REMOTE SENSING APPLICATION TO THE KNOWLEDGE OF ENVIRONMENTAL DYNAMICS FOR A PROJECT OF MANAGEMENT PLANNING IN CENTRAL KARAKORAM NATIONAL PARK, PAKISTAN

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ABSTRACT:

The aim of this contribution is to present the research activities which will be carried out in the frame of the Project "Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush - Karakoram-Himalaya Mountain Complex". The Project will be performed within the cooperation of four scientific partners: IUCN (International Union for the Conservation of Nature and Natural Resources), ICIMOD (International Centre for Integrated Mountain Development), Ev-K2-CNR Committee and CESVI (NGO, Cooperazione e Sviluppo, onlus) with the involvement of international researchers. The local management will be provided in Nepal by the Sagarmatha National Park (SNP), in Pakistan by the Central Karakoram National Park (CNKP) and in Tibet Autonomous Region (China) by the Quomolongma Nature Preserve (QNP). This contribution will provide an overview about the research issues (on forests, biodiversity, glacier changes, livelihoods) mainly based on remote sensing technologies which could be successfully applied on CNKP. The need for integrating remote sensing data and field activities are presented as well. The applied image processing techniques (i.e. radiometric normalization, image geometric rectification and thematic classification) are introduced with an emphasis on the key role played by acquiring field data and evaluating the accuracy. The basis of this discussion is the creation of some base thematic maps realised mainly from remote sensing data.

1. INTRODUCTION

1.1 Background

The development of a management framework and capacity building initiatives are key activities of the HKKH Partnership Project (Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush - Karakoram-Himalaya Mountain Complex) (www.hkkhpartnership.org) to support the management planning process in the protected areas of Sagarmatha National Park in Nepal, Quomolongma Nature Preserve (QNP) in Tibet Autonomous Region (China) and in Central Karakoram National Park (CKNP) in Pakistan.

Concerning Pakistan, the HKKH Partnership Project has committed to contribute to the development of the CKNP Management Plan though a series of coordinated activities, including technical advice on the management planning (through the development of a sound management planning framework), baseline studies, database development, capacity building and the provision of new tools and instruments to assist in the management of natural resources; these activities will be implemented consistent with the Project methodological framework. As such, the development of a comprehensive and adaptive conservation Management Plan and Framework for the CKNP represents the end product of a critical and uniquely designed and conducted participatory process.

This contribution will provide an overview about the research issues mainly based on remote sensing technologies which could be successfully applied on CNKP.

Environmental dynamics are the results of many interacting processes. Each of these processes operates over a range of scales in space and in time and a range of scales may be defined over which it has significant influence on land cover dynamics and geomorphological processes (Dolman, 2003). The lack of thematic maps and environmental information on the whole area suggests a multiscale approach mainly based on the application of remote sensing techniques. A range of very different ideas have been used to formulate the human ability to view and comprehend phenomena on different scales. In remote

sensing analysis data classification may be carried out using hierarchical classification. A sequence of agglomerative steps is used, merging data objects into a new cluster at each step. Such an approach is bottom-up, starting with the set of data objects, considerer independently. Spatial and other constraints may be incorporated, to provide segmentation or regionalization methods (Starck, 1998). An image represents an important class of data structures. Data objects may be taken as pixel, but it is more meaningful for image interpretation if we try, in some appropriate way, to take regions of the image as the data object. Such regions may be approximate but we can consider to know all about their spectral information and ground truth and to use them in the thematic interpretation (supervised/unsupervised or visual classification). In this project the multiscale approach using remote sensing data will be applied to land cover/biomass mapping, land cover change analysis and to some specific glaciological studies in a valley of the Park area.

1.2 Objectives

The objectives of the study are:

- to arrive at an understanding of key system dynamics of a selected valley in the CKNP buffer zone area and use these information as the interpretation keys for the regional mapping;
- to develop a methodology for an integrated case study which can be applied in future research in other locations within the CKNP and beyond;
- support the development of the CKNP Management Plan.

The study will be conducted as a series of thematic studies which will be linked and analyzed in an integrated manner.
Three main themes are proposed:
• forest mapping and land cover change evaluation
• glacier mapping and monitoring
• biodiversity analysis.

The strategy of each action of the project shall be defined in conjunction with the partners, following guidelines and ideas emerged during meetings and e-mail discussions. For this reason, and due to the fact that the availability of some existing data still needs to be checked in detail, this project is expected to evolve further during the project phases.

