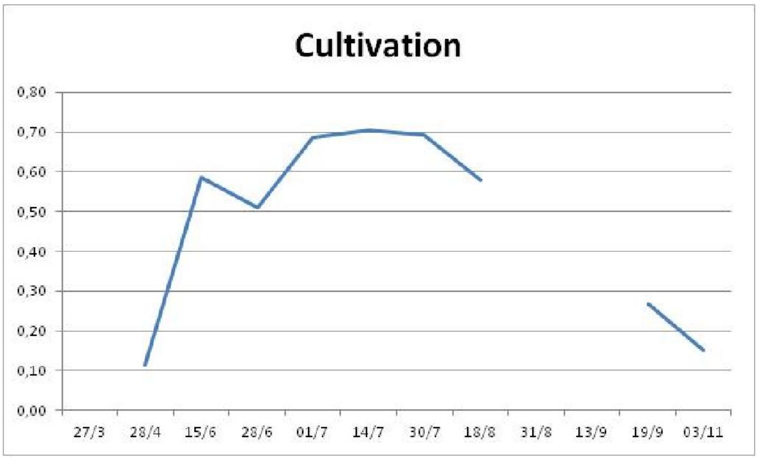


Exhibit 124: NDVI value variation from March to November for the Land cover class “Cultivation”

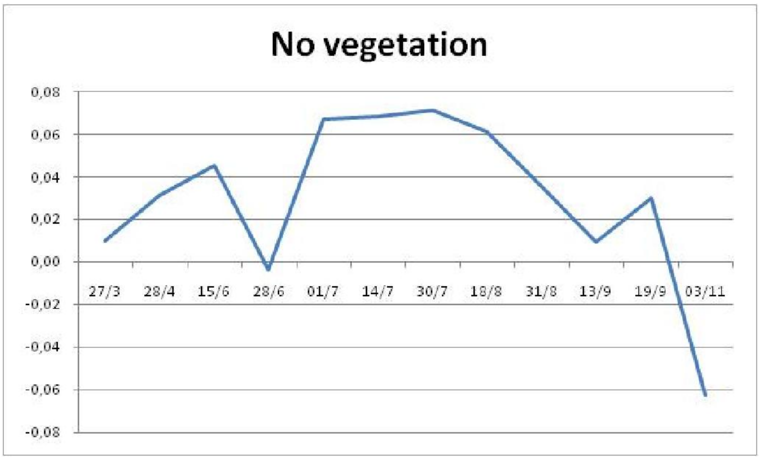


Exhibit 125: NDVI value variation from March to November for the Land cover class “No vegetation”

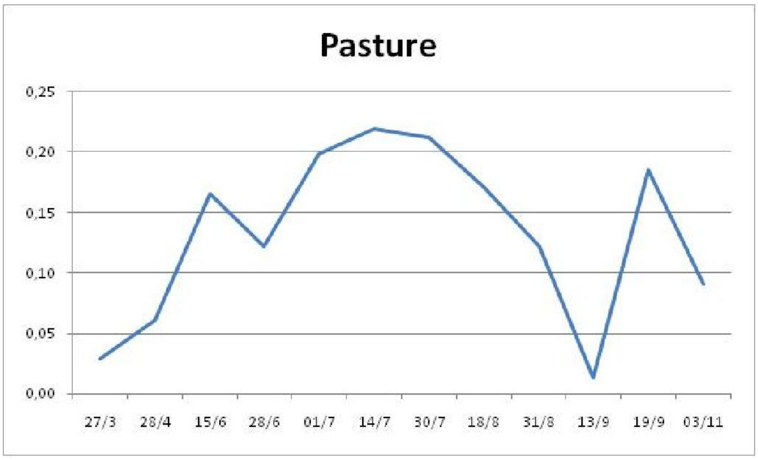


Exhibit 126: NDVI value variation from March to November for the Land cover class “Pasture”

Finally an evaluation of all the Land cover classesis reported in figure 21. The NDVI values for the “Cultivation” class is largely higher that the other classes.

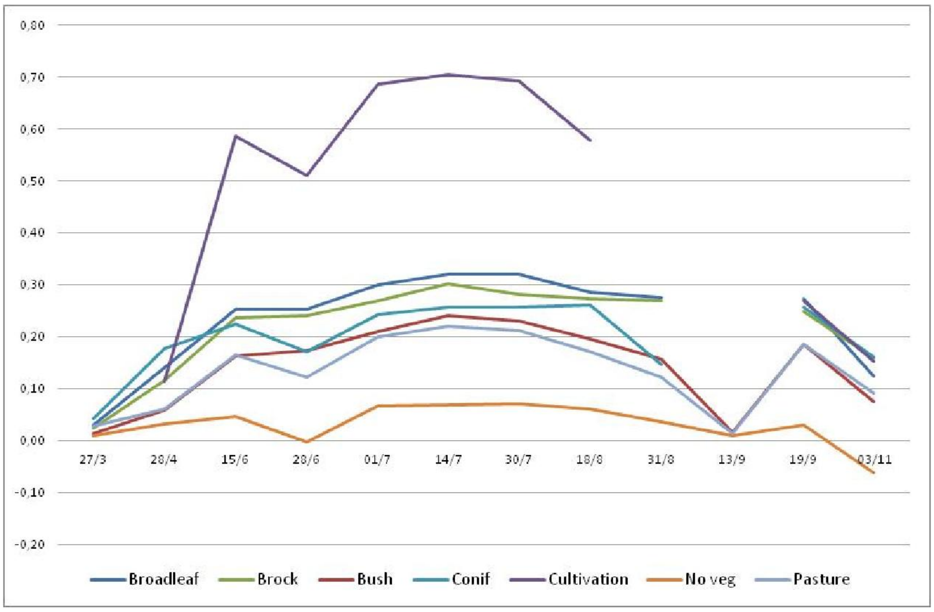


Exhibit 127: Comparison among the NDVI values of the different Land cover classes.

SAVI dynamic

Even for SAVI there is a clear evolution of vegetation index along the study period. (figures 128 - 135)

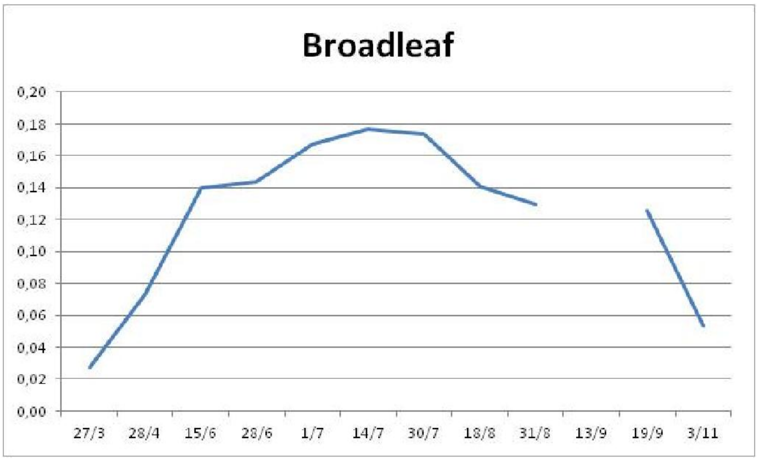


Exhibit 128: SAVI value variation from March to November for the Land cover class "Broadleaf"

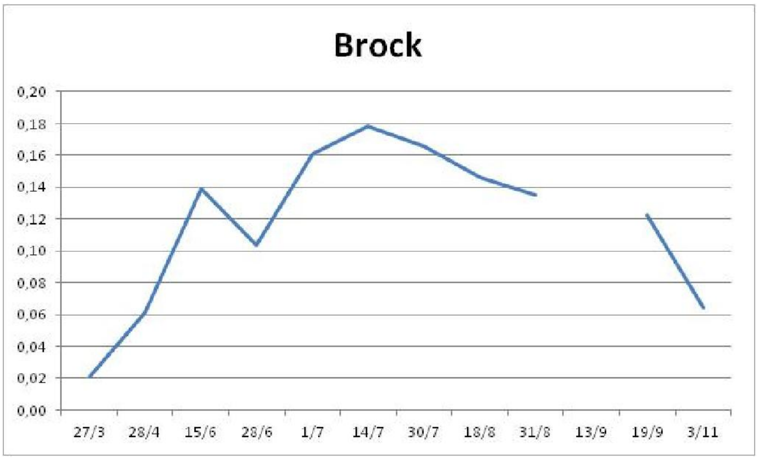


Exhibit 129: SAVI value variation from March to November for the Land cover class "Brock"

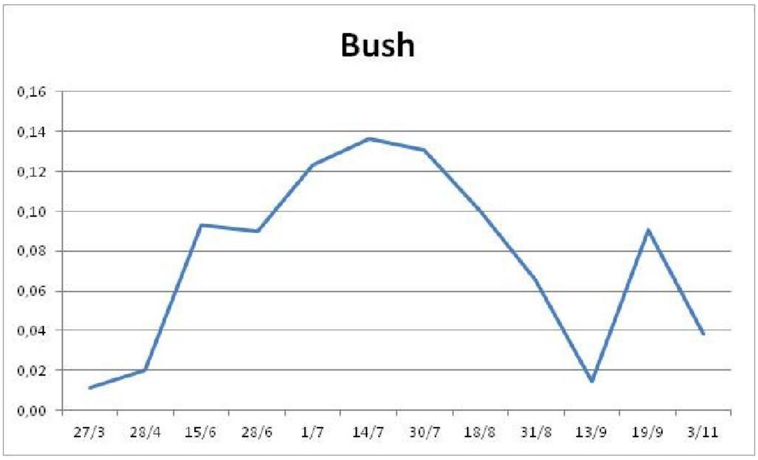


Exhibit 130: SAVI value variation from March to November for the Land cover class "Bush"

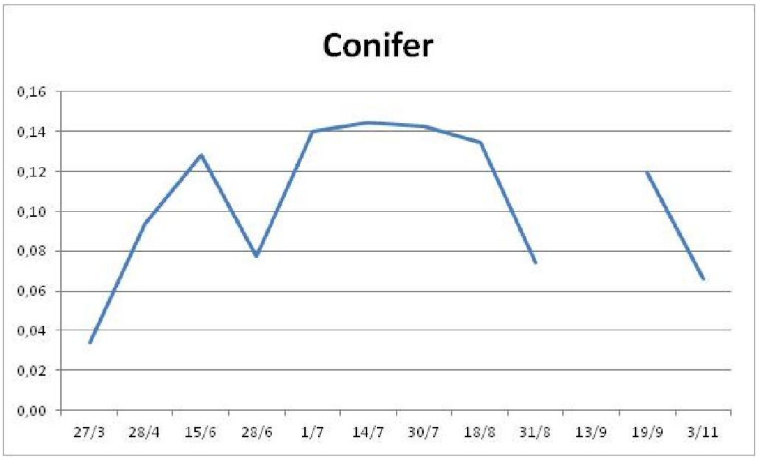


Exhibit 131: SAVI value variation from March to November for the Land cover class "Conifer"

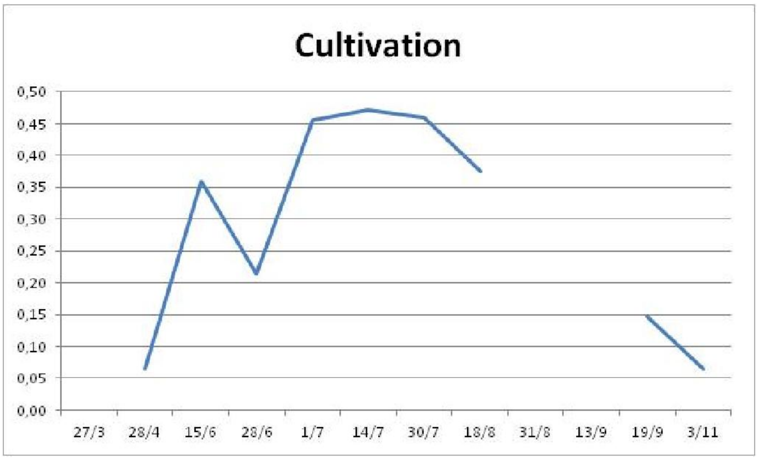


Exhibit 132: SAVI value variation from March to November for the Land cover class "Cultivation"

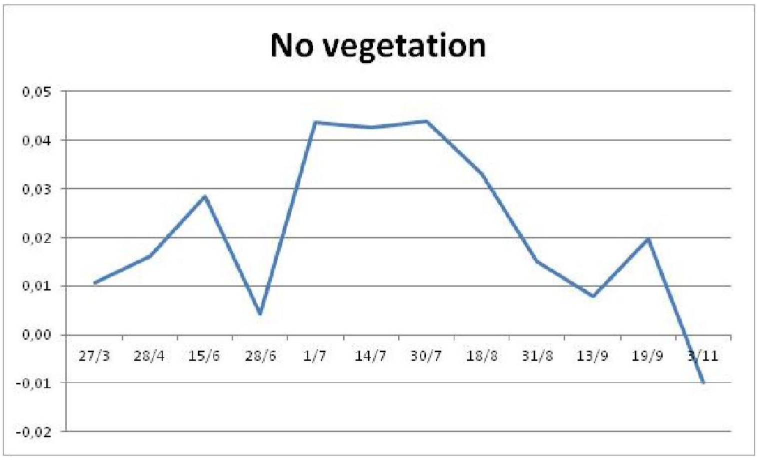


Exhibit 133: SAVI value variation from March to November for the Land cover class "No vegetation"

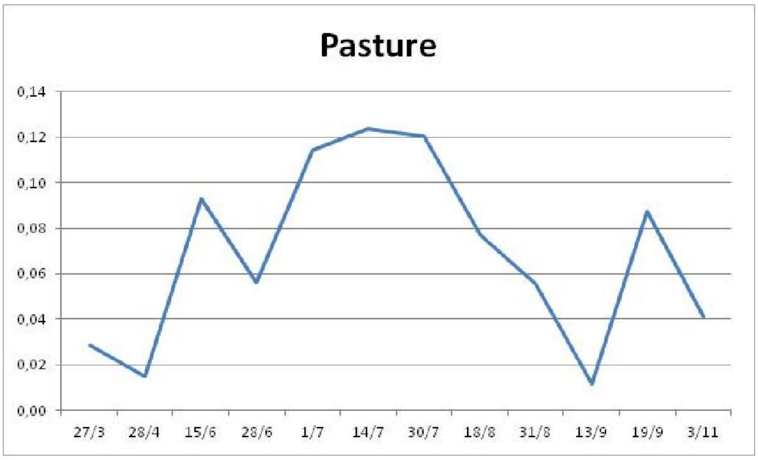


Exhibit 134: SAVI value variation from March to November for the Land cover class "Pasture"

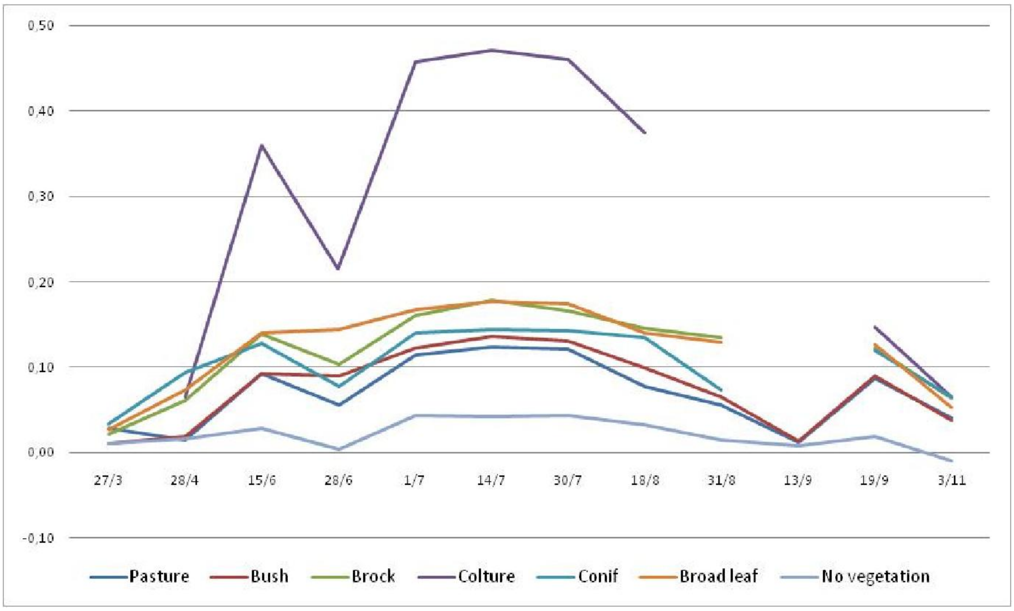


Exhibit 135: Boxplot of SAVI values divided for Land cover classes. SAVI data refer to vegetation index derived for the 30 July 2013

Discussion and "Take home messages":

The analysis of Landsat images and the derivation of vegetation index are really interesting and useful even for the evaluation of seasonal vegetation dynamics. In other word it is not only important to evaluate the presence and distribution of vegetation but even its dynamic along the year.

The analysis of vegetation dynamic could provide useful information on i) the of vegetation phenology and ii) the vegetation peak (useful for a proper management of the pastures) but even about iii) the overgrazing phenomena with sudden decrease of vegetation index in some areas due to overexploitation of the pasture areas.

Even in this case the production of dynamic land cover maps will be a very important tool to improve the management of livestock in CKNP area.

7. Distribution, management and conservation of Large Mammals in the Central Karakorum National Park [9]

7.1 Study area

The Central Karakoram National Park (CKNP; ca. 10000 Km2, with the annexed buffer zone) is a refuge area not only for threatened species (e.g. Schaller 1977), i.e. markhor, musk deer, Ladakh urial, Marco Polo sheep (presence to be confirmed in CKNP) and snow leopard, but also for not threatened but important "flag" species, i.e. Himalayan ibex, Himalayan lynx and grey wolf. The CKNP was proposed in the early 90's of the XX Century to protect the major mountain massifs, watersheds and glaciers of the Central Karakoram region and to form a contiguous conservation area with the Kunjerab National Park and the Deosai National Park.

In practice, the status of the threatened species inhabiting the Central Karakoram National Park is almost unknown, but some information indicates that numbers of the snow leopard and especially of markhor are very low and close to their biological threshold (Shackleton 1997). Over-hunting, habitat loss and isolation of small populations have probably been the main reasons for this depletion (Shackleton 1997). Although a "focal approach" and systematic surveys were proposed as a key action in the IUCN Action Plan for Caprinae (Shackleton 1997) and in the 1999 draft Management Plan (McDonough 1999), very limited sound information is available on the distribution and numbers of local wildlife, presently (e.g. Virk et al. 2003, Roberts 2005). Furthermore, all the information is limited to the border areas of the Park, where human activities are greater and access is easier.

During this 3-year project, some activities have been carried out, as well as data collected, within the CKNP, while detailed information has been collected in the Hushey valley. This valley has a South-North orientation; Hushey represents the highest village, at an elevation of ca. 3200 m a.s.l. In the Hushey valley, the inner part of the Park is composed by 4 main sub-valleys (Aling, Musherbrum, Nandogoro and K6-K7).

7.2 Material & Methods

7.2.1 CKNP level:

(A) A questionnaire relevant to flag/umbrella species in each valley of the CKNP was prepared by Unisi, then distributed and filled in with the help of the local communities, jointly with the Snow Leopard Trust. This approach allowed us to obtain quickly basic data on a wide area as the CKNP. Several steps have been then planned by UniSi to test this information: (i) to control "blank" areas (i.e. areas where information is flawed and/or the presence of some other species, beside those mapped, was suspected) in the field. Data have been scrutinised to test their reliability; (ii) to locate focal areas for conservation of large mammals, i.e. areas where the distribution of flag/umbrella species is overlapping. This step is very important for such a large protected area as the Central Karakoram National Park, encompassing the distribution of four "threatened" species of large mammals; (iii) to assess the reliability of focal areas, in the field.

(B) 3-4 days surveys have been carried out in some of the main valleys of the park, where ungulates occur, in order to (i) assess their abundance/distribution and (ii) train CKNP personnel.

[9] Authors: Sandro Lovari, Anna Bocci (University of Siena, Italy)

7.2.2 Study area level:

In the Hushey valley, data have been intensively collected through:

(A) Counts of large mammals:

- Wild ungulates. Counts have been carried out through standard methods for mountain ungulates, adapted to local terrain. Locations have been mapped and key-areas have been GPS-recorded. For each direct observation, number of individuals and group structure have been noted down.

- Snow leopards and wolves. Counts have been carried out through DNA analyses, from scats. Scats of large predators have been collected along fixed itineraries and analysed genetically (to assess the species, the individual and the sex). Thus, minimum population estimates have been obtained.

(B) Assessment of predation. Scats of large predators have been analysed to determine their food habits and to detect the effects of carnivores on their natural prey and on livestock. Prey species have been identified out of phaenotipic micro-characters of their hair (e.g. structure of cuticula and medulla) and other indigestible remains in their scats. Data have been worked out as frequency of occurrences and percentage of estimated volume, to obtain a final qualitative and quantitative picture of the spectrum of the diet of the snow leopard and of the wolf. These data are useful for the conservation of carnivores, as well as for management purposes.

7.3 Synergy with other groups

During the project, some field missions have been carried out with SLT (Apr. 2010); UniPd (Apr. 2011), KIU (PhD student in Wildlife Conservazion – Dec. 2010, Apr. 2011, Apr. 2012), CKNP staff (wildlife surveys: Dec. 2010, Apr. 2011, Apr. 2012; wildlife courses: May 2011, July 2011, Apr. 2012, Apr. 2013) and WWF-Pakistan (Dec. 2010; Apr. 2011; May 2011; July 2011).

We have been working closely with UniCa, to provide data and information for the thematic maps and the zoning of the Park.

In the last year, we have been working closely with UniTo group, to collect information from the same areas (Minapin, Sikendarabad, Khanday, Hushey) and to define the outlines for an insurance scheme as well as for a vaccination sustainable campaign.

In September 2013, we attended the conference "The Italian science and cooperation at the shadow of K2" (held in Islamabad), with the other teams working in the project.

7.4 Results

7.4.1 Literature review

As to Caprinae, Pakistan is one of the most important countries in the world for their conservation (Shackleton 1997), because most of the taxa present in the country are threatened. The I.U.C.N. Caprinae Action Plan (Shackleton 1997) emphasises how (A) the current distribution pattern of wildlife in Pakistan is to some extent a consequence of persecution by humans and (B) their status is often the consequence of overhunting, poaching, habitat degradation, resulting in population fragmentation and isolation.

As to species accounts:

– Northern Pakistan represents the westernmost part range of blue sheep; Roberts (1977) mentioned its occurrence in the CKNP area (around Shigar and Baltoro glacier). The western distribution of bharal touches the eastern end of the Karakoram (Schaller 1977). Limited range and low numbers make it vulnerable to poaching and habitat loss.

- In terms of relative numbers, the Asiatic ibex is probably the most abundant Caprinae species in north-western India and Pakistan, occupying all the major ranges (Schaller 1977). Competition for food with livestock is a growing threat to Asiatic ibex in Pakistan. As to the CKNP area, there are small populations of ibex in northern Chitral, Dir, northern Swat and in Gilgit around Ishkoman, Yasin, Nagar and Hunza, as well as Astore and in Baltisan throughout the Karakoram (Roberts 2005). Burrard (2008) reports that "there are [were] ibex in plenty" in the Shigar valley, in the first few decades of the last century.
- The occurrence of markhor in the area of CKNP has been reported several times (Schaller & Kahn 1975, Hess 1986), but always at small numbers. Markhor have a limited geographical distribution, their range being squeezed between those of ibex and wild goat. Schaller (1977) reports the presence of the Astor markhor in the Gilgit area; thinly scattered populations have been recorded in Chitral and Gilgit, with the best populations surviving in protected parks or hunting preserves (Roberts 2005).
- The Ladakh urial, like the markhor, advanced into the mountains of northern Pakistan and India mainly by penetrating the major river valleys such as the Kunar, Indus, Gilgit and Shyok (Schaller 1977). As to the CKNP area, some reduced populations still occur along the Shigar and Braldo rivers and possibly along the Indus (Schaller 1977). Roberts (2005) reports the urial surviving in small numbers in the higher hill ranges of Balochistan, with very few surviving anywhere in Chitral or around the main valley of Gilgit.
- Blue sheep occur in the higher, steeper, watershed tributaries of the Shimshall valley (Roberts 2005).
- The musk deer survive in small numbers in Chitral, Gilgit and Baltisan, especially on Deosai plateau, and are more numerous in the Neelum valley of Azad Kashmir and the higher valleys of Indus Kohistan (Roberts 2005).

Ibex and livestock are the main food of wolves in northern Pakistan, where they occur over most of the Himalayan uplands, avoiding only dense forests and steep gorges (Schaller 1977).

The brown bear was once abundant in the Himalaya, but the species is become rare nowadays in the far northern valleys of Chitral, Dir, Swat and Gilgit and the best known population survives in the Deosai Plateau of Baltisan (Roberts 2005), with several tens of individuals. As to the CKNP area, brown bears are reported in low densities from Shigar, Baraldu and Baltoro Glacier, as well as from Nagir, Chaprote and Bar Nullah (Nawaz 2007). Brown bears in the Baltoro valley subsisted mostly on grass and various roots (Schaller 1977).

The snow leopard has a patchy and restricted distribution from across the Himalaya and Karakoram. In particular, in Pakistan, it still occurs from Northern Chitral, through Indus Kohistan, northern parts of Gilgit and Karakoram (Roberts 2005).

The lynx has been recorded in northern Chitral from the Turikho, Baroghil and Kharumbar valleys and the Shandur Plateau (Roberts 2005). In Gilgit it occurs from the northern reaches of Yasin, Nagar and Hunza valleys (Roberts 2005). Although rare in Pakistan, it is still hunted for its valuable fur whenever encountered (Roberts 2005).

7.4.2 Field data

CKNP level:

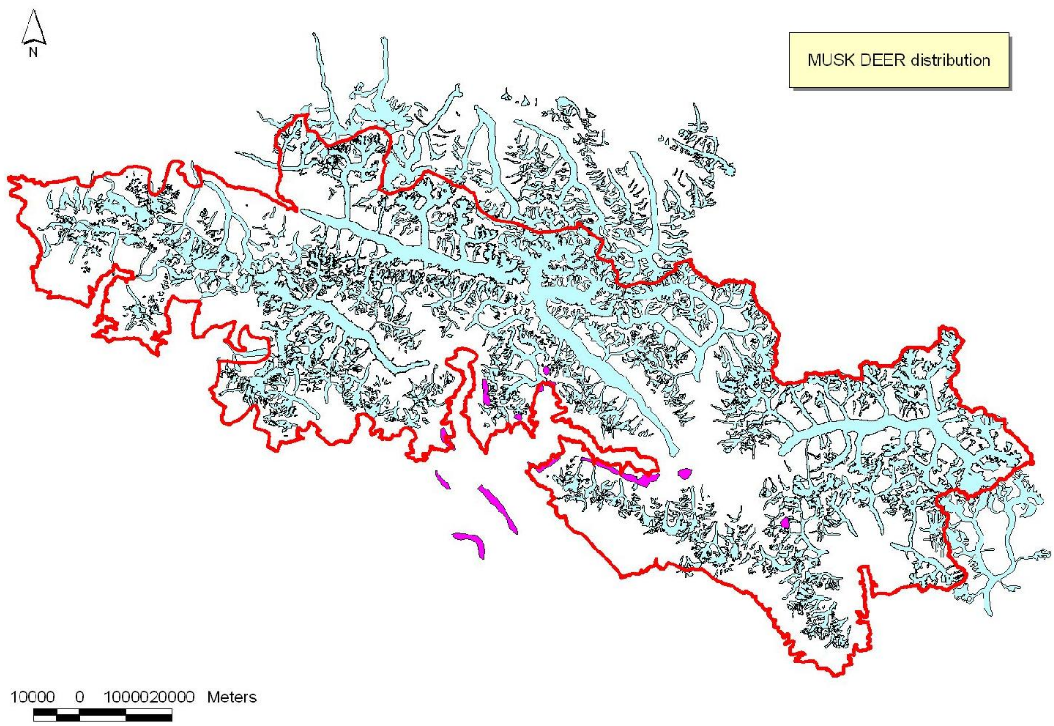
SEED emphasised how a standardised assessment of the distribution and, possibly, of the numbers of large mammals was urgent. For this purpose, ecological overlap and potential competition between large carnivores (snow leopard, wolf, lynx, brown bear), as well as their non-invasive genetic monitoring to assess minimum numbers, deserve to be estimated. In fact, besides the effects of human-related encroachment (e.g. hunting, poaching, logging, livestock raising), the distribution and numbers of wild ungulates are usually a function of the predator impact, as well as of distribution and quality of food resources.

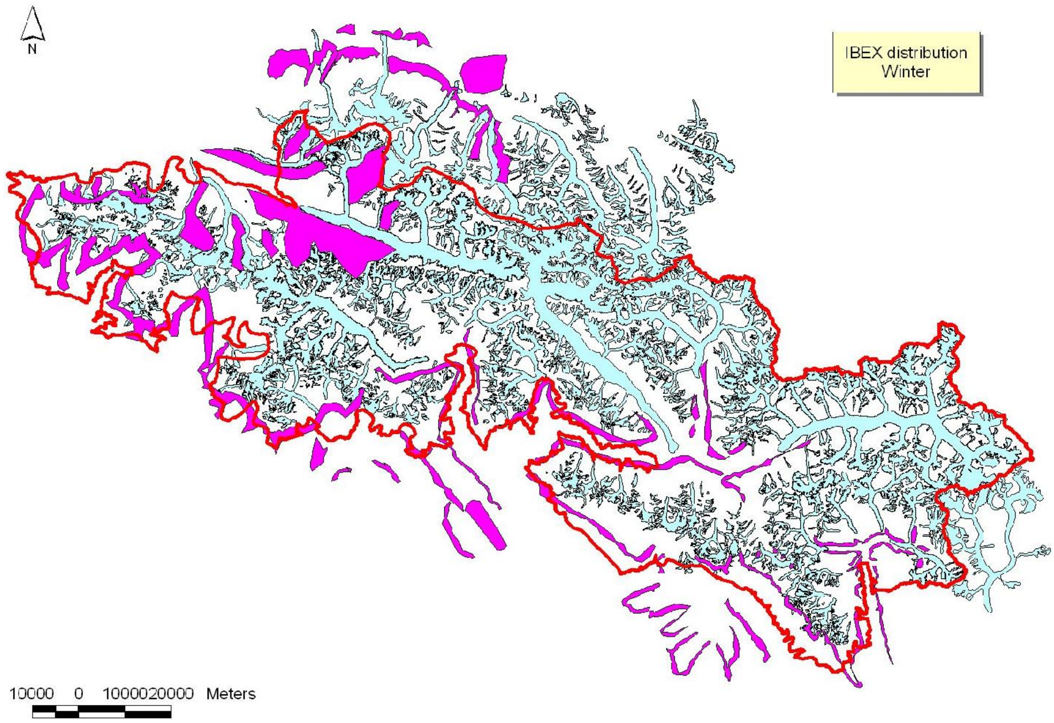
As previously said, a questionnaire relevant to flag/umbrella species in each valley of the CKNP was prepared, distributed and filled in with the help of the local communities and the support of the Snow Leopard Foundation. All information collected were used to draft the annexed maps and to fill in the following table with minimum numbers. This approach allowed us to obtain quickly basic data on such a vast area as the CKNP.

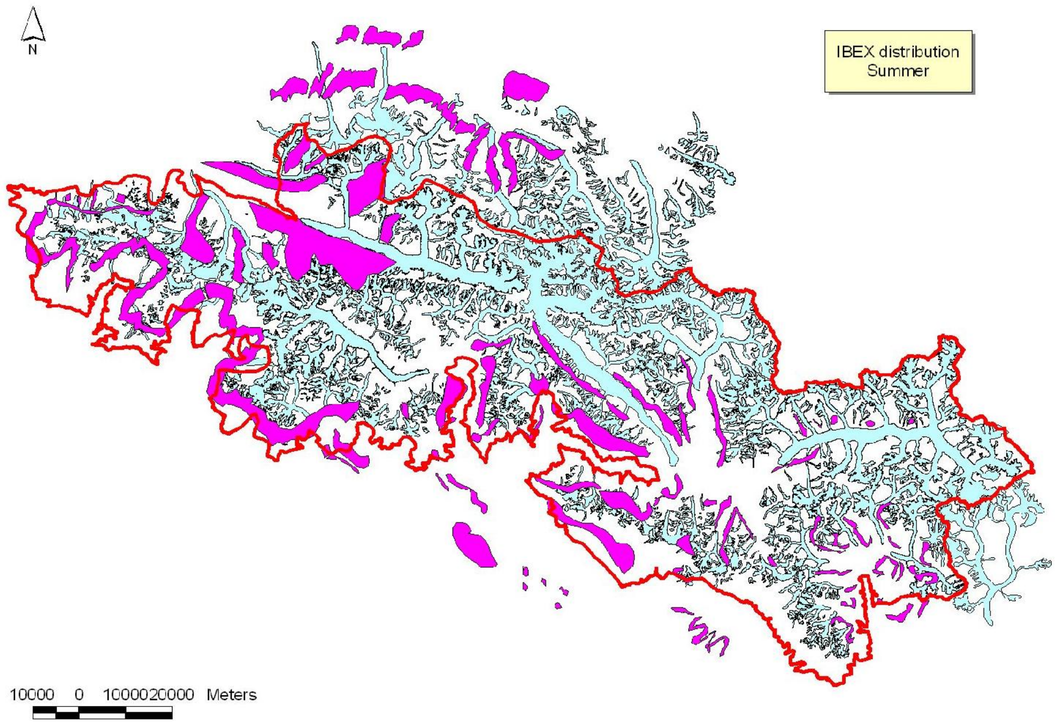
Several "blank" areas (i.e. areas where information is flawed and/or the presence of some other species, beside those mapped, is suspected; Sikendarabad, Minapin, Khanday, Hoo nallah, Apolygon) have been surveyed in the field, in 2013. Some data have also been scrutinised to test their reliability and to assess the reliability of focal areas for conservation of large mammals in the field, i.e. areas where the distribution of flag/umbrella species is overlapping. This step is very important for such a large protected area as the Central Karakoram National Park, encompassing the distribution of four "threatened" species of large mammals.

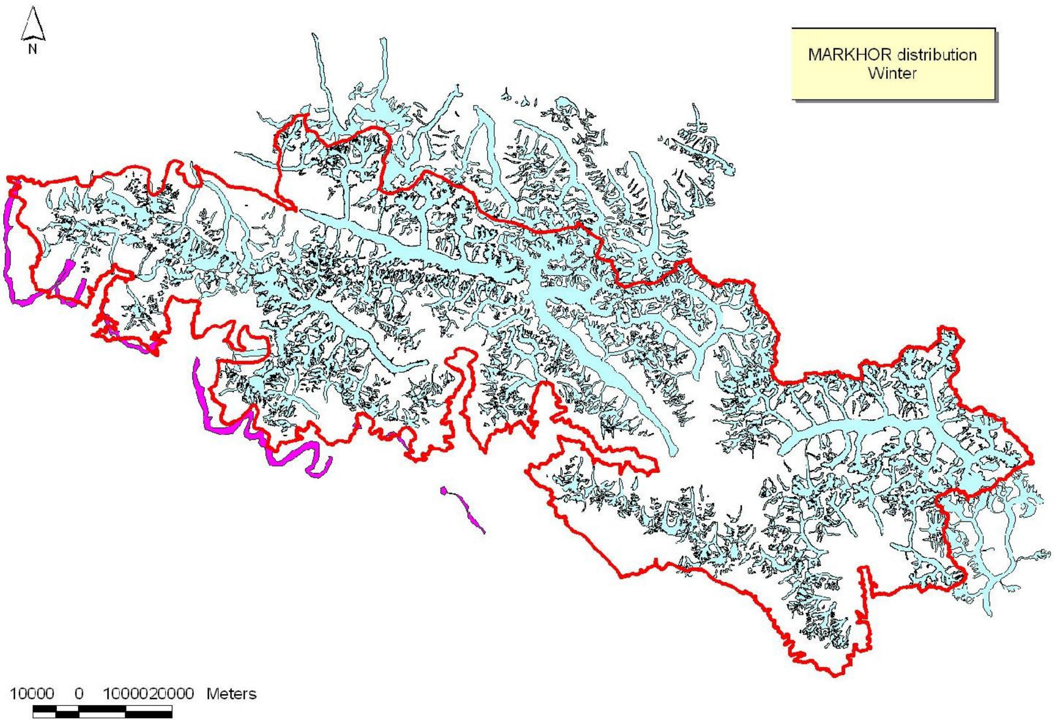
The main constraint to the draft of the maps and the assessment of numbers of large mammals in CKNP is related with seasonal movements that animals make and the problem that usually neighbour valleys may share the same population. As to large carnivores, for example, they tend to live in low densities, especially at high altitudes, moving over very wide areas because of dispersion of their main food resources (wild ungulates). These habits make their conservation particularly difficult because the same individual may visit different valleys, which could upset counts carried out just through sightings or signs of presence. To reduce this problem, data on individual distribution of large carnivores in one study site (Hushey valley) were obtained trough DNA analyses of scats collected over different valleys with a standardised approach (please, see the next paragraph "Study area level"). However, collection and evaluation of these data are difficult, e.g. fresh scats yield better results than old ones.

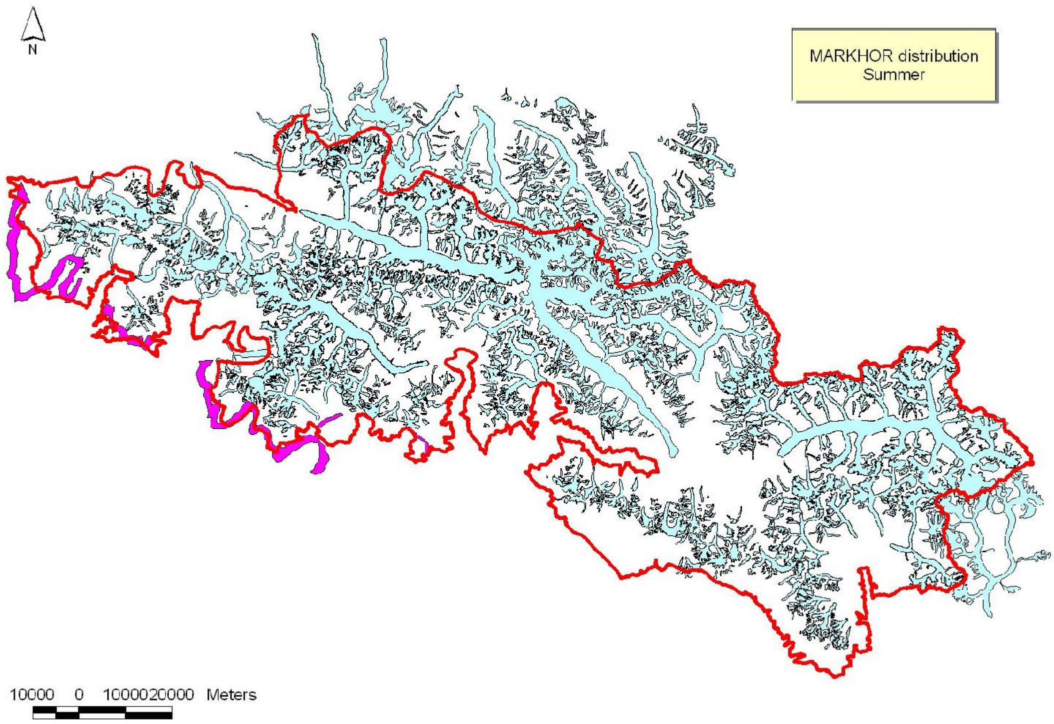
The following figures show the data on distribution (in fuchsia colour) of mammals in CKNP, considering the preliminary boundaries of CKNP developed within the SEED project.

