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Mountainous Regions: Laboratories for Adaptation

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Cover photo: Thom Quine, *A woman with her child in the Peruvian Andes*

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Introduction


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Why Mountains Matter

Gregory Greenwood

It has been a particular pleasure for MRI to work with IHDP on this special issue focused on mountain regions. The Mountain Research Initiative is a global change research initiative jointly authorized by the IGBP and IHDP through their 2001 joint publication, Global Change in Mountain Regions (IGBP REPORT 49/IHDP REPORT 13). MRI has additionally been endorsed by the Global Land Project, a joint IGBP-IHDP effort, as MRI focuses on the GLP scientific issues as they are manifest in mountain regions.

Why should IHDP focus on mountain regions? For those who grew up in mountains or were drawn irresistibly to them in the course of our lives, mountains are fascinating realms that engage our imagination and seem to promise, if not enlightenment, then at least clarity. But an IHDP focus needs a more rational justification: mountains are zones where the signals of global change are particularly clear. At the same time mountains are zones of great importance to humans. Thus values found in or deriving from mountains are greatly exposed to global change, and mountain regions are excellent laboratories for adaptation.

The signals of climate change are particularly visible in mountains, exactly because of the mountains' verticality. The vertical zonation of habitats in mountains, which between the Tropics can start with forests or desert at their base and rise through cooler forests, agricultural landscapes, grasslands and end in the nival zone of permanent ice and snow, recapitulates the progression of habitats from the Equator to the Poles in a tiny fraction of the distance between them. As climate change alters the abiotic controls on these habitats, we can expect, and in fact, already have begun, to see the movement of species over short distances in mountain regions, movements that might otherwise be very difficult to detect at the continental scale. In addition, the proximity of habitats that would otherwise be separated by hundreds or thousands of kilometers allows a fuller range of interactions to drive future biotic community composition and could therefore offer a much richer picture of what climate change might do to biotic systems on the planet. One should not assume that verticality is perfect replacement for vast horizontal distance, but should rather use changes visible in mountain regions to inform investigations at a continental scale.

The verticality of mountains defies gravity, setting up an epic conflict mediated by a host of geomorphic processes

such as erosion, rockfalls, landslides, debris flows, glacier depositions, floods, and avalanches. Mountain landscapes are, compared to the slow changes in lowlands, incredibly frenetic, as water and earth materials pushed skyward by tectonic forces are stripped from the surface and rushed to the sea. All of these geomorphic processes are influenced by global change, especially changes in climate and land cover. Global warming is melting permafrost in steep mountain faces, leading to an increase in rockfall and in debris flows. Changes in land cover can, when coupled with seismic events, themselves highly correlated with mountains, lead to an increase in slope failure, sometimes with catastrophic human impacts.

Climate is not the only global change driver important in mountain regions. The fascination of the mountains on people of all cultures, when coupled with rising incomes and falling barriers to movement, has lead to an explosion of tourism in mountain regions. This tourism takes many forms - from mass tourism in a rapidly industrializing economy such as China to the winter sports economies of the Alps and the Rockies to the adventure tourism of the Himalayas and the Andes - and has led to a dazzling juxtaposition of cultures and exchange, unlike anything one might find now in the Great Plains or the Sahel.

The presence of permanent snow and ice on mountain summits indicates that the zero degree annual isohyet frequently falls in mountain regions. In mid-latitudes the seasonal expansion of snow covered area downslope indicates the movement of that isohyet on an monthly basis. This central tendency and its seasonal variance would be just an interesting factoid, if the isohyet (a line drawn through geographical points recording equal amounts of precipitation during a specific period) did not separate two wildly different environments, one in which water is frequently frozen, white and viscous from another in which it is liquid, often disguised in green and fluid. Nearly all the landscape characteristics that matter are influenced by the position of that isohyet. As it moves on a monthly and an annual scale it drags with it a host of processes that interact with the often highly diverse geology of mountains to produce a wide range of outcomes in a small geographic area.

The presence of the zero degree isohyet in mountains makes mountains similar in many ways to the polar regions, and for that reason MRI refers to mountain regions as the

Third Pole of the planet. Mountains differ in important ways from the polar regions, not the least of which is that mountains are, unlike polar regions, home to a significant proportion of humanity. While in mid and boreal latitudes, mountains have been historically forbidding and menacing, mountains in the tropics have often been the centers of human population, fertile highlands above the arid deserts and humid forests. The high diversity of habitats in mountains translates to a rich array of resources for human use, which can be assembled by overcoming hundreds of meters of vertical rather than hundreds of kilometers of distance.