In many of the elements which will be investigated climatic aspects have direct relevance, and climate change considerations will be built into the thematic studies. Since climate dynamics are expected to be a key driver in the system, climate change considerations will also be given specific attention in the integrated analysis of the study. In addition, an integrated, detailed case study will be conducted in a selected valley in the CKNP buffer zone, complementing the more general baseline studies. The integrated study will bring added value by highlighting the linkages between different aspects of ecological and social dimensions, natural resources and livelihoods, and by attempting to arrive at an understanding of key dynamics of the studied system.

2. METHODOLOGY

2.1 Study area

The Northern Areas (NAs) of Pakistan encompass 72,496 km2 in the north of Pakistan, bordering China, Afghanistan, and India (Fig. 1). Their geographical position represents one section of the Asian high-mountain system of Hindukush-Karakorum-West Himalaya. The original Central Karakorum National Park (CKNP) was formed in 1993 as Pakistan's largest protected area (PA), covering over 10,000 km2 and encompassing some of the world's highest mountains and largest glaciers. Following its official notification and subsequent planning workshops and consultative exercises, the World Conservation Union (IUCN), in August 2004, requested Hagler Bailly Pakistan (HBP) to help move forward the management planning process for the PA. HBP agreed to help by establishing an environmental baseline, carrying out resource-use mapping, and finalizing the boundaries and zoning of the area.

Figure 1. Localization of the Northern Areas (NAs) of Pakistan.

In doing so however, it transpired that for effective PA management the original CKNP would have to be enlarged to encompass a much larger area, which would have to be redefined as the Central Karakorum Protected Area in order to avoid confrontations between the communities with usufruct rights in the PA, and PA managers. (Hagler Bailly Pakistan Management Plan, 2005).

There are no settlements within the current boundaries of CKNP, but in the management planning process the areas surrounding the current Park boundaries may be proposed for protection according to an IUCN Category lower than that suggested for the core area; either as part of an enlarged PA with different zones used within the Management Plan to specify management objectives for core protection, non-exploitative use and sustainable community resource use; or as part of a cluster of different PAs established to reflect the differing management objectives ('Central Karakoram Conservation Complex'). It may also be suggested to establish Community-based Natural Resources Management (CBNRM) in the buffer zones without formally designating them as part of a system of Government PAs. People living in the buffer zones surrounding the core Park area rely heavily on natural resources and ecosystem services provided by the CKNP for their livelihoods. Further, it is envisaged that the national park through effective management can provide an opportunity improved living conditions for the local communities, hence creating an even stronger link between local livelihoods and the Park.

Valleys in the CKNP buffer zone constitute ideal locations for studying and analyzing system dynamics of socio-ecological systems. Agriculture is the mainstay of the population, and climatic dynamics such as temperature and precipitation can be assumed to be key drivers of the system. The ecosystems and agricultural systems are highly dependent on melt water from glaciers. Based on a list of criteria defined by the different research groups, Bagrot valley has been suggested as the location for the study (Fig. 2).

Figure 2. Localization of Bagrot valley.

2.2 Data

The objectives of this interdisciplinary study are mainly oriented to acquire information on actual environmental conditions and to understand its evolution by the analysis of multitemporal data to support the development of the CKNP management plan. The multiscale and multitemporal approach is supported by the large amount of remote sensed available data acquired by different sensors. The management of these resources is supported by the GeoNetwork open source system, implemented by ICIMOD (International Centre for Integrated Mountain Development). GeoNetwork open source is a standards based catalogue application to manage spatially referenced resources through the web (http://www.dss-hkkh.icimod.org:8080/geonetwork/srv/en/main.home).

It provides powerful metadata editing and search functions as well as an embedded interactive web map viewer.

The available and comparable datasets are listed below. Landsat images constitute a good and tested data for the issue mainly oriented to land cover change. Four sets of MSS, TM & ETM+ of 1977, 1992, 2000 and 2001 were acquired, geometrically corrected on an international grid in WGS84 system.

The ground truth and the interpretation keys for forest/biomass and land cover mapping in the Bagrot valley need to be created with a high resolution sensor. ASTER data were chosen and a large set of images were acquired on whole CNKP with a cloud cover <30%. The data acquired from ASTER sensor are distributed by the Land Processes Distributed Active Archive Centre (LP DAAC), located at the U.S. Geological Survey (USGS) Centre for Earth Resources Observation and Science (EROS) http://LPDAAC.usgs.gov.