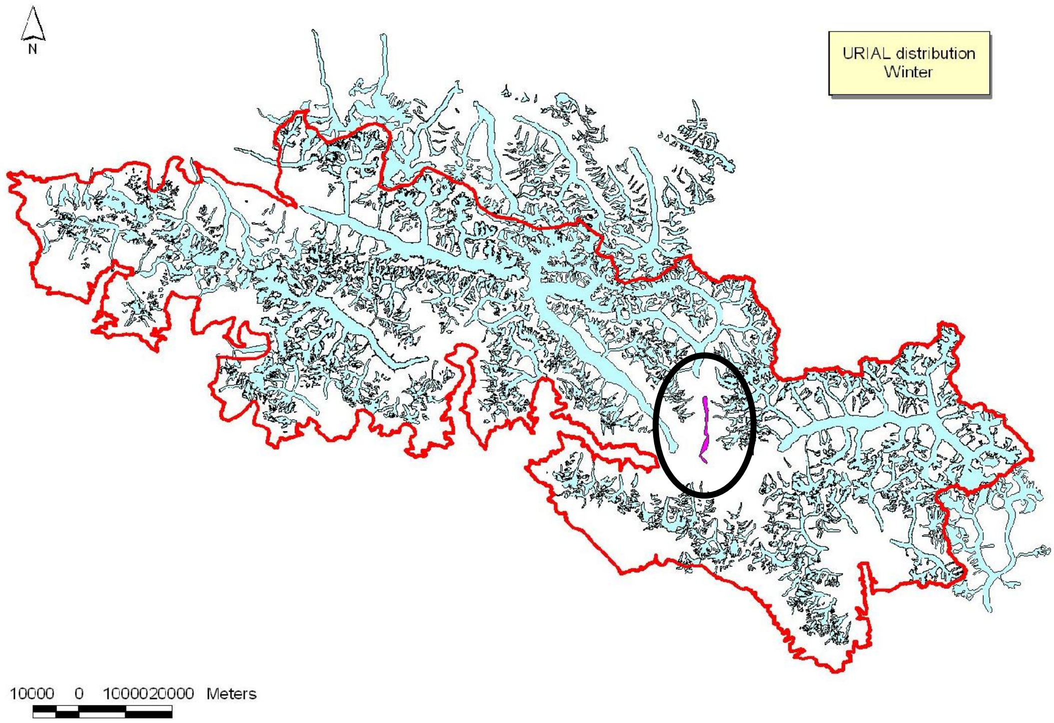


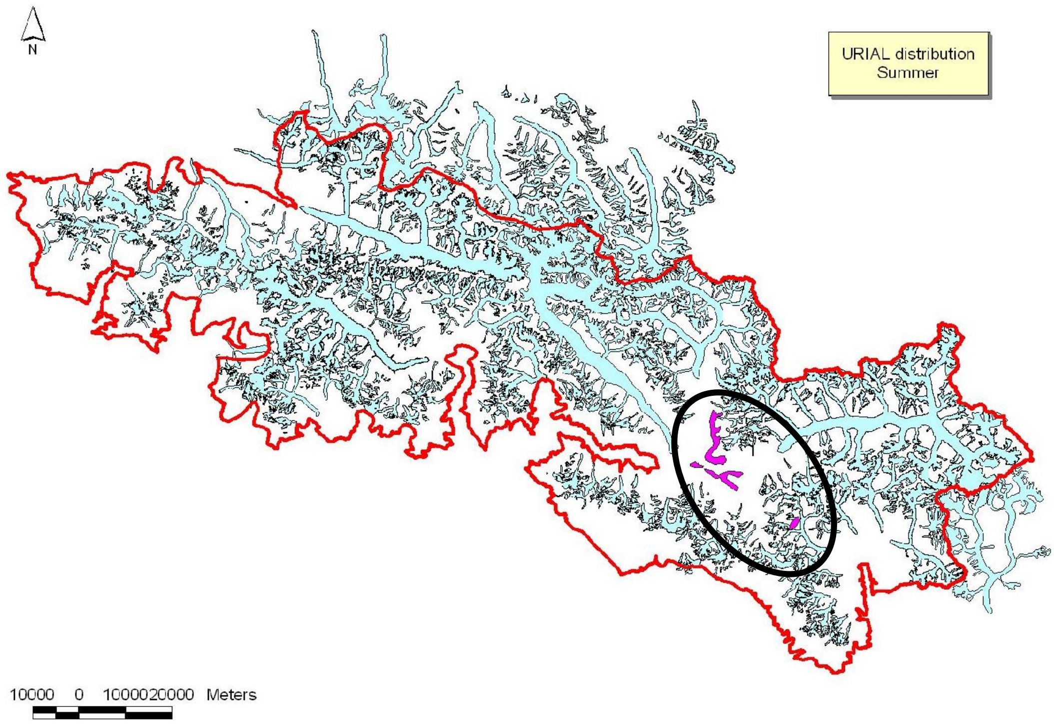

N
IBEX distribution
Winter
10000 0 1000020000 Meters

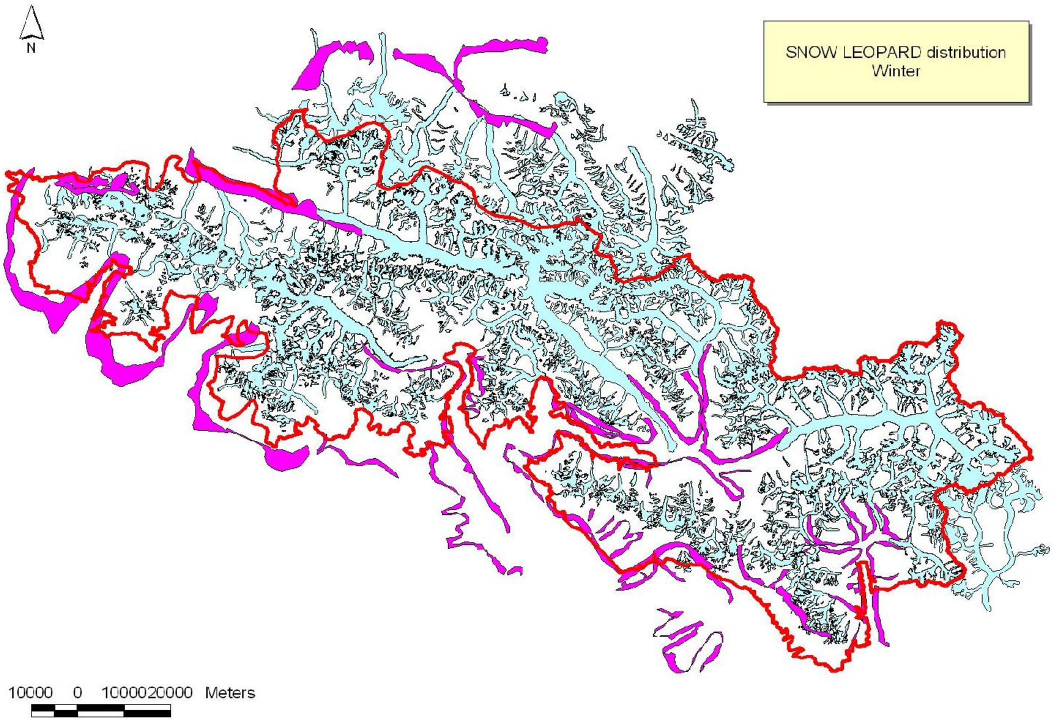

N
IBEX distribution
Summer
10000 0 1000020000 Meters

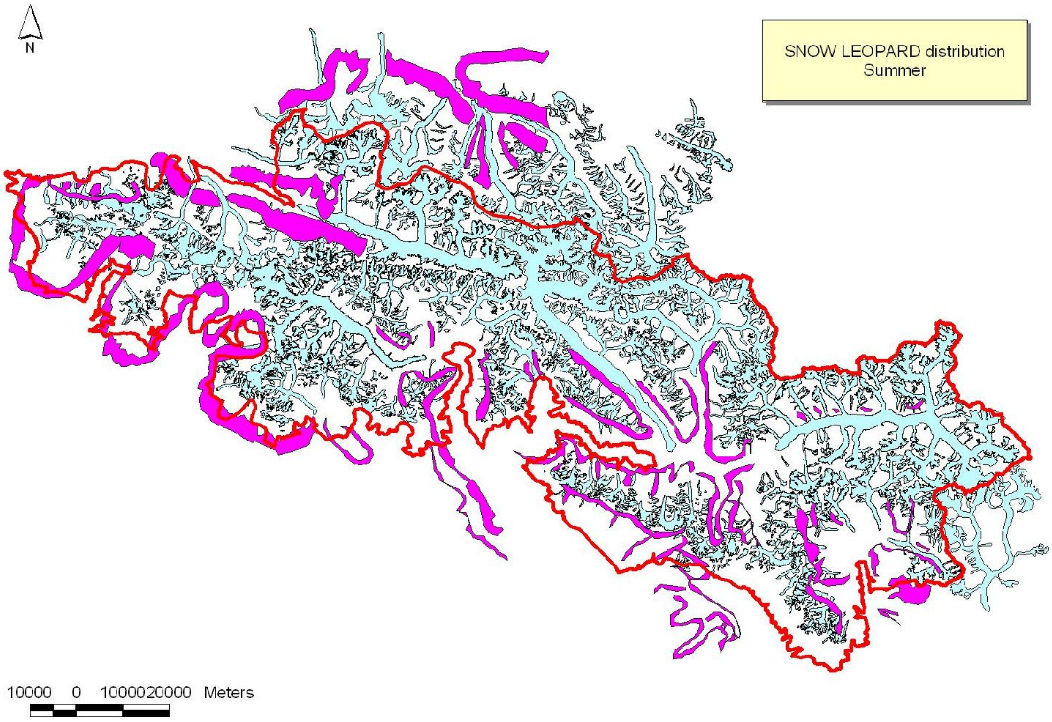

N
MARKHOR distribution
Winter
10000 0 1000020000 Meters

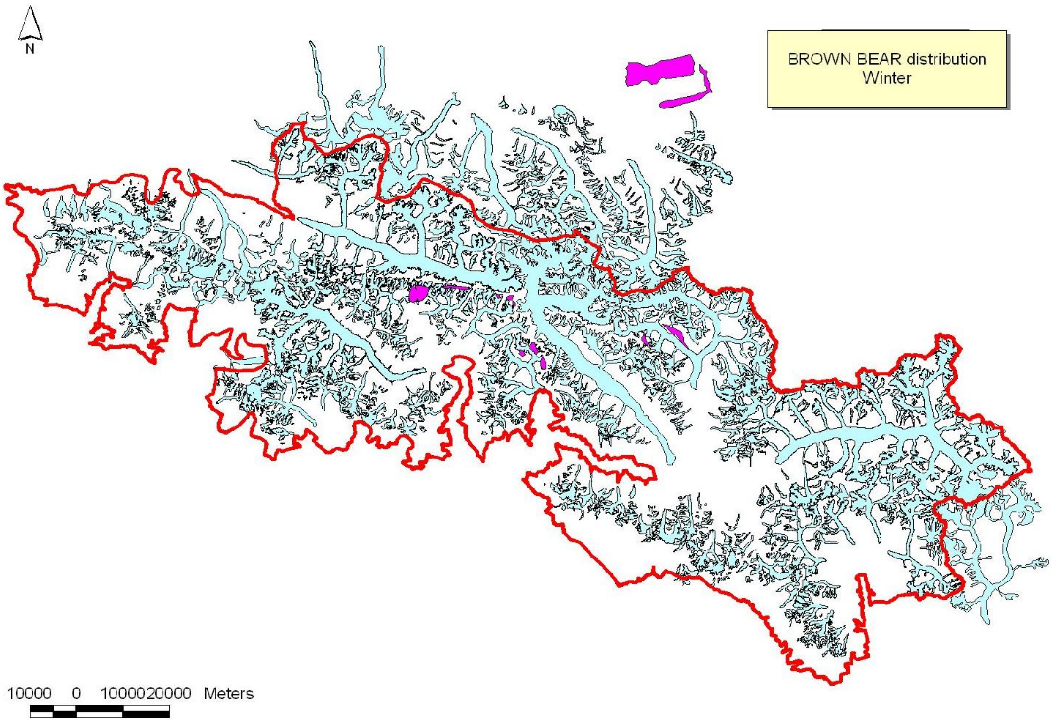

N
MARKHOR distribution
Summer
10000 0 1000020000 Meters

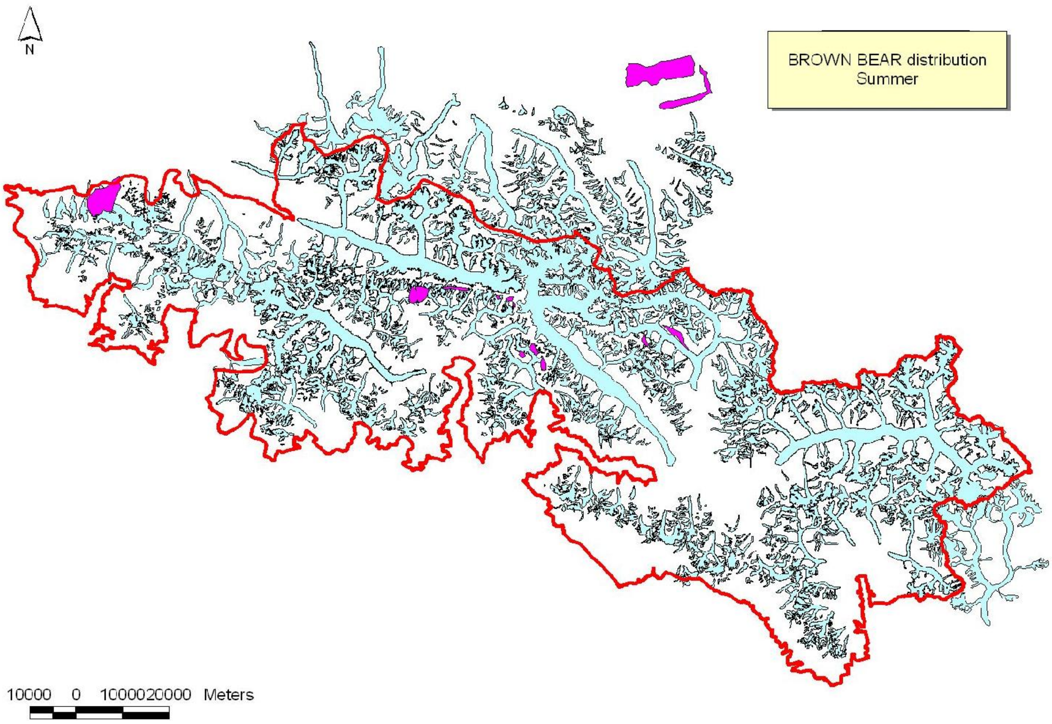

N
URIAL distribution
Winter
10000 0 1000020000 Meters

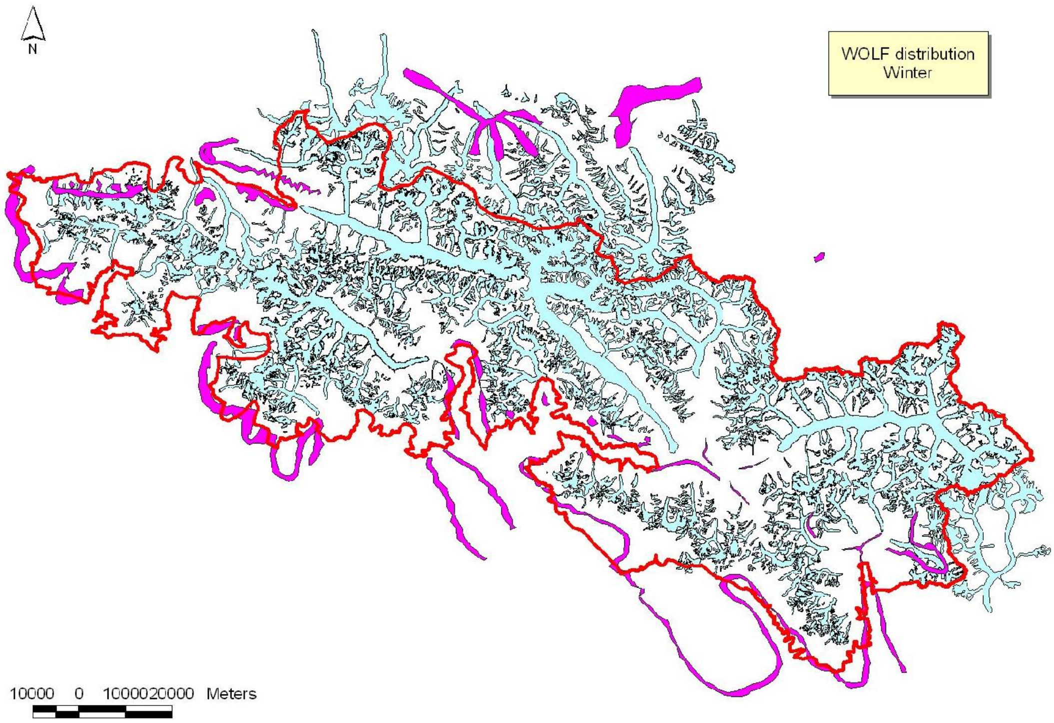

N
URIAL distribution
Summer
10000 0 1000020000 Meters

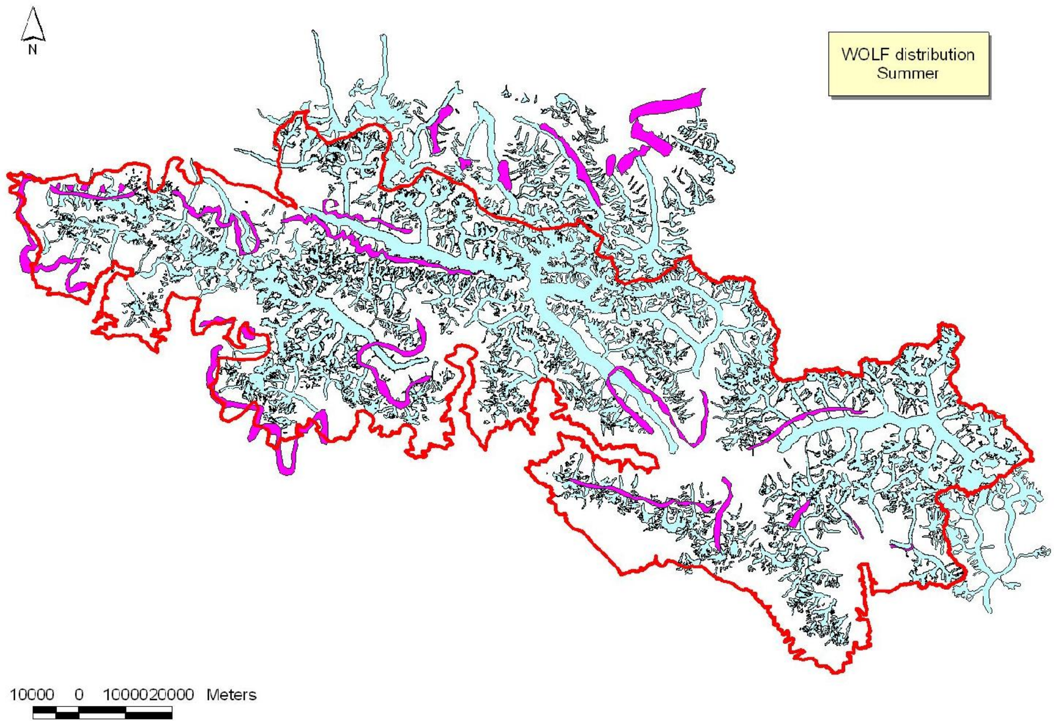

N
SNOW LEOPARD distribution
Winter
10000 0 1000020000 Meters

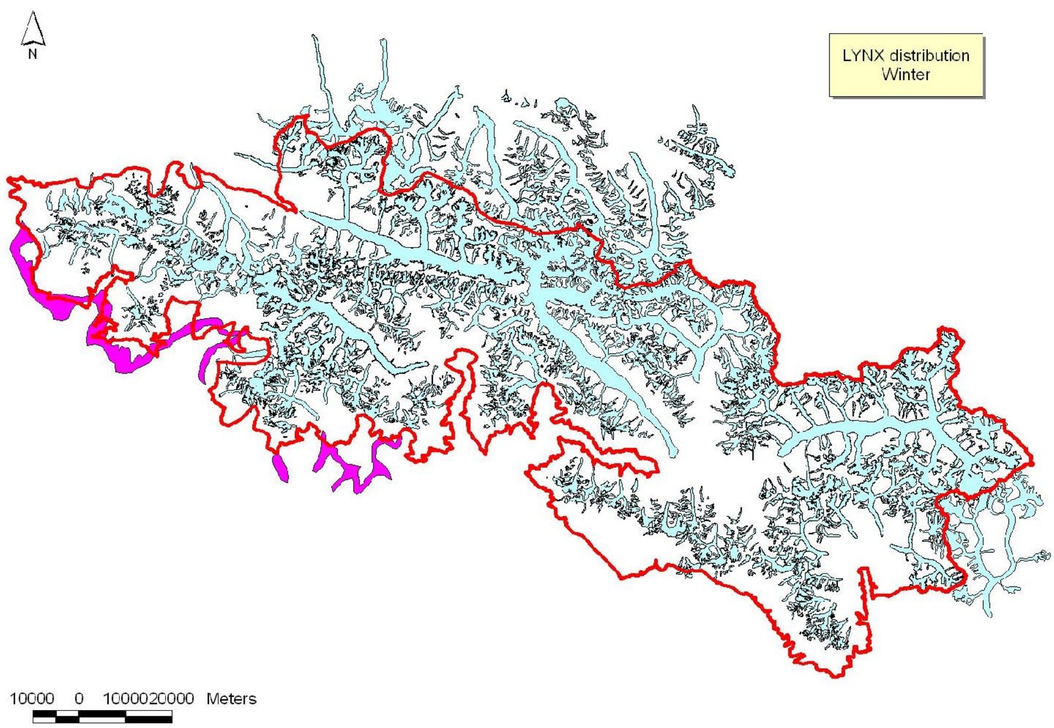

N
SNOW LEOPARD distribution
Summer
10000 0 1000020000 Meters

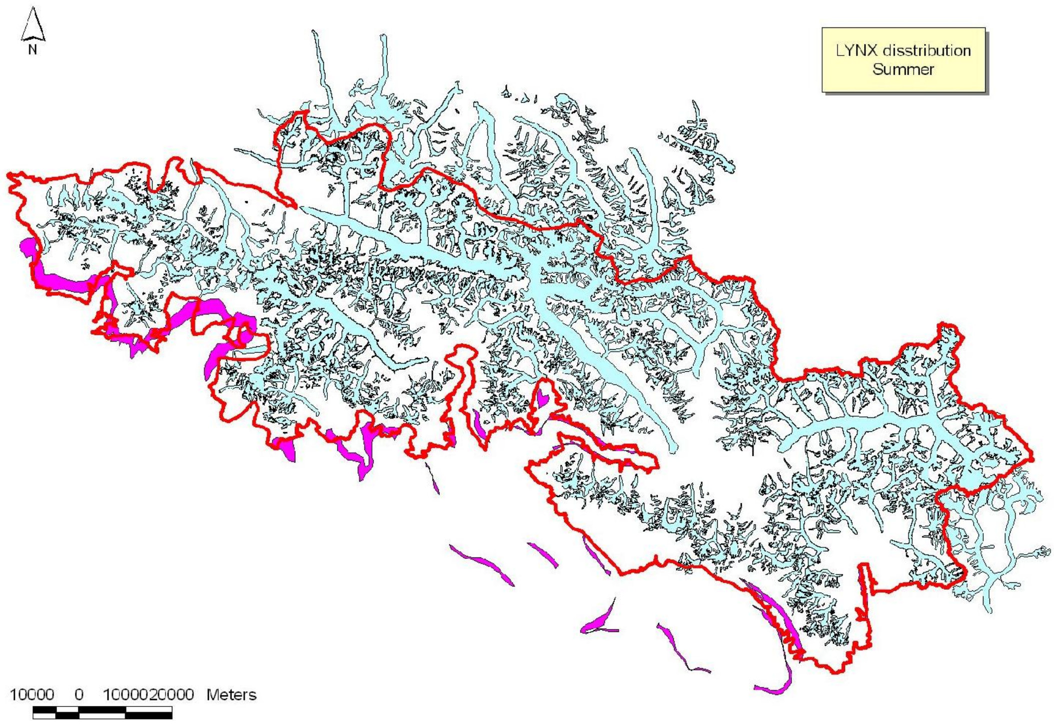

N
BROWN BEAR distribution
Winter
10000 0 1000020000 Meters


N
BROWN BEAR distribution
Summer
10000 0 1000020000 Meters


N
WOLF distribution
Winter
10000 0 1000020000 Meters


N
WOLF distribution
Summer
10000 0 1000020000 Meters





As to numbers, some surveys were carried out in the main valleys of the park, where ungulates occur, to cross-check data in order to also train CKNP personnel. Data on abundance could provide a measure of the relative density of herbivores, which could be used to compare the status of subpopulations from different areas and, in future, that of each area in different years. Initially (i.e. in 2010, at the beginning of the project), the original plan was to train game-watchers to carry out a monthly data collection in the field. Unfortunately, except for 6 of them (hired in 2010), all the game-watchers have been finally hired in early 2013, and then trained in April 2013. Thus, monthly data on large mammal numbers and distributions are available for just few valleys (Hushey, Askoli, Sikendarabad, Tormik). Furthermore, also in these valleys data are not available for all months of 2012 (as just 6 game-watchers were supposed to work over an area of 10.000 km2, they had no enough time, mostly during the summer, to also count ungulates). Finally, data collected (mostly in 2012) were not completely reliable (see below), because each new trained person needed some time to get enough experience in order to collect reliable data. In some valleys, data collected in 2013 helped us to partially revise the minimum number table of large mammals in CKNP showed in the previous reports. We have used a conservative approach, mainly for carnivores, by limiting the local population size estimate to its minimum number.

Valley	Brown bear	Snow leopard	Lynx	Wolf	Markhor	Ladak urial	Marco Polo sheep	Blue sheep	Asiatic ibex	Musk deer
Jaglot/Minapin	0	2	1-2	1	30-60 *	0	0	0	100-150 *	0
Bagrote	0	5	5	2	<50	0	0	0	100	0
Haramosh	0	5	5	5	>10	0	0	0	100	2-5
Astak-Tormik	0	3	2	2	8-12	0	0	0	40-150 *	1-10
Hoper	1	≥ 2	0	≥ 2	0	0	0	0	50-300 *	0
Hisper	0	≥ 2	0	0	0	0	0	0	> 300 *	0
Hushey	0	2	2	2	0	0	0	0	100-500 *	0
Thalley	1	1	3	2	0	0	0	0	50-150	0
Braldu	1	2	2	2	0	30	0	0	50-300	2-6
Basha	≤ 6	1	2	2	0	0	0	0	10-150	2-6
Shigar	0	1	2	2	0	6 ?	0	0	10-150	2-5
Nar	0	3	2	2	0	0	0	0	100 *	0

* Data have been cross-checked and, in some cases amended, by comparisons with data recorded by Park rangers and/or own data.

Study area level:

In one study site (Hushey valley) data have been intensively collected through:

(A) counts of large mammals:

Wild ungulates. Monthly data collection was carried out in 2012 by the local game watcher (Mr. Sakhawat Ali), except for summer months (July and August). Minimum numbers for each month are shown in the following table.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ibex	191	123	91	20	103	55	-	-	42	243	58	473

Ibex numbers increase in December, remaining high during winter and decreasing in spring and summer months. This may be related to several issues: (*i*) the altitudinal movements of ibex (in spring and summer, when moving at higher altitudes, ibex are hard to be spotted), as well as their possible movements to other neighboring valleys; (*ii*) the extremely variable number of days (i.e. effort) dedicated to this assessment each month, as well as the number of sub-valleys visited (the best surveys were probably carried out in December, when many areas where visited in a short lapse of time).

Incomplete reliability of data comes also from the analysis of the structure of the population. The maximum number of kids to the maximum number of females provides a ratio of 0,9. Variability has been great from month to month and hardly accountable (see table below), which may cast a doubt on the reliability of this figure. The following table show the ratio *number of kids to number of females*, that in an healthy population goes from almost 1 in May-June to 0.6-0.7 during the winter:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
KK/FF	0,9	0,9	1,1	0	0	1,2	-	-	0,2	0,9	1	0,7

Furthermore, data on *sex ratio* (males to females) of the population, show that males are more numerous than females (yearly, 1:0,7; 1,3 MM/FF), as shown by the following table:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MM/FF	1,3	2,2	2,8	1	1,1	4,8	-	-	0,6	1,1	0,5	1,2

This issue may depend on an incorrect identification of females and subadult males during counts (this hypothesis is supported by the fact that the number of males is greater in winter, when females have no kid following them) and /or on a sexual segregation in winter months (with females moving to other areas in winter).

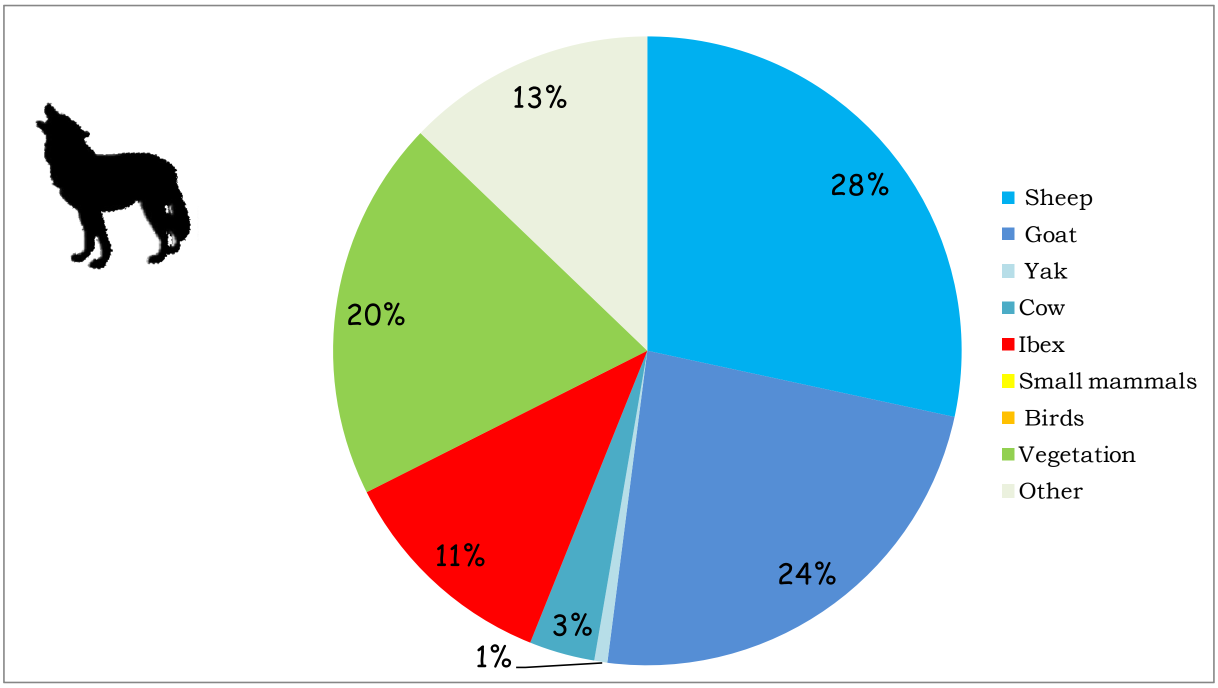
A considerable improvement of these estimates may be expected, if counts will become a routine activity, thus improving game watcher's expertise and eventual reliability.

Data collected in 2013 partially confirmed this trend (also, we do not have all the data: part of them have been lost during the fire that damaged the CKNP headquarter). We are aware that the area to be censused is huge and that we ignore the exact movements of animals, mostly in summer months. May we remark that it is very important that game watchers spend time in the field and collect data using a standardised approach.

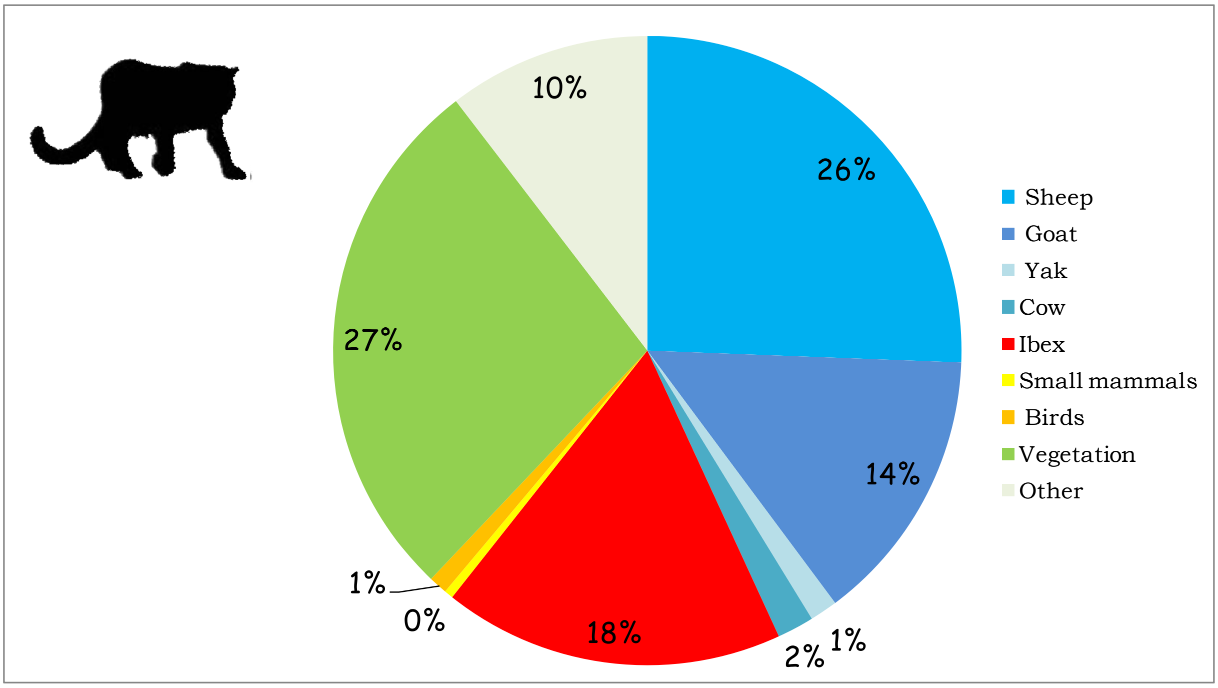
Snow leopards and wolves. Minimum population estimates were obtained from genetics through analyses carried out by Dr. Jan Janecka (Texas A & M University, United States). Three snow leopards (1 male and 2 females) and 3 wolves (1 male, 1 female and 1 undetermined individual) are inhabiting the Hushey valley.

(B) assessment of predation: Data collected from April 2011 to March 2013 have been analysed (N=152 scats; wolf: N=63; snow leopard: N=89).

Results show a greater impact on livestock by wolf (56%; Figure below) than by snow leopard (43%; Figure below). Furthermore, samples of snow leopard are representative of all seasons, while those of wolf have been found only in winter and spring.



As to snow leopard in particular, amongst wild prey, ibex is the staple all year long, mostly during summer, when it builds up 35% of diet, decreasing in autumn and winter, when livestock becomes dominant.



7.4.3 Formative training

Formative training for KIU and CKNP staff has been carried out to widespread outlines of the research program on wildlife conservation and management. A specific training of one PhD level person (Mr. Zafar Khan), has been developed to help the local KIU staff with the required technical expertise in this topic. The PhD student has been directly involved in research activities on wildlife data collection and monitoring. During the research field campaigns the PhD student has worked under the supervision of the UNISI team to improve his expertise. Presently, he is a guest at in our Department in Italy to carry out lab analyses of scats collected in 2012.

Several educational courses have been carried out for CKNP staff (May 2011, July 2011, Apr. 2012, Apr. 2013).

A small book on large mammals of CKNP (Bocci & Lovari 2013) was produced as an output of our research.

7.4.4 Managament indications

CKNP level

ZONING OF THE PARK

An understanding of ecological and conservational principles, as well as reliable ecological data, are fundamental requirements for successful conservation and management actions. Information on population size and distribution of a species is important to assess its status, *i.e*. declining, or stable, or increasing. If numbers of a population are known, its management could be properly addressed. This action is particularly important for protected areas, *e.g*. the Central Karakoram National Park, where several "threatened" species are present and subjected to moderate trophy hunting. Furthermore, an understanding of ecological and conservational principles, as well as reliable ecological data, are necessary requirements for a successful zoning.

Large mammals may be used as umbrella species better than any other taxon. This approach was chosen due to the scarce previous available information on wildlife distribution. An umbrella species is defined as a species with large area requirements for which its protection offers protection to other species which share the same habitat (Groom et al. 2006). Therefore these species are often selected to make conservation related decisions, helping to select the locations of potential reserves, to find the minimum size of these conservation areas and to determine the composition, structure and processes of ecosystems. The term was first used by Wilcox (1984) who defined an umbrella species as one whose minimum area requirements are comprehensive of those of the rest of the community for which protection is sought, through the establishment and management of a protected area. The umbrella species concept has been demonstrated as an effective tool in the conservation of habitat (Launer & Murphy 1993) and it is considered valuable to decision makers. De Vrie (1995) proposed the use of habitat requirements of large herbivores as umbrella species to design large-scale nature reserves and to preserve both, plants and other animals. In particular, the large ranges of mountain-dwelling ungulates are often a consequence of seasonal migrations as a response to seasonally fluctuating food resources. In areas where winters are severe, food availability is decreasing and energetic costs for locomotion and thermoregulation are the highest. Therefore, in mountains, as well as in all populations living in a strongly seasonal climate, seasonal movements (to and from summer/winter areas) may develop as a function of changes in the environment. At the same time, a significant biodiversity-related consideration associated to mountain ungulate conservation is the importance of maintaining sufficient numbers of prey species to support viable populations of large predators, such as the snow leopard, the wolf and the lynx. Each of these predator species has endangered or threatened populations within the Indo-Himalayan region. Large protected areas are important for the conservation of these predators and the ability to co-ordinate conservation efforts in creating large reserves across mountainous borders is highly desiderable.

Viable populations of large mammals require vast areas of land (herbivores: 10000 ha as a minimum threshold, De Vrie 1995; carnivores: at least 100000 ha as a minimum threshold, Belovsky 1987) and all of them can be considered as an umbrella species group for the preservation of plants and others animals. In particular, the requirements of large carnivores should be considered in the final step of a management plan.

Data provided by UniSi have been used since November 2012 to outline *<u>Strictly Conservation Areas</u>* and *<u>Conservation Areas</u>* (see Mari *et al*. 2012), on the basis of "hot spots" areas for large mammal conservation.

<u>RELIABLE COUNTS</u>

Direct counts are fundamental to know basic information on wildlife. Standard census data should be collected in all areas of CKNP, although the techniques to gather the information might be slightly modified according to topography and other logistic constraints.

Participants should be organised in groups of 1 to 3, over different vantage points.

For each valley, the number of people involved will be function of the size of the area to be surveyed.

Wildlife surveys require reliable replications, to be effective. A reliable replication means: (i) the **same people** involved (only if the same people are involved it will be easy to find out the same vantage points used in the past) – it is important that at least *1 person for each group* (team=all the people involved in the wildlife survey; group=part of the team attending specific areas of the selected valley) *is the same than in* *the previous survey*; (ii) **same number of people** (if reliable surveys were carried out in the past, the number of people involved should not be changed, least of all decreased), (iii) **same areas** (the same areas have to be surveyed each time, in order to obtain comparable data; the number of surveyed areas may increase, never decrease).

A good planning is unavoidable to obtain reliable wildlife surveys, and then reliable data. Therefore, an effective organization of wildlife surveys (where to go, how many people and how many teams) will have to be planned well in advance, following the organisation of previous surveys.

The following items will be required during the wildlife survey: camera, binoculars, spotting scope, altimeter, compass, data sheet, GPS, tents, sleeping bags, food items, map of the area.

1. Surveys will be normally carried out twice a year, on May and December (approximately). When access is difficult in spring, surveys will be carried out only in autumn.
2. Surveys will be carried out early in the morning and/or late in the afternoon because most ungulates, *i.e.* ibex and markhor, are active and graze during these parts of the day and can be easily sighted.
3. Vantage points will be established taking GPS references (WGS84-UTM system; dd mm ss). Binoculars and spotting scope will be used to scan wildlife in the area.
4. Direct counts will be used to determine wildlife numbers. The herds seen will be further classified into different age and sex classes (males, females, yearling, kids and undetermined individuals, total; among males, a separate count on trophy size individuals will be made). In autumn counts, the number of kids will be a very useful population parameter to assess reproductive rate.
5. For all wildlife monitoring surveys, the same vantage points, established during the first field survey, will be used. It is strongly suggeted to involve the same people.
6. While using the same vantage points each year, if a certain pasture in one year has an ibex population/herd and, in the next survey season, no ibex herd is seen in the same pasture, from the same vantage points (VP), we should note down that VP and pasture. We should not ignore that but we should write real zero in that place. This will show that the same pasture has been visited in consecutive years. This information will help to analyze data, e.g. the impact of different variables on the ibex population etc.
7. For each observation, also the distance (roughly estimated) and the angle to the North (using the compass) will be useful to locate the herd.
8. Investigation through a questionnaire and general discussions with the local people, shepherds and former hunters living in the village/valley (10% of the population of the Valley – randomly selected) will be carried out.

REINTRODUCTION PROGRAMS

“Reintroduction” is any attempt to re-establish a *taxon*, usually a species, in an area which was once part of its historical range, but from which it has been extirpated or has become extinct The objectives of a reintroduction may include: (*i*) to enhance the long-term survival of a *taxon*; (*ii*) to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; (*iii*) to maintain and/or restore natural biodiversity; (*iv*) to provide long-term economic benefits to the local and/or national economy; (*v*) to promote conservation awareness; or a combination of these. For more details, see http://www.iucnsscrsg.org

In CKNP, there are several wild mammalian species reduced to their minimum threshold. The main causes for this depletion are habitat loss as well as overhunting and poaching. **The removal of these causes is mandatory and a priority for any reintroduction**. For this reason, it is not possible to plan any reintroduction in the near future (until depletion causes have been assessed and removed). Furthermore, reintroductions are quite expensive operations (e.g. trapping operations, helicopter availability, post-release monitoring).

The main priority is to preserve all the species inhabiting the Park, as well as to carry out reliable counts in order to get an idea about not only of reliable number estimates, but also movements between neighbour valleys (by continuing the monthly assessment that game-watchers have just started).

Buffer Zone

TROPHY HUNTING PROGRAMS

A sustainable and conservation-oriented trophy hunting system may be a valid management tool, to increase the economic revenue of local communities, provided that a reliable monitoring of ungulate populations is carried out to assess their conservation status, to plan hunting activities and to promote it as a long-term source of income. A good review of trophy hunting programs in Pakistan has been done in 2001 by D.M. Shackleton, who gives some key recommendations to make this activity a sustainable conservation tool.

Please, find herewith below the main recommendations to be followed in order to make trophy hunting a useful conservational tool:

- Before a new hunting program begins, and especially in the case of a threatened *taxon*, the surveys on which the program and quota are based should be (1) made in conjunction with, or by, an independent party, (2) using a standardized approach (see above). Furthermore, each new trophy hunting program has to be set up with a critical look at defining parameters and methods, considering distribution, numbers and possibly population structure of hunted species.
- The success of CTHPs can only be determined if suitable data is systematically collected and accurately recorded, if results are analyzed, and if reports are produced and made available. In this respect, it is also very important to know movements that species make seasonally, to avoid to hunt the same population in two different areas (therefore doubling the hunting pressure on it).
- Population data and trophy hunting plans should be peer-reviewed by professional wildlife biologists within and outside Pakistan.
- Counts should focus in assessing the structure of the population, not only the number of trophy males.
- For endangered species (e.g. markhor) it is important an accurate check of their status, setting up groups of technicians (not necessarily local) for an unbiased evaluation at regular intervals (e.g. each 3-4 years). Communities are often not completely independent from local NGOs even after 10 years.

It is important to emphasise that ungulate conservation efforts through trophy hunting programs may pose a threat to carnivore conservation. Local communities in fact may consider these responsible not only for depredation attacks to domestic animals, but also for those to wildlife, reducing individuals from the trophy hunted population. It is therefore important for local communities to develop a global approach to conservation, beyond the single hunted species. Local communities need to be better informed and educated about the important role of large carnivores. That’s why each CTHP should have a formal written Conservation Management Plan, that should be periodically revised and updated. Obviously, the objectives must be detectable and assessable, in relation to objectives and goals for both, wildlife conservation and community development.

Furthermore, we suggest that (A) **revenues from trophy hunting should be used also and mostly as compensation for depredation loss and/or to improve preventive measures**; (B) **in all areas where a Trophy Hunting Programme takes place, a vaccination for livestock should be mandatory**. To compensate for depredations, WWF has planned a sustainable mechanism to provide communities with an insurance scheme, that, for the first time, does not make any difference among predators (wolf or snow leopard). We are very pleased that this kind of approach (i.e. protecting all carnivores and making no difference between wolf and snow leopard) have been adopted by the main NGOs (WWF and SLT) active in the area, as most of the people are unable to distinguish between depredations carried out by different predators; thus, if not compensated for wolf kills, communities will kill this predator. We also emphasise how important is the use of local revenue from trophy hunting by the community to compensate livestock depredations, in areas where TH is allowed (for insurance scheme, please, see below).

As to Trophy hunting, our general position statement (ANNEX 5) is consistent with the IUCN/SSC Caprinae Specialist Group's position. In particular, as to the establishment of new TH areas in CKNP buffer zone (more than the 3 areas where the program already stands), we think that trophy hunting programme cannot be started unless the status of the key populations is well assessed through at least 5 years of seasonal data collected in conjunction with, or by, an independent party, and using a standardized approach (please, see above for reliable counts). At the moment, as far as we know, there are no areas in CKNP where reliable and standardised data are available for the last 5 years. We are also aware that SEED project is promoting new trophy hunting areas (through WWF) in ca. 20 valleys of the Park. We are not aware of the actual stage of this process.

CONSERVATION AREAS

These areas have been identified because range of endangered large mammals (*eg* musk deer, markhor, brown bear, snow leopard), and/or forest are present there.

As to large mammal management and conservation, some strict regulation is required:

- regular counts have to be carried out in order to assess population size and distribution, as well as to collect data in order to be able to assess its trend in future;
- controlling illegal hunting, killing of prey and predator species;
- reduction of human activity impact at the minimum level: reducing livestock density in the same areas used by the endangered species should elicit a numerical response from wildlife. Sanitary control of livestock is strictly needed, enhancing the use of treatments and vaccination. Vaccination for livestock needs to become mandatory in these areas, where endangered large mammals live.
- trophy hunting programme for endangered populations cannot be started (unless their status is well assessed through at least 5 years of seasonal data collected in conjunction with, or by, an independent party, and using a standardized approach).

The implementation of such restrictions on the human population and livestock must be accompanied by some form of compensation (see above), but also include responsible involvement of the local community in conservation programs. The participation of local communities in the wildlife conservation process has to be emphasised.

Core Area

STRICTLY CONSERVATION AREAS

These areas have been identified to integrally protect part of the Park where important and endangered wild species live.

These areas has to be strictly regulated in order to completely protect wildlife. They have to be restricted for all the following forbidden activities:

- livestock grazing;
- stay, roaming, camping and fishing;
- any other human activity than assessing wildlife numbers through regular seasonal counts (twice a year) or carrying out research activities (in this case, an official permission has to be released by the CKNP Directorate).

8. Atmospheric sciences [10] [11]

8.1 Atmospheric observations and variability of atmospheric circulation in the Karakoram

With the purpose of providing a first quantitative assessment of the current state of the atmospheric composition variability, atmospheric aerosol properties and their relationship with atmospheric circulation, two experimental campaigns have been carried out in the Baltoro glacier region. Specifically, these experimental campaigns have been carried out at Askole (3015 m a.s.l.) and Urdukas (3926 m a.s.l.) during summer 2011 and summer 2012, respectively. Trace gases and aerosol properties have been analysed as a function of local meteorological parameters and "synoptic-scale" air-mass back-trajectories. This has allowed obtaining the first information about climate forcers (both short- and long-lived species) in this remote mountain area.

8.1.1 Measurement sites

Akole (35°40'N, 75°48'E) is a village (about 300 inhabitants) located in the Braldu valley on the route to the Baltoro Glacier. Urdukas (35° 43' N, 76° 17') is located more than 40 km away from Askole along the Baltoro Glacier. Both measurement sites are well suitable for investigating the transport processes which can occur along the valley and the possible influence of local and regional anthropogenic emissions in affecting atmospheric composition in that pristine environment.

During summer months, the meteorological conditions in the study area are predominantly dry, since precipitation related to the Indian monsoon system is episodic and scarce. The local wind is strongly affected by the development of thermal circulation along the valley, with westerly up-valley winds during the day and easterly down-valley winds during the night.

8.1.2 Material and Methods

During Summer 2011, a 40-days intensive field campaign was carried out at Urdukas. Aerosol concentration measurements were performed by means of an embedded Aeroqual AQM60 system, able to derive aerosol mass values (PM10, i.e., mass of particulate atmospheric aerosol with diameter < 10 μm) throughout an optical particle counter (OPC).

During Summer 2012, trace gases (surface ozone and carbon dioxide) and aerosol measurements were carried out at Askole by using the SHARE–NANO system. This is a transportable (38×50×65 cm, 50 kg) embedded system, characterized by limited power consumption (50 W) which allows the system to be powered by solar panels. The system was equipped with an integrated weather station (Vaisala WXT 520), a condensation particle counter (TSI 3772) able to provide total number concentration for particles with diameters lower than 3 μm, an ozone analyser (Ozone Monitor 220 2B Technologies) and a probe for carbon dioxide measurements (Vaisala CARBOCA GMP 343).