Ten percent of humanity lives within mountain regions. In Europe the proportion is estimated to approach twenty percent, and one can imagine that between the tropics in Latin America and Africa, the percentage might be even higher. Given the great diversity of mountain habitats coupled with the general difficulty of long distance exchange across mountains, mountains are hotspots of human cultural diversity. The proportion of the human species living in mountains probably therefore underestimates the proportion of our species' cultural heritage found in mountains. As global change alters the nature, location and perhaps even the existence of these resources, these frequently elegant solutions to survival in mountains will be challenged.

Perhaps more important in the 21st century are the resources that mountains make available to societies, now quite urbanized, adjacent to mountain regions. While mountains cover about one-quarter of the planet's land surface, they are, outside of the tropics, responsible for nearly half of the freshwater runoff and are thus critical to water supply for urban and agricultural regions. While this dependence on mountains for water takes on acute form in the cities in Peru, Bolivia and Ecuador - where the loss of glacial resources could very soon have serious repercussion on urban water supply - even in basins such as the Rhine and the Rhone in Europe, changes in the quantity and timing of water delivery due to climate change impacts on snow cover in mountains will challenge down stream water managers.

Challenges to human livelihoods derived from mountains will not come only through direct changes in climate and in the export of water, but will also come through the import of tourists and new residents. In Europe the main destination of tourists is currently the Mediterranean littoral in the summer, with winter tourism in the Alps significant but secondary. However as summers in the Med become increasing hot, European mountain regions may come to resemble the "hill stations" of the Himalayas, to which the wealthy retreated from the pre-monsoon hot season on the plains. In many parts of the developed and even developing world, the rising incidence of second homes is leading to new forms of exchange, creating both winners and losers. In mountain regions of post-communist countries, the transition to market economies has led to remarkable changes in land cover and economy, independent of climate change.

Beyond the question of climate change impacts on both residents and users of mountain regions lies the question of human response to global change through adaptation and new institutional arrangements. Mountain regions are often contested spaces. While indigenous people developed local institutions to mediate exchanges across vertical gradients (e.g. the organized seasonal transhumance of livestock in the Alps), external users of mountain resources (mining companies, urban water districts, hydroelectric producers) often imposed state-based institutions to govern access to resource over great horizontal distances. In regions such as the Rockies of western North America, nation building proceeded through sectoral institutions (forest services, water engineering agencies) that essentially denied the existence of mountains as a territorial entities and instead viewed them as separate bundles of resources. Only recently for instance has California (USA) recognized the existence of the Sierra Nevada through the creation of a state institution, the Sierra Nevada Conservancy, to complement the actions of a myriad of state and federal sectoral agencies.

Thus mountains reminds us of the governance challenges tied to the coupled human-earth system , a concept at the heart of the ESSP. While the introduction of the coupled human-earth system of a planetary scale into public discourse is a major accomplishment of the ESSP members, and essential to any global scale mitigation effort, adaptation to global change remains fundamentally a local or regional activity, authorized and supported by policy action at the national and international levels. The overlay of different institutions and the interaction of different interests governs the fate of mountains regions and cultures, and is thus the starting point for adaptation to global change. While this situation is not unique to mountain regions, it epitomizes the tensions between urban and peripheral regions, between the particularities of place and identity and the generalities of global scale interactions that will characterize our species search for sustainability in the 21st century.

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IHDP Endorsed Research Network

The Mountain Research Initiative: From Theory to Practice

Claudia Drexler

Photo: Upper Mustang; copyright Omar Elsayed

Scientific milestones and dogged persistence

The Mountain Research Initiative (MRI) promotes and coordinates research on global change in mountain regions around the world. In its seven years of existence, it has actively participated in the design of the international research agenda. Its important role is mentioned in the UN Secretary General August 2007 report on Sustainable Development in Mountain Regions. Through its regional networks, MRI catalyses the interdisciplinary research needed to fill current knowledge gaps.