The first land cover mapping on the whole park will be performed using a large set of IRS data acquired in 2005 and 2006.

Russian topographic maps at the scale of 1:100.000 are available.

2.3 Approach

In this project thematic data will provide tools for understanding the causes and the consequences of environmental dynamics and to contribute to a proposal of a Management plan. Three main integrated activities are planned:

- Forest research
- Biodiversity research
- Research on glacier changes.

Forest research: forests constitute an important resource for local livelihoods in the CKNP area, and support a large section of the biodiversity in the area. Forests are also one of the most strongly exploited ecosystems in the Park and its buffer zone, and deforestation is a major problem.

Forests of the CKNP are affected by several disturbances. It appears relevant to preserve/restore the (actual) forest ecosystems developing Sustainable Forest Management plans (SFM). The first step is to acquirre data about the status of the forested areas and to propose a quantitative approach for its characterization using both biomass indexes by remote sensing and field measurements.

The proposed project by the University of Padova is aimed to:
• provide a first inventory of the forest ecosystem of the CKNP and to estimate the potential annual growth in biomass and the sustainable harvesting;
• promote a participatory Forest Management with local communities in a selected valley (pilot area);;
• study the possible effects of climate changes on the most vulnerable high mountain forest ecosystems of the CKNP.

In the framework of these activities remote sensing data play an important role linked to the environmental and topographic features of these areas, where the climate and the slopes are a natural barrier. The first step will be the validation of remote sensing data with the knowledge of a set of interpretation keys in terms of land cover, biomass density, tree line definition and change detection analysis. A set of sampling plots will be defined according to a stratified system (in relation to forest type, stand structure and management type, economic/ecologic importance) and the relation with the radiometric response inside the plot will be evaluated. This activities will be performed in a multiscale schema with three Work Packages (Fig. 4).

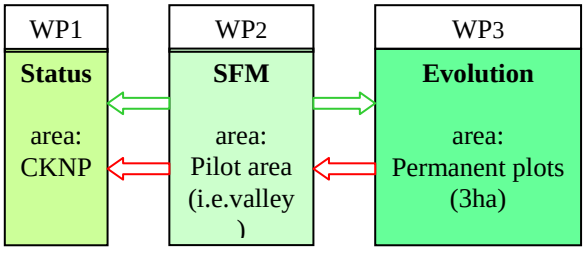

Figure 3. Proposed activities in CKNP

In the Table 1 each work package is described in terms of area of interest, using of satellite data, field work and expected outputs.

Monitoring changes in forest is therefore essential. Further, climatic changes are expected to have considerable impacts on forests, and gathering information on climate change effects on the most vulnerable high mountain forest ecosystems of the Park area is vital for planning responses. A monitoring system of the forests dynamic in different sites (from middle altitude to the tree line) will be developed. Permanent plots will be established in Bagrot valley, and will be used to define in detail the structure and the dynamic of the high altitude forests.

	WP1: status	WP2: SFM	WP3: Evolution
Study area	CKNP	Bagrot valley	Permanent plots
Remote sensing activity	Land cover map; land cover change	Biomass indexes	
Ground activities	Georeferenced ground plots via a stratified sampling (species, biomass, structure, density...)	Full inventory of the forest resources in the selected valley (composition, structures, diameters, heights, growth rates, regeneration, degradation …) Participative forest management: training, knowing the local traditions, population needs…	Effects of global warming on high altitude forests (treeline) Temperature-limited ecotones are very sentitive LTER area (Alps, Appennines, Himalaya) Full mapped permanent stand (1 ha) 3 different altitudes Position, diameters, heights, Age, tree ring wi, leaf mass etc…)
Expected outputs	Map of the forest cover (IPCC def.) and stands properties rate of deforestation (ha y-1)	Forest management plan (model for other valleys of CKNP)	forest dinamic possible “markers” of climatic change
General benefits	to support the Managemant Plan to increase the awareness and kwnoledge of local communities to promote collaboration among Institutions (KIU, HKKH partners, WWF, NAs Forest Department, etc..)		

Table 1. Description of the Work Packages.

In the Fig. 4 an ASTER image displays the area of the Bagrot valley. The area appears covered by forest on the hill, the slopes are bare with evident processes of erosion.