[10] Authors: Elisa Palazzi, Paolo Cristofanelli (CNR ISAC, Italy)
[11] Most of the content of the present report is part of original research papers submitted/under revision in international journals. Please, do not quote or distribute without first contacting the authors (p.cristofanelli@isac.cnr.it; e.palazzi@isac.cnr.it)

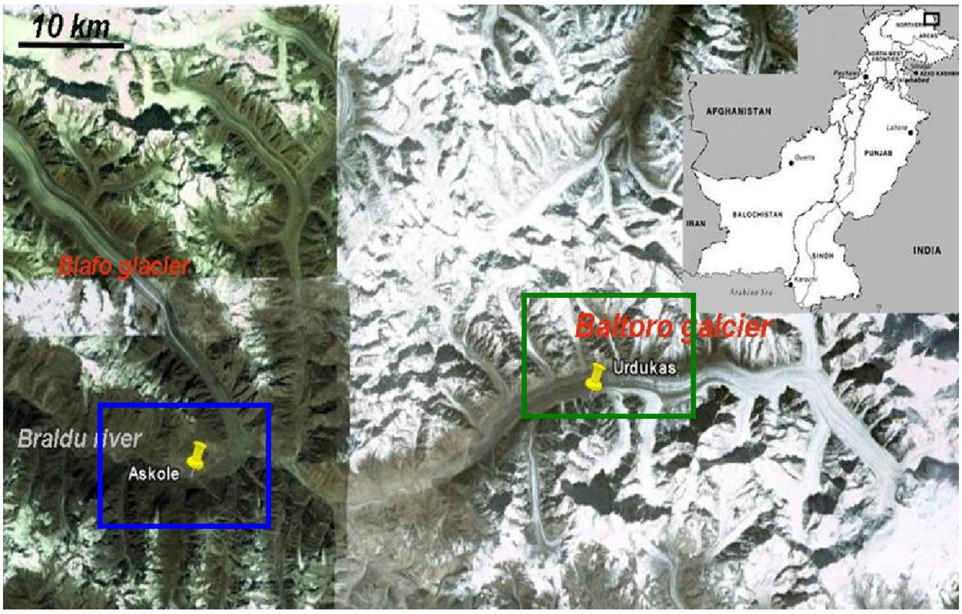


Exhibit 136 Satellite image of the Braldu Valley in the Pakistan Northern Areas, where the sampling sites Urdukas (green square: year 2011) and Askole (blue square: year 2012) are located.

HYSPLIT Back-trajectories

In order to determine the synoptic origin of air masses reaching the measurement sites, 5-day back-trajectories were calculated every 6 hours (at 4:00, 10:00, 16:00 and 22:00) with the HYSPLIT back-trajectories model (Draxler and Hess, 1998). The model calculations were based on the GDAS meteorological field produced by NCEP with a horizontal resolution of 1°x1°. Sub-grid scale processes, such as convection and turbulent diffusion, cannot be represented by the model. To partially compensate such uncertainties, additional back-trajectories were calculated, with endpoints shifted by ± 1° in latitude/longitude.

8.1.3 Results

Summer 2011 field campaign

Hourly PM10 values observed at Urdukas from July 21st to August 30th 2011, shown in Fig. 1.2, are characterised by an average value of 7.7 ± 7.1 µg/m3 (± 1-sigma). Such PM10 levels are rather low with respect of those observed during typical summer time conditions at other sites located in the central and southern Asia. As an instance, Shafer et al. (2010) reported average PM10 values of 25 µg/m3 at Biskhek (1250 m) and Karakol (2050 m), Kirghizstan, while PM10 ranging from 55 to 45 µg/m3 have been observed at Manora Peak (1940 m asl), northern India (Ram et al. 2011). Nevertheless, the PM10 at Urdukas appeared higher than the values observed during the same period at the Himalayan site of NCO-P (Nepal, 5079 m a.s.l.) where the average PM10 value was 1.1 ± 1.6 µg/m3.

An inspection of the PM10 time series suggests that two different regimes of aerosol variability characterized the sampling site during the field campaign: the first period (21-27 July) was characterized by low PM10 values (about 3 µg/m3), while the second period (28 July-30 August) was characterized by an increase of a factor 2.4 of the mean PM10 concentrations.

With the aim of investigating the possible role played by the large-scale atmospheric circulation in modulating the observed PM10 behaviour, air-mass back-trajectories ensembles have been calculated with the HYSPLIT model. The trajectories analysis highlighted that during the first measurement period (21-27 July, when lower PM10 were observed) the Baltoro glacier region was affected by a “regional” circulation, while later (when higher PM10 characterized the measurement site) the air masses were characterized by “long-range” fingerprints which possibly favoured the advection of air-masses richer in mineral dust from the Taklimakan region (Exhibit 138). Under these conditions a "special event" with PM10 hourly value exceeding 300 µg/m3 was detected.

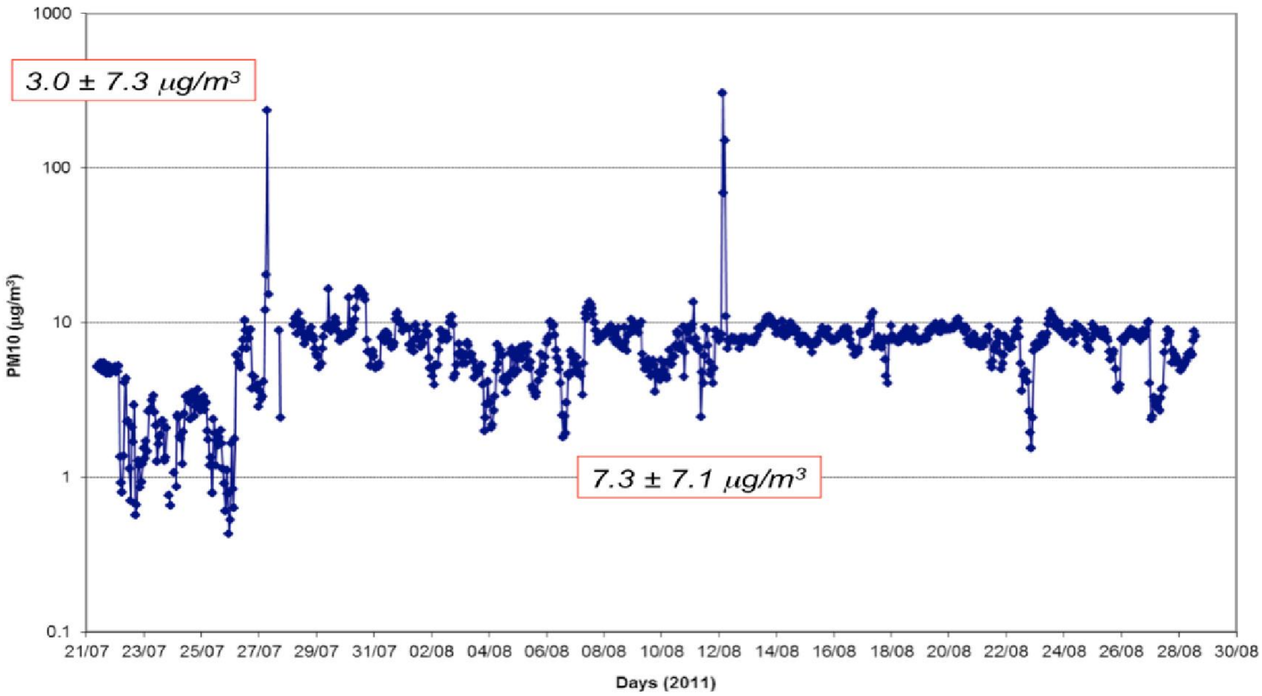


Exhibit 137 PM10 concentrations at Urdukas during the summer of 2011 (July 21st - August 30th). Red boxes report mean and standard deviation of PM10 concentrations associated to two different periods, 21–27 July upper box) and 28 July–30 August 2011 (lower box).

Summer 2012 field campaign

During the experimental campaign carried out at Askole on summer 2012, the first continuous characterization of trace gases and aerosol particles variability was obtained for the Baltoro glacier region. Meteorological parameters and carbon dioxide (CO_2: 394.3 ± 6.9 ppm, N=6057) data were collected for the whole campaign period (with a major data gap on19th - 31st October due to a failure of the acquisition system), while surface ozone (O_3: 31.7 ± 10.4 ppb, N=3711) and particle number concentration (Np: 1571 ± 2670 cm-3) were collected until 7th October and 23rd September, respectively.

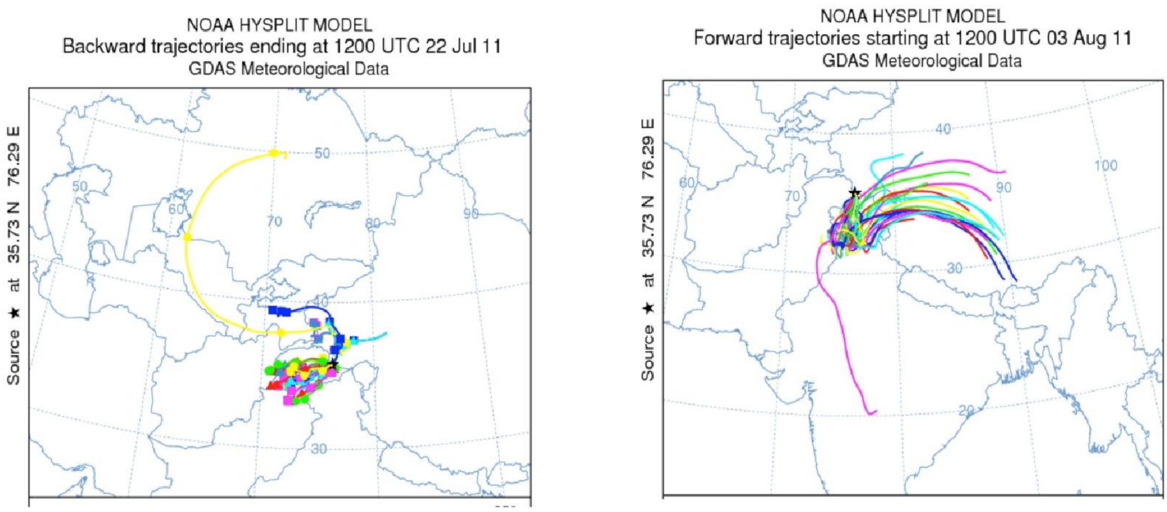


Exhibit 138 HYSPLIT back trajectories ending at 12:00 UTC of July 22nd (August 3rd) on the left (right) panel.

The mountain wind regime clearly influenced the diurnal behaviour of atmospheric composition at the measurement site. In fact, aerosol particles and trace gases showed a typical diurnal cycle. The lowest particle concentrations were observed at night, while a considerable increase was present around noon (Exhibit 139). This behaviour suggests that aerosol particles from the lower troposphere can reach Askole owing to the day-time up-valley winds, while during the night cleaner air masses, more representative of the upper troposphere, are transported by down-valley winds. The influence of the mountain wind regimes on O3 and CO2 was investigated by considering the average diurnal variation of normalized values (ΔO3, ΔCO2), obtained by subtracting the daily means from the actual 15-min O3 and CO2 mixing ratio values.

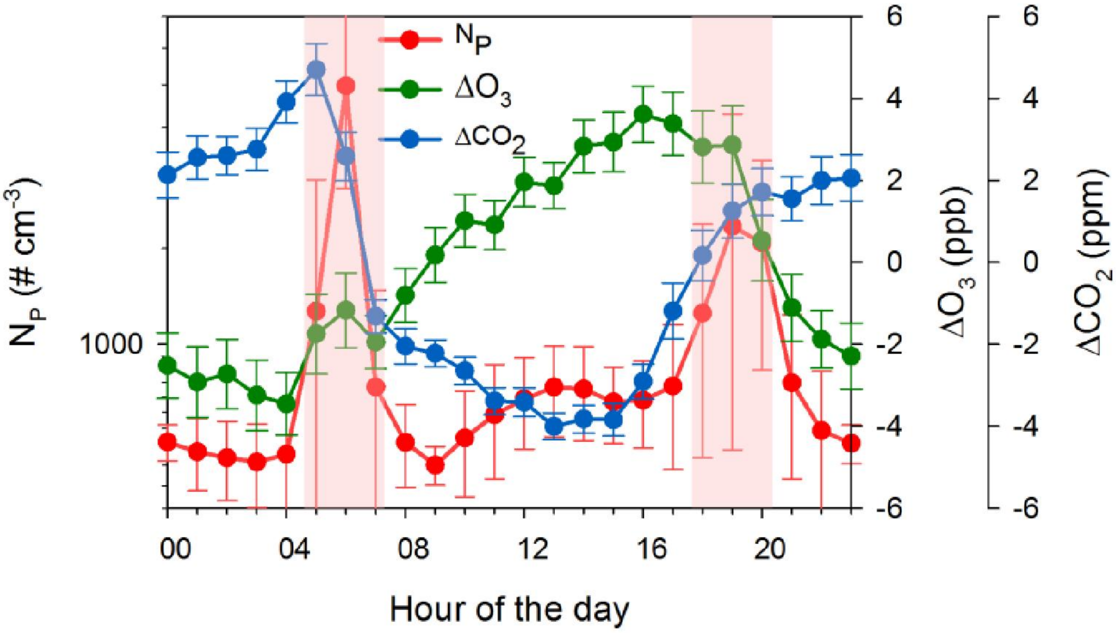


Exhibit 139 Typical diurnal variations for Np (red), □O3 (green) and □CO2 (blue). The vertical bars denote the expanded uncertainties ($p<0.05$) of the mean, while the shadow areas the periods possibly affected by the "local pollution events".

The average diurnal variation of surface O3 was also characterized by lower values during the night (00:00 – 4:00) and a peak during the afternoon-evening (14:00–19:00), with an average diurnal cycle amplitude of about 8 ppb. On average, the diurnal O3 peak occurred with a few hours delay with respect to the Np peak and in correspondence with the maximum of the up-valley wind speed (Exhibit 140). As corroborated by other studies considering data from other mountain stations in the world (see e.g. Cristofanellli et al., 2010; Cristofanelli and Bonasoni 2009), this suggests a mechanism of transport of air-masses rich in O3 from along the valley, possibly influenced by photochemical production due to the regional-scale anthropogenic precursor emissions.

The presence, during day-time (nigh-time), of air-masses representative of the lower troposphere (free troposphere) is also confirmed by the CO2 average diurnal variation, which showed lower mixing ratios (on average: -4 ppm) with respect to night-time values. In fact, during the summer season, air masses from the atmospheric boundary layer are depleted in CO2 with respect to the free-troposphere or upper tropospheric air masses, due to the vegetation uptake by photosynthesis (e.g. Colombo et al., 2000).

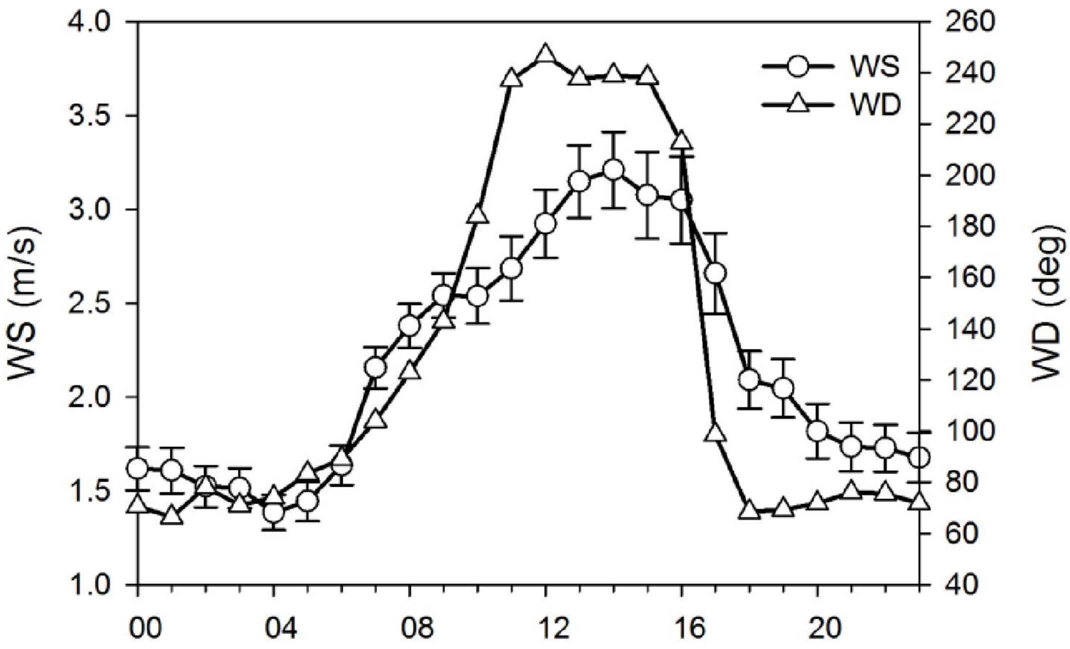


Exhibit 140 Average diurnal variations for wind speed (WS) and direction (WD). The vertical bars denote the expanded uncertainties ($p<0.05$) of the mean.

The most striking feature in the Np observations, shown in Exhibit 141 , is the presence of systematic concentration peaks which occurred in the early morning (from 5:00 to 7:00) and evening (from 18:00 to 20:00). A detailed inspection of the internal working parameters of the SHARE-NANO system did not reveal any evident malfunctioning able to explain these anomalous peaks. The time of day at which these peaks occurred perfectly corresponds to the time at which people from the village are used to burn biomass, especially for cooking purposes. At Askole, during summer season, the population uses very simple cooking systems, often represented by open fires with rough chimneys that guarantee the smoke ventilation from traditional houses to the outdoor. It is thus conceivable that the particle peaks could be ascribed to the domestic emissions from the village nearby.

Excluding the “local contamination events”, the Np median concentration at Askole (676 cm-3) is comparable with the median value (657 cm-3) obtained during the same period at the NCO-P. For NCO-P the Np variability appeared to be in agreement with early measurement results provided by Sellegri et al (2010). However, it should be pointed out that NCO-P is strongly affected by the occurrence of new particle formation events, which can significantly affect Np. In order to compare the Askole results with other mountain measurements performed in Asia, we calculated Np for STP conditions (i.e. 1013 hPa and 0 °C). At the Mukteshwar station (at the foothills of the Indian Himalayas at 2180 m a.s.l.) and at Mount Waliguan (China, 3816 m a.s.l.), as presented by Komppula et al. (2009) and Kivekäs et al. (2009), average particle (10–800 nm) number concentrations were more than 50% higher (3480 cm−3 and 3280 cm−3, respectively) than at Askole (1038 cm-3). The Mukteshwar station, located at a lower elevation, is much more influenced by the very high concentrations encountered in the boundary layer of the Indo-Gangetic plains.

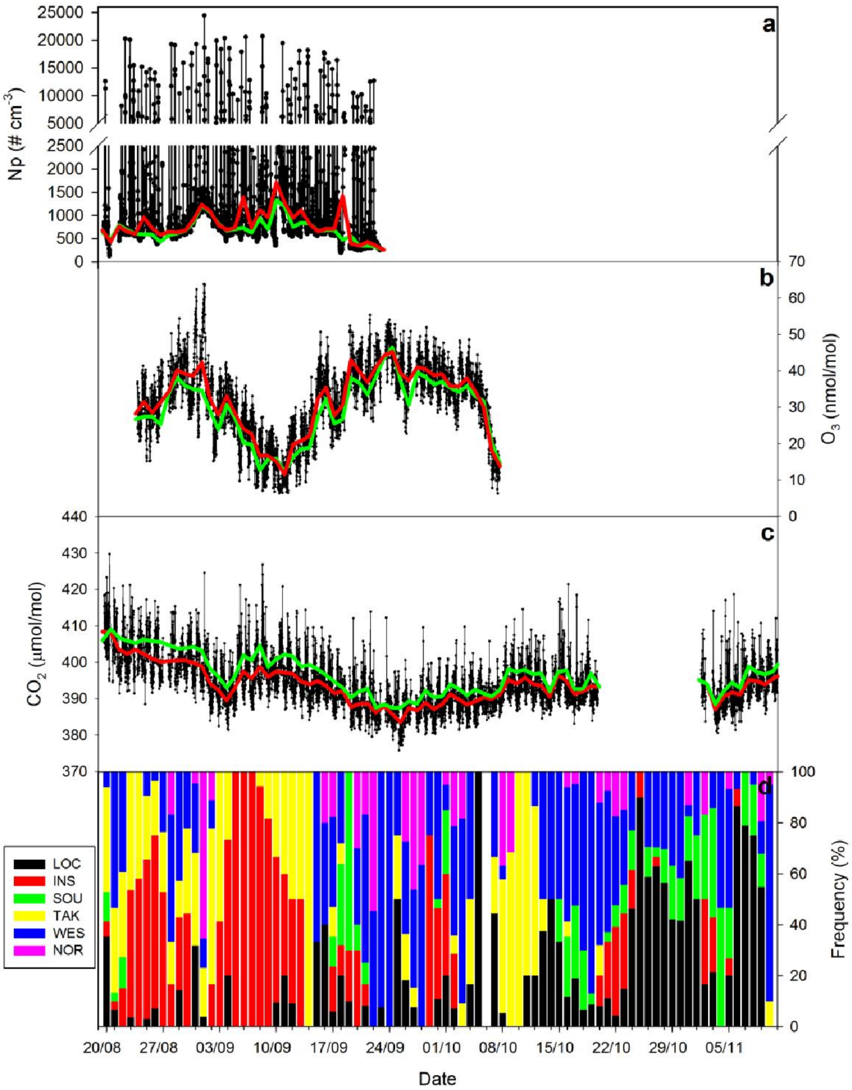


Exhibit 141 Time series of CPC particle number concentration (Np, panel a), surface ozone (O3, panel b), carbon dioxide (CO2, panel c) and daily air-mass circulation occurrences (panel d, WES-Westerly; TAK-Taklamakan; LOC-Local; SOU-Southern Pakistan; INS-Indian Subcontinent; NOR-Northerly). Red lines denote daily averages (computed excluding the "local contamination events"), while green lines represent night-time (between 21:00 and 4:00) averages.

By neglecting the "local contamination events", the O3 average values (31.8 ± 9.9 ppb) were lower than the mixing ratios values observed during the same period at the NCO-P (38.6 ± 8.0 ppb) which were not statistically different from the "representative" monsoon values reported by Cristofanelli et al. (2010) for years 2006 and 2007 (39 ± 10 ppb). The lower O3 values observed at Askole are significantly influenced by the transport of air-masses poor in O3 from Indian Subcontinent and Taklimakan desert, as deduced by HYSPLIT analyses. As pointed out by laboratory/model studies (e.g. Hanisch and Crowley, 2003) and atmospheric observations (e.g. Bonasoni et al., 2004; Umann et al., 2005), mineral dust may decrease tropospheric O3 due to heterogeneous chemistry and a decreased efficiency of photochemical production. It is thus conceivable that air-masses coming from Taklamakan desert were characterized by low O3 values. During these specific periods, also increases of CO2 daily values were observed. Indeed, due to the stronger anthropogenic emissions, CO2 is expected to have high source over the Indo-Gangetic plains (e.g. Baker et al., 2010). On the contrary, the Taklamakan desert with its arid climate, barren land or sparse vegetation, can not be considered as a sink region for CO2 (Hou et al., 2013), especially during the vegetative season.

As already mentioned, besides being affected by a significant diurnal variability, the atmospheric composition measurements at Askole were also characterized by significant day-to-day variations, well visible in Fig. 1.6, indicating that processes occurring at synoptic (or larger) scales can play a role in influencing aerosols and trace gases behavior in this remote region. With the aim of specifically investigating this point, hourly Np, O3 and CO2 values were analyzed as a function of the different air-mass origins and paths. Even if particular caution should be used in interpreting these modeling tools in a complex high mountain region like the Karakorum, some robust features have been pointed out. To summarize, lower O3 and higher CO2 values were observed in concomitance with possible air-mass transport from South Asia and Taklamakan desert, while higher O3 mixing ratios have been mostly tagged with westerly and northerly air-masses, possibly indicating transport from the free troposphere. Concerning Np, contributions from the Indian Sub-continent appeared to be the dominant one for "intermediate" values (from 500 to 900 cm-3). This can be understood as indicative particles concentration background in the free troposphere over the HKKH region, driven by long-range transport. In parallel, INS air-masses also contribute for the 50% of the upper Np values (> 1300 cm-3), indicating that long-range transport from South Asia is a major source of fine particles in the Karakorum.

8.1.4 Summary

During summer 2011, PM10 measurements were carried out at Urdukas, along the Baltoro Glacier. Even if relatively low PM10 values were observed on average (7.7 ± 7.1 µg/m3), transport of mineral dust from the Taklimakan desert episodically increased the aerosol loading (with a peak event of 300 µg/m3).

The experimental campaign carried out at Askole on summer 2012, indicated that the domestic combustion could represent a possible systematic source of contamination in the valley. Excluding these local contamination events, mountain thermal wind regime dominated the diurnal variability of Np, O3 and CO2. Nevertheless, the variability of the observed climate forcers appeared to be dominated by day-to-day changes. Part of the day-to-day atmospheric composition variability can be ascribed to synoptic circulation variability. In particular, low O3 and high CO2 values were observed associated with possible air-mass transport from South Asia and Taklamakan desert, while long-range transport from South Asia was a major source of fine particles in the Karakorum, and higher O3 have been mostly tagged with air-masses possibly from the free troposphere.

As suggested by previous works (e.g. Yasunari et al., 2010; Qian et al., 2011), aerosol particle represent a major concern for mountain cryosphere in Karakorum and Himalayas, due to its possible role in influencing snow melt and glacier "health". Even if during this experimental campaign no information about light absorption properties were available, a major concern can be represented by the possible transport of absorbing particles (i.e. black or brown carbon) to the higher valley, where the Baltoro glacier is located.

8.2 Climate and glacier trends and related model projections on medium-long term

For management purposes it is important to develop both medium (~2050) and long (2100) term projections for the state of Karakorum glaciers and of their role of "water towers". It is clear that any change in glacier surface and volume affects water availability, and these changes can in turn be affected by meteorological conditions and climatic variations, such as changes in precipitation and temperature. These processes will impact on future water availability of CKNP and adjoining valleys that will affect both human beings and ecosystems. To tackle this issue it is necessary to develop an average representation, at regional scale, of the cryospheric and hydrological processes that characterise the Central Karakoram National Park (CKNP) region, which will be quantitatively modelled at the spatial scale of individual glaciers and sub-basins in the hydrological research carried out in SEED.

8.2.1 Study area

Unique interactions among the atmosphere, cryosphere, and hydrosphere systems and influences from multiple climatic regimes, make the Hindu-Kush Karakoram Himalaya (HKKH) region extremely complex and prevent from treating it as a single region. The HKK in the west and the Himalaya in the east, schematically represented in Exhibit 142 (Palazzi et al., 2013), differ primarily in circulation patterns, in sources and types of precipitation and, by consequence, in glacier behavior and dynamics. The eastern Himalaya is dominated by the southwest Indian monsoon: precipitation occurs during summer months (typically from June to September), owing to the moisture advected northwards from the Indian Ocean (e.g., Li and Yanali, 1996; Wu and Zhang, 1998; Krishnamurti and Kishtawal, 2000).

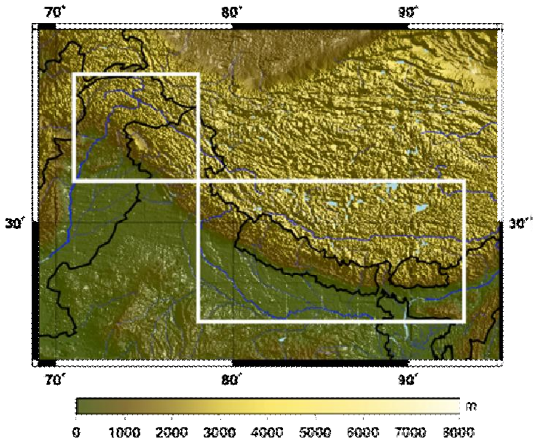


Exhibit 142 Map of the study area and of the HKK (West) and Himalaya (East) domains.

In the HKK, which encompasses the area covered by the Central Karakoram National Park, precipitation occurs mainly during late winter and early spring, carried on westerly winds (western weather pattern, WWP). WWPs originate in the Atlantic/Mediterranean region (Singh et al., 1995; Archer, 2001; Archer and Fowler, 2004; Treydte et al., 2006; Syed et al., 2006), pick up moisture in the Arabian sea, Persian Gulf, Red sea and, to a lesser extent, the Mediterranean basin, and rain out as they encounter the HKK slopes. WWPs represent the main nourishment, in terms of rainfall and mostly snowfall, for the Karakoram glacier systems and, as such, a fundamental reserve of water for Pakistan in the dry season. On the contrary, the monsoon circulation exerts a limited effect on the overall summer precipitation in the upper Indus basin and Karakoram regions (e.g., Wake, 1989), since the mountains generally limit the intrusion of the monsoon.

8.2.2 The NAO-precipitation relationship in the HKK

Winter precipitation in the Karakoram is generated by westerly perturbations (WWPs) originating in the Mediterranean/north Atlantic region. The dynamics of these mid-latitude perturbations is affected by the North Atlantic Oscillation (NAO) in such a way that larger precipitation in HKK is typically recorded during the positive NAO phase. This can be clearly seen in Exhibit 143, where the correlation coefficients between a NAO index and winter precipitation from three observation-based gridded datasets (GPCC, CRU, APHRODITE) and the ERA40 reanalyses are shown.

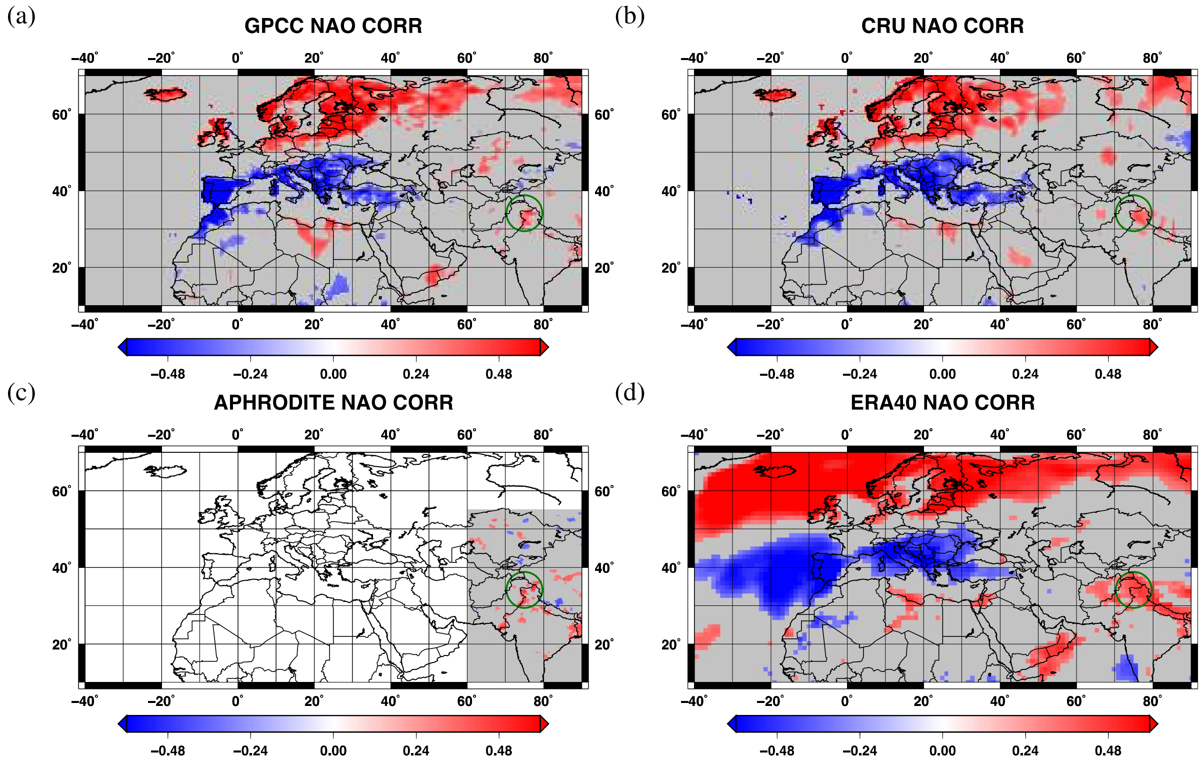


Exhibit 143 Correlation coefficients between NAOI and winter precipitation from (a) GPCC, (b) CRU, (c) APHRODITE and (d) ERA40. Colors indicate statistically-significant correlations at the 95 percent confidence level. Non-significant correlations are marked in gray. The green circle highlights the area of positive correlation centered on HKK.

However, we found that the link between NAO and winter precipitation in the HKK is not simply due to the propagation of the westerly perturbations but it is the product of a complex synoptic pattern of moisture transport and evaporation from low-latitude seas. To identify the main sources of moisture for the HKK precipitation, we analyzed the links between evaporation, tropospheric winds, sea surface temperature, precipitable water and the NAO index over an area extending approximately from the Mediterranean to the Indian subcontinent: these relationships are shown in Exhibit 143. The results indicate that the most important moisture sources for precipitation in the Karakoram are localized in the Persian Gulf, the northern Arabian Sea and the Red Sea. Enhanced moisture transport from these reservoirs to the HKK region occurs during the positive NAO phase, through a mechanism that involves NAO-induced changes in evaporation and tropospheric circulation. The enhanced humidity over northern Pakistan and northern India during the positive NAO phase is picked up by the WWPs coming from the Mediterranean, leading to significant precipitation as these systems reach the HKK mountain slopes.

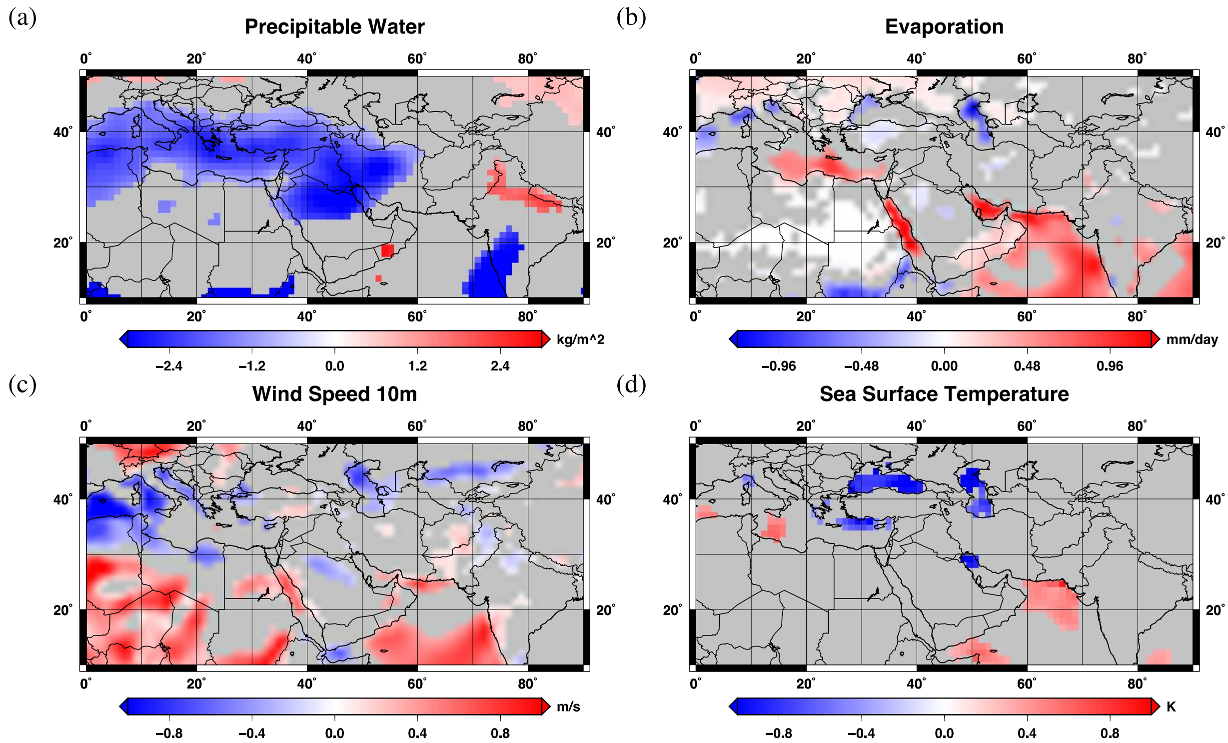


Exhibit 144 Difference between the positive and the negative NAO composites of (a) precipitable water, (b) evaporation, (c) 10m wind speed and (d) sea surface temperature. Colors indicate statistically significant values at the 95 percent confidence level; gray indicates non-significant values.

8.2.3 An assessment of the current precipitation in the HKKH region: models and measurements

We have analyzed the properties of precipitation in the whole Hindu-Kush Karakoram Himalaya (regional perspective) using currently available data sets. We have considered satellite rainfall estimates (TRMM), reanalyses (ERA-Interim), gridded in situ rain gauge data (APHRODITE, CRU, and GPCC), and a merged satellite and rain gauge climatology (GPCP). The data are compared with simulation results from the global climate model EC-Earth (v2.3).

Exhibit 145 shows, as an example, the spatial map of summer precipitation, averaged over the decade 1998-2007, in the HKKH region from the various employed data sets.

As shown in Exhibit 142 with the white boxes, we have defined two domains containing the two sub-regions of the HKKH affected by different circulation and precipitation patterns: the Hindu-Kush Karakoram (HKK) in the west (containing the focus region of the SEED project), prone to the arrival of westerly winds in winter and early spring and the Himalaya in the east, affected by the summer monsoon circulation and related precipitation. We have analyzed the precipitation annual cycle (see Exhibit 146, left panel) and long-term trends (summarized in Table 31) of summer and winter precipitation in the two domains, focusing on mountain areas with elevation higher than 1000 m.

Left panel of Exhibit 146 shows that all data sets, despite having different resolutions, coherently reproduce the mean annual cycle of precipitation in the western and eastern stretches of the HKKH. While for the Himalaya only a strong summer precipitation signal is present, associated with the monsoon, the data indicate that the Hindu-Kush Karakoram receives water inputs also in winter.

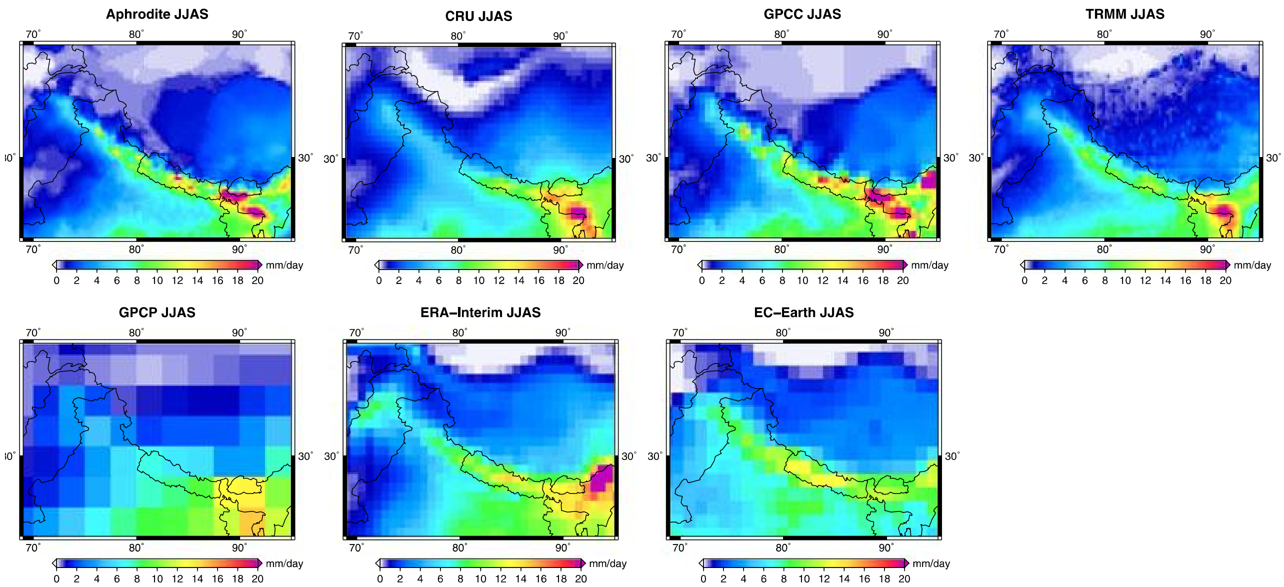


Exhibit 145 Multiannual mean (1998–2007) of summer (JJAS) precipitation over the region between 69°E–95°E and 23°N–39°N from the APHRODITE, CRU, GPCC, TRMM, GPCP, ERA-Interim, and EC-Earth model data sets.

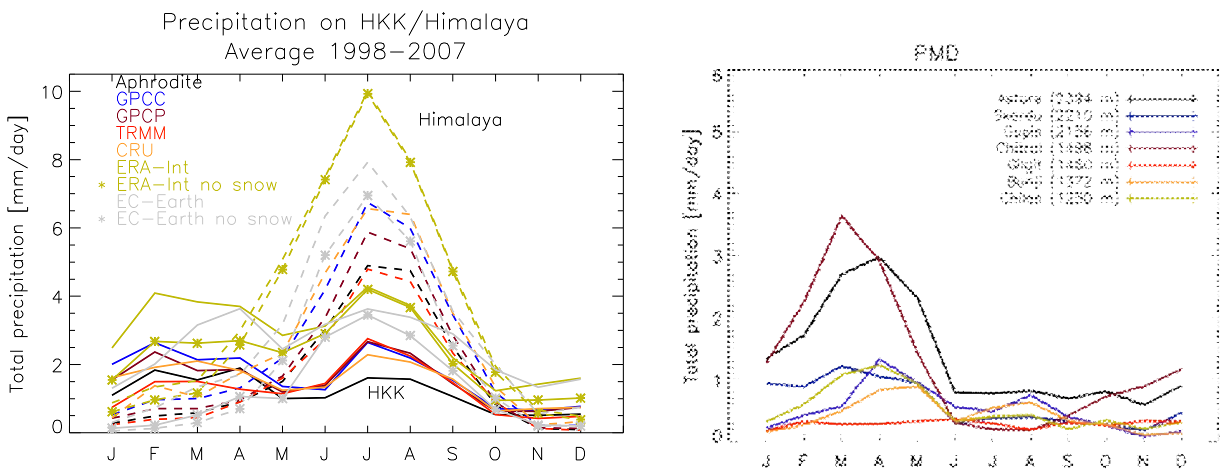


Exhibit 146(Left) Monthly climatology of precipitation (averaged over 1998–2007) for the HKK (solid lines) and the Himalaya (dashed lines) sub-regions, for the datasets indicated in the legend. The lines with stars indicate liquid precipitation only. (Right) Mean annual cycle of precipitation inferred from PMD station data (see the legend).

For completeness, the right panel of Exhibit 146 shows the mean annual cycle of precipitation inferred from seven in-situ station data located in the upper Indus basin, northern Pakistan, operated by the Pakistani Meteorological Department (PMD), to be compared with the filled lines in the left panel. Monthly precipitation amounts at the seven PMD stations display clear differences at the different locations, owing to geographical position, altitude and wind exposure. In general all stations indicate that winter (December to April) precipitation dominates over summer precipitation. In particular, multiannual mean winter precipitation values exceed more than twice the summer precipitation values at the Astore, Skardu, Chitral and Chilas PMD stations. All these stations are located in the southernmost part of northern Pakistan.

The time series of seasonal precipitation (not shown here for brevity, see Palazzi et al., 2013) confirm that the various data sets, in spite of their relative biases, provide a consistent measurement of the interannual precipitation variability in the HKK and Himalaya region. As summarized in Table 2.1, the longest observational datasets among those we have employed indicate a statistically significant decreasing trend in summer (monsoon) precipitation in the Himalaya. None of the data sets, however, gives statistically significant precipitation trends, either positive or negative, in HKK during winter.

Table 44 Precipitation Trends (in mm/d/yr) in the HKK and Himalaya During Summer (JJAS) and Winter (DJFMA) for the Various Data Sets (in Parentheses the Years Over Which Trends Have Been Calculated). Bold Figures are Significant at the 95% Level (p-value Indicated in Brackets)

	JJAS		DJFMA	
	Himalaya	HKK	Himalaya	HKK
APHRODITE (1951–2007)	**–0.010(p=0.001)**	0.0	0.0	–0.003
CRU (1950–2009)	–0.008	0.002	**0.005(p=0.004)**	–0.001
GPCC (1950–2009)	**–0.021(p=0.001)**	0.0	**–0.004(p=0.000)**	0.002
TRMM (1998–2010)	0.015	0.057	–0.006	0.041
GPCP (1979–2010)	–0.012	**0.017(p=0.045)**	**–0.010(p=0.001)**	–0.007
ERA-Interim (1979–2010)	0.027	–0.011	–0.002	–0.012
EC-Earth (1950–2009)	**0.008(p=0.002)**	0.005	–0.001	0.0
* ERA-Interim (1979–2010)	0.027	–0.011	0.0	–0.007
* EC-Earth (1950–2009)	**0.014(p=0.000)**	**0.007(p=0.027)**	**0.001(p=0.050)**	0.001

The seasonal precipitation trends for the seven PMD stations mentioned above are shown for completeness and for comparison in Exhibit 112 (JJAS, red lines; DJFMA, blue lines) and summarized in Table 32 (trends that are statistically significant at the 95% level are shown with the bold style). The figure and the table show that the statistically significant precipitation trends are all positive. Unlike the data from the in-situ stations, none of the spatially averaged precipitation time series shown in Table 31 provides statistically significant evidence of long-term trend in HKK in winter. In HKK during summer, GPCP provides a statistically significant increasing trend of 0.017 mm/d/yr.