Origins and mission of the Mountain Research Initiative

The first milestone in the history of MRI was the IGBP workshop on mountain issues, at the ICIMOD in Kathmandu, Nepal, from 30 March to 2 April, 1996. Alfred Becker[i] and Harald Bugmann[ii], the driving forces behind the workshop, wrote in the workshop report that "considering the recent developments of the state of natural and socio-economic systems in mountain regions, it can be concluded that these systems are at risk and need special attention, in particular with respect to the possible impacts of global change. Intensified, collaborative and coordinated research is required, which can be fostered through an international research program" (IGBP REPORT 43, P 31).

IHDP, IGBP and GTOS joined forces during the following years to collaboratively define the objectives, approach and activities of this new research programme, the Mountain Research Initiative.

The final product of this effort, a joint report of IGBP, IHDP and GTOS, was published in 2001[1] and lists four dimensions of research within the new initiative:

1. Long-term monitoring of environmental change in mountain regions: mountain-specific indicator groups can be cryospheric indicators such as snow conditions, glaciers, permafrost and solifluction processes, mountain plant communities, mountain soils and freshwater ecosystems.
2. Integrated, model-based studies of environmental change in different mountain regions: these studies include coupled ecological, hydrological and

land-use models for the simulation of land cover and land surface processes, or the development of regional atmospheric models.

3. Process studies along altitudinal gradients: such studies include assessments of runoff generation and flow path dynamics on steep hill slopes, and studies of the relationship between diversity and ecosystem function, taking advantage of the strong changes of diversity along altitudinal gradients.
4. Sustainable land-use and natural resource management advice, with three priority areas: changes in forest resources, intensification and/or extension of agriculture and grazing and changes in water resources due to changing water use by humans.

The notion was never that MRI, as institution, would direct such a programme. Rather, the idea was that MRI, both as institution and as a community of researchers, would facilitate the emergence of such research through the promotion and coordination of research funded and conducted by a myriad of agencies and individuals around the world.

Actions on the global level: Design of an international research agenda

The MRI Coordination Office in Berne, Switzerland, was established in 2001 at the Swiss Academy of Sciences using funding from several Swiss agencies and the ETH. The MRI team, led by Dr. Mel Reasoner, set off to foster and coordinate the 4 types of research listed above. Dr. Greg Greenwood succeeded Dr. Reasoner as Director in 2004.

A first major product of the initiative was the publication of a "Global Change in Mountain Regions – An Overview of Current Knowledge"[2]. This 700 page compendium with over 70 contributions from all continents provides an overview of what is known and what directions research should take in the future with regard to five research areas: paleoenvironmental changes, cryospheric changes, hydrological changes, ecological changes. and human dimensions.

The GLOCHAMORE project translated the global goals of IGBP Report 49 into more specific, disciplinary objectives coupled to a recommendation for the inter and transdisciplinary research approaches targeted on UNESCO Mountain Biosphere Reserves (MBRs) around the world. The "GLObal CHAnge in MOuntain REgions" project, coordinated by MRI and by Prof. Dr. Georg Grabherr at the University of Vienna, was a Specific Support Action of the EU's Sixth Framework Programme on "Sustainable Development, Global Change and Ecosystems". The GLOCHAMORE Research Strategy[3], the project's final product, is a integrated and implementable research strategy to better understand the causes and consequences of global change in mountain regions around the world. The strategy is a consensus document, developed through consultation with the international community of scientists and Biosphere Reserve managers at five workshops and one final conference, structured according to the four aforementioned core activities of MRI (http://mri.scnatweb.ch/projects/glochamore/).

Actions on a regional level: How to fill the scientific gaps?

In 2006, the MRI moved from strategy development to implementation through the initiation and support of regional networks of global change researchers. As MRI is a promotion and coordination effort, it cannot simply "do" the research necessary in a region, but must induce research groups and individual scientists to fill the scientific gaps defined by the GLOCHAMORE strategy.

Thus, four programme activities are at MRI's core:

1. MRI strives to enlist key scientists who, in turn, promote the inter and transdisciplinary research through their national or multinational research funding agencies. By engaging these champions of global change related mountain research, MRI can vastly improve its effectiveness.
2. MRI supports the formation of new research partnerships and catalyses groups and individuals to develop project proposals for funding agencies. This is a direct and efficient way to create the kind of research defined in the GLO Strategy.
3. MRI facilitates the development of peer-reviewed papers on key, specific scientific issues, such as the carbon cycle in mountains, the transfer of hydrologic knowledge from scientists to managers and the food security of mountain inhabitants dealing with climate changes. These contributions to the literature focus the community's attention on some of the most important issues in mountain regions.
4. MRI distributes relevant information to researchers on global change in mountains. By increasing the flow of information to these researchers, MRI seeks to create additional interaction and a more solid sense of community among them.