Using a dendro-ecological approach (analysing the tree rings) the past dynamic will be studied, thereby facilitating an assessment of possible future evolution of the stands. These plots will represent the “starting point” from where the future forest dynamic can be inferred. It is envisaged that these plots will be used to detect possible variation in stand composition and structure and to relate the variations to the dynamic of the climatic conditions or variation of the anthropogenic pressure. Further, it is proposed to compute the climate-growth relationships performed on a linear and non linear basis and to identify the main climate factors affecting the cambial activity. Results from this activity are highly relevant for the planning of conservation measures and responses to climate change impacts.

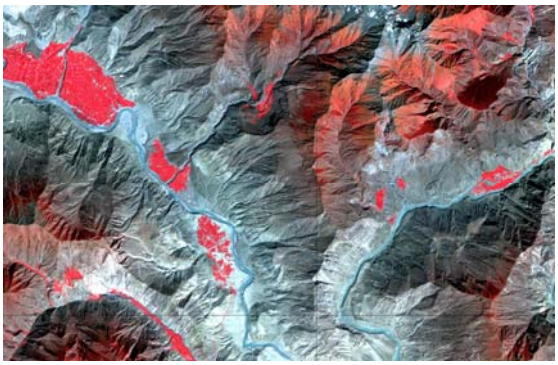

Figure 4. ASTER image of the study area

Since forests are an important resource for local livelihoods, there are direct links between the thematic studies on forest and on livelihoods. This will be highlighted in the report developed.

Biodiversity research: the biodiversity research conducted within the Park aims to identify conservation priorities, relationships between threatened species and habitats and relationships between species distribution and environmental features. This will entail an assessment of how environmental changes such as climate change affect animal communities. Identification of processes of local adaptation and evolution in response to environmental changes, such as climate change, will further be included, and studies of specific species which can be seen as indicators will be conducted. An understanding of these dynamics is essential for planning and implementing management responses for biodiversity conservation.

Long-term monitoring is essential for understanding the evolution of ecosystems and the response to environmental changes, such as human alteration of landscapes and climate change. A number of areas will therefore be selected for establishment of permanent monitoring plots. These will cover both forested areas and areas in and around the tree line. This will allow an assessment of the effects of climate change. The permanent plots should be established in areas of the Park where collaboration with local communities is feasible and forested areas are still present. Bagrot valley conforms to these preconditions.

The monitoring will probably focus on reptiles and terrestrial insects (ants and coleopterans). These groups are good indicator of the health of terrestrial ecosystems, and include endemic species that are assumed to have high conservation value. Baseline data that can be used to assess the long term variation of environmental quality in response to the ongoing changes

will be obtained from the monitoring plots. The results of the monitoring performed in 2008-09, and the outcome of the collaboration with local communities and KIU, will be used to define a protocol for the future long term monitoring of CKNP. Coordination will be ensured with activities focusing on forest and remote sensing, as well as the thematic studies in the integrated case study. Possible linkages to the livelihood research, e.g. through use of specific species by local communities, will also be investigated.

Research on glacier changes: glaciers and the melt water they provide are essential for livelihoods and ecosystems in the Park area, and assessing changes in these is therefore vital. A glacier inventory was recently conducted in CKNP by ICIMOD. This inventory will provide the basis for the analysis devoted to quantifying the ongoing glacier variations. To quantify long-term glacier changes and to evaluate the relation between the behaviour of CKNP glaciers and the last century climate evolution, local and detailed studies will also be needed. Research on glacier changes, and especially on their water runoff, will therefore be conducted within the framework of the integrated study in the Bagrot valley.

Given the major role played by glacier meltwater in the valley socio-ecosystem, the study on glacier changes will provide central elements for the case study.

It is the principal aim to contribute to the knowledge of high elevation glacier variations. This topic is of particular interest due to the ongoing climate change which is driving a worldwide strong glacier recession. For the high elevation glaciers in Pakistan the effect to a changing climate, (e. g. melt down, increase of supraglacial debris thickness and coverage, generation and/or expansion of supraglacial lakes and changes in the dynamic regime), are crucial in relation to the evaluation of water availability and natural hazards. For performing such a study it will be necessary to apply different approaches including direct (field) and indirect (remote sensing) investigations. The application of satellite data, needed to cover such a wide area (10,000 km2), consists of two different levels of analysis:

• the study of the present glacier geometry and morphology, from high resolution data and multi-spectral classification methods

• The study of the recent and ongoing glacier changes from multi-temporal analysis (i.e.: by intercomparison of images acquired in different times).