Table 45 Summer and winter precipitation (mm/day/decade) trends at the seven PMD stations. Bold figures: statistically significant trends

	Astore	Skardu	Gupis	Chitral	Gilgit	Bunji	Chilas
	1954-2012	1953-2012	1955-2012	1965-2012	1945-2012	1953-2012	1953-2012
JJAS	0.044	0.022	**0.100**	0.047	0.030	**0.068**	**0.064**
DJFMA	-0.061	**0.080**	**0.112**	-0.024	-0.009	0.022	0.003

Precipitation data from the EC-Earth GCM are in good agreement with the climatology of the gridded-observations and reanalyses, in terms of the overall rainfall spatial distribution (Exhibit 145) and rainfall seasonality (left panel of Exhibit 146). Unlike the observations, however, the model shows an increasing summer precipitation trend in the period 1950–2009 in the Himalayan region (see Table 31), possibly as a result of the poor representation of aerosols in this type of GCMs.

To better understand the impact of the modeled aerosols in this kind of GCMs, as well as of other model components or of the model spatial resolution, on the simulated HKKH precipitation, we have extended the EC-Earth analysis outlined above to an ensemble of thirty-two CMIP5 models. Differences in the employed models are related to their spatial resolution, the inclusion of interactive schemes for e.g., the chemistry-transport module, the representation of the aerosol radiative and indirect effects on clouds and precipitation. We have evaluated the historical model outputs against the two longest precipitation data sets available, the CRU and GPCC data. The models have been evaluated in terms of both individual model outputs and multi-model ensemble mean (MMM).

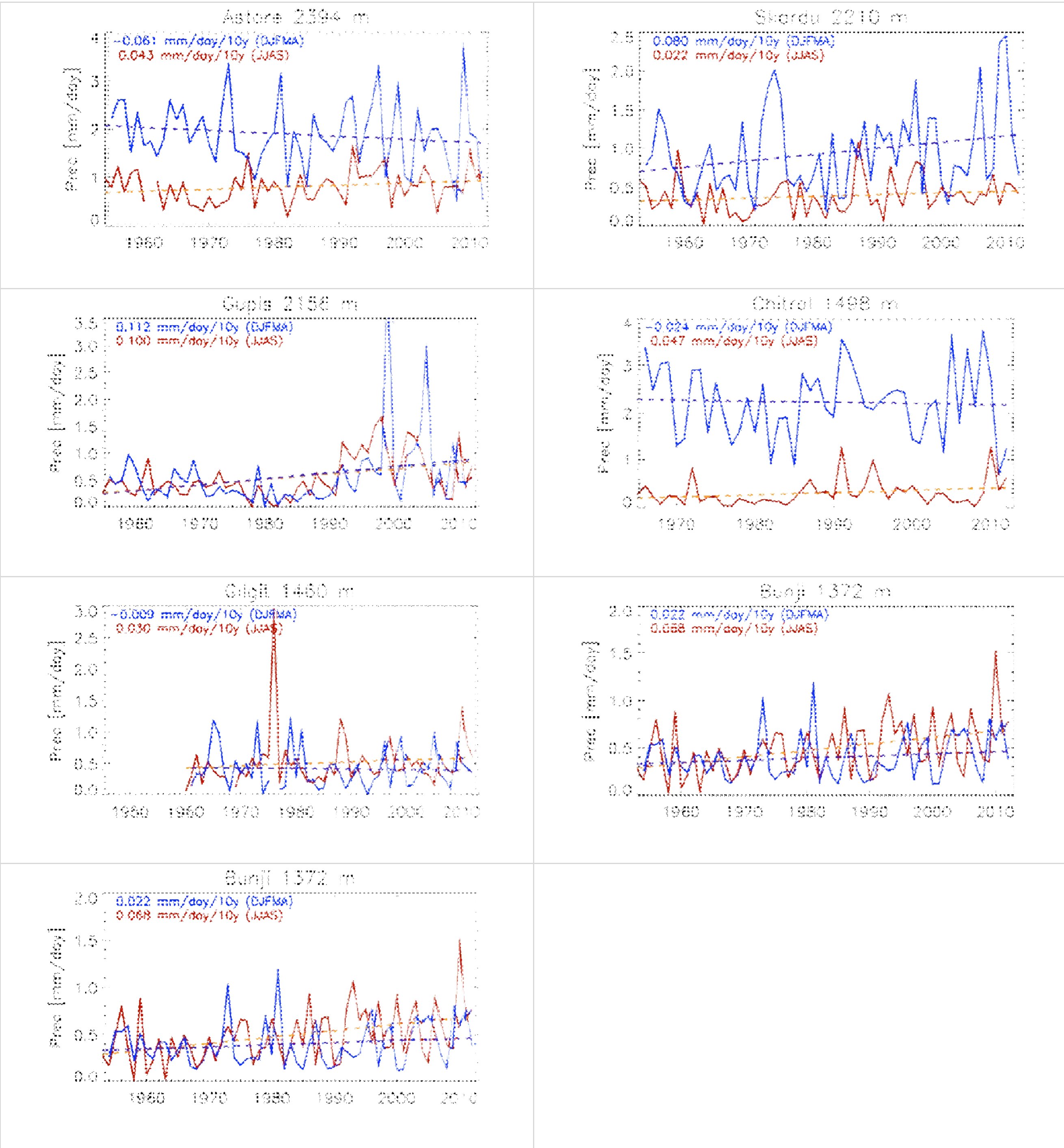


Exhibit 147 Winter (blue) and summer (red) total precipitation trends at the seven PMD stations in the Upper Indus Basin

Exhibit 148 shows the mean annual cycle of precipitation in the Himalaya (a) and Karakoram (b), calculated as the multi-annual average over the years 1901-2005 for each CMIP5 model (grey lines) and for their multi-model mean (MMM, black line). The solid blue and red lines represent the mean annual cycle of precipitation over the years 2006-2100 in the RCP 4.5 and the RCP 8.5 future scenarios, respectively, for the CMIP5 MMM (see section with precipitation scenarios). The CRU and GPCC observations are shown with the pink and green lines, respectively. The "historical" MMM (black line in Exhibit 148) overall shows an overestimation, compared to observations, of the climatological precipitation annual cycle in both HKK and Himalaya regions all over the year. This wet bias is consistent with the bias commonly seen in the precipitation simulated by the state-of-the-art GCMs over high-elevated terrains, such as the Tibetan Plateau, as reported in Su et al (2012). However, the models exhibit a large spread relative to the MMM.

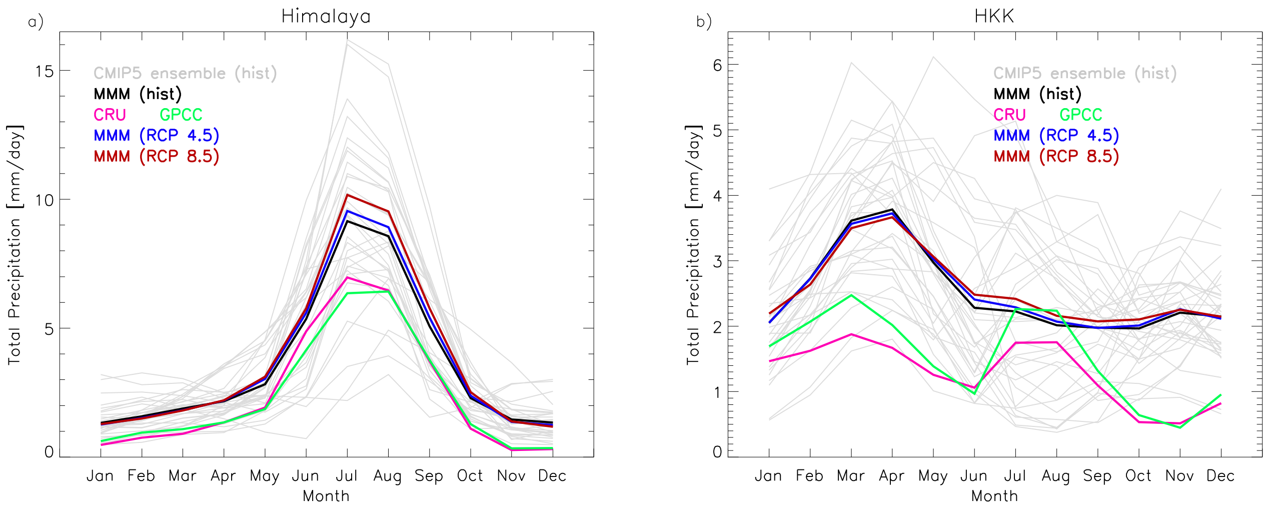


Exhibit 148 Mean annual cycle of precipitation in the Himalaya (a) and HKK (b), calculated as the multi-annual average over the years 1901-2005 (historical period) for each CMIP5 model (grey lines) and for their multi-model mean (MMM, black line). The solid blue and red lines represent the mean annual cycle of precipitation over the years 2006-2100 in the RCP 4.5 and the RCP 8.5 future scenarios, respectively, for the CMIP5 MMM. The CRU and GPCC observations with the pink and green lines, respectively.

The inter-model differences are particularly important in the HKK region, where precipitation annual cycles with very different characteristics are simulated. We grouped the CMIP5 models providing a similar representations of the annual precipitation cycle in the HKK sub-region using a hierarchical clustering analysis, with a standard Euclidean distance as a distance metric and a complete linkage scheme for linking clusters together, so assuming no a priori knowledge about the features of any model. We identified four model clusters in the HKK region, giving rise to the four precipitation annual cycles shown in Exhibit 149 (the shaded area includes the individual model realizations, the MMM is shown with the black solid line with symbols, the CRU and GPCC observations are shown with the pink and green lines respectively). The models in the first and in the second cluster simulate very small amounts of precipitation during summer compared to winter/early spring precipitation. The main difference between them is that the models in the second cluster simulate on average larger precipitation amounts. The models in the third cluster display high precipitation values from March to August and one peak around May; all over the year precipitation values are strongly overestimated with respect to the CRU and GPCC observations. Finally, models in the fourth group present a simulated annual cycle which is most similar to the CRU and GPCC observations, in which the yearly precipitation distribution exhibits two peaks, one in late winter/early spring and the other in summer. This seasonal distribution of precipitation has been described and discussed in Palazzi et al (2013) and reflects the two main seasonal precipitation sources in the area, the wintertime western weather patterns and the summer monsoon. A third, lower, maximum in November can be mainly attributed to one single model (MRI-CGCM3). The mean annual distribution of precipitation reproduced by these models, however, exhibits a systematic wet bias relative to the observations. All models belonging to this cluster have a resolution of either 1.125° 1.25° longitude (high-resolution models), except the NorESM family models, having a coarser resolution of 2.5° longitude.

It was hardly possible, however, to clearly identify what model features play a dominant role in simulating precipitation annual cycles with a certain shape or amplitude, or in simulating the long-term precipitation trends that are in best agreement with the observations.

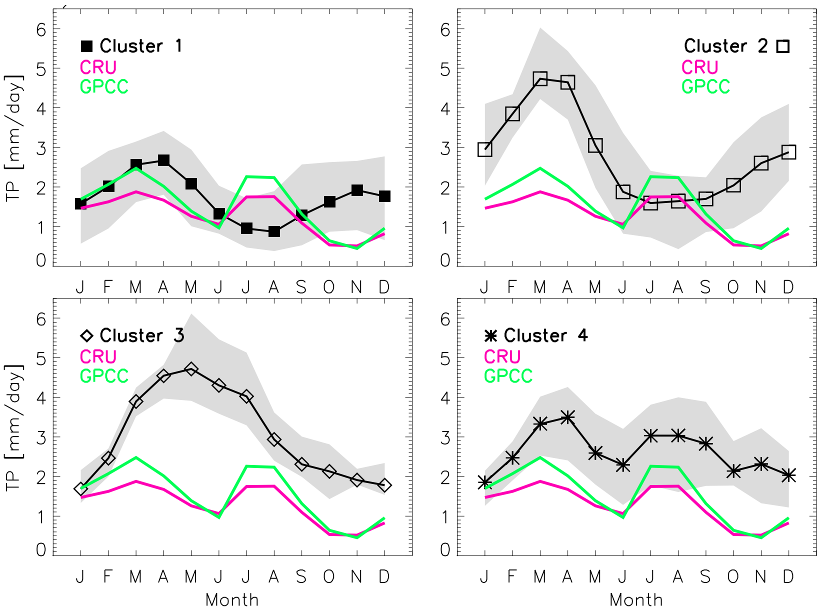


Exhibit 149 Mean annual cycle of precipitation in the HKK simulated by all models within each cluster (the grey shaded areas indicate the variability range of the models) and by their MMM. CRU and GPCC observations are shown with the pink and green lines, respectively.

As for the historical (1901-2005) trends simulated by the CMIP5 GCMs (shown in columns 2 and 3 of Table 33 for the HKK region only), we found that only seven GCMs simulate, in agreement with the CRU and GPCC observations, a statistically significant decreasing trend in the Himalaya during summer. These models do not have particularly high horizontal resolution (from 1.875 to 2.8125° longitude), but all of them account for the indirect effect of sulfate aerosols and have an interactive aerosol scheme. Three models, on the other hand, simulate statistically significant trends of opposite sign for the historical period in this region and season. The other models simulate generally lower trends, either positive or negative, that are not statistically significant at the 95% level of confidence.

In the Himalaya during winter, the MMM does not indicate significant precipitation trends in the historical period: about half of the models provide negative precipitation trends, the other half provides positive, increasing precipitation trends. On the other hand, only two models give a statistically significant trend, indicating a decrease of total precipitation at a rate of about -0.2 mm/day per century in the period 1901-2005. It is worth pointing out, however, that the two observational datasets give different pictures of the historical winter precipitation trend in the Himalayan region: CRU data show a slight, positive and not significant trend, while GPCC shows a negative, statistically significant precipitation trend (-0.36 mm/day per century). In the HKK region (Table 33), both observational datasets indicate positive, though not significant, precipitation trends in summer in the period 1901-2005. The MMM indicates a significant positive trend in this region and season, probably due to the significant positive trends, in the range from 0.3 to ~0.6 mm/day per century, simulated by five models. In the HKK region in winter, the MMM indicates negative precipitation trends throughout the historical period, statistically significant at the 95% confidence level.

Table 46 Trends (in mm day−1 per century) in the HKK region during JJAS and DJFMA, in the periods 1901-2005 and 2006-2100 (RCP4.5 and RCP8.5 scenarios) for the CMIP5 models and for the MMM. Historical precipitation trends for the CRU and GPCC datasets are also indicated. Statistically significant trends are highlighted in bold. Starred entries indicate models with a fully interactive aerosol module; bold entries indicate models representing the indirect aerosol effect.

	JJAS			DJFMA		
	Historical 1901-2005	RCP4.5 2006-2100	RCP8.5 2006-2100	Historical 1901-2005	RCP4.5 2006-2100	RCP8.5 2006-2100
Observations						
CRU	0.083			**0.399**		
GPCC	0.101			0.002		
CMIP5 models						
bcc-csm1-1-m	**0.544**	0.596	0.493	-0.091	0.126	-0.078
bcc-csm1-1	-0.061	0.158	0.054	-0.238	-0.198	0.011
CCSM4	-0.019	0.004	0.255	-0.264	-0.089	-0.292
CESM1-BGC	-0.352	0.522	-0.193	-0.271	-0.117	-0.529
*CESM1-CAM5	**0.550**	**-0.739**	0.054	-0.045	-0.058	0.226
EC-Earth	0.186	0.023	0.033	-0.013	**0.458**	0.344
FIO-ESM	0.335	0.116	0.184	-0.228	-0.506	**-1.141**
GFDL-ESM2G	-0.003	0.297	**0.674**	0.159	-0.070	0.025
GFDL-ESM2M	**0.628**	0.254	**0.613**	0.017	-0.126	0.044
MPI-ESM-LR	-0.013	-0.064	-0.258	-0.510	-0.528	**-1.140**
MPI-ESM-MR	-0.052	0.173	0.005	-0.286	0.199	**-1.010**
***CanESM2**	0.030	-0.104	0.011	0.000	-0.114	0.181
CMCC-CMS	0.261	-0.013	-0.129	-0.194	**-0.871**	**-0.840**
CNRM-CM5	0.040	-0.102	**0.338**	0.339	0.160	**0.989**
***CSIRO-Mk3-6-0**	0.079	0.143	-0.054	-0.242	**0.378**	**0.554**
***GFDL-CM3**	-0.071	**0.334**	0.296	0.039	-0.066	-0.398
INM-CM4	0.044	0.052	0.196	-0.178	-0.098	**-0.591**
IPSL-CM5A-LR	-0.009	**-0.287**	-0.120	-0.250	0.426	-0.600
IPSL-CM5A-MR	0.188	0.065	**0.300**	-0.373	0.469	-0.234
IPSL-CM5B-LR	-0.015	0.151	**0.633**	-0.106	0.476	**0.736**
***MRI-CGCM3**	**0.462**	-0.214	**0.470**	0.014	0.275	**1.117**
CMCC-CM	0.147	-0.045	0.073	-0.163	0.332	0.305
FGOALS-g2	0.055	**-0.204**	0.192	0.185	**-0.578**	**-0.608**
***HadGEM2-AO**	0.003	0.206	0.044	-0.128	0.254	**0.418**
***ACCESS1-0**	-0.133	**-0.423**	-0.196	0.181	0.013	0.167
***ACCESS1-3**	0.062	**-0.276**	-0.351	0.142	0.085	**0.300**
***HadGEM2-CC**	-0.243	0.189	0.142	-0.099	**0.345**	0.187
***HadGEM2-ES**	-0.206	**0.271**	0.265	-0.046	-0.009	0.242
***MIROC5**	**0.300**	0.238	**1.100**	-0.037	-0.017	-0.248
***MIROC-ESM**	-0.160	-0.216	0.002	0.019	-0.166	**-0.598**
***NorESM1-M**	-0.115	0.290	0.412	0.023	-0.131	-0.105
***NorESM1-ME**	**0.534**	0.281	0.425	0.308	**-0.452**	**-0.530**
MMM	**0.094**	0.054	**0.186**	**-0.073**	-0.006	**-0.097**

8.2.4 Simulation of the current snow depth in the HKKH region

The HKKH mountains feed the most important Asian river systems, providing water to about 1.5 billion people. As a consequence, changes in snow dynamics in this area could severely impact water availability to downstream populations. Despite their importance, the snow amount, spatial distribution and seasonality in the region are still poorly known, owing to the limited availability of surface observations in such remote high elevation areas. Owing to the lack of reliable observations, we have analyzed the snow depth representation for the HKKH region in a set of CMIP5 GCM simulations. We found that the models with high spatial resolution (between 0.75-1.25 degrees) represent a more realistic spatial pattern of the winter snowpack with respect to the lower resolution models. The seasonal snow cycle displays a unimodal regime, as shown in Exhibit 115, with a snow depth maximum in February/March and almost complete melting in summer. The models generally indicate thicker snow depth compared to the ERA-Interim/Land reanalysis for the control period 1980-2005.

During the historical period, the average winter snow depth ranges between 5.8 and 27.6 cm in the Himalaya region and from 24.6 to 91.6 in the Hindu-Kush Karakoram region, depending on the model. We recall that since these values represent averages over two large boxes (Exhibit 142), which include snow-free areas, they are not representative of the actual average snow height in snow-covered areas. The overall historical trends indicate a decrease of snow depth. According to the models, the Hindu-Kush Karakoram mountains experienced a significant decrease of -2.7 cm/100y while the Himalaya registered a weaker, statistically non-significant decrease of -1.2 cm/100y (equivalent to decreases of 3.9%/century and 6.7% per century respectively, compared to the historical average).

Exhibit 151 shows the spatial patterns of the DJFMA snow depth trends for each of the high-resolution GCMs in the period 1911-2005 (95-years long period). We reported only the statistically significant trends at the 95% confidence level. We compared the GCM results to the 20CRv2 reanalysis.

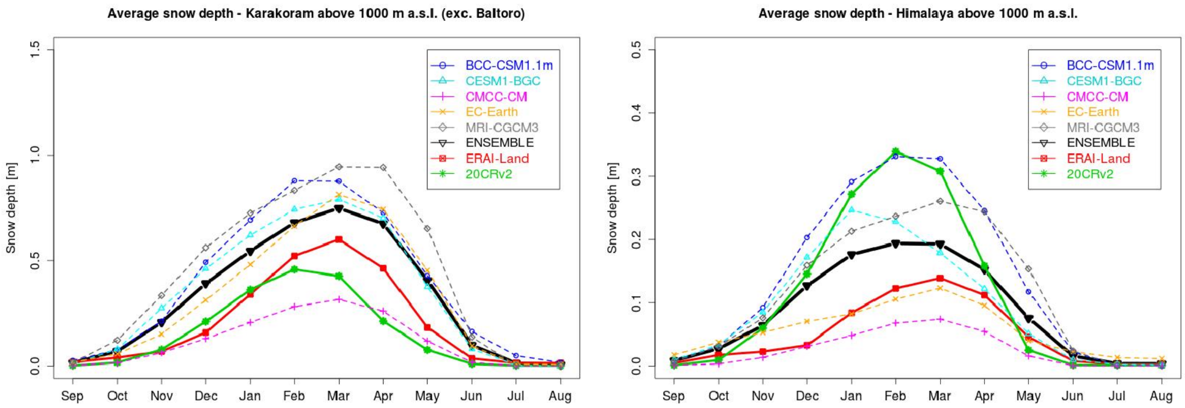


Exhibit 150 Seasonal variability of snow depth in HKK (left) and Himalaya (right) above 1000 m a.s.l., obtained from the high resolution CMIP5 GCMs. The panels refer to the multiannual monthly averages over the reference period 1980-2005.

While the reanalysis displays a snow depth increase especially over the Tibetan Plateau and Western Himalaya, the GCMs show more stable snow depth conditions, except for some scattered areas. The MRI-CGCM3 model identifies a positive trend in the HKK region and CESM1-BGC produces a negative trend in the western Himalaya.

Absolute validation of GCM results against “ground truth” remains a challenge in such orographically complex areas, owing to the insufficient availability of surface observations. This consideration, together with the remarkable inter-model variability detected here, should be taken into account when applying the snow output of a single GCM for hydrological modeling or impact studies of climate change.

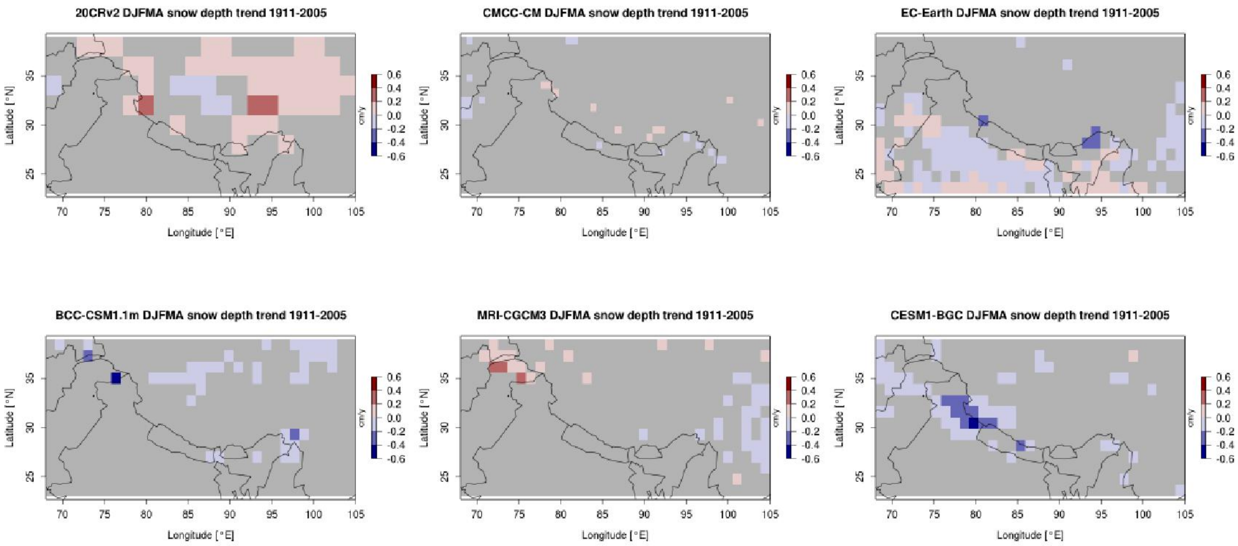


Exhibit 151 Spatial distribution of the winter (DJFMA) snow depth trends, estimated over the period 1911-2005 and significant at the 95% confidence level

8.2.5 Precipitation and snow depth future projections

Precipitation

Daily precipitation data from the EC-Earth model and from the CMIP5 ensemble have been used for analyzing projections of summer and winter precipitation in the HKK and Himalaya regions in the two emission scenarios RCP 4.5 and RCP 8.5.

Exhibit 152 shows the time series of precipitation (after filtering with a 5 years running mean) from an eight-member ensemble of the EC-Earth model in the period 1850-2100 (Palazzi et al., 2013). The most extreme RCP 8.5 scenario for the period 2006-2100 is shown in the figure (the results obtained under the intermediate RCP 4.5 scenario are discussed but not shown for brevity). In order to highlight the interannual variability of the model precipitation, we report the EC-Earth simulation run at ISAC-CNR with a thick black line. In Himalaya during summer the EC-Earth model members indicate an increasing trend in precipitation under the most extreme RCP 8.5 scenario (Exhibit 152d), corresponding to an increase of about 0.008 to 0.014 mm/d/yr. In the RCP 4.5 scenario the increasing precipitation trend continues till about 2050, when it stabilizes and a slight decrease starts, giving rise to no statistically significant trend in summer precipitation. In the Himalaya during winter, one out of eight EC-Earth members provides a statistically significant increase in precipitation in the RCP 4.5 scenario, and another member shows a trend in future precipitation in the RCP 8.5 scenario. Three (five) out of eight EC-Earth members give a statistically significant increasing trend in winter precipitation in the HKK of about 0.3 to 0.4 (0.4 to 0.7) mm/d/(95 years) under the RCP 4.5 (RCP 8.5) scenario. No statistically significant precipitation trend is found during summer in the HKK in the RCP 4.5 scenario, while in the RCP 8.5 scenario, two members give an increase in summer precipitation of about 0.5 mm/d/(95 years).

Exhibit 153 shows the seasonal time series of the precipitation anomalies from 1870 to 2100 in the Himalayan and HKK regions. The anomaly is evaluated relative to the average precipitation in the baseline period (1901-2005). The individual GCM outputs are shown with the grey lines, the multi-model mean (MMM) with the black solid line (historical period), and with blue (RCP 4.5) and red (RCP 8.5) thick lines. The CRU and GPCC precipitation anomalies are shown with the pink and green lines, respectively. The future (2006-2100) trend values of summer and winter precipitation (in mm/day/century) in the HKK region only can be seen in Table 33. In the HKK region future precipitation projections in summer indicate, on average (MMM), a positive trend in both scenarios, statistically significant only in the RCP 8.5 hypothesis. Looking at the results of the individual models displaying statistically significant trends, it is interesting to note that, while in the RCP 4.5 scenario both positive and negative trends are simulated, in the RCP 8.5 scenario the statistically significant trends are all positive, indicating that, in this scenario, not only the

Himalayan region, but also the HKK is expected to experience a future increase in summer precipitation. In the HKK region in winter, the MMM indicates negative precipitation trends throughout the historical period and the future decades. Future precipitation trends are statistically significant under the RCP 8.5 scenario.

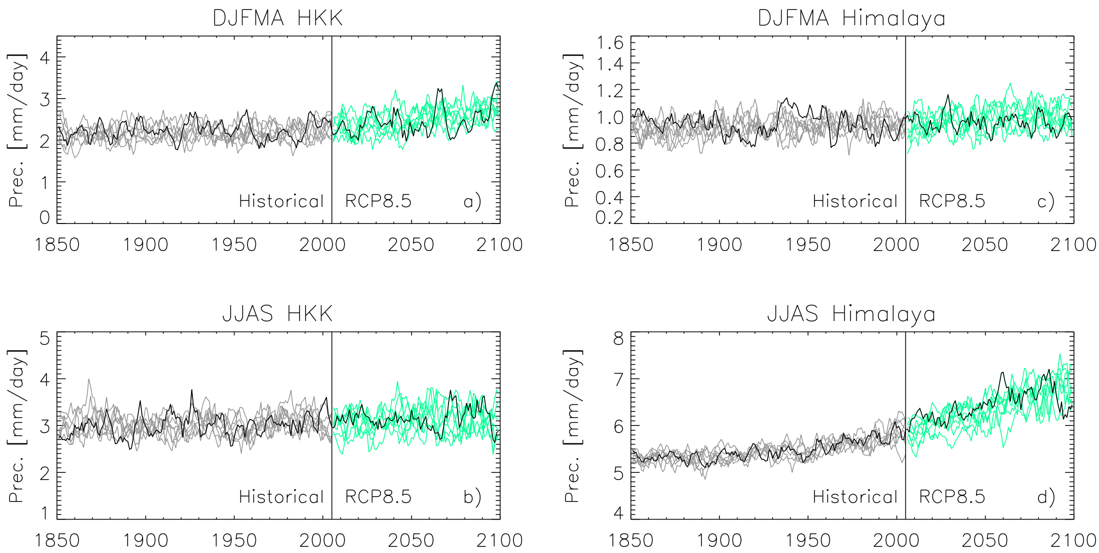


Exhibit 152 Time series of precipitation over (a and b) HKK and (c and d) the Himalaya domain during DJFMA (a and c) and JJAS (b and d) from the eight realizations of the EC-Earth model ensemble for the period (1850–2100) in the RCP 8.5 scenario (for 2006-2100). The individual member of the EC-Earth ensemble run at ISAC-CNR is indicated with a thick black line. The time series have been filtered with a 5 years running mean.

For the Himalayan region (trends values not directly shown) regardless of the model picture of the historical precipitation trends, almost all GCMs simulate increasing summer precipitation trends up to 2100 in both emission scenarios, and in most cases these trends are statistically significant (particularly for the RCP 8.5 scenario). The multi-model mean shows, for the Himalaya in summer, statistically significant increasing trends in 2006-2100 of about 1.13 mm/day per century (RCP 4.5) and 1.86 mm/day per century (RCP 8.5). The Himalayan region is therefore expected to experience a future, and overall significant, increase in total precipitation amounts during the monsoon season. In the Himalaya during winter, the MMM does not indicate significant precipitation trends in the future decades. Future projections of winter precipitation in the Himalayan region are much less clear than for summer. In the RCP 8.5 scenario, we find a slight prevalence of models giving statistically significant decreasing precipitation trends, but no conclusive considerations can be drawn from our analysis.

Snow depth

The future changes of snow depth in the HKKH region are estimated considering only the five CMIP5 GCMs with highest resolution, being these models able to capture the more realistic distribution of snow depth and area in the HKKH mountains. For each model, the fields have been temporally averaged over the winter season (DJFMA) and spatially averaged in the two domains, HKK and Himalaya, weighting each pixel by its fraction of area above 1000 m a.s.l.

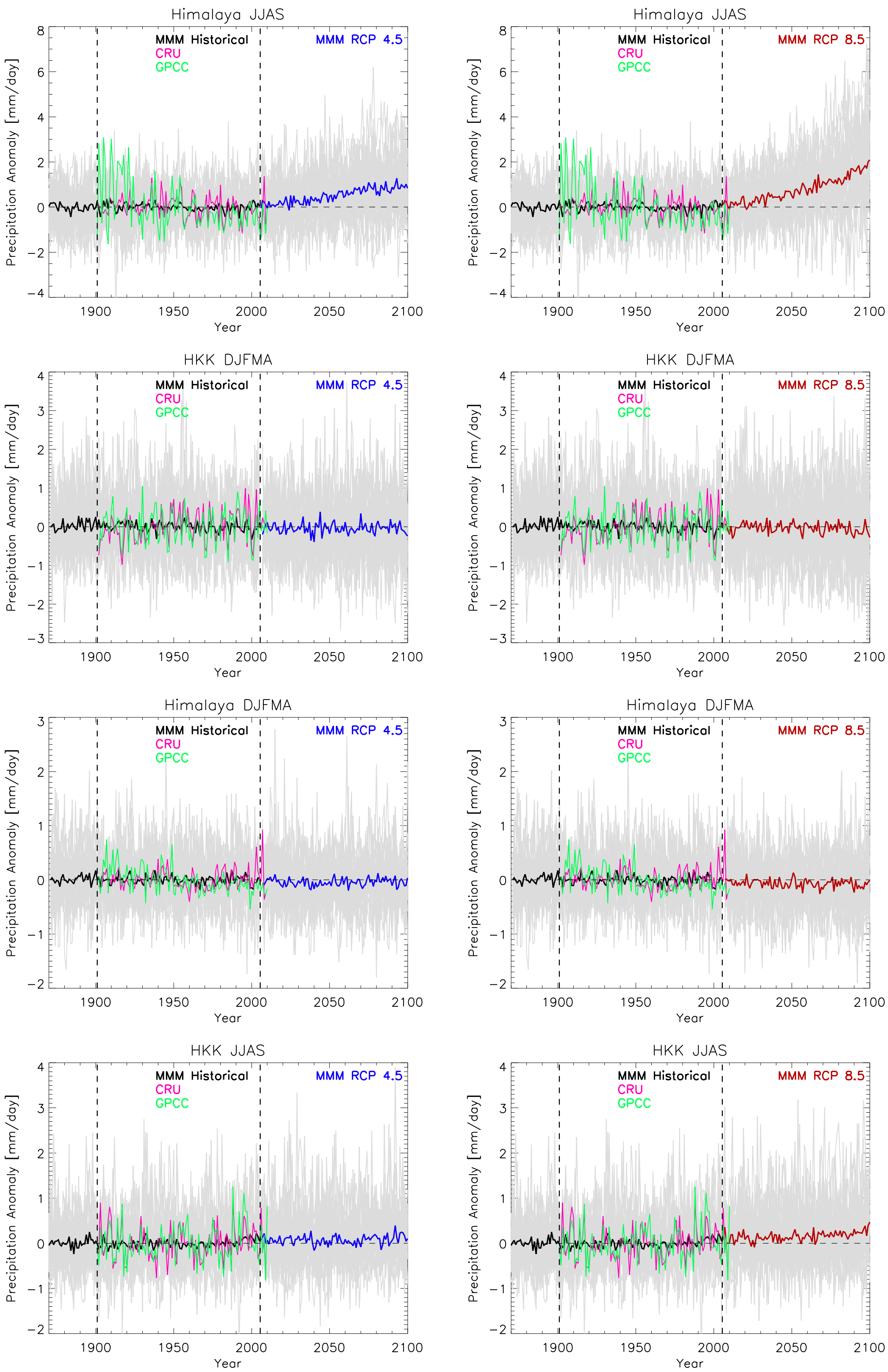


Exhibit 153 Time series of precipitation anomalies in the Himalaya and in the HKK during summer and winter from 1870 to 2005 and from 2600 to 2100 (RCP 4.5, left column; RCP 8.5, right column). The individual models of the CMIP5 ensemble are shown in grey, the CMIP5 multi- model mean (MMM) is shown with the black (historical period), blue (RCP 4.5 scenario) and red (RCP 8.5 scenario) solid lines. CRU and GPCC observations are shown with the pink and green lines, respectively. The anomalies are evaluated with respect to the 1901-2005 baseline period.

Exhibit 154 shows the average winter snow depth time series and the corresponding ensemble mean for the HKK and the Himalaya.

In future projections, snow depth is found to significantly decrease in both regions and for both scenarios. The simulations for the Hindu-Kush Karakoram, in the RCP4.5 scenario, indicate a snow depth decrease which is about twice stronger with respect to that estimated for the historical period (-5.5cm/100y); the more extreme RCP8.5 scenario indicates an even stronger, and highly significant, snow depth reduction of -19.2cm/100y. These are equivalent to respectively 8% and 28% reductions in snow depth per century, compared to the historical average.

In the Himalaya, the models predict a strong and highly significant snow depth decrease of -5.4 cm/100y and -8.9 cm/100y in the RCP4.5 and RCP8.5 scenarios respectively (equivalent to decreases of 30% and 49% per century respectively). The expected relative decrease is much stronger in the Himalayan range, in agreement with previous studies that found Himalayan glaciers more sensitive to climate change.

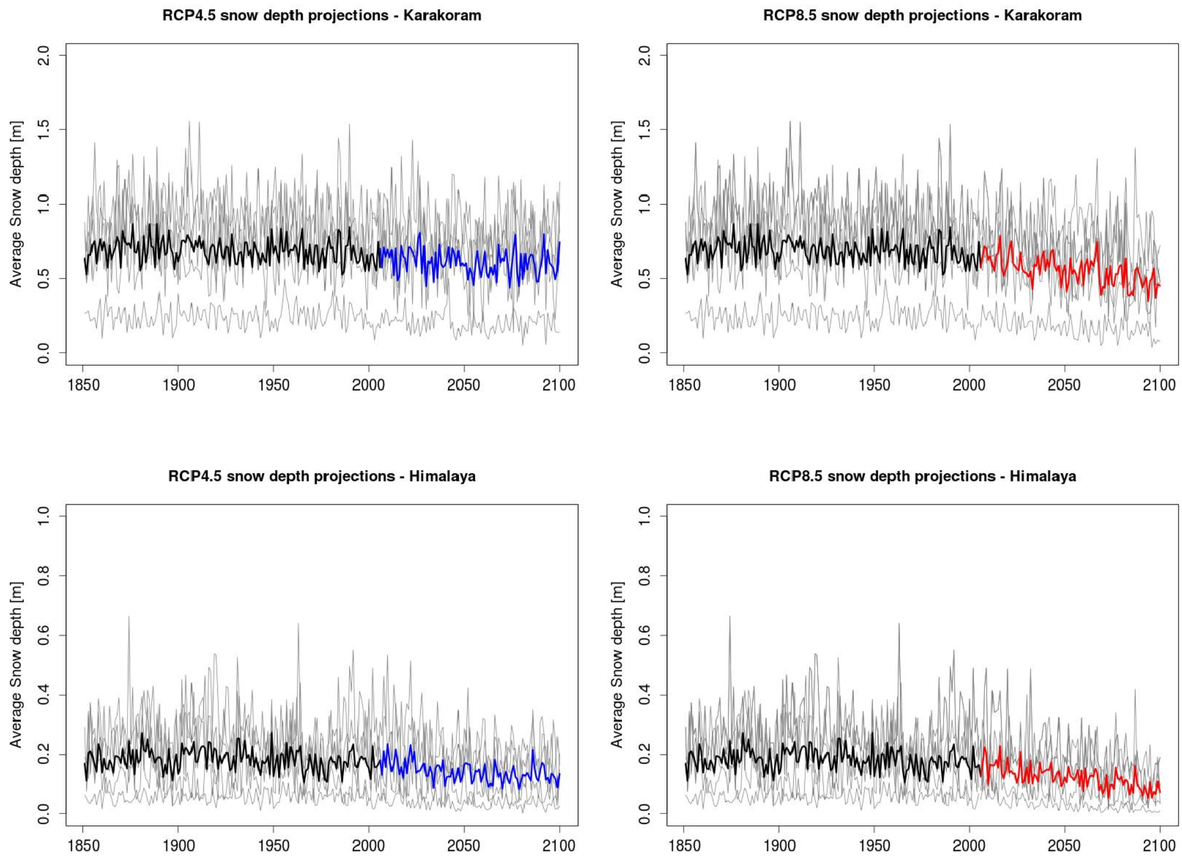


Exhibit 154 Winter snow depth projections for the historical period and for the 21st century (RCP4.5 and RCP8.5 scenarios) in Hindu-Kush Karakoram (top) and Himalaya (bottom), averaged by weighting by the fraction of area of each pixel with altitude above 1000 m a.s.l.. Grey lines represent high-resolution CMIP5 models, bold lines represent the ensemble means of historical (black), RCP4.5 (blue) and RCP8.5 (red) simulations.

8.2.6 Management indications

Our analyses highlight that the absolute validation of GCMs, both in terms of precipitation and snow thickness, against the ground truth is a challenge in orographically complex areas such as HKK region, also owing to the insufficient number and uneven distribution of surface observations. This feature, along with the remarkable inter-model variability, should be considered when using the precipitation and snow output of a single GCM or of a GCM ensemble to feed hydrological models and to make assessment studies. Climate downscaling methods, both dynamical and statistical/stochastic techniques, are strongly envisaged.

9. Remote sensing support in the development of the Geographic Information System for the CKNP [12]

9.1 General aim of the activity

The main objective of this activity was the acquisition and processing of environmental data for cartographic purposes. New data was acquired in the field and from remote sensing images and new thematic maps were produced and integrated in GIS environment.

These maps result from the interaction of multidisciplinary and interdisciplinary activities between Italian and Pakistan researchers and they were discussed with the local communities.

One of the main objectives was the mapping of CKNP border and its internal subdivision on the basis of the indications from the researchers, local communities and geographical and environmental features.

In the last semester the activities were focused on:

- The final classification of land cover classes and the support to the biomass and increment estimations
- The acquisition of the last GPS points and treks for the final maps with the indication of villages, roads, trekking routes, cultural routes, peaks, passes.
- The integration of the final indications of the researchers and technicians involved in the project for the definition of the park boundaries.
- These activities were discussed and supported by the several research groups and integrated with the field activities.

The study and the products of the research were focused on the specific area of CKNP, including some portions of the valleys, as it is reported in the maps.

9.2 Land cover mapping and biomass estimation

The whole work has been done in collaboration with the research group of TESAF Department – University of Padova. The complete methodology and the results are described in the previous report (June 2013) and summarised in the document: “FOREST RESEARCH AND MANAGEMENT FINAL REPORT, SEED Report by TESAF DEPARTMENT UNIVERSITY OF PADOVA, DECEMBER 2013”.

The general method proposed in SEED project follows the remote sensing method and it is based on vegetation indexes and spectral classification of forest classes extracted from field sample plots. Models to estimate biomass, derived from remote sensing, need further calibration with ground data before using to predict AGB (Above Ground Biomass) for a given landscape. In this work a direct radiometric relationship (DRR) was created, linking spectral values extracted from vegetation indexes to measured forest variables.

[12] Authors: Maria Teresa Melis (University of Cagliari, Italy)

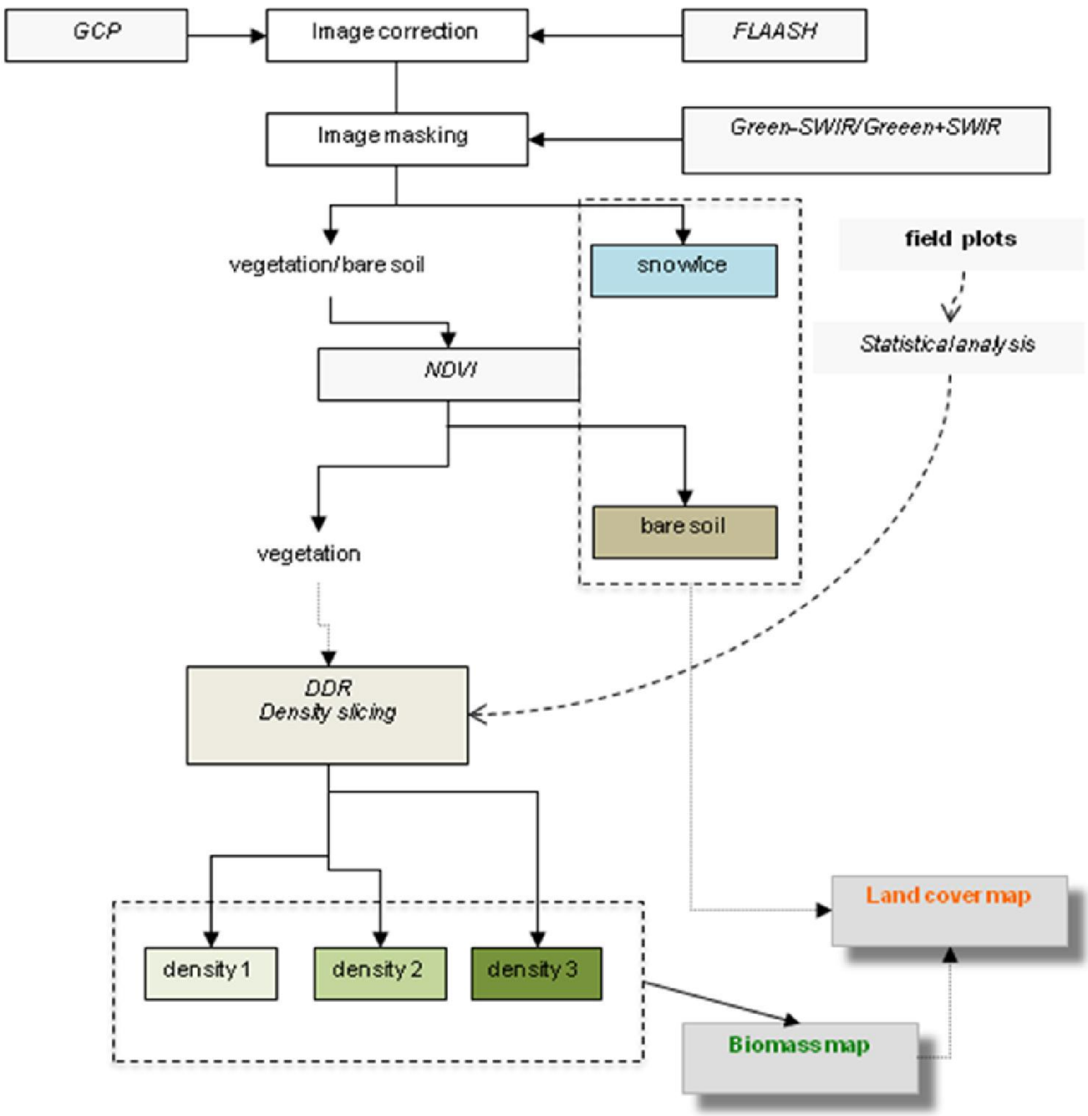


Exhibit 155 The steps of the image processing and mapping

The final geodatabase based on remote sensing processing and field calibrations was used to produce the Land Cover map at the scale 1: 125.000 (see Exhibit 156).