Photos: Upper Mustang; copyright Astrid and Prem Gurung

Scientific networks and their outputs

A large part of MRI's activities occurs through the three regional networks: MRI Africa, MRI American Cordillera and MRI Europe. Research networks in Monsoon Asia and in Central and Northern Asia are in the planning stages. Within these regional networks, MRI attempts to catalyse global change research in the thematic fields defined in 2001 and specified in the GLOCHAMORE Research Strategy. It does so principally through the development of new funding proposals, but also through the engagement of regional leaders and the development of region-specific communication products.

The functioning of MRI's regional networks and their scientific output can be illustrated by an example of an individual network:

MRI Europe
(http://mri.scnatweb.ch/networks/mri-europe/)

The Mountain Research Initiative initiated the "Global Change Research Network in European Mountains" in 2006. It aims to connect and support global change researchers working in different mountain regions throughout Europe. Networking meetings convened by MRI and its regional partners allow participants to exchange ideas and to locate opportunities for collaboration. As of fall 2008, MRI Europe had grown to almost a 1,000 active scientists.

MRI is the information clearinghouse for the network members and the MRI Europe database, website and bimonthly Newsflash are the network day-to-day tools.

The scientific outputs of MRI Europe include the drafting of proposals for funding agencies and the creation of regional research agendas.

Proposals
MRI allocates considerable time to the implemention of the GLOCHAMORE Research Strategy though the development of research proposals, be it as initiator or partner. In 2007 and 2008, seven proposals to European funding agencies such as COST and FP7 have resulted from MRI Europe. Among them is the proposal to the European Science Foundation for a "Network for Integrated Assessment of the Dynamics of Mountain Catchments under Global Change" (NET-DYNAMO), submitted by Prof. Dr. Martine Rebetez of the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Dr. Rüdiger Grote of Institute for Meteorology and Climate Research, Germany (IMK) and Prof. Dr. Ulrike Tappeiner of the University of Innsbruck, Austria, with assistance from MRI in October 2007. This Research Network Programme aims at producing policy-relevant integrated assessments under global change scenarios in selected mountain catchments by means of existing models. The ESF recommended this programme for funding in June 2008 and is currently seeking funding from its member organisations.

Working towards a research agenda for the Carpathians
The Science for the Carpathians (S4C) initiative developed within the European network at an unprecedented speed. In spring 2008, a group of researchers with a mandate from the Interim Secretariat for the Carpathian Convention (ISCC,

Photo left: Upper Mustang; copyright Omar Elsayed

Photo above: Astrid Björnsen Gurung, MRI, Switzerland, and Jill Baron, CIRMOUNT, USA at MRI's workshop "Interdisciplinarity in Mountain research", Brig 2008; copyright MRI

UNEP-Vienna) requested the MRI's assistance in organising science in the Carpathian region. The MRI worked with the Jagiellonian University, the European Academy Bolzano (EURAC), Joanneum Research, the University of Applied Sciences Eberswalde and the Humboldt University of Berlin to organise the first S4C meeting in May 2008 in Krakow, Poland. The goal was to set the first milestones for a new science network for global change research in the Carpathian mountains. The workshop aimed at defining the current status of global change research in the Carpathians, drafting a research agenda for topics relevant to the region and establishing an active science network. The S4C initiative received the support of the Conference of the Parties of the Carpathian Convention at their meeting in Bucharest in May 2008.

The future of the MRI

The current time horizon for the MRI is October, 2010, which will signal the end of the second three-year grant from the Swiss National Science Foundation (SNF/FNS). MRI will seek further funding thereafter.

Examples of what the MRI intends to accomplish during this time include:

Implementation of Net-DYNAMO

Assuming that Net-DYNAMO is funded through the ESF and begins work in 2009, workshops will develop one or more integrated assessment methodologies based on existing models and scenarios, and on cross-site analysis of results. The network includes scientists working across Europe as well as in adjacent countries and on catchments in Africa, South America and North America. The network will strengthen European capacity to perform integrated assessment at policy relevant scales and provide continent-wide analyses of scenarios and adaptation proposals in sensitive mountain regions.