The first part of the study will include the analysis of the glaciers present shape and size, including supraglacial debris coverage (a fundamental requirement for evaluating glacier energy and mass balances), presence and size of supraglacial lakes and roughness evaluation. In addition glaciological and geomorphological interpretations will be performed on the processed images, in order to detect signals of glacier dynamics (e.g.: looped moraines for glacier surge-type phenomena). A fundamental basis for this research plan will be the inventory of glaciers and glacial lakes in Pakistan carried out by ICIMOD which is involved as partner in this project.

The second part of the research will include the quantification of recent area and volume changes (thus permitting to evaluate the water equivalent volume changes) and the evaluation of changing rates (if they are detectable from satellite images). Moreover will be detected glacier variations as increasing supraglacial debris coverage, change in number and/or size of supraglacial lakes, changes of glacier terminus positions.

Two activities complete the interdisciplinary approach for the knowledge of the environmental and social dynamics in the park; the results of these analysis may help to understand better the human impact and its role in land cover change dynamics: livelihood research and Community perceptions of climate change.

Livelihood research: the high dependence of the local population on ecosystems and the services they provide entail strong linkages between social and ecological aspects of the system. Pilot research on social and livelihood dynamics will be conducted within the framework of the valley-level case study. Through the pilot study, a methodology and research tools will be developed which can be replicated by other stakeholders in the framework of the management planning process to produce baseline data on livelihoods and socio-economic situation in the area surrounding the CKNP. The developed methodology will moreover constitute the basis for a livelihood and socio-economic monitoring system which can be maintained and used by the Park staff during the implementation of the CKNP management plan.

The following aspects will be included in the research: governance, livelihoods/ resource use, culture/ identity and gender/ women. Use and importance of forest, biodiversity and glaciers in local livelihoods will be assessed in the study, ensuring strong linkages to the other thematic studies in the integrated case study. Specific emphasis will further be placed on assessing the vulnerability of local livelihoods to climate change impacts (e.g. use of natural resources; degree of dependence on vulnerable natural resources; perceptions of changes in resource availability; exposure and vulnerability to climate-induced hazards; degree of and opportunities for livelihood diversification). Further, the study is closely linked to the study on community perceptions of climate change (see below). The study will therefore be conducted in coordination with the study of local perceptions of climate change impacts and coping strategies. The combined results will contribute to an understanding of impacts and vulnerability in the project area, and will be a resource when planning management responses.

Community perceptions of climate change: an assessment of community perceptions of changes in the climate, impacts, coping strategies and potential adaptation initiatives will be carried out. The objective is to generate basic information on how changes in the climate are perceived by local communities, and how people are coping with and adapting to them. The information obtained will be analyzed to produce an overview of climatic changes from the local communities' perspective, and their impacts on lifestyle and livelihoods. The results can help identify vulnerabilities and areas where immediate interventions can be made to help the local communities adapt. Since communities have long experience of adjusting to and coping with a variable climate, local knowledge and existing coping strategies can be a resource when planning responses. Further, information on local coping mechanisms facilitates the development of responses which support the existing systems and strategies. Additionally, the activity will contribute to raising awareness of climate change and its impacts among local communities, which is a crucial first step towards effective responses. The study will be conducted as an interview-based survey.

The study of community perceptions will be linked to the research on forests and glaciers, to assess community perceptions and awareness of changes in these resources, and strategies to adapt to them.

3. CONCLUSIONS

Interdisciplinary research is especially useful when studying issues which are very complex and which require understanding of knowledge and methods beyond those of a single academic discipline. It therefore lends itself well to the topic of complex socio-ecological systems. Using an interdisciplinary approach, the study will contribute to understanding of the dynamics of a system represented by a valley. It is envisaged that this understanding will be useful for policy makers and resource managers when making hard decisions on priorities for resource management, conservation and climate change adaptation initiatives. The study can further be seen as a pilot study, and the methodology developed upscaled to other locations. It is further envisaged that the different methodologies developed for the thematic studies will facilitate the establishment of a permanent monitoring system of different aspects of socio-economic systems in the Park and its buffer zone.

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