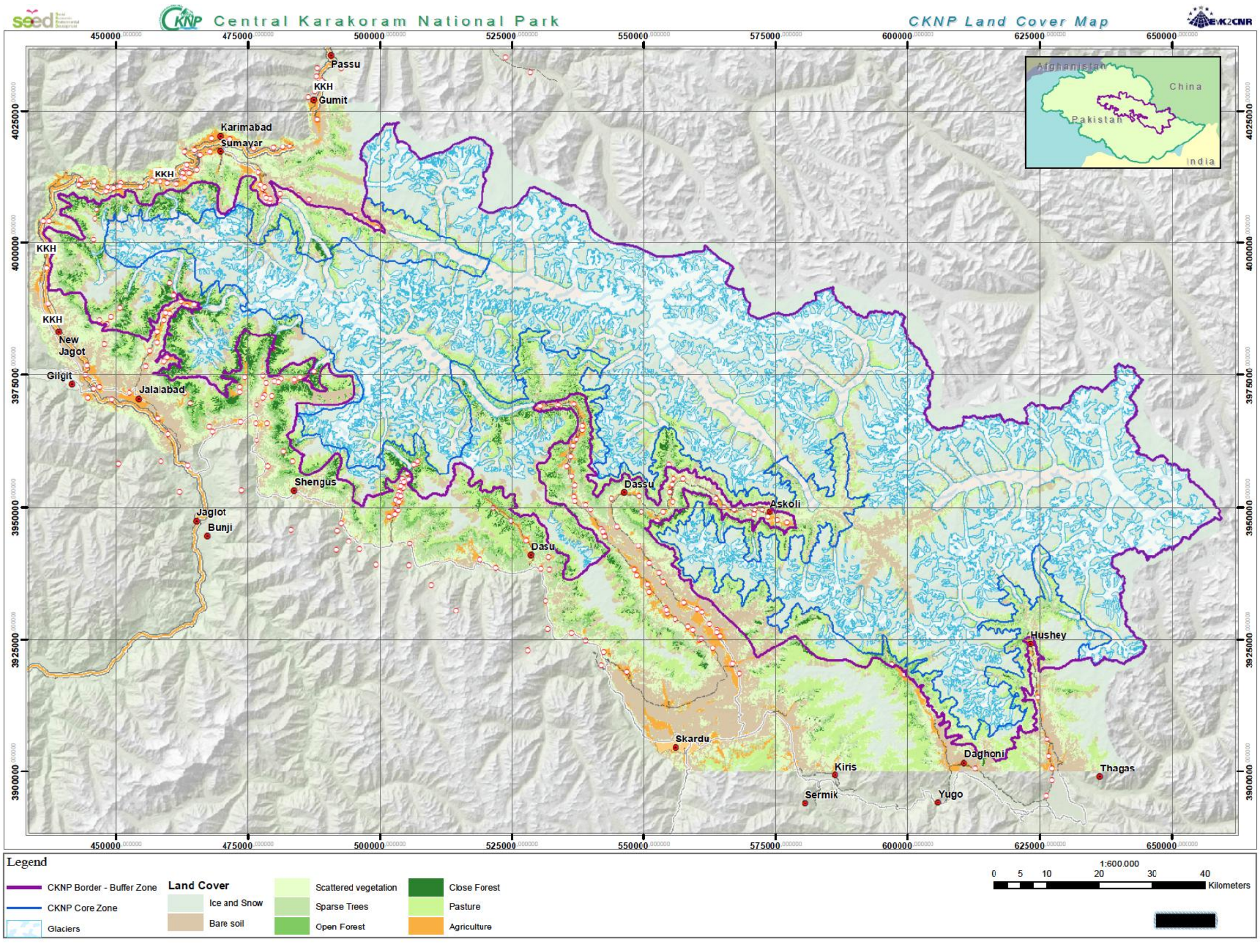


Exhibit 156 The Land Cover Map

9.3 Thematic maps

As it is explained in the previous reports, the absence of topographic maps in appropriate scale and available for the research groups has led to the need of using the DEM as a reference basis for the extraction of topographic parameters. This activity was integrated by the information acquired in the field with the GPSs to locate the features.

Furthermore, the map with the final discussed park boundaries was done.

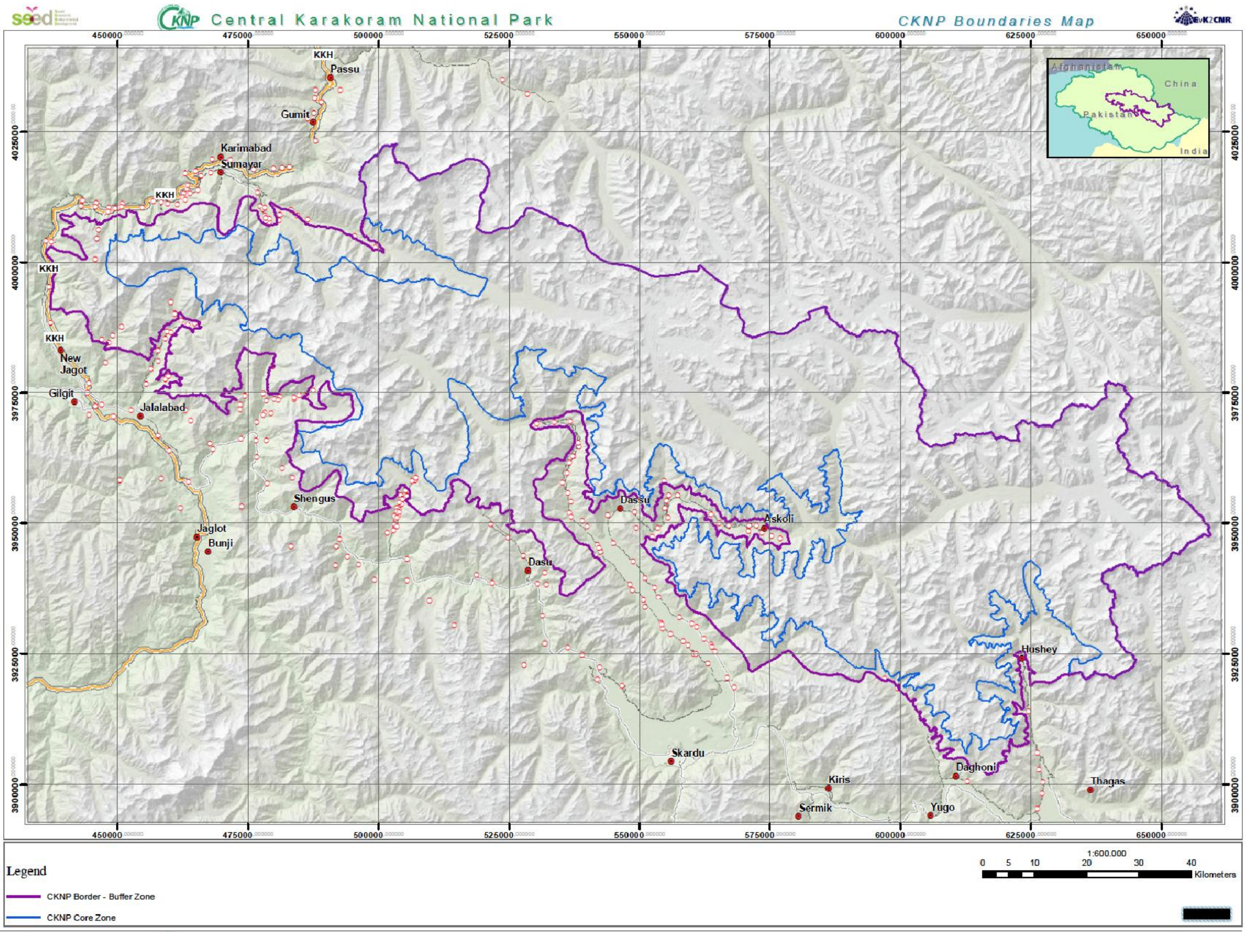
The adopted methodologies for the extraction of the thematic features of each map and the rules for the boundaries definition are discussed in the previous report (June 2013).

During this semester the following final maps were prepared:

- CKNP Boundary Map
- CKNP Tourism Map
- CKNP Use Rights Map
- CKNP Zoning Map

In the next pictures the sketch of the maps and the specific legends are shown.

The maps are attached to the official document "Management Plan for Karakorum National Park".



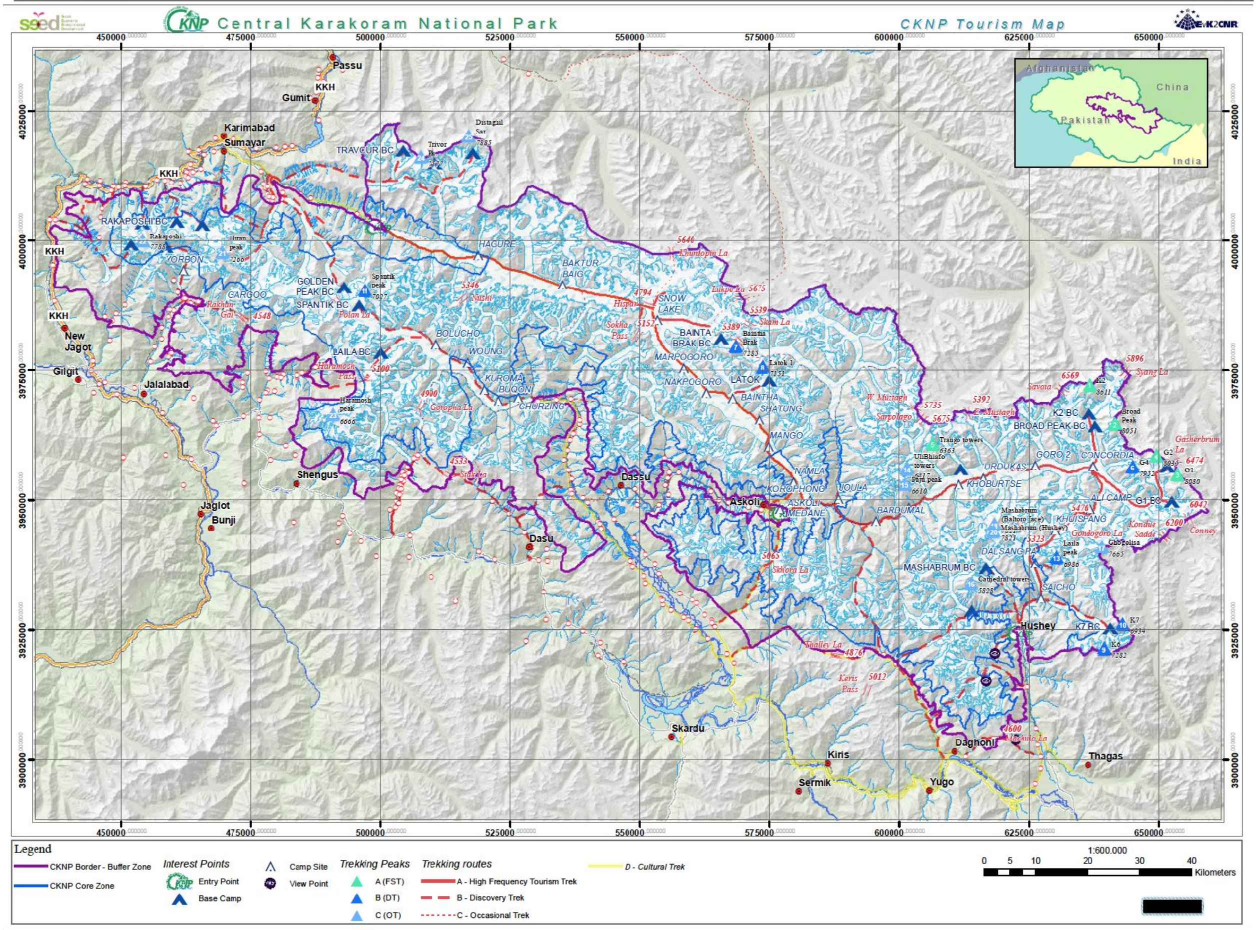


Exhibit 157 The Tourism Map

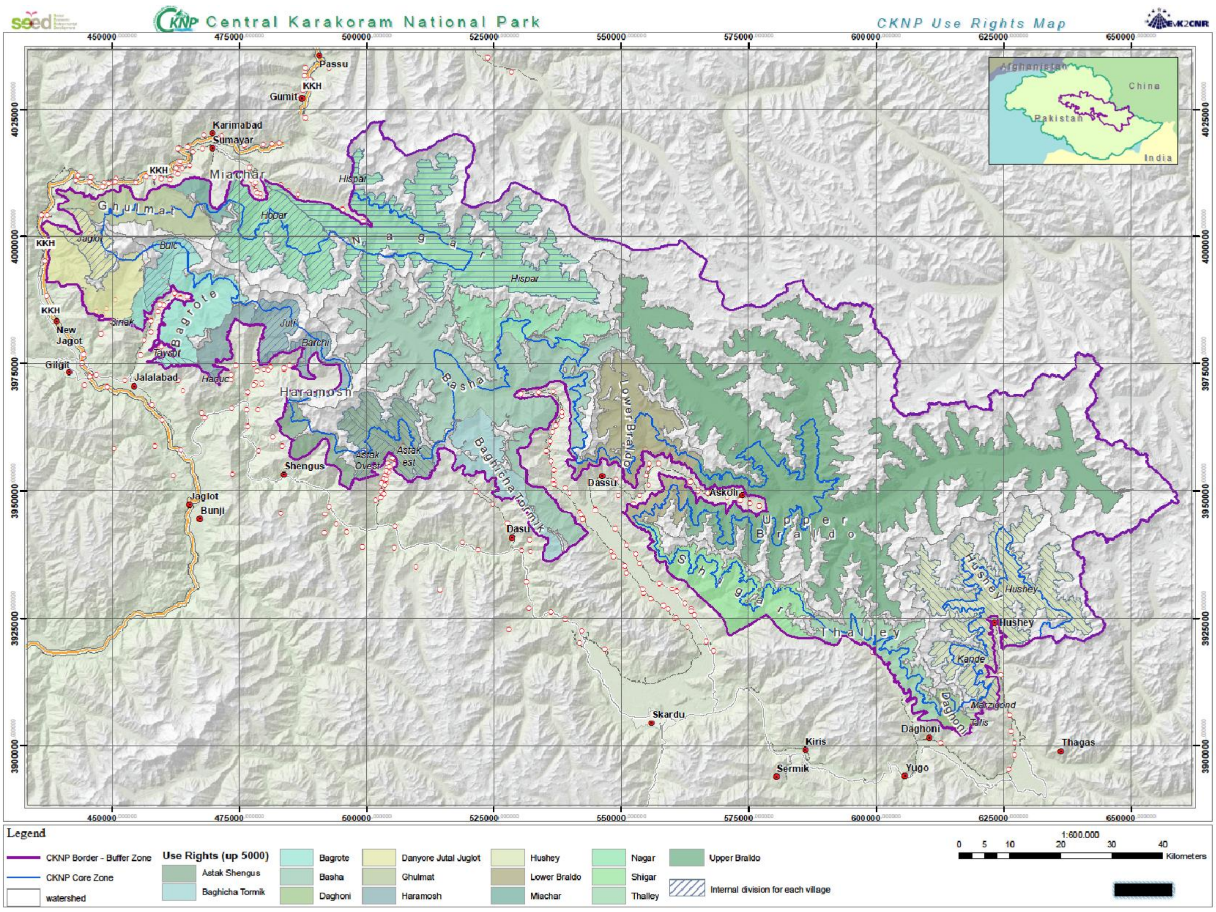


Exhibit 158 The Use Rights Map

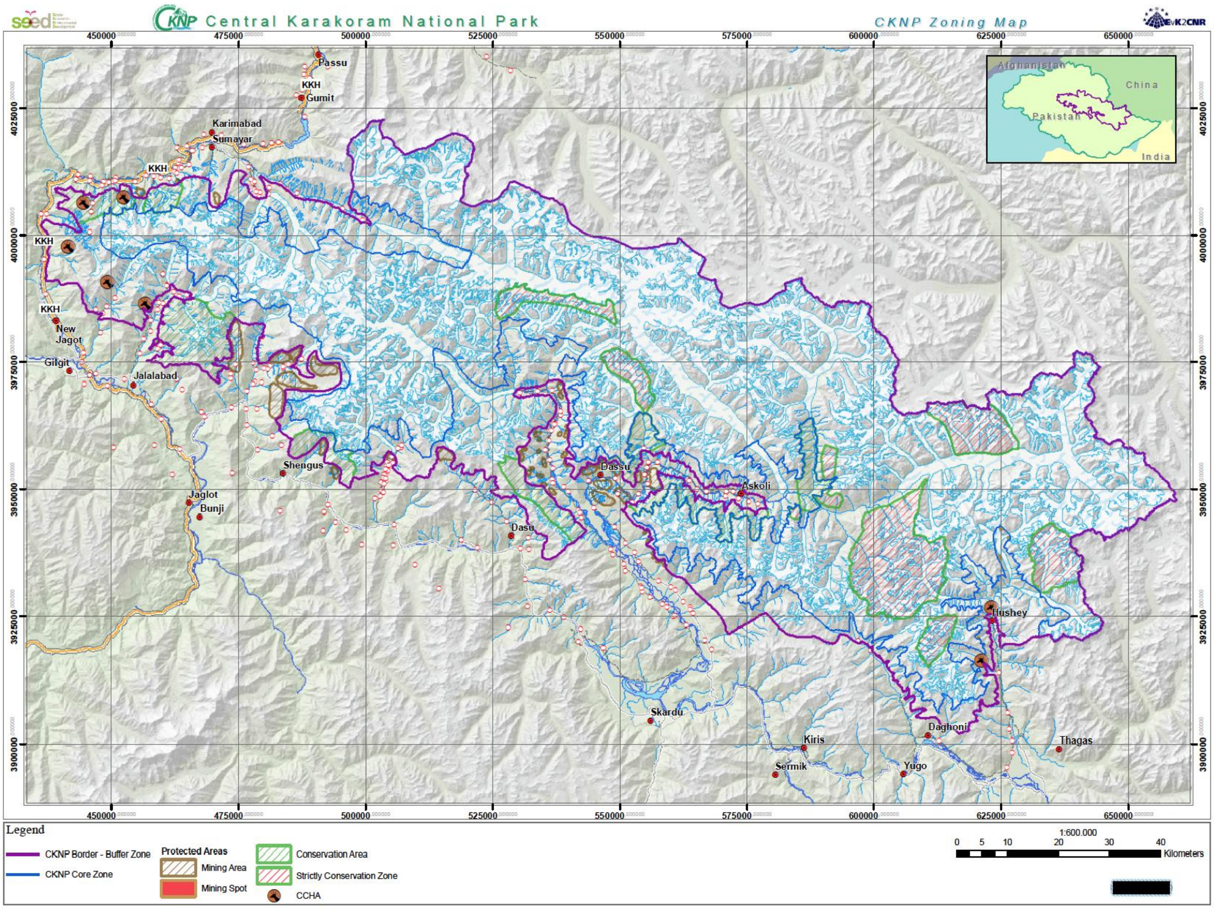


Exhibit 159 The Zoning Map

RESEARCH BASELINES FOR CENTRAL KARAKORUM NATIONAL PARK MANAGEMENT PLAN

RESEARCH PROTOCOLS

1. GLACIOLOGY Guidelines to Perform Field Surveys

ABBREVIATIONS

2D two-dimensional
3D three dimensional
AAR Accumulation Area Ratio
AML Arc macro Language
ASTER Advanced Spaceborne Thermal Emission and Reflection radiometer
DTM Digital Terrain Model
DDF Design Definition File
ELA Equilibrium Line Altitide
ESA European Space Agency
ETM+ Enhanced Thematic Mapper plus
GIS Geographic Information System
GLCF Global Land Cover Facility
GLIMS Global Land Ice Measurements from Space
GTN-G Global Terrestrial Network for Glaciers
HRV High Resolution Visible
ID IDentification
IGS International Glaciological Society
NDVI Normalized Difference Vegetation Index
NIR Near Infrared
NSIDC National Snow and Ice Data Center
RMSE Root Mean Square Error
SoW Statement of Work
SPOT System Pour l'Observation de la Terre
SRTM Shuttle Radar Topography Mission
TM Thematic Mapper
TSL Transient Snow Line
UNESCO United Nations Educational, Scientific and Cultural Organisation
USGS United States Geological Survey
UTM Universal Transverse Mercator
WGI World Glacier Inventory
WGMS World Glacier Monitoring Service
WGS84 World Geodetic System of 1984

1.1 Carrying out mass balance measurements

The focus of this paragraph (taken from Kaser *et al*., 2003) is the application of the "direct glaciological method". This method determines the surface net mass balance over given time periods. Measurements are best carried out twice per year –at the end of the humid and the end of the dry season. More visits may be necessary to maintain instruments and stakes in the glacier. The net mass balance has to be measured on a selected number of sites. For clarity, in subsequent chapters, the two dates of subsequent visits to the glacier are called t_1 and t_2. (t_1, might be October 1_{st} in 2012, and, t_2, October 1_{st} in 2013). Since accumulation and ablation measurements require different techniques these to topics are presented separately.

Ablation measurements

Net ablation can occur on bare glacier ice in the ablation zone low on the glacier and, under strong negative mass balance conditions, also from firn in the upper regions of the glacier. Typically, stakes are drilled into the glacier in the ablation zone and changes in surface level are measured against stake height. For ablation conditions, the level, measured (between t_1 and t_2), drops (or the distance from the stake top increases). The density of glacier ice is considered constant at 917 kg m^{-3} and there for the specific mass balance in [m we] or [kg m^{-2}] is calculated from the product of the level change between readings and the ice density.

In the accumulation zone, if firn ablation can be expected, stakes must also be set in those areas. Density of the ablated material must be made prior to the ablation, that is at t_1, at near the stake location but not close enough to the stake to affect measurements.

Ablation stakes

Ablation stakes can be made from a variety of materials. The stakes must not self drill into the ice by their own weight or by melting due to the absorption of energy. For ablation greater than 0.5 m yr^{-1}, a sectioned stake is usually needed. Plastic or metal pipe in sections about 2 m long have been used. The sections are kept together either by interior plugs inserted into the pipe, by wire or cable ties, connecting each section through holes drilled in the sides, or by exterior sleeves. Metal stakes have one major disadvantage, in areas with high air temperature or high insolation, stakes warm up or absorb energy that cases them to melt out of the bore holes in which they originally were set. Metal stakes will also melt down into the ice, thereby reducing the read ablation values from their true values. This problem can be reduced by inserting a wooden plug at the bottom end of the stake, thereby reducing the thermal conduction from the stake to the ice. Plastic stakes are lightweight and may appear ideal. However, some plastics (e.g. PVC) become brittle at low temperature and splinter easily when winds pick up. Plastic stakes can therefore not be recommended. In many places, including low latitude countries, bamboo stakes have proved suitable: they are easily available, strong, resistant to weather, have a low thermal conductivity and low weight, and they are inexpensive. Wire connections are useful for bamboo stakes. Connecting devices are shown below. A disadvantage of the wire connection may occur when the lower stake emerges only very little from the ice. The upper stake is then laying on the surface and it can be difficult to find the site, particularly if it is, in addition, covered by lets say a thin autumn snow cover. The advantage of any particular system depends on the availability of materials locally, the cost, and weight. In places where glaciers can or will be revisited repeatedly during a season, such stakes

may be very useful. However, a lost stake from melting out is a severe blow to any mass balance program and the choice of stake material must be made in accordance with the expected frequency of visits to the glacier. Kaser *et al*. (2003) strongly recommend any mass balance program to make their own evaluation of different stake materials in parallel to establish which materials suit their needs the best. *There is no single best way to measure mass balance that is applicable to all glaciers*. However it *is* important that whoever makes decisions on changes to methods of measuring mass balance does so backed up with much knowledge, and perhaps most importantly, much experience from the field.

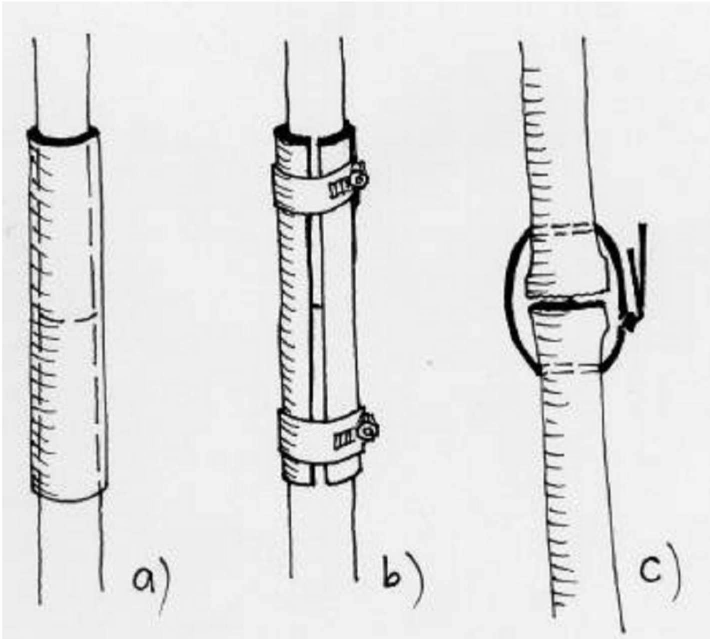


Exhibit 1 Connection devices for ablation stakes: a) rubber tube, b) metal sleeve, c) wire connecting bamboo stakes (from Kaser et al., 2003).

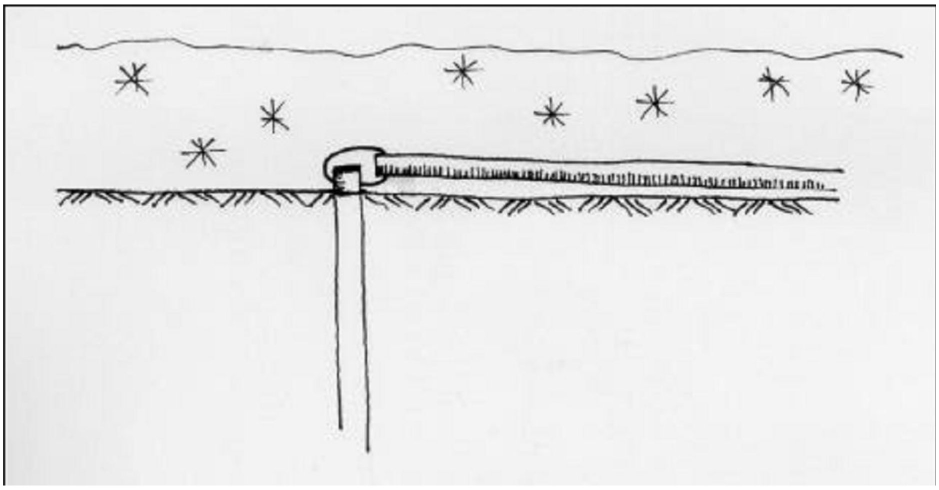


Exhibit 2 A stake buried by a rather thin snow cover (from Kaser et al., 2003)

Selecting sites

Ablation, in comparison to accumulation, is rather uniform and point measurements can be representative over large areas. This implies that significant small scale (10^{-2} – 10 m) differences can be averaged out over long periods (>days). Statistical analyses from a variety of studies agree that 10 – 15 ablation stakes are sufficient to estimate a glacier's mass balance, independently from the size of the glacier (e.g. Fountain and Vecchia, 1999). A useful distribution is on a longitudinal axis along the central flow line of the glacier and some additional crosswise profiles where accumulation differences due to wind distribution, shading, or avalanching may be significant. On many glaciers, ablation stakes are distributed more or less regularly over the ablation area with no particular structure . Stakes should be established at the same position each year. By "same position" we mean within about 100 m. This means that a stake location is a circle of 50 m radius on the glacier. Within this radius, mass balance is not expected to vary significantly. These values only apply to a larger glacier that is 500-1000 m wide and several km long. On a smaller glacier it becomes more critical to re-establish stakes at the same position. Establishing the location of stakes can be made by either using a hand-held GPS with pre-programmed waypoints or using a sighting compass and landmarks such as peaks, ridges or other features in the surroundings to establish the point by optical intersection. Regular surveying can of course also be made but requires heavy equipment and larger number of personnel. Establishing stakes at predetermined locations has the advantage that values from different year can be compared directly. Remember that mass balance is strongly elevation dependent, primarily because melting decreases with altitude since it depends on temperature, which decreases with altitude. This means that on any glacier which has a large elevation span (ca. 1000 m) the strongest variation in mass balance will be along the long axis of the glacier. The primary goal for setting stakes should therefore be to cover as much elevation as possible, especially important is to maintain stakes at both high and low altitude, near the head and terminus of the glacier, respectively. Lateral variations in mass balance originate from shading of the glacier. If your glacier is located so that there is reason to suspect that certain sites on the glacier receives much less or more energy, lateral stakes should be placed to capture the decreased or increased melt in such area. Kaser *et al*. (2003) recommendation is to concentrate on establishing 10-15 stakes along a longitudinal profile covering as much elevation as possible. Stakes should be placed so as to be evenly distributed in altitude, not distance on the glacier. This means closer distance on steeper parts of the glacier and more distance between stakes on flatter areas. Lateral extending of the stake network should be made either in a cross like figure or in a diamond like figure where lateral stakes are set in altitudes between the central stakes. The latter supports best the contour type evaluation of mass balance.

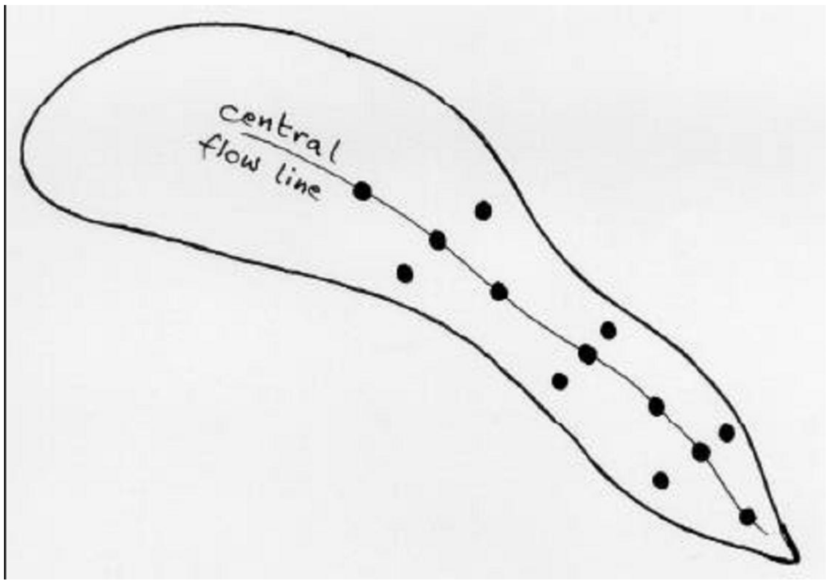


Exhibit 3 Stake setting along the central flow line of the glacier and some additional crosswise profiles (from Kaser et al., 2003).

The stakes should be numbered and tagged by a small metal plate, tied with wire to the upper end of the stake. The stake number is stamped or scratched into the plate together with the year of drilling in the stake (a lost stake may re-appear again). Several numbering systems are practiced from a chronological numbering to spatial numberings that infer stake location. For example, along the central flow line stakes are numbered 10, 20, 30, 40, etc., and lateral stakes are numbered 21, 23, 25 on the left-hand side and 22, 24, 26 on the right-hand side. Note that any numbering system which allows the unambiguous

recognition of stakes is of value. Due to the ice movement stakes are dislocated from their original position after some time. Depending on the glacier velocity the stakes must be repositioned occasionally. Often, this can be conveniently done when the stakes are ablating out entirely.

Drilling ablation stakes

Ablation stakes are drilled into the glacier using either a mechanical hand auger or with a steam drill. For deep emplacement (>3 m) a steam drill is usually easier. Because of heat loss along the sides, a typical steam dill has a depth limitation of 8-12 m. The depth of the holes for the stakes depends on the magnitude of expected ablation between the measurement interval. The greatest ablation is usually highest close to the terminus and can reach up to 10m or more per year. Thus, drill limitations may dictate the minimum time interval between visits.

The reading of ablation stakes

For net ablation measurements the length of the stake from the free end to the surface, L, is measured at two (t_1, t_2) or more (t_n) successive dates. At t_2, the last measurement of the ablation season, the depth of snow over the ice is also measured. The difference between exposed stake lengths, $L_{i(t2)} - L_{i(t1)}$ plus snow depth at t_2, gives the net ice ablation at this point. If snow covers the surface during both visits, then it has to be accounted for in each visit.

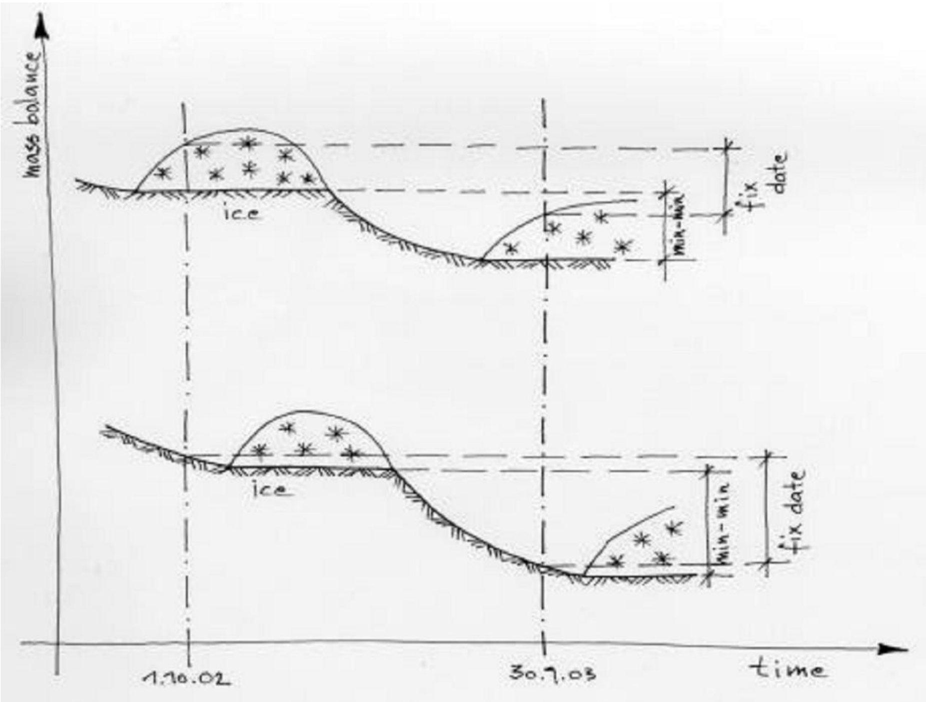


Exhibit 4 The seasonal development of the surface in the ablation zone (from Kaser et al., 2003)

If snow covers the last visit and remains snow covered for the rest of the season, presumably, the time of maximum ablation (minimum mass balance) took place at some point earlier. Weather records from a nearby station help with determining more accurately the date of snowfall and therefore the date of minimum glacier balance.

Mapping the ablation area

The knowledge of the pattern of bare ice appearing at the end of the observation period (particularly at the end of the ablation season) is of great use when drawing the mass balance features into a topographic map. It would be best to measure the extent of bare ice by geodetic methods but a field mapping supported by photographs taken from different points is sufficient.

The steam drill

A butane (or propane) burner heats water in a boiler and generates steam. When the valve is opened the steam escapes through the nozzle of a drilling pipe at the end of an insulated hose. The condensing steam transfers energy to the ice causing it to melt. The high degree of latent heat contained in the steam guaranties a very efficient energy flow from the boiler to the ice. The entire drilling device consists of the steam generator, the rubber hose, and the drilling pipe with interchangeable tips. It can be carried on the back like a rucksack and can be operated by one person. A small drill tip (21 mm in diameter) creates hole diameters of 30 to 35 mm and a large drill tip (30 mm in diameter) creates hole diameters of 35 to 45 mm in ice.

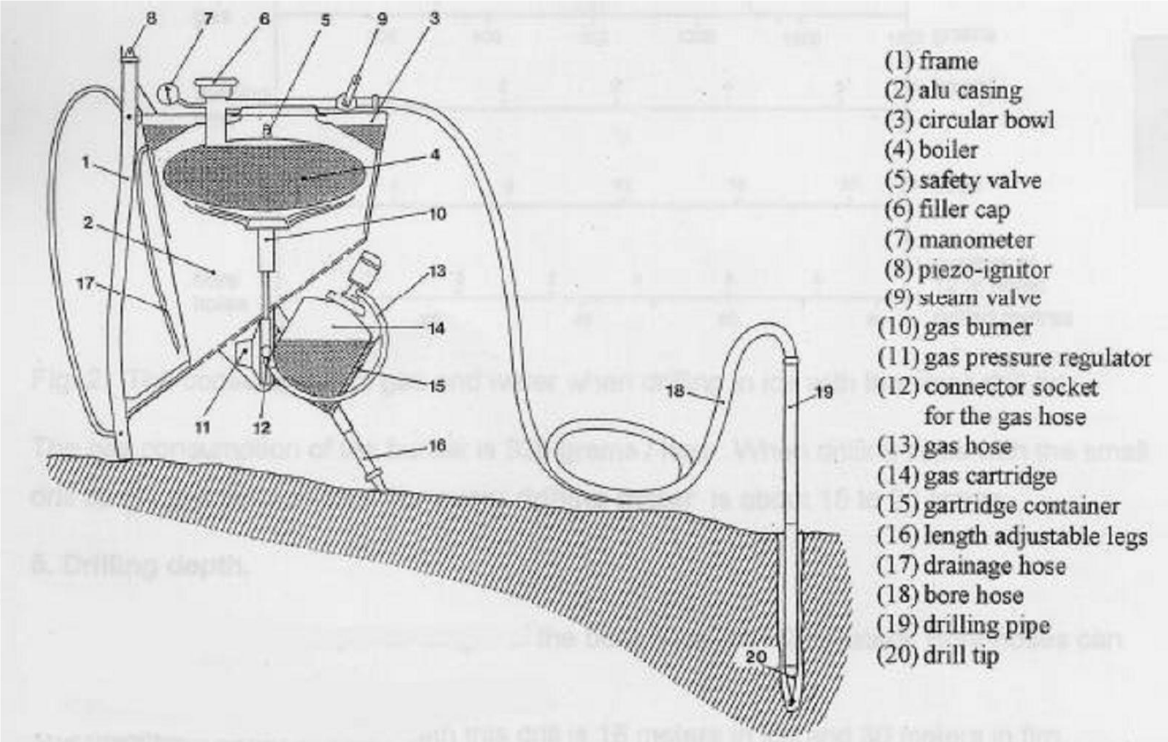


Exhibit 5 The steam-driven HEUCKE ICE DRILL (from Kaser et al., 2003)

Exhibit 6 Drilling an ablation stake with the Heucke steam drill at Concordia – Baltoro Glacier (Photos by C Mayer)

Exhibit 7 Drilling an ablation stake with the Heucke steam drill at Khoburtse Glacier (Photos by C Mayer)

Exhibit 8 A bamboo ablation stake installed at Khoburtse Glacier (Photo by C Mayer)

Exhibit 9 An ablation stake installed at at Khoburtse Glacier. This stake is also equipped with thermistors and data loggers to record debris temperature data along the debris vertical profile (Photo by C Mayer)

Accumulation measurements

The net accumulation is measured by digging pits at each of the stakes in that area of a glacier where snow has accumulated during the immediate past period (t_1 to t_2) of investigation (i.e. season or mass balance year). Like in the ablation zone, the amount of accumulated snow is measured in water equivalent length units [m we] or water mass per area units [kg m^{-2}]. This is calculated from measured snow depths and the respective snow density. For the necessary measurements the snow cover has to be penetrated to the last observation dates (t_1) horizon either by digging snow pits or by taking cores with a respective drill.

Selecting the sites

The accumulated snow cover has usually a rather complex distribution of depths but comparable uniform density profiles. Because of the logistical limitations, the number of measurement sites is limited and depend on the extent and the complexity of the respective accumulation area. Typically, 3 – 5 measuring points are suggested. These points with depth and density measurements are complemented by spatially extensive depth information from probing. Successful probing depends on a reference layer of clearly greater density (usually the previous summer surface), which can be identified. If no reference layer can be found when probing, which is rather probable under low latitude climates the number of measuring points must be increased. The location of accumulation measurements must represent a possibly large surrounding area. To a certain extent, the field experience of the investigator can help to find most representative sites.

The identification of previous year layers

Net accumulation is, as the net ablation too, determined in respect to a previous surface position. Whereas this can be easily determined in the ablation zone because of the ice surface, any natural or artificial marking in the accumulation zone made at t_1 will be buried by snow by t_2. Under mid-latitude conditions, a well definable layer usually develops at the end of the ablation season. This is because the surface had experienced melting, collected dust during the ablation season, and re-froze before the arrival of winter snow. This reference layer is characteristically dusty and hard. Thus, all snow superimposed on this hard dusty layer is considered to be new accumulation. Under low latitude conditions measurements of net accumulation are more complicated. Neither in the monsoon type regime (Ageta and Fujita, 1996), where accumulation appears during the warm season, nor in tropical regimes, where melting occurs all the year round, does a hard dusty layer develop. Sometimes a dust layer will be found on low latitude glaciers, but they are seldom regularly developed and are often linked to individual events such as storms rather than to the end of the ablation season. In this case, artificial markers are needed. Dust or soot are not suitable because it will tend to wash out and will alter the surface energy balance leading to increased local ablation. Accumulation stakes can be installed with a piece of tape marking the level of the surface prior to the accumulation season. These stakes have to be quite stable since they have to erect substantially for not being buried entirely by subsequent snow. Markers fixed on stakes and buried by the accumulated snow can only be found by digging a snow pit.

Still, the pit can also be used for the necessary density measurements. In the accumulation area it will be very important to establish the net addition of mass. Sometimes the previous years surface may be difficult or impossible to distinguish. In such cases we recommend to sprinkle saw dust, preferably dyed dark with a water insoluble dye. Saw dust is very useful since it is lightweight when dry but becomes more immobile on a snow surface since it soaks up water and becomes heavier. Dusting should be made so that the surface is not completely covered with sawdust but is neither so lightly dusted so that identification of the dust in a snow pit may be impossible. When digging a snow pit at the stake the following year, the sawdust can be distinguished and the previous surface positively identified. It is also possible to cycle through a series of colours so that deep pits can verify several years of accumulation. This is however not necessary for the standard mass balance program. If sawdust is sprinkled around a stake it is advisable to spread dust over a relatively large area and make notes on the size of the area. This becomes useful if the stake is lost during the year, e.g. snowed over. The likelihood of hitting the dust when digging in the assumed area of the lost stake is higher the larger the area that is sprinkled with saw dust.

Snow density

The best way to measure the density of a snow pack is by digging a snow pit and making careful measurements of the snow density down the pit wall. Coring may be easier and faster, but the action of coring compresses the snow somewhat leading to over estimating the actual snow density. The size of a snow pit and its shape depends on the expected depth. The deepest point of the pit should be a square approximately 0.5 x 0.5 m to provide sufficient room for making density measurements. Also, for density measurements and stratigraphy observations, one continuous wall from the top to the bottom of the pit must be planned. This measuring- wall is oriented to avoid direct sunlight.

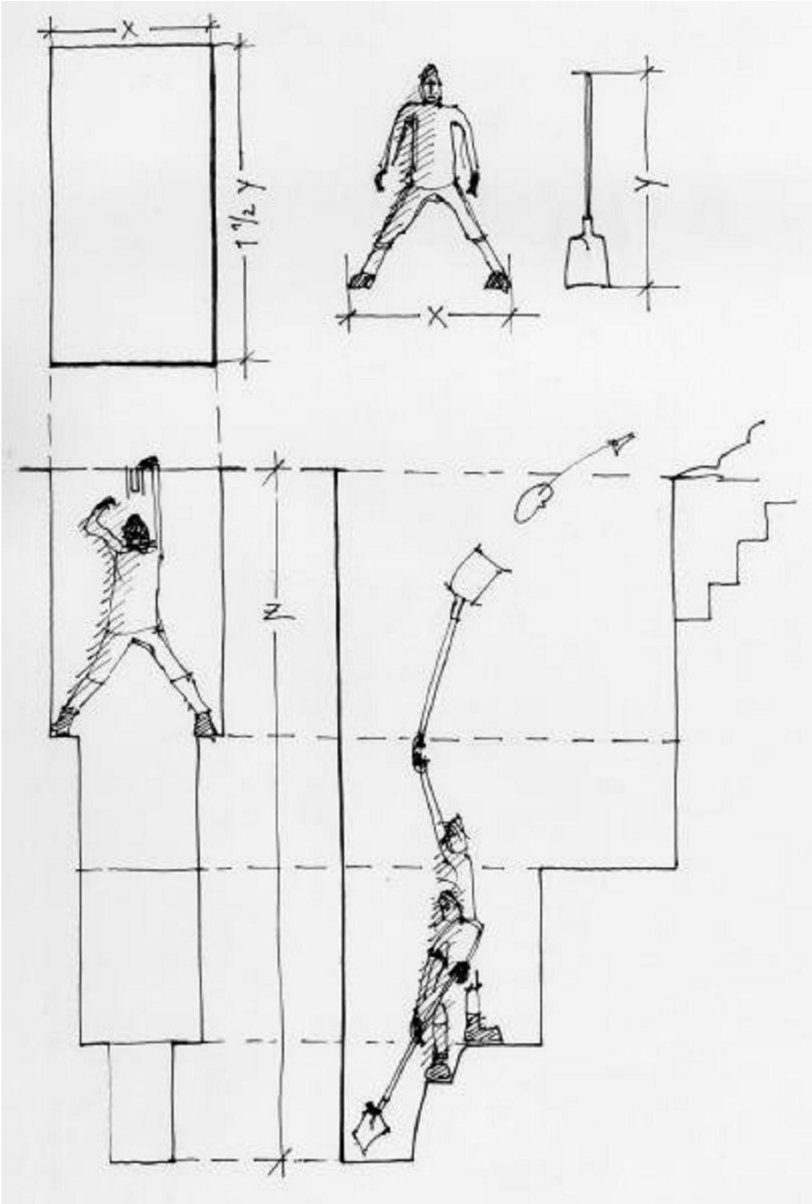


Exhibit 10 Shape and size of a 5 – 6 m deep snow pit (from Kaser et al., 2003).

Each experienced investigator has their own technique and philosophy for planning a pit dig to achieve the proper depth, size, and measuring wall. The above reported figure is one such suggestion. Note that measures are not in usual length units but in relation to the human body and, to some extent, related to the length of the shovel. It is generally advised that all walls should be kept perpendicular while digging and all angles as right angles. This is the most effective way to reach the required depth with a minimum of volume to be removed. A well made pit is shown below.

Exhibit 11 Digging a snowpit (see the vertical profile for snow layer analysis and sampling) at the Godwin Austen basin (Photo by C Mayer).

Exhibit 12 Digging a snowpit at the Gasherbrum basin (Photo by C Mayer)

The **snow density** ρ, is determined by measuring the weight (mass), *m**, of a snow sample of sample volume, *V**:

$$\rho = m / V^{-1}$$

For this purpose, tubes with a volume capacity of 500 cm^3 (usually with a length of 20 cm with the respective diameter) are very practical. They can easily be made from stainless metal. Note, however, that the sharp side must not affect the sampling of the volume. Since the aim in context of mass balance investigations is not primarily the variation of density with depth but the determination of the water column stored in the accumulated snow pack, samples must not be taken horizontally but as vertical cores each one beneath the other. If clear changes in snow properties are met, which indicate a certain event or change in the accumulation processes, this can be considered by accordingly separating the density measurements. Necessary tools and their use are shown here following.

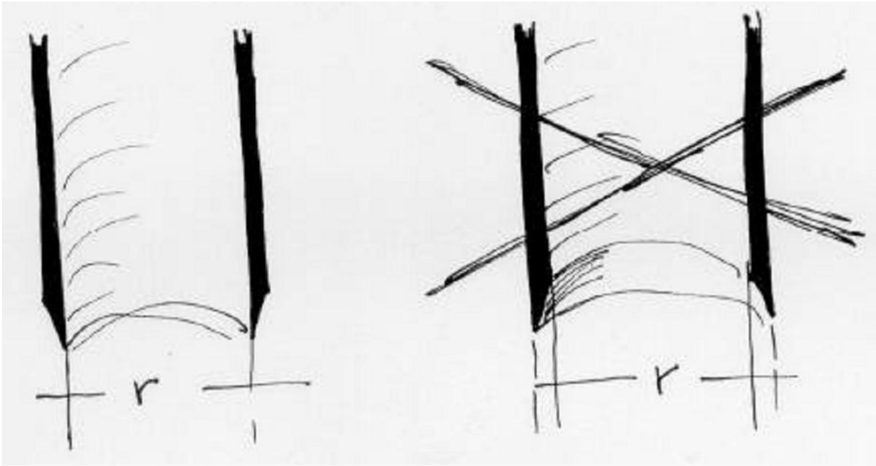


Exhibit 13 The sharp edge of a density tube must not affect the sample (from Kaser et al., 2003)

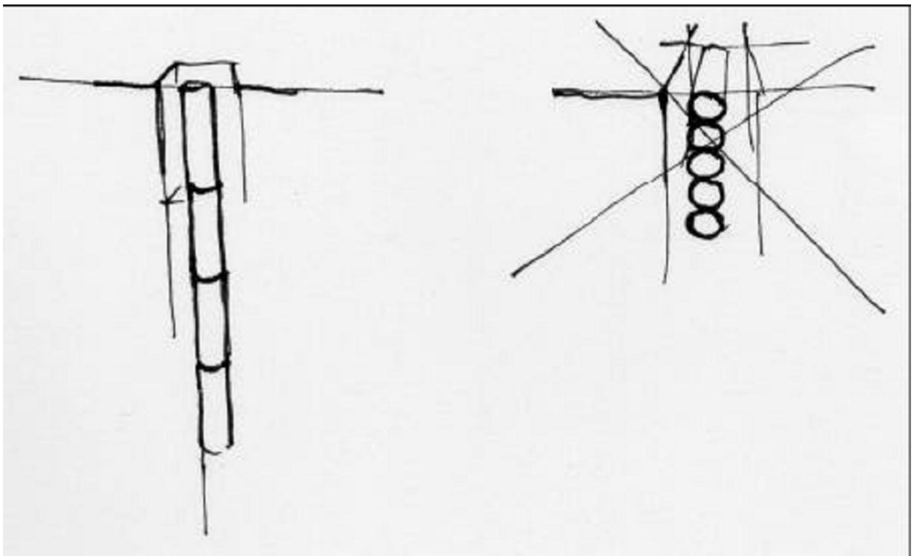


Exhibit 14 For mass balance purposes sampling is better made vertically (From Kaser et al., 2003)

Each measurement is recorded in a field book filing up the lengths of the samples in one column, the density in the next column, the length-weighted mass in the third. For a final check the sum of taken sample lengths is compared with the separately measured total depth of the pit from the surface to the reference layer.

In many cases, a stratigraphic description of the snow layers can be very helpful when analysing the data and when comparing the results from different snow pits. This has not to be as sophisticated as for avalanche studies, but should consider major changes in the snow pack (change from crystals to grains, dust layers, descriptive free water content, ice layers etc.), which can be related to certain weather conditions throughout the accumulation season.

Exhibit 15 Firn core at the Godwin Austen Glacier (Photo by C Mayer).

1.2 The locating of the measuring points

The position of the measuring points must be known. In mass balance analysis, a best guess estimate of the location of the points on a good map may be sufficiently accurate to obtain a reasonable mass balance. This caused by the extrapolation from points to surface area values, and as long as the point is within the area it represents, then the exact position is not required. Importantly, the input data must be more accurate than the method of analysis by an order of magnitude to obtain the best results possible. In many cases, at least the ablation stakes are located each year geodetically, which provides data for analyzing the ice velocity.

The snow pits are usually dug relative to topographic features on the glacier, which are rather constant over long periods. Thus, their position is relatively easy to determine from a map and rather constant in time.

Exhibit 16 The GPS Master station located at Urdukas (Baltoro Glacier). In 2011 it was used as reference station to evaluate stake positions and then glacier surface velocity (the measurements were acquired twice, at the beginning and the end of the field work thus permitting a comparison of the surveyed data).The GPS Master station was located close to the Share AWS (on the right in the photo provided by C Mayer).

1.3 Practical experiments and methodology for monitoring the mass balance of debris covered glaciers.

Since in the CKNP several debris covered glaciers are located (see Mihalcea *et al.*, 2006; 2008; Mayer *et al.*, 2006; 2010) we consider fundamental to add information on the best practices to monitor such glacier type, which are peculiar and need to be analysed with further details. A debris covered glacier is a glacier with the largest part of its ablation area covered by debris ranging from a few cm up to 1-2 m or more (Benn and Evans, 2010).

Supraglacial debris cover is crucial in determining rates and magnitudes of buried ice ablation (Østrem, 1959; Nakawo and Rana, 1999) that is reduced (Mihalcea *et al.*, 2006) when the debris thickness is higher than a *critical value* (Mattson and Gardner, 1989).

On debris-covered glaciers, a "stake farm" experiment to determine the *critical debris thickness* (see Mattson and Gardner, 1989) should be performed on representative area, which presents an wide range of debris thicknesses.

Usually this experiment is performed at the mean elevation of the ablation zone over an 10x10 m area: The stakes are drilled at sites with different debris thickness on flat surfaces: few mm to 30-50 cm. One or more stakes should be positioned on debris-free ice on a flat surface or over surfaces with varying exposition (S, N, W, E). Thin debris cover (0.1 -4 cm) greatly influence the ablation rate, then at least 10 stakes should be drilled within this thickness range. The "stake farm" experiment is very useful to establish the curve of ablation rate as a function of debris thickness by eliminating the elevation effect.

When installing stakes in debris covered areas the following procedure should be followed:

1) Select the site : elevation, position (longitudinal/cross profile or "stake farm" experiment)
2) Aspect and slope measurements
3) Debris thickness (DT) measurements
4) Debris cover characteristics: grain size, colour, whether or not the layer is stratified.
5) Remove cautiously the debris by leaving one site of the profile undisturbed to be able to observe and characterize the vertical profile and measure the thickness
6) Drill the ablation stake
7) Measure the stake length above the ice (L_{ice})
8) Reconstruct the original debris profile by repositioning the material trying to maintain the original conditions as much as possible (larger clasts at the surface and small grains at the bottom of the layer if is the case).
9) Measure the stake length above the debris (L_{debris}). Please pay attention that the stake length difference: L_{ice}-L_{debris} should correspond to the original debris thickness (DT)

Exhibit 17 Installing ice ablation stakes on debris-covered ice (Photos by C Mihalcea)

Exhibit 18 Stake farm to measure ice ablation with varying debris thickness (Photos by C Mihalcea).

Exhibit 19 Debris cover measurements (Photos by C Mihalcea)

As above mentioned describing the installation of ablation stakes on bare ice, The stakes should be numbered and tagged by a small metal plate, tied with wire to the upper end of the stake. Due to the ice movement stakes are dislocated from their original position after some time. Depending on the glacier velocity the stakes must be repositioned occasionally. Often, this can be conveniently done when the stakes are ablating out entirely.

Ice ablation on debris-covered glaciers

On DCGs the supraglacial debris mantle greatly influences the surface ablation rates and their distribution.

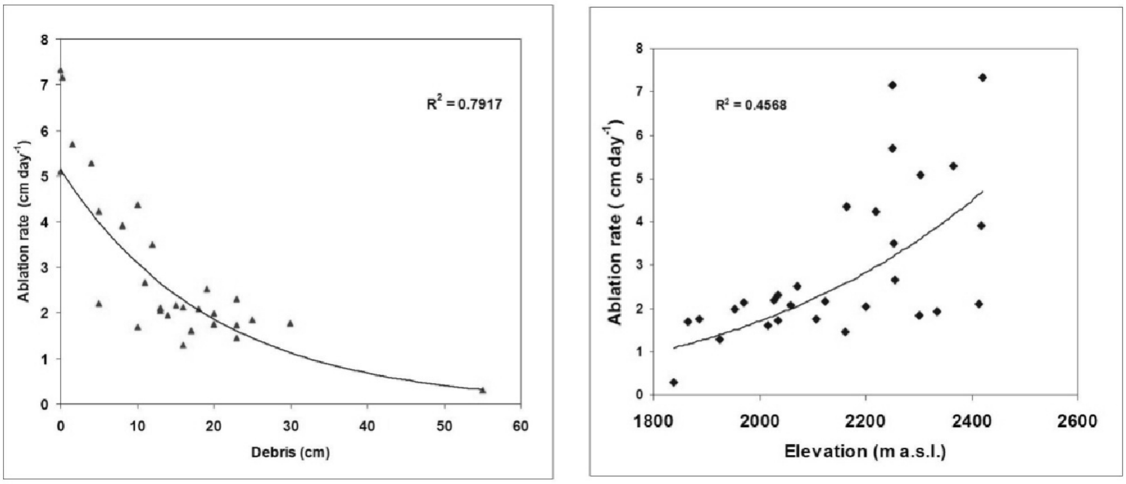


Exhibit 20 Ablation rate versus debris thickness and elevation at Miage glacier (Italian Alps).

The strong variability of ablation rates measured on the selected DCGs surface (see the above reported figures) is due to the large spatial variations in debris thickness: from a few millimeters on the upper part of the glacier, ice cliffs and crevassed areas, to more that 3-4 m thickness at the terminus. Therefore, downglacier increase in debris depth leads to a positive relationship between ablation rate and elevation in the debris-covered zone, the opposite to debris free glaciers (Mihalcea *et al*., 2006). Elevation alone (i.e., when the effect of different debris thickness is removed) is not a sensible factor in controlling ablation rates on some DCGs (e.g. Lys and Miage glaciers) due to relatively low altitude differences along the whole debris-covered tongue (this is not valid for large DCGs such as Baltoro glacier).

Generally, it appears that the complexity of the ablation pattern increases in the upper tongue sector and crevassed areas, where the debris thickness variability is high. This is due to differential ablation and high ablation rates, which occur on the ice cliffs, areas with supraglacial lakes and seracs.

High ablation rates in the upper part of ablation area may support the final dynamic separation between the upper debris-free sector and the debris-covered tongue. This pattern is observed on some Italian debris-covered glaciers during the last years (i.e.: Brenva and Belvedere glaciers, Italian Alps).

Different studies demonstrate that also surface characteristics (roughness, slope, aspect) and debris properties (albedo, humidity, grain size, thermal resistance and void space) are key factors in the ablation variability on DCGs, but modelling energy fluxes over surfaces with high variability of these conditions is quite difficult (Nakawo *et al.*, 2000).

Debris cover characteristics

Continuous debris mantles at the glacier surface can result from rockfall events generally in the accumulation area, but also in the ablation area, originated from the lateral rock walls (Deline 2002) and the melt-out of englacial debris that has been elevated from the bed along the shear plans (Benn and Evans, 2010). Exceptional rockfall events occurred in the past on several glaciers which completely covered the ablation area of originally debris free glaciers, thus making them actual DCGs (e.g.: in 1920 it happened on Brenva Glacier, Mont Blanc area, Alps, see Deline, 2002). In other cases the transformation from debris free glaciers to debris covered ones took from decades to centuries (e.g.: Miage Glacier on the Alps and Baltoro Glacier in Pakistan).

Supraglacial debris cover commonly exhibits a great variability in thickness, lithology and grain size, reflecting the distribution of debris sources and transport paths, and subsequent reworking on top and within the glacier . Debris variability (spatial distribution, grain size) on the glacier surface is responsible for large differences in the distribution of thicknesses and therefore in thermal properties of the glacier surface over short distances, resulting in differential ablation (Benn and Evans, 2010).

Due to low albedo and high thermal conductivity, a thin debris cover increases melting of ice while a thick debris layer insulates the underlying ice and retards melt rates compared to surrounding bare ice surfaces (Østrem,1959; Nakawo and Young, 1981, Mattson and Gardner, 1989).

The lithology on a debris-covered glacier is usually very complex in relation to the litology of the surrounding rock walls and comprises: granite, gneiss, schist and limestone. The debris properties: colour, grain size and shape (granulometry), determine the surface albedo, layer porosity and structure influencing the thermal impact of debris on the ice ablation.

Where the debris cover is thicker (in areas close to the glacier terminus, where velocity is lower and the debris profile remains undisturbed or on the median moraines), the debris profile often shows a stratification (vertical sorting): fine debris in the deepest layer at the contact with the ice; mixed granules sand and a few pebbles in the internal layers and the last level close to the surface consists of coarse clasts with high void ratio (Kirkbride *et al.*, 2006). The lithology of the debris cover on Baltoro glacier is very complex. In principle it shows a mixture of granite, crystalline schists and limestone.

Exhibit 21 Debris profiles and measurements at Miage Glacier (Alps).

Surface temperature

Surface temperature (Ts) is the most important parameter when studying the surface energy balance of a debris covered glacier. It contributes directly or indirectly to all terms except the short wave radiation flux (see Mihalcea *et al.*, 2008b).

Supraglacial temperature measurements are of two types: field measurements with high temporal resolution (5 and 10 min) by thermistors and remotely sensed measurements from instantaneous ASTER surface kinetic temperature (90 m pixel size). The thermistor probes operate over a -30 to + 50 °C temperature range with a resolution of 0.25 °C at 0 °C degrading to 0.4 °C towards the extreme values. In our study thermistor probes were attached with their tips to rock surfaces, because an experiment demonstrated that this is the most stable method to measure surface temperature on debris-covered ice (Mihalcea *et al.*, 2008b). A comparison between the two sets of data evidence that, where the debris cover is discontinuous at the pixel scale, generally ground-based data are higher than the ASTER data. A 24 hour high resolution Ts measurement series shows differences between the minimum and maximum of up to 25-30 °C due to the rather low heat capacity of the debris cover. There is a high correlation Ts-SWin (Ts increases and decreases rapidly as response to SWin variation during clear sky and cloudy days) on debris-covered ice, demonstrating the influence of SWin on Ts. An important parameter that greatly influences the Ts distribution is debris thickness as can be derived from ASTER data: Thin debris cover corresponds to low Ts and thicker debris to higher Ts due to the reduced influence of the underlying ice and the associated 0 °C temperature at the debris-ice interface.

The surface temperature distribution on debris-covered glaciers has a large spatial and temporal variability and therefore it is difficult to model. An empirical model was developed and applied to Baltoro glacier and we obtained a good correlation between modelled Ts and ASTER Ts data. A physically based model that gives a correct formulation for Ts from the general meteorological parameters would give better results, but it is difficult to produce distributed results, because the conditions at the debris-covered glacier rapidly change.

Exhibit 22 Surface temperature measurements (Photos by C. Mihalcea).

2. FORESTRY Reforestation Guidelines: Brief Notes for the Storing and Seeding of Seeds

2.1 Seed collection timing:

Table 1 Best timing for *Pinus* and *Picea* cones harvesting.

Species	Timing
Pinus wallichiana	Early October
Picea smithiana	Late September/ Early October

2.2 Storing of cones

Once cones of conifers species (*Pinus wallichiana* and/or *Picea smithiana*) have been collected, they should:

- Placed in large sacks
- Fill the sacks with cones only up to one –half to avoid heat buildup
- Ensure that filled sacks are tied at the top to allow for cone expansion
- Store the filled cone sacks on their side not upright.
- Change sacks if they get wet.
- Store the sacks in a dry, cool and ventilated place.

Generally, freshly picked cones are very moist, and is essential to reduce the moisture gradually to prevent fungi spread and mimic, at the same time, the natural maturation process. Try to avoid, if possible, the picking of cones during wet weather. Alternatively, reduce the number of cones per sack to promote uniform and faster drying.

It's important to keep the bags not in direct contact with soil to avoid soil moisture to spread into the sacks. After 2/3 weeks the cones will dry and ultimately they will open, making seeds extraction simpler.

2.3 Seeds extraction

First it's important to evaluate if cones dryness is sufficient to allow a complete extraction of the held seeds:

- Check that the cones scales are sufficiently open to allow an easy extraction of seeds on all (or most) of the cones length.
- Check more than one cone per sacks to evaluate the dryings process status.

From each cone a careful extraction of seeds is mandatory to avoid damages. Seeds shall be extracted on a fine knitted towel by gently shaking the cones. Spruce seeds are comparably smaller than pine one and should be handled with more care. In particular:

- Avoid seed's extraction in open environment to prevent seeds dispersion by wind gusts.

If possible, try to clean the seeds from the debris and eventually take the seed wings off by gently pressing it. This will facilitate the seeding process.

2.4 Storing of seeds

Once extracted, seeds shall be preserved inside sacks and stored in a dry and cool location (Temperature shall be equal to or below 5°C). Seed can be satisfactorily stored in this condition until the following spring, provided it is kept cool, in sealed sacks. Make particular attention on selecting the location for the seed storing: try to avoid as much as possible places which can be reached by rodents (mice, squirrels, etc). Place barriers or hang the sacks on the roof to make it harder to reach. Ideally, seed storing location should be close to the area selected for reforestation or at least at a similar altitude. This is important to couple local climate with seeds, making them ready to germinate.

2.5 Pre-seeding treatment

This section deal with the most important activity to perform before seeding. Seeding can be done in late autumn-early winter (*Winter seeding*) or in spring time when snow melts (*Spring seeding*).

A) *Winter seeding*: winter seeding shall be preferred whenever possible if the following conditions are met:

- reforestation location already chosen
- fence/protection of young seedlings from livestock browsing already built (or in the case if it is not needed).
- Seeds extraction completed before snow accumulation on reforestation ground.

Treatment of seeds: no particular treatment is needed to increase seeds germinability. The seeds dormancy will be naturally broken when warmer temperatures and water availability increase as snow melts in spring time.

B) *Spring seeding*: if winter seeding is not possible, an additional treatment shall be performed:

- Stratification: seeds shall be placed in a box filled with sand and kept wet with cold water (5°C) for at least 4/5 days. This treatment is necessary to break the dormancy and allow a fast germination once the seeds are sow.

2.6 Seeding

Every 1 meter (3 feet) make a small (5 inch x 5 inch) hole in the ground with a shovel. Brake the soil surface and the largest pieces of soil and create a soft, uniform and well mixed seeding ground for the seeds. Try to make the seedbed firm and horizontal.

Place 5 seeds on the seedbed trying to keep them separated one to each other. Cover the seeds with an uniform depth of soil so that the seed is not visible but mechanical impediment is not preventing seed germination. (be careful: pine and spruce seeds need a very tiny layer of soil to cover them, otherwise they do not have enough energy to germinate).

If possible, irrigate the hold to fix the seeds and to increase water availability.

Move 3 feet apart and make the next repeat the operation. If seeding on a slope, follow the contour line (move horizontally and do not go uphill, see fig. 1).

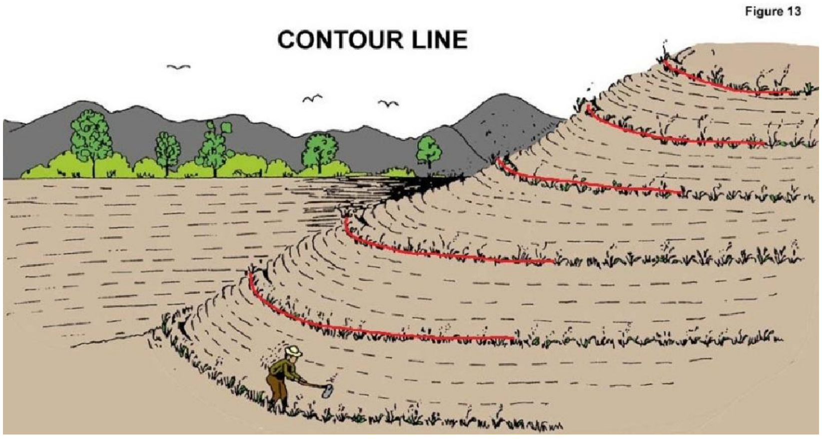


Exhibit 23 Contour seeding is following the red line, making holes always at same altitude

3. WILDLIFE
Wildlife surveys: standardization of methods and periods for CKNP Area

3.1 Standardize data collection

In order to enhance collaboration among stakeholders working on Wildlife in CKNP area and to make data available for all partners, a standardized data collection should be considered. Therefore priority valleys for CKNP management should be agreed and for each valley specific action plans should be developed mentioning specific tasks, roles, sharing of resources and costs. Data collection and filing should be carries out in a standardize way.

Methods, data and objectives of surveys should be shared among all the stakeholders (i.e. if surveys are carried out to set up a trophy hunting programme, the goal of the survey has to be clear to all the interested organizations).

The basic concept is to operate with the same methodology and in the same periods for the wildlife surveys.

3.2 Proposed Wildlife Surveys

Survey team

Each survey team should be made up by groups composed by 1 to 3 members. For each valley to be surveyed the number of people involved will be function of the extension of the area to be surveyed.

Wildlife surveys require reliable replications, to be effective. A reliable replication means: (i) the **same people** involved (only if the same people is involved it will be easy to find out the same vantage points used in the past) – it is important that at least *1 person for each group* (team=all the people involved in the wildlife survey; group=part of the team attending specific areas of the selected valley) *is the same than in the previous survey*; (ii) **same number of people** (if reliable surveys were carried out in the past, the number of people involved should not be changed, least of all decreased), (iii) **same areas** (the same areas have to be surveyed each time, in order to obtain comparable data; the number of surveyed areas may increase, never decrease).

Planning

A good planning is essential to obtain reliable wildlife surveys, and then reliable data. Therefore, an effective organization of wildlife surveys (where to go, how many people and how many teams) should be planned well in advance, following the organisation of previous surveys.

For this purpose, a valley specific action plan should be drafted and shared 1-2 weeks before the surveys, in order to inform the other stakeholders working in the area about the planning. This document has to mention vantage points to be used (a map should be attached), people involved, days of the survey, specific tasks, roles, sharing of resources and cost by each partner.

Requirements during survey

The following items will be required during the wildlife survey: camera, binoculars, spotting scope, altimeter, compass, data sheet, GPS, tents, sleeping bags, food items, map of the area.

If the planning is well done and the number of groups and vantage points known well in advance (i.e. we know, by now, that 3 groups are needed for the Nar valley, therefore a team of 9 people), also the material retrieval (each group has to be provided by 1 compass, 1 GPS and 1 spotting scope; i.e. if 3 teams are needed to survey the Nar valley, 3 GPS, 3 spotting scopes and 3 compasses should be available) among all partners will be easier.

Objectives of the survey

1. To count and estimate the population of Himalayan ibex and Markhor in the catchment area/valley.
2. To record any other wildlife species observed in the area.

Methodology of the survey

1. Surveys should be normally carried out twice a year, on May and December (approximately). In very few areas, surveys will be carried out only in Autumn, because of difficult access in spring.
2. Surveys should be carried out early in the morning and/or late in the afternoon because most ungulates, *i.e.* ibex and markhor, are active and graze during these parts of the day and can be easily sighted.
3. Vantage points should be established taking GPS references (WGS84-UTM system; dd mm ss). Binoculars and spotting scope will be used to scan wildlife in the area.
4. A camera should be used to take photographs of pastures where observations are carried out.
5. Direct counts should be used to determine wildlife numbers. The herds seen will be further classified into different age and sex classes (males, females, yearling, kids and undetermined individuals, total; among males, a separate count on trophy size individuals will be made). In autumn counts, the number of kids will be a very useful population parameter to assess reproductive rate.
6. For all wildlife monitoring surveys, the same vantage points, established during the first field survey, should be used. It is paramount to get involved the same people.
7. While using the same vantage points each year, if a certain pasture in one year has an ibex population/herd and, in the next survey season, no ibex herd is seen in the same pasture, from the same vantage points (VP), we should note down that VP and pasture. We should not ignore that but we should write real zero in that place. This will show that the same pasture has been visited in consecutive years. This information will help to analyze data, e.g. the impact of different variables on the ibex population etc.
8. For each observation, also the distance (roughly estimated) and the angle to the North (using the compass) should be useful to locate the herd.
9. Investigation through a questionnaire and general discussions with the local people, shepherds and former hunters living in the village/valley (10% of the population of the Valley – randomly selected) should be carried out.

4. MOUNTAIN HYDROLOGY Stream flow measurement protocol

4.1 Introduction

We present here a suggested protocol, or guideline, for in stream discharge measurement within the CKNP, and generally speaking within Northern Karakoram, for the purpose of water resources monitoring. The protocol focuses upon methods for flow measurements within high altitude, mountain areas, with target streams typically featuring i) torrential regime, i.e. with low, and possibly null, discharges during Winter, and increasingly high discharges during Spring and Summer, ii) unregulated regimes, in the absence of significant upstream water regulation, as e.g. when dams or reservoirs are present, and iii) natural channel, i.e. with no artificial channel modification. Under such hypothesis, in stream discharge measurement is utmost complex, because i) high flow variability is observed, implying high variable flow sections, ii) no estimate of discharge is possible from upstream release at hydraulic structures, and iii) no simple area-velocity-discharge, or *stage-discharge* curves, are easily available based upon regular flow section geometry. Under such circumstances, flow magnitude assessment and continuous measuring requires at least two steps, i.e. i) installation of a hydrometric station, continuously recording flow depth, and ii) calibration of a specific *stage-discharge* relationship, developed for the measurement section. This is further complicated by the intrinsic complexity of the environmental and topographic conditions of the monitored areas, featuring periods of (very) low temperatures, and chances of soil movement and radical channel modification during flood events. In our best knowledge, besides some indication concerning in channel flow measurements using wading, there is no protocol or standard approach available for installation (e.g. Marangunic, 2007), choice of characteristics and management of such a network of stations, and solutions need be found on a case by case basis, and considerable educated guess based upon on site expertise is required. The authors of this suggested protocol possess now a considerable experience in the area of hydrological monitoring in mountain areas, including design and installation of several hydrometric stations in the Alps, the Andes, Himalaya, and Karakoram. Thus, the suggested guideline stems from the experience of the proposers and actually mirrors the presently available state of the art within this field of expertise. The hydrometric stations discussed within the development of SEED project, and reported within the IPMP, were installed and are managed according to the proposed guideline, and we suggest that design and installation of a new network of stations within the CKNP may follow the indications given here.

4.2 Discharge measurements.

To measure stream flows in natural or artificial channels, several methods are available. A rough distinction can be made as follows:

- *Eulerian methods.* Flow is evaluated by observation of some physical variables related to discharge (velocity, flow depth, pressure ...) from a fixed stand point;
- *Lagrangian methods.* A stem of the river is considered and the along-track variation or motion of the physical variables (float, tracer, etc..) provides indication of flow discharge.

Further difference is given by time span of observation:

- *Continuous*, i.e. a physical variable (e.g. flow depth) is monitored at regular intervals in time; this is possible installing gauge stations with data loggers and specific sensors case by case;

- *Sporadic*, i.e. a physical variable (e.g. flow velocity or discharge) is monitored spot; to set up a good number of observed data it's necessary to plan many measurements campaigns so as to record the different flow conditions.

Eulerian methods

Eulerian methods concern different variables:

1.1 *Direct discharge measurement*. Water is gathered into a tank and discharge is obtained *vs* time;
1.2 *Direct velocity measurement*. Flow discharge is deduced from velocity and flow area:

$$Q = V \cdot A;$$

1.3 *Flow depth measurement*. Flow discharge is estimated by way of stage-discharge curve.

Direct discharge measurement.

Direct discharge measurement in natural stream is not usually possible, unless for very small streams, due to the considerably high flows.

Direct velocity measurement.

Area/velocity method deliver discharge by integration of flow velocity upon flow area:

$$Q = \iint_A V(x, y)\, dxdy \ ,$$

and normally flow velocity is measured into a number of small areas. Finally discharge is estimated as the sum upon the whole area:

$$Q = \sum_{i=1:n} V_i A_i \ .$$

A number of vertical wedges is defined and average velocity is calculated in each. Verticals are uniformly spaced to capture velocity change across the section. As a rule of thumb, distance between two verticals should not exceed 5% of the total width and discharge between them should be less than 10% of the total flow.

Water depth < 1.0 m.

In this case it is possible to make the measurement of the velocity with a Doppler flow tracker; this instrument is able to measure fields of flow velocity in 3D (XYZ) and to estimate discharge through velocity/area (1 measure of speed at 0.6*h for $h < 0.6$ m and 2-3 points for $h > 0.6$ m, ISO-USGS standards). The flow tracker is used with wading technique and section geometry is calculated to allow extrapolation of the stage-discharge relationships, either by way of Manning's equation, or by direct calibration.

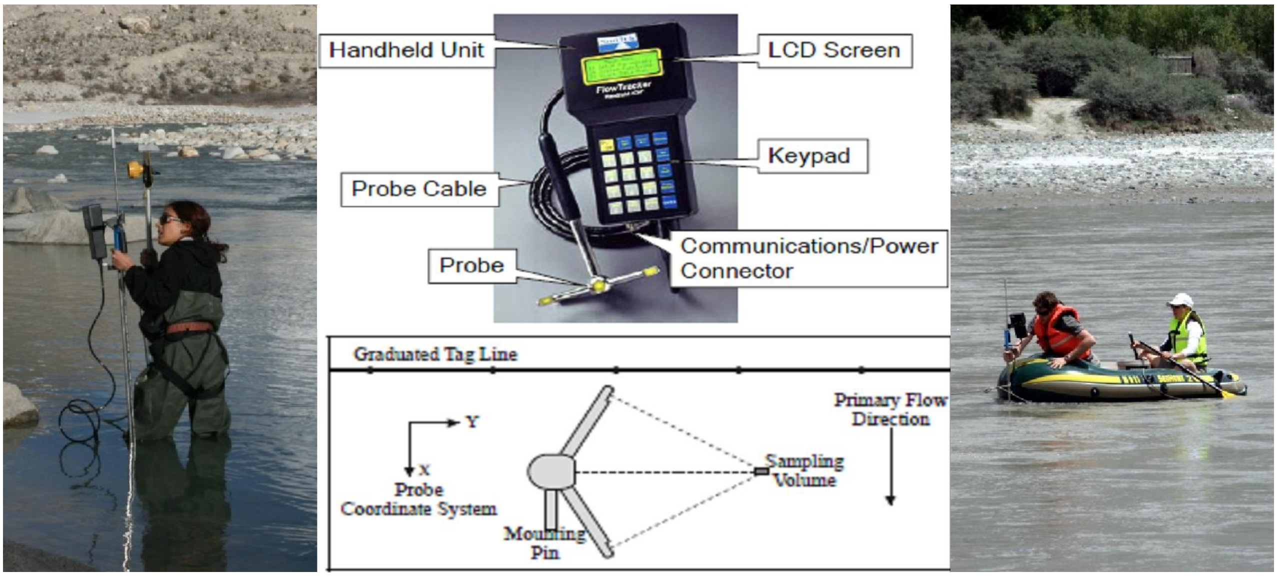


Exhibit 24: Flow Tracker instrumentation and measurement.

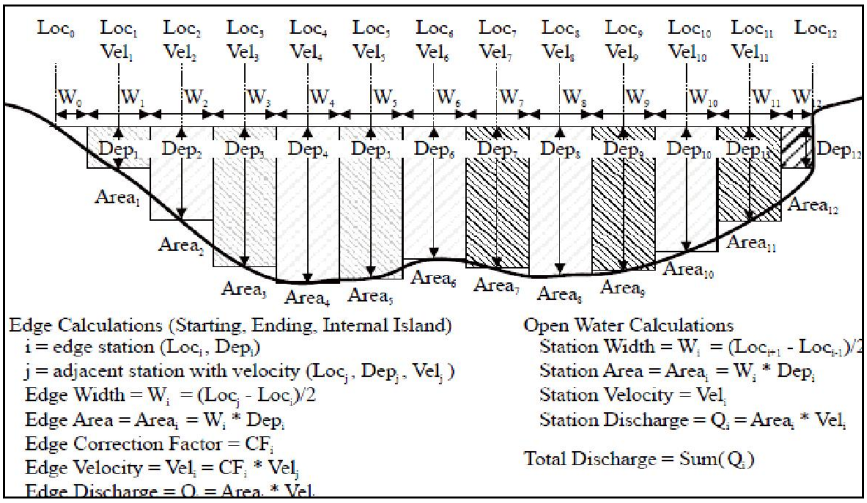


Exhibit 25 Mid Section River Discharge Measurement Equation. U.S. Geological Survey (USGS), ISO standards 748 (1997) and 9196 (1992). E.g. Corbett (2005)

Flow tracker measurement procedure:

- Cross section benchmarks location;
- Measuring tape extend;
- Instrument setting;
- Space sampling setting;
- Point by point measurement

1) distance from the start;
2) water depth;
3) stream velocity.

Water depth > 1.0 m.

In this case due to high water depth and flow velocity it is not possible for an operator to carry out wading measurements. The velocity may be then measured by dipping in the stream of a whirl flow meter, from a bridge or a boat. Rotation velocity of the whirl allows estimation of flow velocity. Due to its precision, the instrument is easily employed to survey hydraulic capacity with simultaneous measures, in the more meaningful points of a section. If water speed is too high for the whirl to be stable, it is necessary to employ a torpedo stabilizer (between 5 and 150 kg) with the aim of forcing the whirl parallel to the flow.

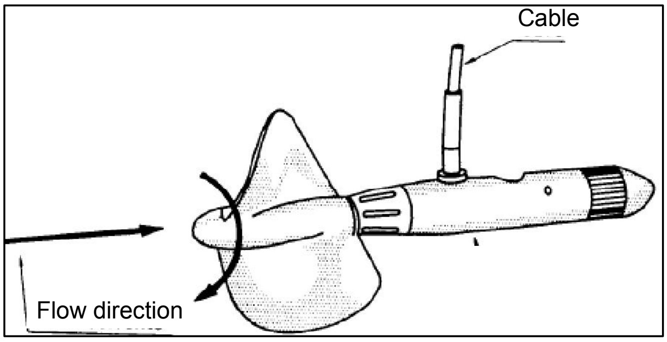


Exhibit 26: Whirl flow meter.

Indirect hydraulic approach and flow depth measurements.

The basic assumption is that the fluid flows throw the stream under uniform motion, i.e. "known a river bed, cross section shape, slope, roughness of the surface, a give discharge can move in uniform motion with a certain average speed and a slope of the free surface equal to the channel bottom slope". Given the average speed it is enough to multiply it for the wet area to obtain the discharge:

$Q = V A$

Wet area A is a function of flow depth h:

$A = A(h)$,

Normally taken in the deepest point of the cross section, *thalweg*. Using the Chezy formula for flow velocity under uniform motion $V = \chi(Ri)^{0.5}$ flow discharge is estimated :

$$Q = k_s \sqrt{i} R^{2/3} A(h),$$

That is via Manning's equation. Wet area and hydraulic radius are univocal functions of the flow depth. Therefore, discharge is fixed once flow depth is known.

"In natural water bodies, displaying variable bottom, it is rare that the uniform motion is really observed. However, if a stem of river bed with regular enough slope, sufficiently stable bottom and side walls and far enough away from hydraulic structures like dams, etc.., is considered, conditions of permanent, albeit not uniform motion, exist, so that a specific link between discharge and depth is still usable."

In such case this mathematic link can be determined in empirical-experimental ways, by making several stage-discharge measurements. The *stage-discharge* law is normally expressed in chart form or via tables, as obtained by interpolating equations obtained from data, such as:

$Q = Q_0 + ah^m$,

with Q_0 stream flow for the zero depth of the hydrometer, and a and m are calibrated parameters. Clearly, intense flow events may modify the river bed and the shape of the section, and thus *stage-discharge* relationship. Thence, continuous field measures are necessary in order to re-calibrate the relation $A = A(h)$, and $Q = Q(h)$.

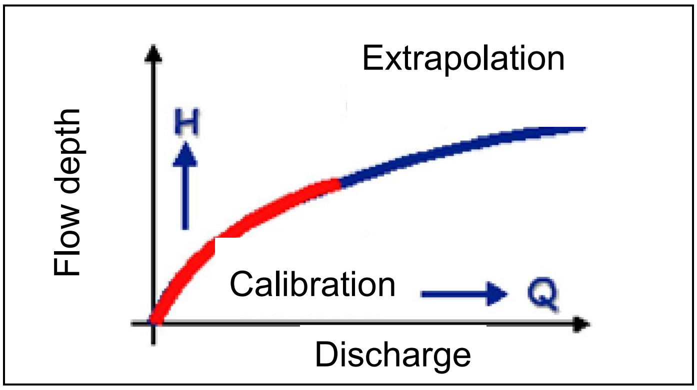


Exhibit 27: Stage-discharge calibration and extrapolation.

Operatively, the continuous measurement of flow depth may be obtained via two different approaches, depending on whether the device is immersed into water or dangle above the surface.

Pressure transducer: this sensor is based upon a piezo-resistive sensing element converting hydrostatic pressure into an electrical signal. The device is fixed into a pipe immersed into water and it is statically compensated in pressure by means of a pneumatic tube carrying atmospheric air, integrated within the connection cable linking the device to the data logger. This device is normally little expensive, and relatively easy to install. It is ideal for well-defined cross sections, like canyons, where the shape of the boundary is stable and not changing in time, due e.g. to water erosion. The pipe protects the sensor by sediment and stones transported by the flow that could damage it. Unfortunately, during heavy floods water may detach the pipe and break the device, and freeze and thaw cycles could spoil the sensitive part of the instrument.

Exhibit 28: Pressure transducer mounted at the bridge near Paiju.

Sonic sensor: short ultrasonic pulses in the range of 10 to 70 kHz are emitted by the transducer toward the water surface, then reflected by water surface and received back by the device. The pulses travel at known speed, and the elapsed time from emission to reception is proportional to distance. So, known the fixed position of the sensor and its offset from *thalweg* it is possible to evaluate flow depth. The mounting and maintenance of the device may be complicated, especially within orographically complex areas, given that this must normally be hung above the water surface by way of steel frames, or from a bridge. Occurrence of vibrations, say due to wind or moving machines (cars, trucks), and motion of a bridges may disturb the sensor. This device is also more expensive, e.g. as compared against piezo-resistive devices, and it's suggested where it is not possible the use of a piezometric sensor. Typical situations are wide cross sections, with low banks slope and high flow.

Exhibit 29: Sonic sensor mounted at Shigar's bridge.

Lagrangian methods

Salt tracer.

This technique can be used as either alternatively or complementarily to velocity/area methods (e.g. Kite, 1992). In sites with high turbulence, velocity and flow depth, where wading or use of whirl would be complicate/dangerous, tracers can be used alone, and calibration of stage discharge curve can be done by coupling (as many as possible) flow measurements with as many water depth measurements. Otherwise, if section area can be measured, but velocity cannot be estimated by way of flow meter, tracer methods provide discharge estimation that can still be used to calibrate Manning's equation. The principle of dilution allow discharge estimation by dilution of salt, injected with known concentration. Since tracing must be uniform within the flow, injection must occur several meters upstream of the flow measuring section.

Two techniques of tracing measure can be used, namely i) constant injection, and ii) impulsive injection (Figure 1.1). In both cases the tracer is injected upstream of the measuring station far enough to obtain complete mixing. As a rule of thumb the necessary length upstream can be found multiplying 20 times the channel width B: L_{up} = 20-25 B.

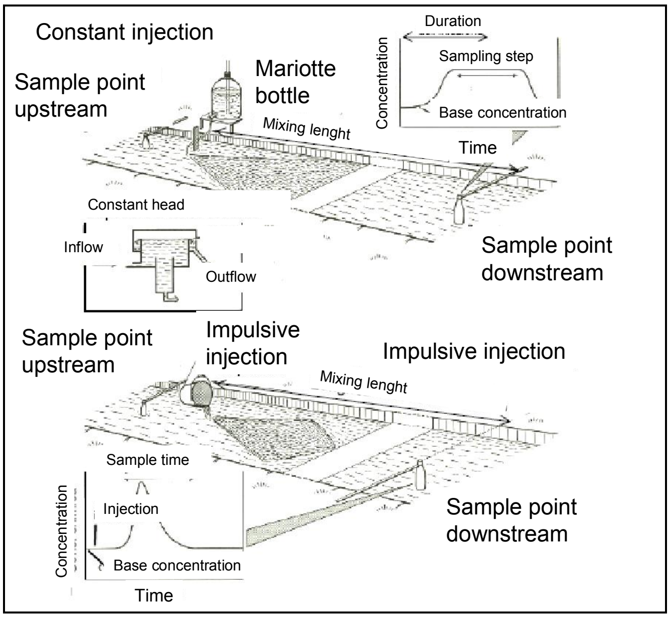


Exhibit 30: Tracer discharge measurement; up: continuous injection, down: spot injection.

In the case of the dilution method, with continuous injection the salt with a concentration C_0 known is added to the stream at a defined constant rate Q_0. This is carried out normally by application of a Mariotte flask or similar equipment. Because of dilution the tracer solution has at the measuring site the concentration C_m under the unknown discharge Q_m:

$$C_0 \cdot Q_0 = C_m \cdot Q_m$$

Thus giving: $Q_m = (C_0 \cdot Q_0)/C_m$

With impulsive injection a volume V_a of solution containing a certain weight W_t of salt is dropped in the stream. Discharge is valuated as follows:

$$Q = \frac{(C_i - C_b)V_a}{\int_0^\infty (C_v(t) - C_b)dt} = \frac{W_t}{\int_0^\infty (C_v(t) - C_b)dt}.$$

Where C_i is the initial concentration of the injected solution, C_b the base concentration, C_v the concentration of the downstream sample measured in times. As a rule of thumb one can use salt in reason of 0.2-1 kg/m^3s^{-1} (*e.g.* Hubbard and Glasser, 2005).

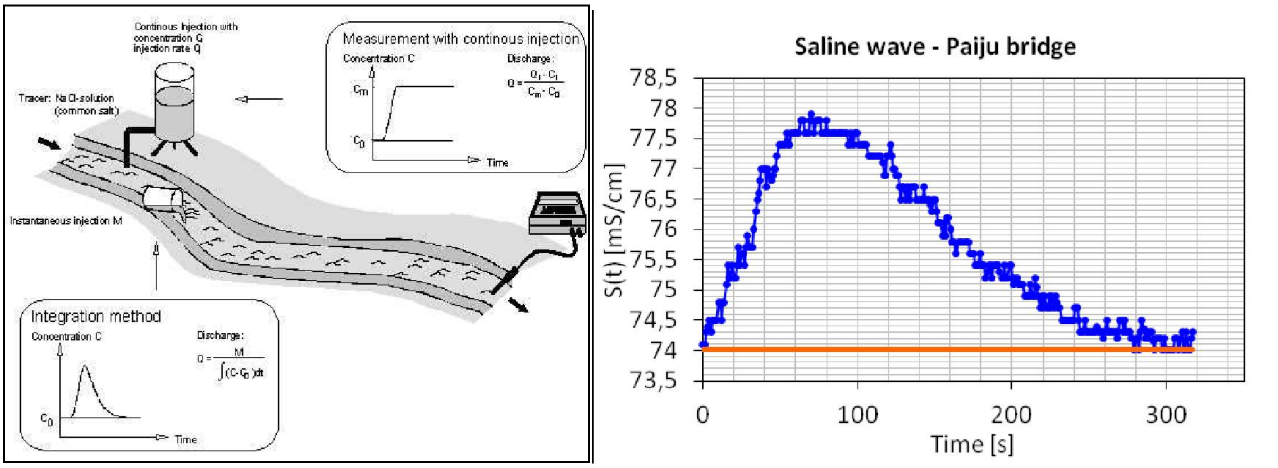


Exhibit 31: Tracer discharge measurement and sample of conductivity recorded at Paiju bridge with a 6.4 kg salt injection (resultant Q=26.5 m^3/s).

4.3 Installation of hydrometric gauge stations.

Instrumentation

- Datalogger and waterproof box;
- Sensor;
- Link cables.
- Power supply: solar panel, battery and regulator;

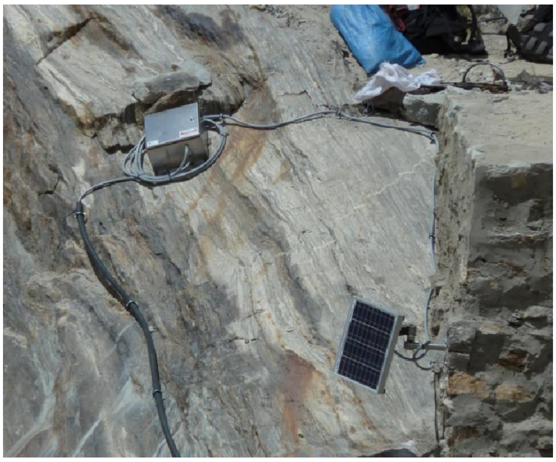


Exhibit 32: Instrumentation at Paiju bridge.

Figure B3.1.

Gauge location

- choice of the kind of sensor according to the morphologic and hydraulic conditions;
- stable and well defined cross section;
- the least possible turbulent flow conditions;
- easy to reach place;
- good sun aspect for the solar panel.

Installation

Case of piezometric sensor:

a) Regulation of the length of the pipe according to the distance between box location and dipping point;

b) Insertion and locking of the sensor with cable ties into the HDPE pipe (1 ¼ inches diameter);

c) Fixing of the pipe to the rock with collars and steel cable;

d) Fixing of the box and of the solar panel and making of all connections;
e) Testing of the correct functioning of the station and checking of the water depth measure;

Case of sonic sensor

a) Design, forging and positioning of the support;

b) Fixing of the box and of the solar panel;

c) Positioning of the cables;

d) Making of all connections;

4.4 Topographic surveys.

Theodolite plus distantiometer or total station.

The theodolite is a precision instrument for measuring angles in the horizontal and vertical planes. It consists of a movable telescope mounted within two perpendicular axes, the horizontal and the vertical axis. When the telescope is pointed at a target object, the angle of each of these axes can be measured with great precision, typically to seconds of arc. The distantiometer (or electronic distance meter EDM) is a precision instrument for measuring distances. When the theodolite is integrated with the distantiometer we have the so called total station (figure 1), that allows the measurements of both angles (vertical and horizontal) and distance.

Exhibit 33: Total station.

How to set up a theodolite and make surveys.

First, a mark in the floor has to be made in order to identify the station point (that from now on we call A) for future surveys. Over this point the tripod has to be positioned and the theodolite has to be placed over it and elevated up to survey's eyes. Adjust the theodolite to level by adjusting the tripod legs and the screws: turn the screws A and B (figure 2) in opposite direction to center the bubble along the AB axis then turn the screw C to bring the bubble to the center of the circular level. Please note that the theodolite has to stay exactly over the mark of the floor.

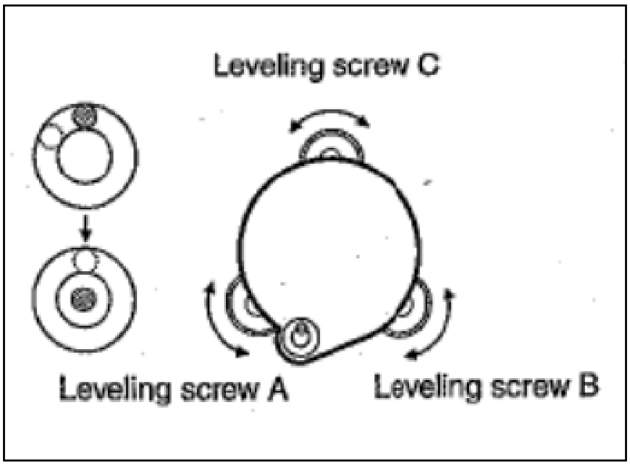


Exhibit 34: Diagram for leveling with screws.

Then level the instrument precisely, using the plate level:

1) Free the horizontal motion clamp and rotate the instrument horizontally until the plate level is parallel with line AB;
2) Bring the bubble to the center of the plate level by turning screws A and B in opposite directions;
3) Rotate the instrument by 90° around its vertical axis and turn screw C to center the bubble once more;

4) Repeat procedures 1) and 2) for each 90° rotation of the instrument and check that the bubble is correctly centered for all four points. If after 180° rotation, the bubble is off center, remove half the error in the bubble centering. Check that when you have swung another 180° back to the initial point, the bubble offset is the same as the offset you allowed to remain in the 180° rotated position.

Once the theodolite is leveled, double check the optical plummet to make sure that it is still centered. Now the instrument is ready to make surveys.

First of all the distance (h_T) between the mark on the floor and the optical plummet has to be measured. Take also note of the elevation H_A (m a.s.l.) of the station point A. In the point to be measured (point B) there should be a person with a rod of a known height (h_S) and a prism. Look through the main scope of the theodolite and aim the crosshairs at the point B. Twist the locking knobs to hold the theodolite in position on the exact point. View the horizontal and vertical angles and distance in the viewing scope on the side of the instrument. Take note on a field tab (table 1). Turn the vertical and horizontal axis 180° and re-aim the crosshairs at the point B, twist the locking knobs and take note of the measured angles and distances. In this way both face-left and face-right angle measurements are taken to eliminate most of the instrumental errors. Survey the other points in the same way.

Table 2 Example of a field survey log.

h_T [m]		1.5 m		
point	**h_S [m]**	**θh [gon]**	**θv [gon]**	**d [m]**
B face left	1.3	64.33	107.43	5.121
B face right	1.3	264.34	292.57	5.121
C face left	1.3	62.87	109.05	6.813
C face right	1.3	263.34	291.18	6.812
D face left	1.0	14.782	102.57	13.456
D face right	1.0	214.701	297.52	13.457

Exhibit 35: Topographical surveying of a river cross section.

Data analysis

Most of the instrumental errors can be eliminated averaging the face left and face right angle measures. In particular, the corrected vertical angle θ_v^* is valuated as follows:

$$\theta_v^* = \frac{\theta_{v\ face\ left} - (400 - \theta_{v\ face\ right})}{2}$$

And the corrected horizontal angle θ_h^* as follows:

$$\theta_h^* = \frac{\theta_{h\ face\ left} + (\theta_{h\ face\ right} + 200)}{2} \qquad \text{if } \theta_h > 200 \text{ gon}$$

$$\theta_h^* = \frac{\theta_{h\ face\ left} + (\theta_{h\ face\ right} + 200)}{2} \qquad \text{if } \theta_h < 200 \text{ gon}$$

The coordinates x and y of the measured points can be evaluated as follows:

$$\begin{cases} x_B = x_A + (d \cdot \sin(\theta_v^*) \cdot \sin(\theta_h^*) \\ y_B = y_A + (d \cdot \sin(\theta_v^*) \cdot \cos(\theta_h^*) \end{cases}$$

Where x_A and y_A are the coordinates of the station point.

And the elevation of the points H is given by:

$$H_B = H_A + h_T + d \cdot \cos(\theta_v^*) - h_S$$

Where h_T is the distance between the mark on the floor and the optical plummet of the theodolite, H_A is the elevation [m a.s.l.] of the station point and h_S is the height of the prism.

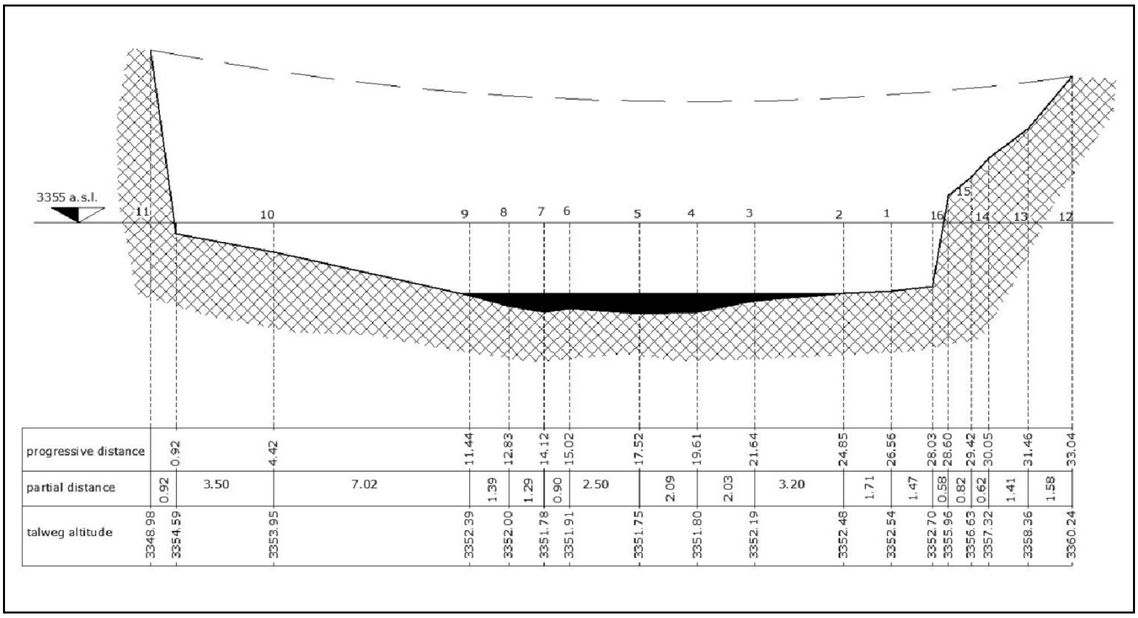


Exhibit 36: Paiju cross section.

GPS

Instead of the classical topographic methodology is alternatively or complementary possible to use the GPS, eventually combined with GLONASS. This approach let to the absolute positioning (WGS84 World Reference System) without any orientation and the coordinates of each point are immediately available. Precisions depend both on the used methodology, absolute positioning, real time kinematic (RTK) or differential (DGPS), and on the satellites visibility. In Gilgit-Baltistan region probably the only available method is the absolute one. Due to the intrinsic weakness of the precision concerning elevations the ideal configuration results combine GPS and direct measuring, with the rule or the level. With the GPS is possible to easily and quickly determine the planimetric coordinates fixing the altimetry with the levelling or measuring directly with the meter; e.g. in the case of a boat survey across a river, the water depth is measured manually while the position could be taken with the GPS.

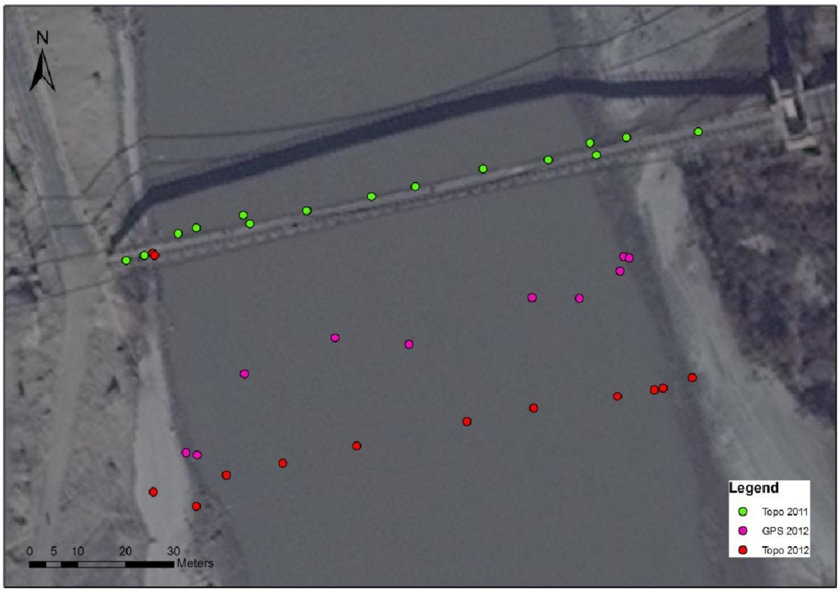


Exhibit 37: Topographic surveys at Shigar bridge.

Exhibit 38: boat survey at Shigar bridge.

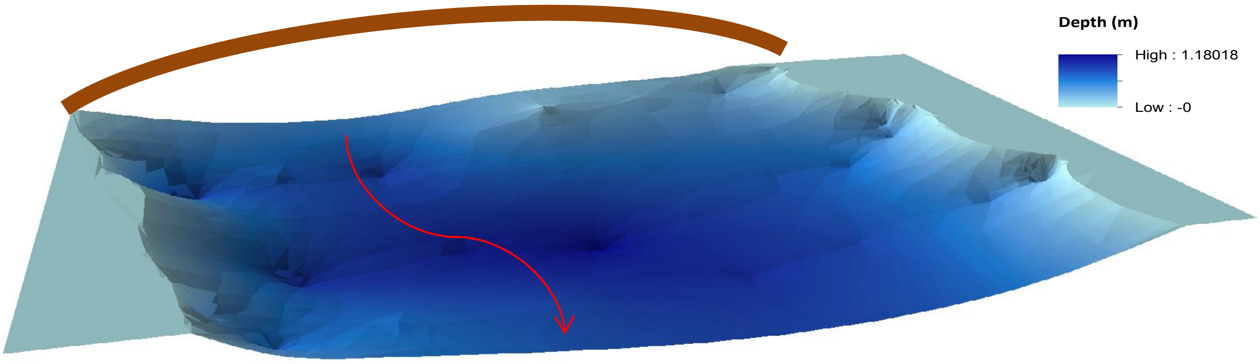


Exhibit 39: Digital depth model at Shigar bridge.

4.5 Stage-discharge curve.

Availability of observed data.

Whenever are available many observations corresponding to the different flow conditions it is possible to get the stage-discharge curve by the interpolation of the data and calculating immediately the *a* and *m* value of the power law equation $Q = Q_0 + ah^m$.

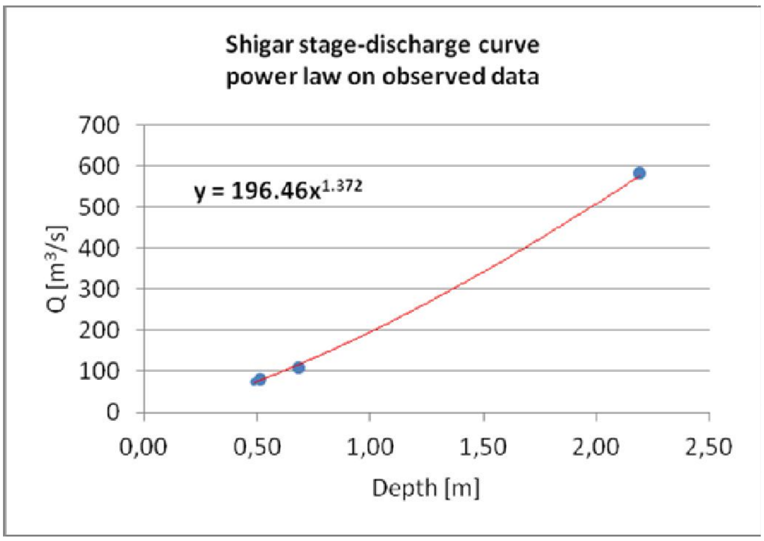


Exhibit 40: Stage discharge curve Shigar at Shigar, power law.

If the uniform motion conditions are fulfilled that *m* value should be close to 1.5.

Hydraulic simulation.

If observed data, as usual, are not enough or to validate the interpolated stage-discharge curve, different simulations are carried out with a hydraulic software, such as HEC-RAS (one-dimensional steady flow analysis) developed by the US Army Corps of Engineers.

1-D model implementation procedure:

- Defining cross sections geometry; minimum two, one upstream and one downstream;
- Setting river bed slope as boundary condition;
- Deciding the range of flow values to perform in the simulation;
- Choosing the hydraulic regimes, critical, sub-critical or mixed.

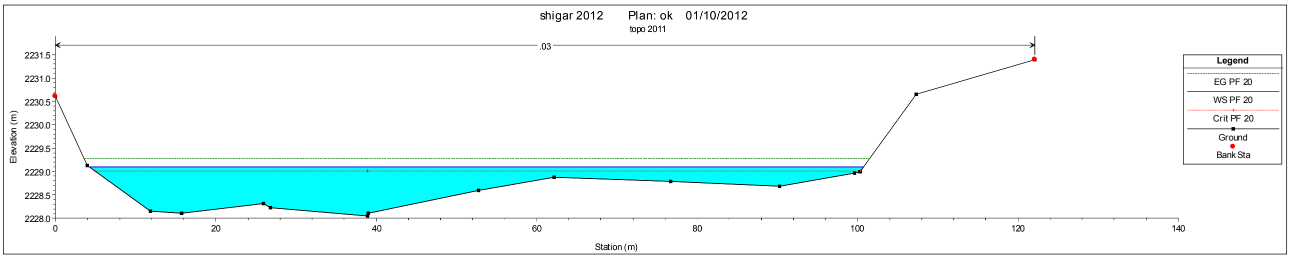


Exhibit 41: Hec-Ras simulation at Shigar cross section for Q = 100 m^3/s.

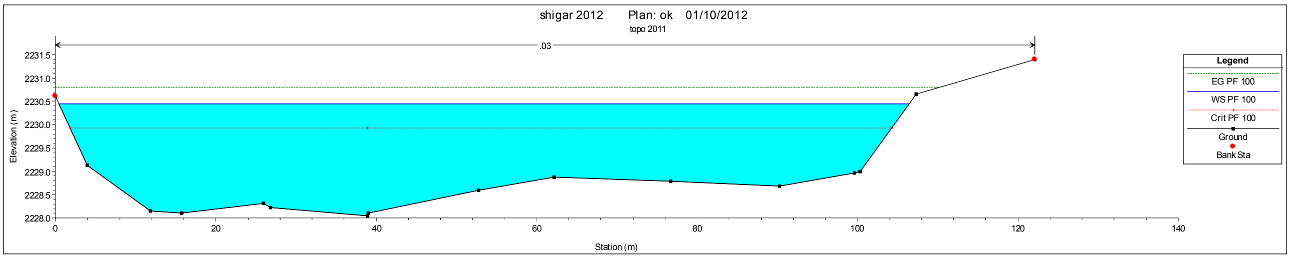


Exhibit 42: Hec-Ras simulation at Shigar cross section for Q = 500 m^3/s.

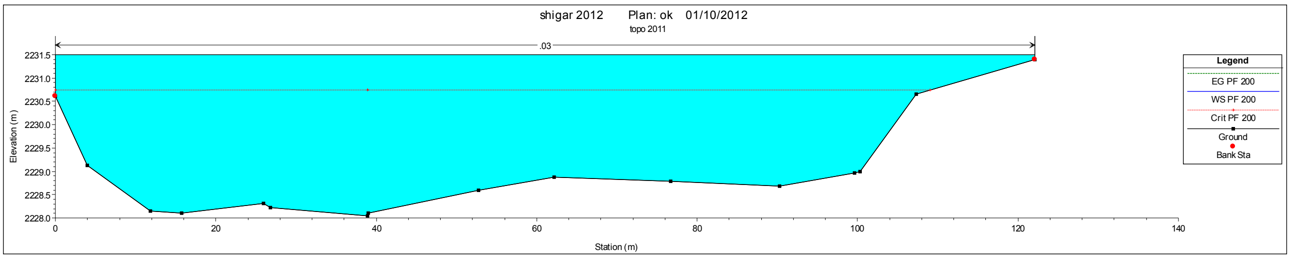


Exhibit 43 Hec-Ras simulation at Shigar cross section for Q = 1000 m^3/s.

The obtained values are then interpolated with the best performing law and compared to the available observed data:

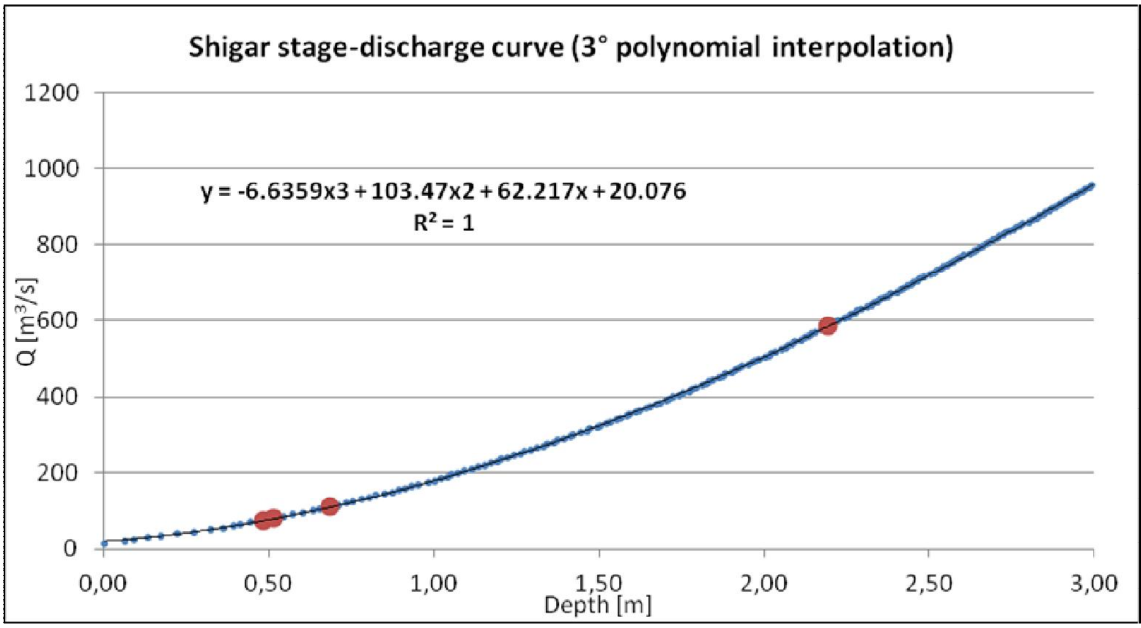


Exhibit 44: Stage discharge curve Shigar at Shigar, polinomy.

4.6 Practical remarks

The proposed protocol may be considered as a preliminary approach to suggest a procedure for designing and building of a hydrometric network within the CKNP. Some main issues in the realization of a hydrographical network can be thus schematized as follows, depending upon type of installed devices (*i.e.* sonic gauge or pressure transducer).

1) Low accessibility of the interest sites, also considering the transport of material necessary to installation.

2) Instrumental malfunctioning (e.g. intrinsic of the device, due to cold climate, and/or for suspension load, bed load). This is especially for pressure gauges, but applies also for sonic gauges, say if cables and other pieces are nearby the floodplains.

3) Difficult positioning in thalweg (pressure gauges).

4) Complicate installation by hanging (sonic gauge).

5) Difficult flow measurements by wading and/or tracer for bigger flow sections.

6) Morphologic conditions of the river bed, evolving in time, and modifying stage-discharge relationship.

7) Choice of a design discharge.

1) The chosen sites may to coincide with the presence of roads near the river bed, and in particular in presence of narrowing and bridges. Even when accessibility is given only by trails, accurate choice of the station site may be carried out so that they are more accessible. The necessary tools me be carried by porters during an expedition.

2) The stations should be installed in a repaired as possible position, to decrease the chance of malfunctioning due to environmental conditions and hydraulic stressing, e.g. for high turbulence and solid load. However the stations will demand continuous monitoring, likely by CKNP staff, with regard to possible malfunctioning, but even for data downloading, etc.

3) The pressure devices should be in the thalweg line, or lowest bed part, to avoid null reading of the sensor in presence of water. Positioning of the sensor in thalweg would however expose the sensor to current and solid load. So the device should be protected by use of hoses, either in plastic o metal, and shielded from the intrusion of sand and gravel.

4) Mounting a sonic gauge may be complicated, due to the device hanging frame (see Figure 2.20 here). Also, presence of strong wind may hamper measurement by vibration or by movingthe device. This needs be taken into account when planning installation.

5) Wading techniques are suitable for measurement of stream flows in mountain torrents of small size, or better with acceptable flow depth and velocity. The calibration of the stage-discharge equation is easier under these conditions. Use of tracer is suitable, but some knowledge of flow depth in the section is still necessary.

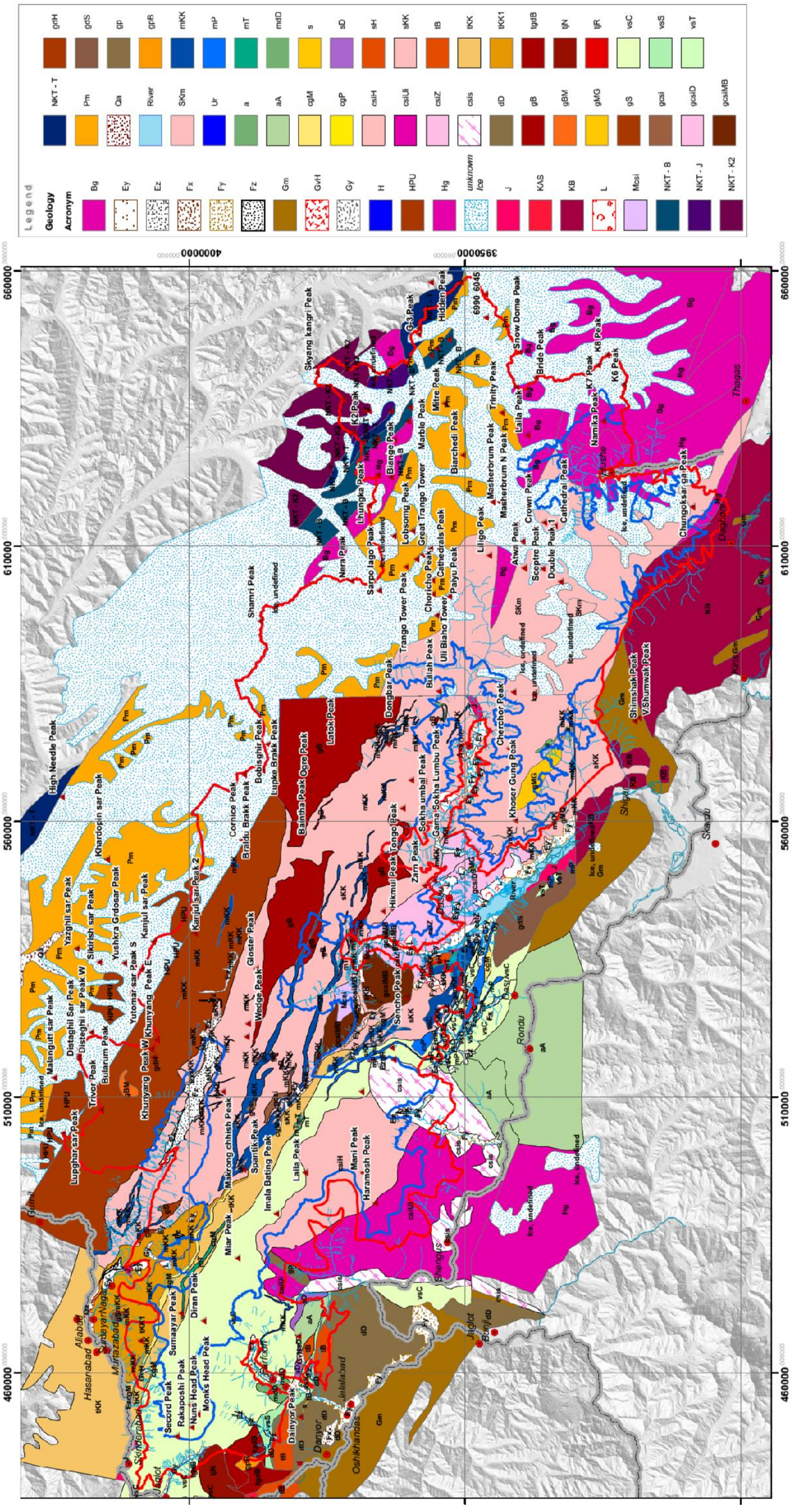
6) Flow measurements and section survey should be made at least each year, at the onset of thaw season, to account for variation occurring during seasonal high flows. Ideally, for the most accessible sections, surveys should be done after each noticeable flood event. Also, because for high flows immersed devices (pressure gauges) may be damaged, maintenance is necessary therein.

7) Ideally, a design flow discharge should be estimated whenever it is necessary to install a hydrometric station, aimed to i) know the greatest flow conveyed in the section when it is naturally defined, ii) define the width of the section whenever artificial confinement would be necessary (e.g. by side walls). This could be done by way of critical flow design, pending the choice of a reference return period.

Research Baselines for Central Karakorum National Park Management Plan

ANNEXES

ANNEX 1: GEOLOGICAL MAP



Annex 1: CKNP Geological Map

ANNEX 2: REFERENCE LIST TO BE USED FOR A GEOLOGICAL MAP FINALIZATION

Zanchi A., 1993 Structural evolution of the North Karakorum cover, North Pakistan, in: P.J. Treloar, M.P. Searle (Eds.), Himalayan Tectonics, 74Geol. Soc. London (1993), pp. 21–38 Spec. Publ.

Zanchi A., and M. Gaetani, 1994 -Introduction to the geological map of the North Karakorum Terrain from the Chapursan valley to the Shimshal pass 1 : 150,000 scale- Riv. Ital. Paleontol. Stratigr., 100, pp. 125–136 1

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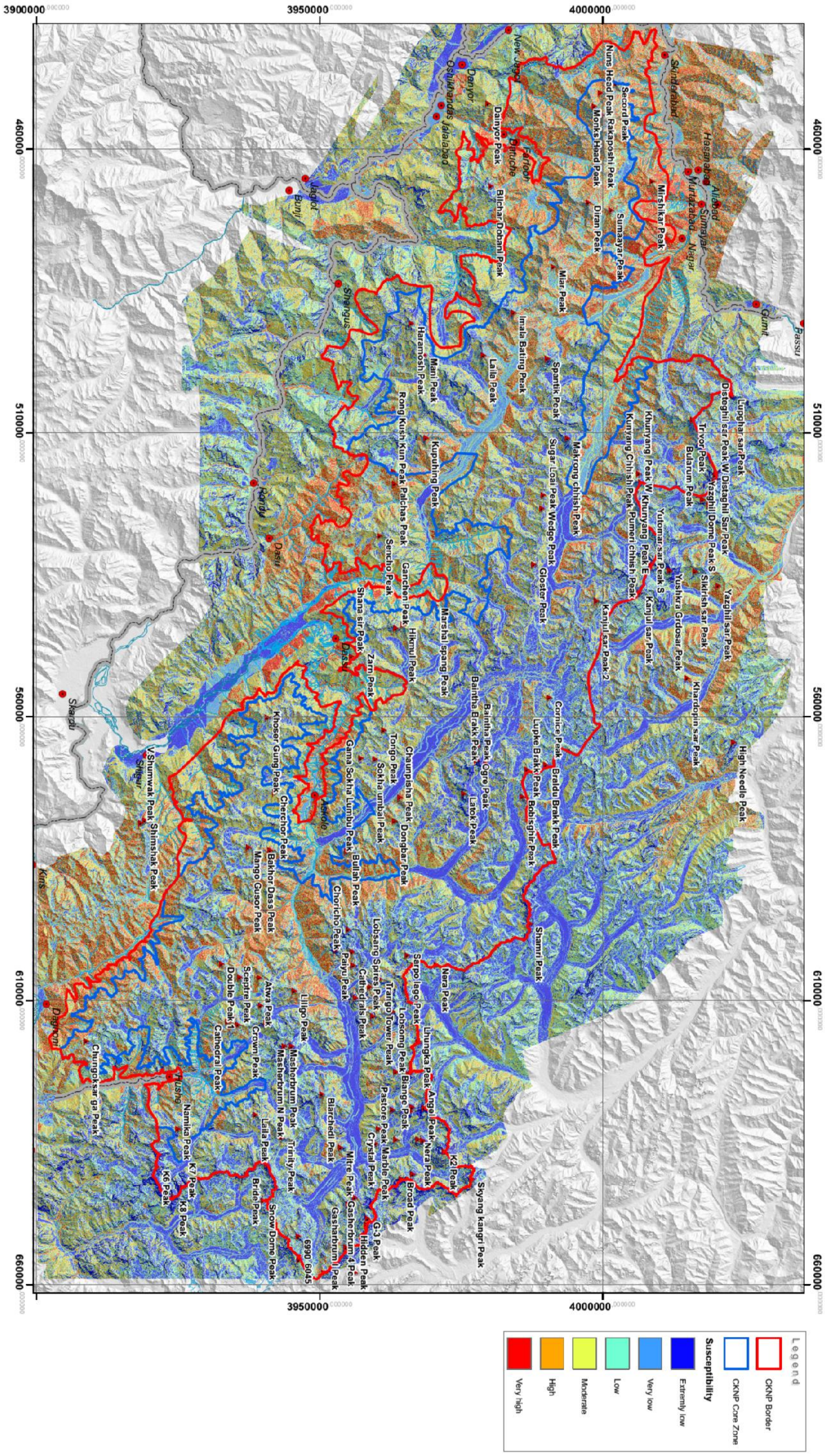
ANNEX 3: LAND SUSCEPTIBILITY MAP



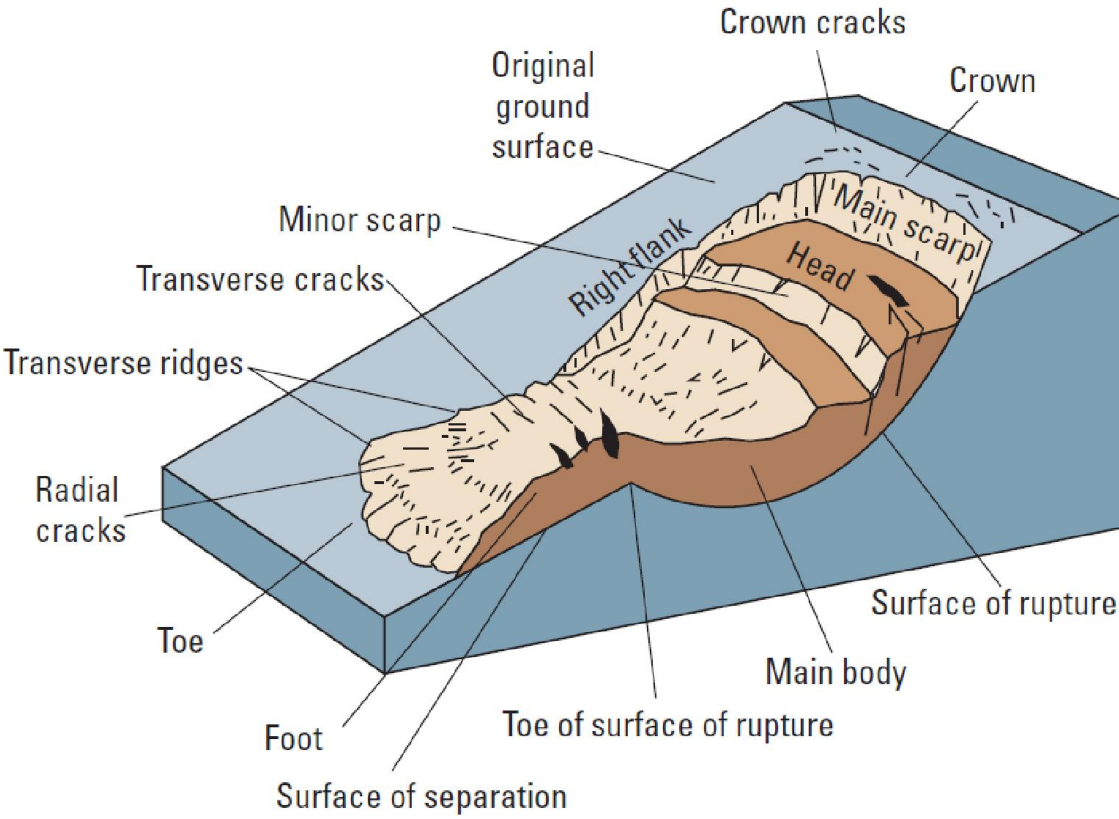
Annex 3: CKNP Land Susceptibility Map

ANNEX 4: LANDSLIDE MANUAL
a short guideline

What is a landslide?

A landslide is a movement of soil (rock, debris, or earth) down a slope under the influence of gravity. The fracture of the slope happens when gravity exceeds the strength of the materials (USGS, 2013).

There are several classifications for landslides and they are associated with the movement mechanism, the failure type, the material involved and the movement velocity. To be able to understand each other, a common terminology is required. Figure 1 reports the main useful terms to describe a landslide phenomenon.



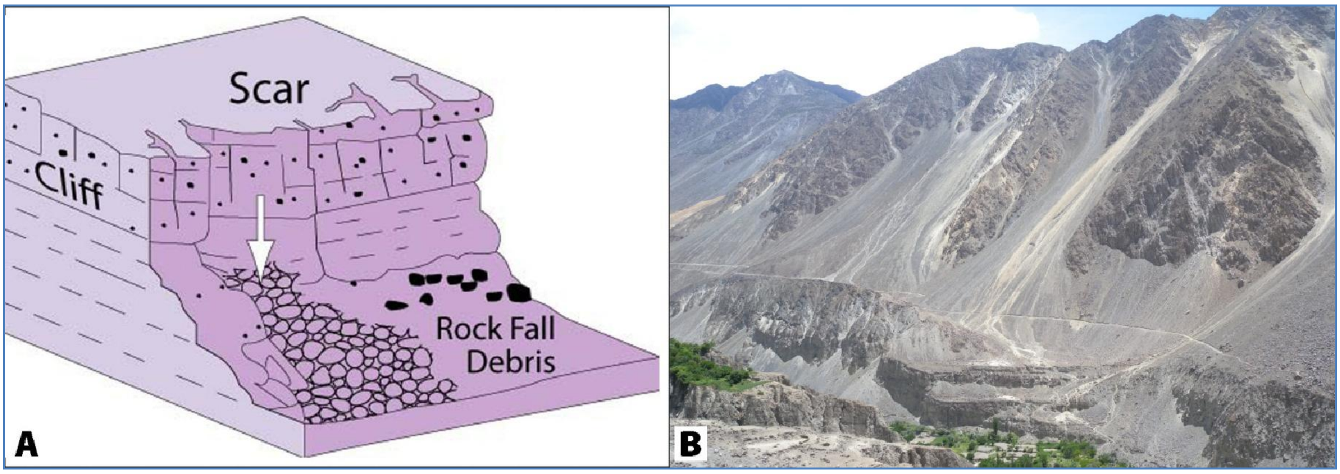
Annex 4-1: An example of a rotational landslide evolving in an earthflow (from Varnes, 1978; USGS, 2013)

Basic types of landslides

As mentioned above, landslides can be classified into different types on the basis of the type of movement and the type of material involved. In brief, the material in a landslide mass is either rock or soil (or both); it is described as earth when mainly composed of sand-sized or finer particles and debris when composed of coarser fragments. The type of movement describes the internal mechanics of the occurred event: fall, topple, slide, spread, or flow. In the following pages, landslides will be described using terms that refer respectively to material and movement as, rockfall, debris flow, etc. Landslides may also be defined as complex when more than one type of movement is identified, as, for example, rock-slide, debris flow, etc.

Rock fall

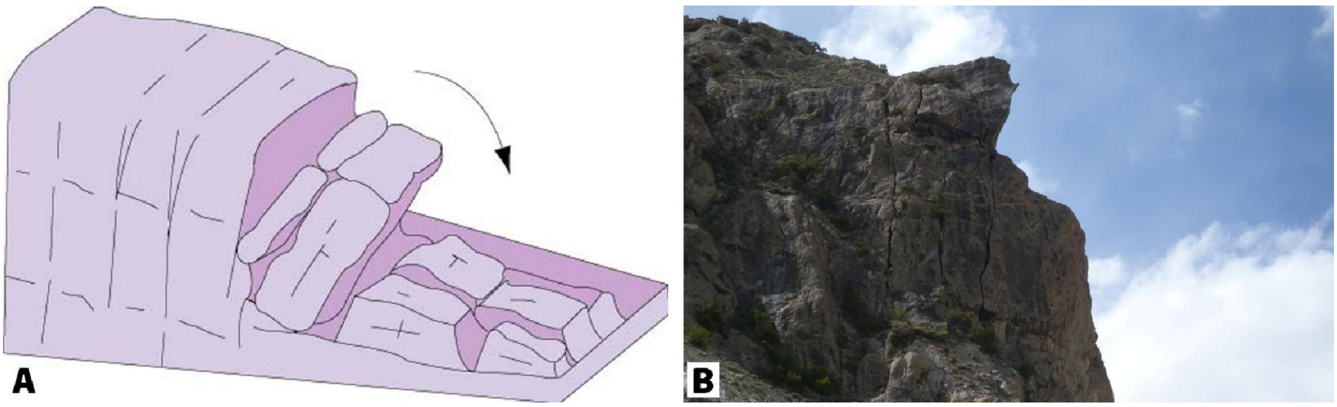
Rock or earth can have abrupt downward movements causing the material detachment from steep slopes or cliffs. The fallen material lies on the lower slopes at lower angles giving origin to the so-called talus or debris fan. While falling the material can brake on impact and/or roll along the slopes until the terrain becomes more flat. The movement is from very to extremely fast. The triggering mechanisms can be due to undercutting of the slope (such as stream and river erosions, or differential weathering, such as the freeze/thaw cycle), human activities such as excavation during road building and (or) maintenance, and earthquake shaking or other intense vibration.



Annex 4-2: A) Rock fall (www.bgs.ac.uk); B) Bagrot valley, a beautiful example of scars as a consequence of rock fall.

Topple

While a topple is occurring, the moving mass has a forward rotation out of the slope. The phenomenon can be driven by gravity exerted by the weight of material upslope from the displaced mass. Or can be due to water or ice intrusions in the cracks inside the mass. Topples can occur in rock, debris (coarse material), or earth materials (fine-grained material). The movement is from very to extremely fast. The triggering mechanisms can be due to gravity, water or ice intrusions in the cracks, human activities such as excavations during road building and (or) maintenance, and earthquake shaking or other intense vibration qwa as in the case of rock fall. Undercutting can be another option.



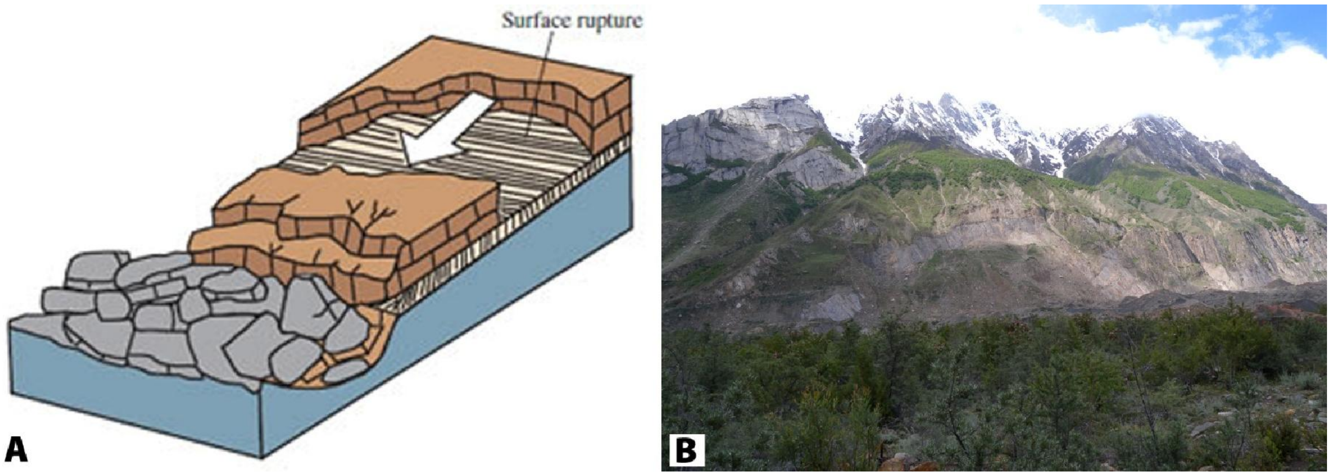
Annex 4-3: A) Rock topple (BGS, D. Petley – blogs.agu.org, 2013); B) Chogolungma glacial valley, an example of unstable northern slope, ready to collapse.

Slides

Down the slope, there can be a movement of soil or rocky mass that can occur on weak surfaces or on relatively thin zones of intense shear strain. This movement can have different paroxysmal phases along different ruptures. Surfaces can be planar, and in this case we can talk about translational landslide, or can be concave and we can have rotational landslide.

Translational landslide

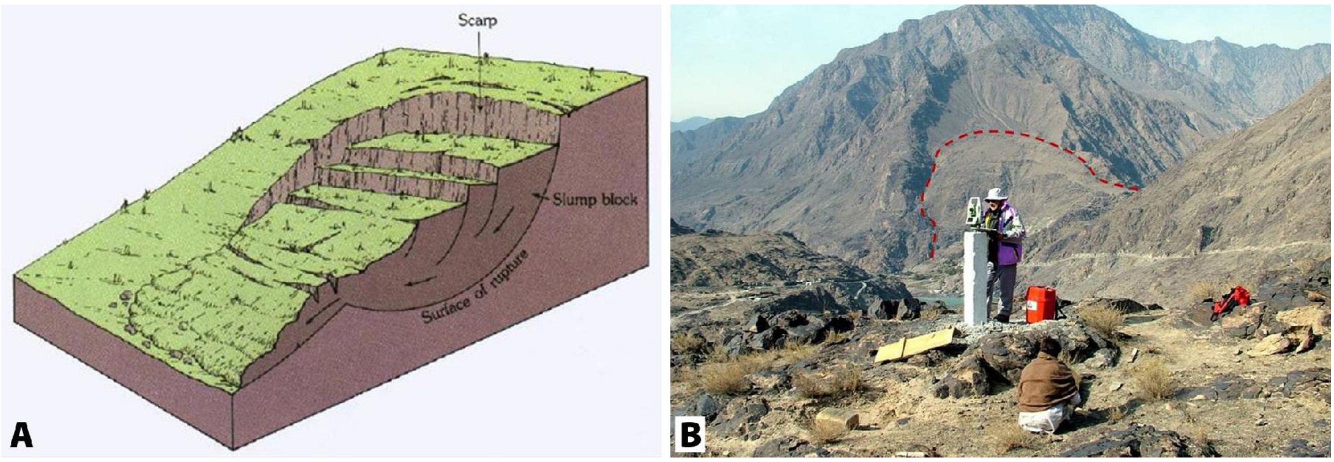
The mass is moving out or down along a well-defined planar surface. The material involved can be loose, unconsolidated or soils or slabs of rocks or a mix of them. The failing surface can occur along a weak plane as geologic discontinuities such as faults, joints, bedding surfaces, or the contact between rock and soil. The movement can vary a lot with an initial slow motion. Some movements can be also extremely rapid. The rainfall can be considered one of the main triggering mechanisms, but these types of landslides can be also earthquake induced.



Annex 4-4: A) Translational block landslide (USGS, 2013); B) Chogolungma glacial valley, a translational landslide upstream of Arandu village.

Rotational landslide

The mass, in this case, is moving on a concave sliding "spoon-shaped" surface. The head of the moving mass can be usually considered almost straight and the upper surface of the displaced material may tilt backwards towards the scarp. When the sliding surface is not unique but it is made of several parallel curved surfaces, the landslide is called a slump. The velocity range is wide, from extremely slow to extremely rapid. The possible triggering factors are: intense and/or sustained rainfall or rapid snowmelt which can lead to the saturation of slopes and increased groundwater levels within the mass provoking the event. Another cause of sliding can be the erosion at the base of slopes. These types of slides can also be earthquake-induced.



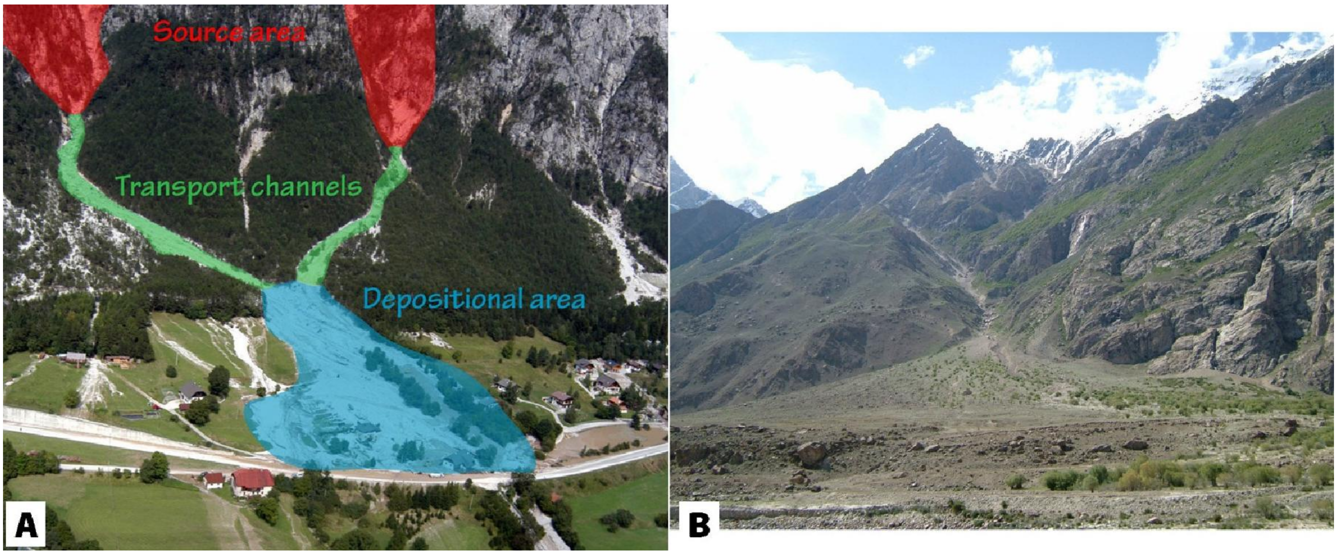
Annex 4-5: Rotational landslide: A) sketch (E.J. Tarbuck and F.K. Lutgens, The Earth, 1984); B) Chilas, in the background, an ancient rotational landslide.

Flows

A flow is a continuous movement where the shear surfaces are short-lived, closely spaced and usually not preserved. The behavior is similar to the one of a viscous fluid, varying due to the water content, mobility, and evolution of the movement. According to the materials involved, flows can be distinguished as: debris flow, earthflow and slow earthflow (creep).

Debris flow

A debris flow is a rapid mass movement where loose soil, rock debris and sometimes organic materials are combined with water forming a slurry that flows downslope. Occasionally, a debris flow can originate as a rotational or translational slide that gains velocity due to the internal loose cohesion and increasing water content. Debris flows can be deadly as they can be extremely rapid and may occur without any warning. This type of phenomena is usually triggered by intense surface-water flow, due to heavy precipitation or rapid snowmelt mobilizing loose soil or rock on steep slopes.



Annex 4-6: A) Debris flow areas (Calligaris et al., 2011); B) Biafo glacial valley, an example of debris flow.

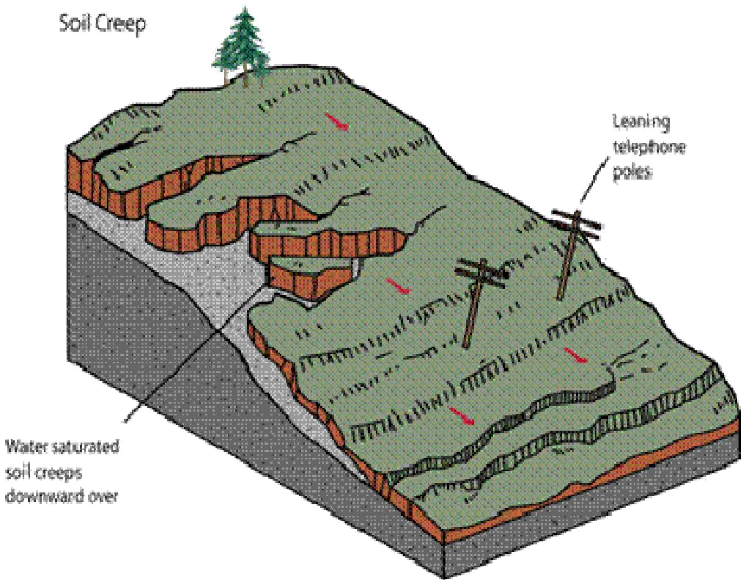
Earthflow

Earthflows differ from debris flows only due to the type of material involved, that is mainly fine-grained soil, clay or silt, but also very weathered, clay-bearing bedrock. They usually occur along gentle slopes moving with a plastic behavior which can continue for several kilometers. The velocity can range from very slow (creep) to rapid flow with devastating consequences. Earthflows can be triggered mainly by the intense and heavy rainfalls saturating the soils. Stream erosion at the bottom of the slope, as well as sudden increased load and earthquakes can all be triggering factors for this type of event.

Annex 4-7: Earthflow example from a Kirghizistan area (J. Lent, 2008).

Slow earthflow (creep)

When an earthflow slowly evolves developing a low velocity, this earthflow can be defined as a creep. The interested portion of material is made up of the shallower part of the soil moving as a plastic or viscous flow with strong internal deformation. For seasonal creep phenomena, rainfall and snowmelt are typical triggers, whereas for other types of creep there could be several causes, such as chemical or physical weathering, leaking pipes and poor drainage.

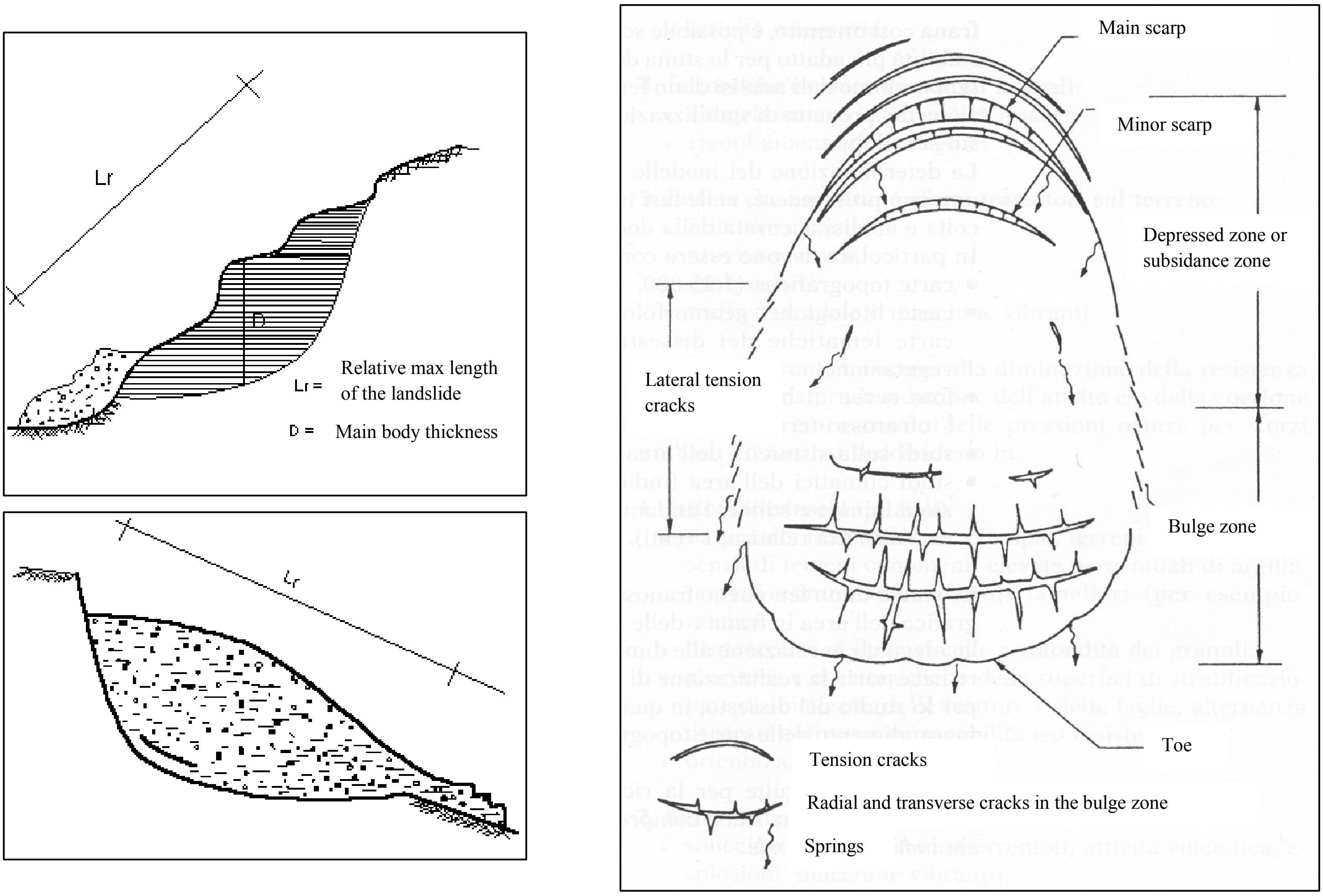


Annex 4-8: Creep (http://gsa.state.al.us/gsa/geologichazards/Landslides.htm, 2013).

What to do on field, how to recognize a landslide and how to outline it

As previously specified, a landslide is a mass of rocks, or debris or soil or a mixture of them, moving downwards essentially due to gravity. To recognize a landslide the main thing to do is to try to recognize a specific shape, typical of a type of landslide or to recognize, on field, some specific indicators as tension cracks or fallen boulders. This permits to identify a potential landslide site. Once an area appears to correspond to a landslide phenomenon, it is important to compile the attached form where the most important information about the phenomena are present. It is important to have a GPS or a map and to define where the phenomenon is (x and y coordinates). A tape measure can be useful in identifying all the characteristics of the landslide (max length, tension cracks openings…). Second, it is important to try to classify the landslide by checking with a cross on the Landslide form the identified type of landslide.

Third, take one or more photos in order to show those to who do not have the opportunity to be on field.



Annex 4-9: Rotational landslide morphometry.

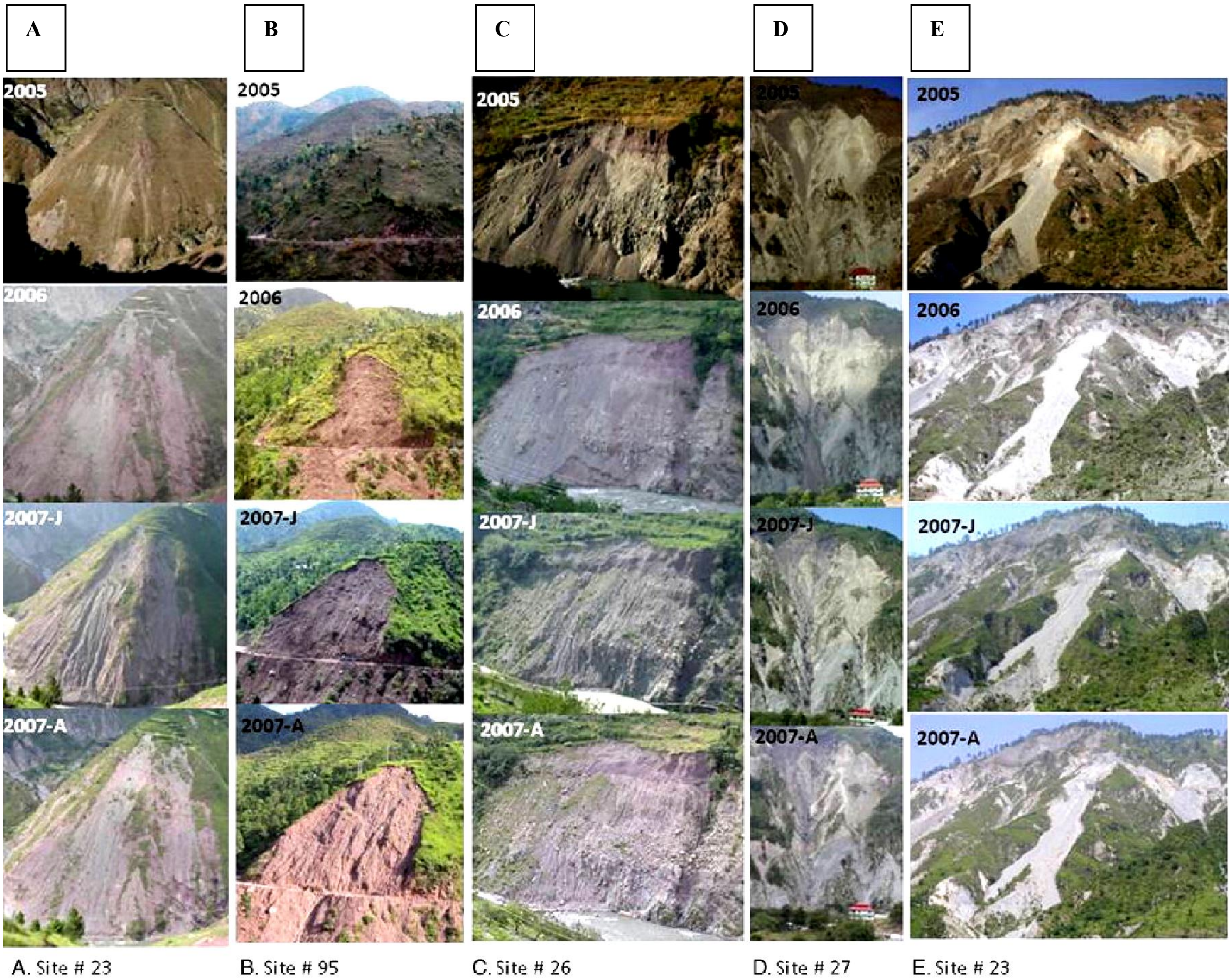
Some examples of commonly found landslides in azad Kashmir

Both examples present a very high susceptibility due to the proximity to the Kashmir Boundary Thrust (2 km), the Muzaffarabad Formation (dolomite, limestone, clastics), the steepness of the terrain, and the road itself.

A

B

Annex 4-10: A) Landslide along the Neelum River due to Seismic Activity of 2005 (Debris Fall); B) Debris Flows.



Annex 4-11: Examples of repeat photography at five different sites in different years. (A) Landsliding along Kunhar River in Kaghan valley. Initial earthquake shaking produced very few shallow slope failures but produced extensive fissures and cracks, which resulted in extensive secondary landsliding. (B) Landsliding along main Muzaffarabad–Chakothi road in Jhelum Valley. Secondary landsliding occurred along the fissures produced by seismic shaking. (C) Rapid growth of vegetation on almost vertical slope along the Kunhar River in Kaghan valley. More than 70% of the slope is re-covered by vegetation by 2007. (D) and (E) Shallow rockfalls in Kaghan and Neelam valleys, respectively. No significant changes occurred after the earthquake. J = June; A = August.

Landslides Identification Form

Date: ______________________ No: __________________

Surveyor: (Name, Surname, Organization)____________________________________

Village/Area/Valley: ____

Position - using coordinate system WGS 84 – UTM 43 N
(I.E.: 36°25'58''N 74°35'28''E; or kilometric coordinates).

Coord X:____________________ Coord Y:__________________________

Z (m a.s.l.):__________________

Landslide is: Active, reactivated, quiescent, old landslide

Vegetation cover: bare soil, meadow, shrub, closed forest

Land use: cultivated areas, wood, uncultivated, artificial surfaces (built areas, roads), pasture

Infrastructures Involved: road, house, bridge, track

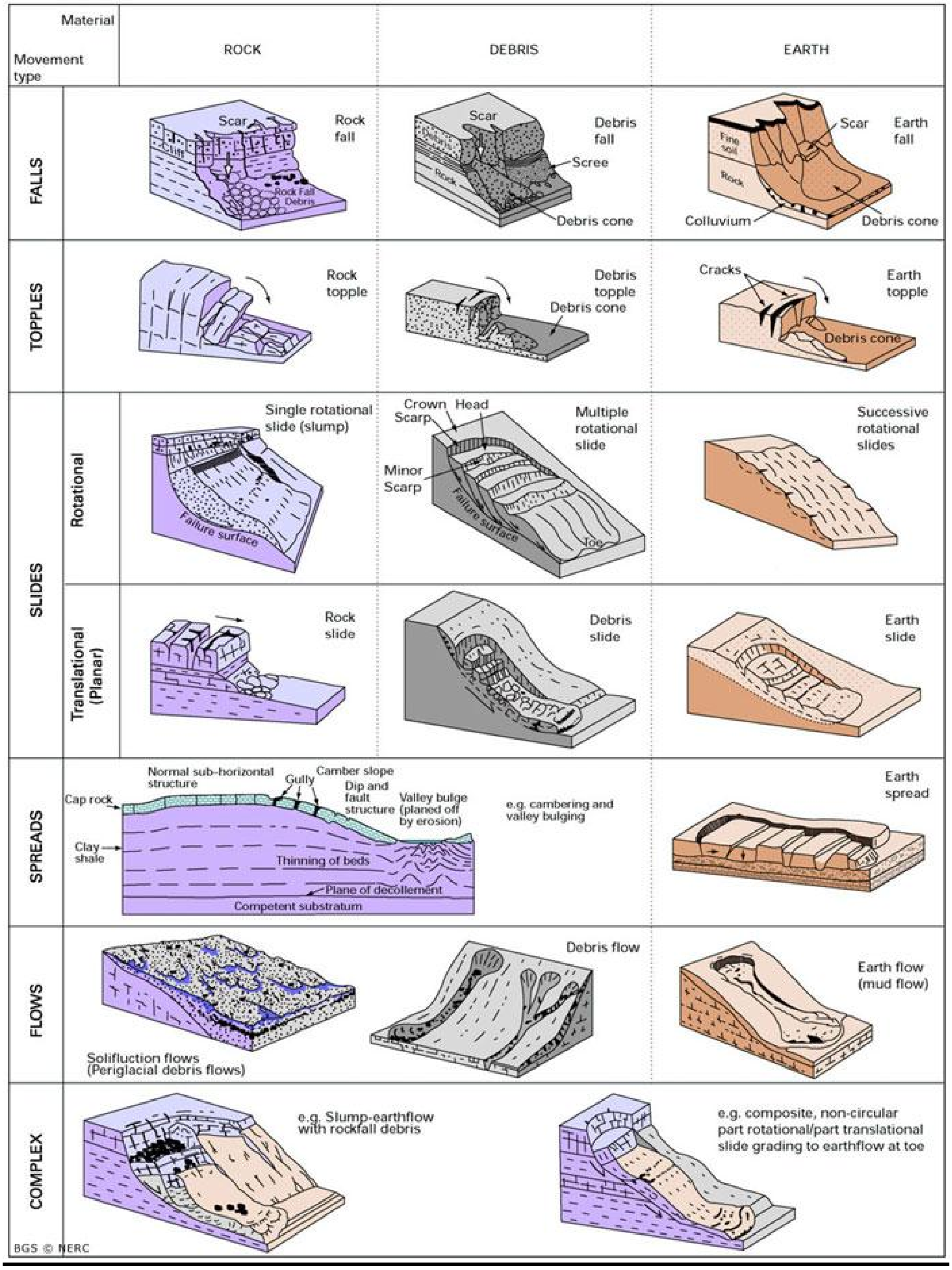
Previous events, damages, people involved

Hydro conditions: wet, dry, drained

Notes:

Photos (one or more):

Data is collected for academic purposes. Please give accurate information regarding the landslide event. Information may be published.



Annex 4-12: Types of landslides (circle the recognized type) Source: USGS, Classification of type of landslip (modified after Varnes, 1978 and DoE, 1990).

ANNEX 5: TROPHY HUNTING PROGRAMMES

As a position statement, the University of Siena (hereafter Unisi) agrees with the IUCN/SSC Caprinae Specialist Group's position on trophy hunting programmes. The IUCN Caprinae Specialist Group, as well as Unisi, recognize that, under appropriate management conditions, trophy hunting can be a valid component of conservation programmes for Caprinae and their habitat. We **support** trophy hunting programmes which satisfy the following criteria:

- A science-based harvest plan to limit as much as possible the difference in age structure between trophy hunted and unhunted populations. Harvest of trophy males must be limited in numbers, target the oldest age classes and allow for a substantial number of mature males to die of natural causes. Present knowledge is insufficient to estimate the proportion of males who must not be harvested to avoid negative long-term ecological or genetic consequences for the population. Excessive levels of trophy hunting may lead to selection for small horns, or alter the life-history strategy of male Caprinae, possibly decreasing subadult survival.
- A conservation-oriented use of the funds generated by trophy hunting. We **do not support** trophy hunting of Caprinae for purely economic goals. We **support** programmes which will demonstrate that a substantial part of the revenues is used to foster effective conservation, habitat protection, population monitoring, environmental education, or research. We **support** community-based trophy hunting programmes where funds are channelled into local conservation initiatives.

We **do not accept** the following practices, sometimes associated with trophy hunting:

- Trophy hunting of Caprinae for purely economic goals, where revenues go into general government funds or are absorbed only by International outfitters.
- Alienation of local communities to favour foreign trophy hunters. Support of local communities is essential for the success of conservation programmes.
- Predator control, with the sole goal of increasing the availability of trophy males.
- Artificial feeding to increase horn growth.
- Selective hunting, with the goal of affecting horn morphology, or artificial introductions of individuals thought to have genetically larger horns.
- Hunting regulations which allow outfitters to overharvest an area and then move to different areas.

Furthermore, in parallel to trophy hunting programmes, we would like to remark that surveys are the most important tool to assess if trophy hunting is or will be sustainable.

The wildlife surveys require reliable replications, if they have to be effective. A reliable replication means: **(i)** the **same people** involved (only if the same people are involved, continuity of methods will be enhanced e.g. use of the same counting techniques, as well as vantage points, used in the past); **(ii)** the **same number of people** (if reliable surveys were carried out in the past, the number of people involved should not be changed, least of all decreased), **(iii)** the **same areas** (the same areas have to be surveyed each time, to obtain comparable data; the number of surveyed areas may increase, never decrease).

Therefore, an effective organization of wildlife surveys (where to go, how many people and how many teams) is needed not to damage conservation: e.g. often 3 days are not enough to carry out surveys in harsh terrain.

Furthermore, the involvement of expert personnel (not necessarily local) for an unbiased evaluation has to be planned at regular intervals (i.e. every 3-4 years).

ANNEX 6: LANDCOVER

Classes definition

The number of classes and their definitions is a tradeoff between the need to precisely assess ecosystems distribution inside the Park borders and the limits imposed by the satellite images classification procedure. Additionally, being the land-cover mapping an important management tool for Park staff, clarity and reduced redundancy are essential characteristic. Therefore, 8 classes have been developed, enough general to encompass a wide variety of similar environments and enough different each other to simplify their recognition and maximize their management usefulness. The classes are: Bare soil, scattered vegetation, sparse trees, open forest, closed forest, grassland, agriculture and snow-ice.

Table 1: Land cover classes identified for the Central Karakorum National Park, their definition and the main species present.

Class	Definition	Main Species
Bare soil	Nude soil, bare rock, debris covered by isolated plants	*Capparis, Ephedra, Cardus*
Scattered vegetation	Scattered and fragmented *chamaephytes* vegetation.	*Artemisia, Juniperus*
Sparse trees	Tall shrubs or single trees. C.c. < 10% and height < 5 m.	*Juniperus, Rosa, Artemisia*
Open forest	Partially forested. 10% < C.c. < 50%. 5m < mean height < 15m	*Juniperus, Pinus, Picea, Salix*
Close forest	Dense forests. C.c. > 50 %. Mean height > 15m	*Jun., Picea, Pinus, Betula, Salix*
Agriculture	Fields/orchards/plantations/villages.	*Populus, Salix,* crops
Grassland	Dense grassland & meadows	*Carex, Poa*
Snow & Ice	Snow covered land/ice	

Each class has been coupled to specific spectral values. Additionally, the classes composed by vegetation are matched to on-field measurable parameters: the ground vegetation cover (for bare soil/scattered vegetation/sparse vegetation/open forest/close forest) and the mean heights of tallest trees (for sparse trees/open forest and close forest). Specifically, mean heights of trees was used to distinguish, with precise and rapid analyses, the different classes representing arboreal vegetation.

Vegetation cover

The vegetation cover is defined as the ratio between the horizontal projection of trees/shrubs canopy on the soil and the total soil surface, in percent. The green dots represent the area occupied by the plant canopy while the larger black circle is the surface of the study area. The vegetation cover therefore is given by the ratio between green and white.

Mean height of tallest trees

As mean height of tallest trees we intend the mean heights of the 4-5 tallest trees, if present, on the area.

Bare soil

A class representing predominantly unvegetated surfaces (bare rock, nude soil), or surfaces with reduced vegetation cover in the form of single, isolated plants normally of xeric species as *Capparis*, *Ephedra* or *Cardus*. Also glacial masses covered by debris (rocks) are indicated as bare soil.

Annex5-1: Steep slopes, scarcely vegetated, are represented by Bare soil class. (Hispar valley)

Scattered vegetation

A class composed mainly by herbaceous/shrub *Chamaephytes,* of which *Artemisia* shrubs are the most common. Few isolated scattered Junipers or others shrub/trees might be present.

Annex5-2: Artemisia shrubs are covering large section of the CKNP, forming the Scattered vegetation community. (Bagrote valley)

Sparse trees

It's a class with a reduced tree canopy cover (<10%) which therefore cannot be classified as a forest according to FAO standards. The tree individuals present are sparse and small (less than 5 meters high). Usually Junipers are the dominant tree species, together with *Rosaceae* and *Artemisia* in the shrub/herbaceous layer respectively.

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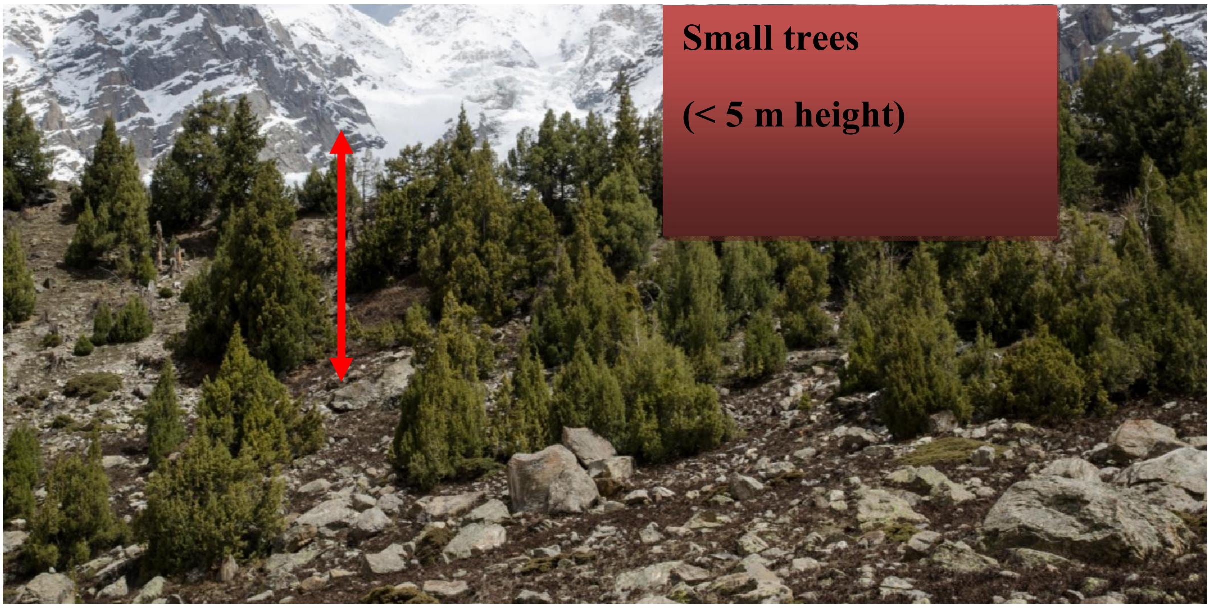

Annex5-3: Sparse trees class. *Juniperus turkestanica,* in this case, is not forming a forest (according to FAO standard). (Astak valley)

Open Forest

It's the first vegetation class which can be classified as forest according to FAO standards. The vegetation cover is between 10 and 50% and the mean height of tallest trees is between 5 and 15 meters.

Usually, open forests are the result of long lasting degradation of previously closed forest or forest growing on poor, rocky or dry soils. In this category are included the forest which should actively be managed and in which once degradation drivers are reduced, reforestation is suggested. The species composition of this class can be various, from degraded spruce (*Picea smithiana*) and Pine (*Pinus wallichiana*) to dense Juniperus woodland.

Annex 5-4: Open forest class, in this case as a result of large forest degradation (Jaglot valley).

Close forest

It's the land-cover class including the most productive forests. The vegetation cover is above 50% and the mean height of tallest trees it's above 15 meters.

The sustainable forest management will be applied mostly to this category. Usually this class is composed by dense forests of spruce (Picea smithiana), pine (Pinus wallichiana) and/or birch (Betula utilis). Most of the CKNP increment and biomass is found within this class.

Annex 5-5: Close forest of Birch (*Betula utilis*) and spruce (*Picea smithiana*), Bagrote valley.

Grassland

The class representing most productive pastureland, usually located in between 4000 m and 5500 m a.s.l.., grassland can be found also in between patches of forest. The vast alpine grasslands of CKNP are mainly composed by *Poa* and *Carex* species (Du, 1998). The abundant winter snowfall covers them from mid-October until June. Transhumance of local livestock population to this high-altitude area is a common practice all over the study area during the summer months.

Annex5-6: Grassland. (Hispar valley)

Agriculture

Agriculture areas, in the forms of fields, orchards or poplar/willow plantations are common along the valley floor up to an elevation of 3000 m a.s.l..The vast majority of those are irrigated through water channel since precipitation are scarce, especially during summer months.

Annex 5-7: Marzigond village, lower Hushey valley.

Snow – Ice

Glacial masses and snow covered surfaces are covering large sections of CKNP. Only “white” glacier without surface debris are classified as snow-ice.

Annex 5-8: Barpu glacier, Hopar valley.

Land cover of the Central Karakorum National Park

Methodology

Three cloud-free Landsat 5 Thematic Mapper (TM) images with 30x30 m spatial resolution were used. The images, acquired at product level 1T (radiometrically and geometrically terrain corrected) from the GLOVIS web-portal (http://glovis.usgs.gov/), were specifically chosen for the month of August to capture full vegetation development at all possible altitudes. Throughout the paper, all analyses were performed on the 6 non-thermal bands of the composite (three visible and three infrared). Conversion of reflective band data (Digital Number) into at-sensor reflectance was performed using the specific ENVI ® toolkit separately for the 6 bands of each Landsat image.

A DEM, derived from the high-spatial-resolution multispectral images of ASTER (GDEM2) was acquired to derive slope and aspect values. These data were used to delineate the watersheds of the park on the basis of the drainage network extracted from DEM and to calculate slope and aspect for the terrain correction of spectral values.

Training and Validation dataset

Two separate datasets were used, one for training of classification algorithm and one for the validation and accuracy assessment of the final maps.

Training datasets were collected in various CKNP valleys in the period between April 2011 and May 2013. These were composed by field surveyed plots with additional expert identified blocks of pixels. Both were used to identify on the satellite images polygons of pixels representative of each class. 69 field plots were surveyed in one valley to provide training pixels with specific reference to the natural vegetation land-cover classes. The expert identified plots, instead, were digitalized from 47 georeferenced digital photographs collected with a high resolution/definition camera from favorable locations in 8 different valleys. The overall training dataset was composed by a total of 1891 pixels clustered in 107 polygons, with at least 210 pixels in each land-cover class. Each polygon was located sufficiently far away from the others to reduce spatial autocorrelation. To evaluate the separability of land-cover classes, and therefore ensure exclusivity and exhaustivity of training data, transformed divergence values were calculated.

An independent validation dataset, composed of 334 ground control points gathered in 10 valleys was used to validate the final maps and assess their accuracy. The points were collected in the field, using a GPS device.

Satellite data pre-processing

Following data acquisition, images were pre-processed through topographic correction. We opted for the classic C-Correction first introduced by Teillet et al. (1982) because of its simplicity and effectiveness in improving image quality . This is a wavelength dependent method that calculate new values of corrected reflectances for each pixels. The corrected bands were stacked together and a mosaic of the three corrected Landsat images was created to cover the entire study area.

The Normalized Difference Vegetation Index, calculated as $NDVI = (B4 - B3)/(B4 + B3)$, was used as an additional band to the 6 Landsat non-thermal bands to increase classification accuracy .

Classifications

To ease visual image analyses snow and ice were identified using the NDSI index calculated as $NDSI = (B2 - B5)/(B2 + B5)$ and masked by applying a threshold value.

Processed images were classified according to a combined classification involving the use of NDVI and classic algorithm (Minimum Distance, MD).

NDVI has been adopted extensively to quantitatively assess vegetation density due to the simple and direct calculation process, the ability to distinguish between vegetation and soil, the proportionality with chlorophyll content (and therefore vegetation amount) and the low sensitivity towards irradiance and other atmospheric disturbances. Additionally, where partially vegetated areas are diffuse, NDVI was shown to be more affected by changes in vegetation cover than by changes in canopy thickness. One of the main limitations in the use of NDVI as a proxy for vegetation cover is its saturation at high canopy density. The low mean density of CKNP forests and the ample vegetation classes adopted in the CKNP land cover partially overcome this problem. Another limit inherent in the use of a vegetation index is that NDVI alone does not differentiate between vegetation types. We used a mix of supervised classification and ancillary data to separate the signal of dense vegetation classes. A treeline threshold (4000 m), based on field observations and data from the literature, was used to automatically classify the pixels with high NDVI as grassland. The actual treeline of CKNP forests is located at 3800/3900 m a.s.l. We set a higher altitudinal limit to allow for some resolution errors between the GDEM and satellite images. The supervised classification was used to extract grasslands and agriculture pixels lying at lower elevation (<4000 m a.s.l.). However, spectral differences between these two classes are often minimal (i.e. due to the similarity of vegetation growth form and density), making class detection difficult and reducing final accuracy. In the CKNP area, fields are mainly located at low elevation on valley bottoms, surrounded by bare soil. Grasslands, on the contrary, are located above tree line (>4000 m a.s.l.) or between patches of forest. This spatial difference makes recognition of agriculture areas relatively simple. We developed a mask based on the 3000 m contour line, manually modified on a GIS using a FCC image of the terrain corrected Landsat images. The final classification was developed through a decision tree.

Accuracy assessment

Table 2 Overall accuracy and Kappa statistic for the landcover

Method	Min Dist
Overall accuracy	80.24%
Kappa statistic	0.7691

The combined use through the decision tree of NDVI index and supervised classification resulted in acceptable level of accuracies (80.24% in MD) and kappa statistic (0.7691). Open forest resulted the class with the lowest producer's and user's accuracies (0.7 and 0.65). Similar results have been obtained for the extremes classes, bare soil and close forest, with producer's and user's accuracies close to or above 0.90. Acceptable accuracies were obtained also for the intermediate classes, as scattered vegetation/sparse vegetation classes (0.72 and 0.75, respectively in MD).

Land cover characteristic of the CKNP

The land cover map developed for the Central Karakorum National Park revealed important information regarding vegetation distribution inside the study area. Grasslands cover the 11% (1350 km2) of the total surface (11862 km2), followed by scattered vegetation (7.9%) and sparse vegetation (4.2%). Open and close forests represent the 2.6% and 2% respectively (310 and 230 km2), while agriculture the 1.2%. Un-vegetated surfaces are the large majority, 70.6%, with 16.3% of the area being bare rock and 54.3% covered by snow or ice. Large differences are evident between the different valleys (Tab. 8), both in grassland and forest cover.

Table 3: Land cover (in % of total valley area) for the different valley and total valley surface (in ha). (AG: agriculture, GR: grassland, SV: scattered vegetation, SP: sparse vegetation, OF: Open forest, CF: Close forest, SN: Snow and Ice, BR: bare rock).

Valley	AG	GR	SV	SP	OF	CF	SN	BR	TOT
Astak	0.7	14.5	5.5	3.7	5.7	4.5	45.5	19.9	26948.64
Bagrote	3.0	16.3	8.6	8.0	7.8	9.1	28.1	19.1	43245.7
Baltoro	0.0	1.6	5.2	0.1	0.0	0.0	78.7	14.5	170940.5
Basha	1.7	14.2	6.4	5.8	4.0	2.0	46.3	19.5	166826.7
Biafo	0.0	4.9	3.6	0.4	0.2	0.1	74.6	16.2	82837.37
Braldu	2.0	16.8	14.8	10.0	3.5	1.6	37.7	13.7	106888.1
Danyore	1.0	15.3	9.5	8.8	8.1	8.8	32.9	15.6	11609.64
Dumordo	0.0	5.4	6.2	0.9	0.2	0.0	74.2	13.1	84726.04
Haramosh	2.1	19.1	6.7	6.7	6.8	12.9	29.5	16.1	48623.05
HIsper	0.1	6.3	7.3	1.9	0.5	0.1	62.6	21.1	130567.4
Hoper	1.9	10.4	6.7	5.4	2.9	1.7	47.9	23.0	42585.02
Hushey	0.4	10.8	8.6	3.7	1.2	0.1	64.2	11.0	103918.8
Jutal/Jaglot	0.9	12.2	12.7	9.6	7.7	6.4	32.6	17.9	10168.2
Kharku	0.0	28.3	24.1	1.2	0.1	0.0	38.3	8.0	4987.26
Minapin	8.8	10.6	9.9	9.9	5.7	5.0	24.8	25.4	37383.84
Shengus	0.2	20.3	8.8	5.2	6.7	4.4	44.1	10.3	13390.11
Shigar	0.1	23.7	15.1	5.1	2.3	1.4	34.8	17.5	38884.37
Thalley	2.6	24.4	12.6	6.3	4.6	0.5	42.5	6.5	39524.31
Tormik	3.2	36.1	5.5	6.5	7.6	4.4	24.8	11.8	22099.41

In general, surface covered by vegetation is lower in the valleys lying north of the main Karakorum ridge. In example (Fig), Hispar valley, located in the Northern area of the Park, have 16% of the total valley area covered by vegetation (7.35% scattered vegetation, 6% grassland, 0.64% for open and close forest) while in Haramosh valley, located in the more humid south-west area, vegetation cover is 52% (19% grasslands, 13% close forest, 6.8% open forests, 6.7% for both scattered and sparse vegetation).

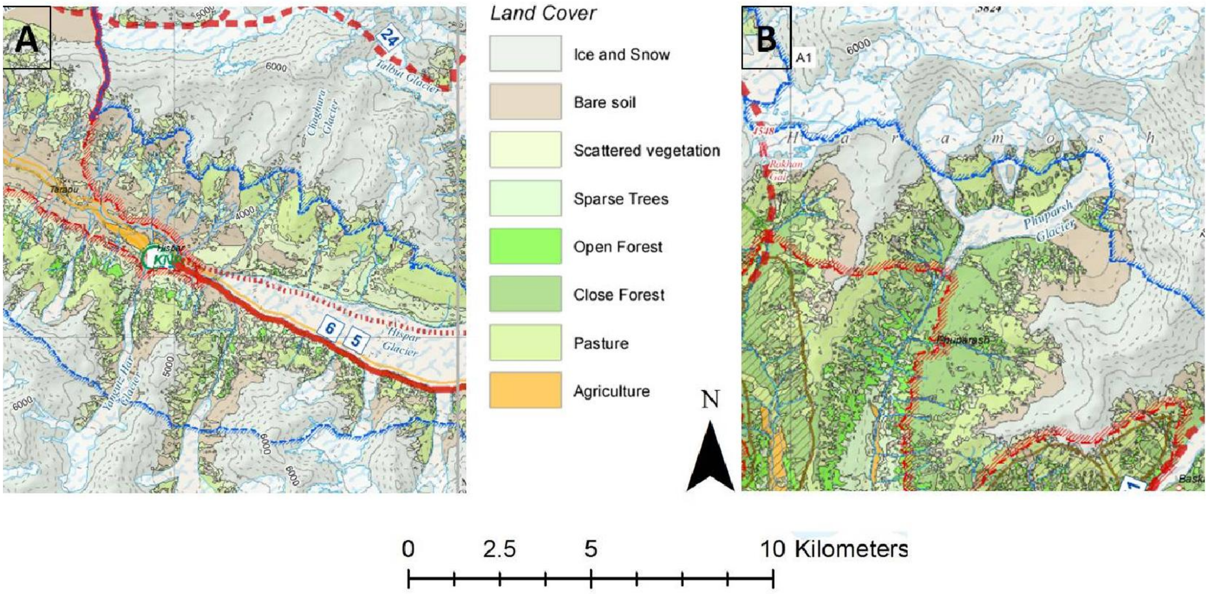

Exhibit 5-9: Example of land cover map for A) Hispar valley (North of Karakorum main ridge) and B) Haramosh valley (South West of Karakorum main ridge). The two valleys are separated by less than 10 km large mountain ridge, however, their land cover appear very different.

RESEARCH BASELINES FOR CENTRAL KARAKORUM NATIONAL PARK MANAGEMENT PLAN

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