Collaboration with the Austrian Academy of Sciences on MRI Europe

After 1 September 2008, the "Forschungsstelle für Gebirgsforschung: Mensch und Umwelt" (IGF) of the Austrian Academy of Sciences has agreed to take the lead role in the implementation of MRI Europe. MRI and IGF will consult regularly under a Memorandum of Understanding on policy direction. The "MRI Europe" programme and the position of Dr. Astrid Björnsen Gurung will be adopted and financed by IGF while the office infrastructure and logistics will remain with the University of Berne. This cooperation between the MRI and the IGF will lead to joint Swiss-Austrian initiatives, increasing the impact of each institution and leading, hopefully, to increased cooperation with other, similar research institutions in Europe.

Peer-reviewed papers on issues of key concern

MRI will be coordinating workshops leading to papers on key global change issues for mountain regions including but not limited to the following:

- *Science for the Carpathians (S4C):* this paper will provide an overview of global change research in the Carpathians and describe potential elements of a research strategy for the Carpathians. Partners: Jagiellonian University (Poland), European Academy Bolzano (EURAC, Italy), Joanneum Research (Austria), University of Applied Sciences Eberswalde, and Humboldt University of Berlin.
- *Cordillera Forest Dynamics Network (CORFOR):* this paper will provide a preliminary evaluation of climate change impacts on forests along latitudinal gradients. Partners: National University of Colombia, Medellin, USGS Western University Research Centre.
- *Carbon and water in mountain forests*: this paper will describe climate change impacts on montane forest cycling of C and H20. Partner: forest ecology, ETH Zürich, Switzerland.
- *Mountain waters:* this paper will provide a translation of climate change scenarios into water resources management approaches. Partner: hydrology group, University of Bern, Switzerland
- *Food security:* this paper will examine climate change impacts on food security issues, their causes and potential adaptation measures in the mountain regions of developing nations.

Conferences 2010

MRI and the Centre for Mountain Studies of Perth College are planning a conference with the working title "Perth 2010 - 5 years after Perth I" as a follow-up to the 2005 Open Science Conference "Global Change in Mountain Regions". The 2010 conference aims at communicating new results between scientists working in the mountains of both industrialised and developing countries around the world and present scientific advances on the topics defined in the GLOCHAMORE Research Strategy.

A first "Forum Carpathicum" is planned for September 2010 as the first international and interdisciplinary meeting of researchers working on global change topics in the Carpathians.

Conclusion

During the 2007-2010 period, MRI will continue to work within all three regional networks in Africa, the Americas and Europe. By 2010 the MRI will also expand these activities to the Asian mountains.

The history of MRI is a the story of a shift from abstract ideas towards concrete activities and real people. Whereas the compilation of the GLOCHAMORE Research Strategy was an intellectual challenge, defining and evaluating globally compelling global change research topics, the current challenges are much more human and entrepreneurial. How can we build active and growing communities and how can we make sure that their members in turn produce the products that we need? This move epitomises the IGBP – IHDP relationship within ESSP. While the natural world studied by IGBP scientists is the basis of our life, human actions determine what we make of it, its products and its future.

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mri mountain research initiative

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ii. Forest Ecology, Swiss Federal Institute for Technology, Zürich, Switzerland

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The Chagga Homegardens on Kilimanjaro

Claudia Hemp, Andreas Hemp

Diversity and refuge function for indigenous fauna and flora in anthropogenically influenced habitats in tropical regions under global change on Kilimanjaro, Tanzania

Humans continuously inhabitated the slopes of Mt. Kilimanjaro for the last 2000 years (Odner 1971). However, during the last decades the human population increased dramatically from about 100,000 people in 1913 (Raum 1914) to 1,053,204 people in 2002 (National Bureau of Statistics 2003). As such, the population has multiplied 10 times in 90 years. Most of the population is concentrated at an altitude betwe(en 1000 and 1800 metres, with densities varying from 500 to 1000 people per km² in some areas. Here a very remarkable kind of land use prevails: dense "banana forests" with a scattered upper tree layer, the so-called Chagga homegardens, in English "banana grove", in German "Bananenhain", in Chagga language "mndà`". Due to this sustainable and well developed agroforestry system degradation in this vegetation belt is rare, despite the enormous population. In their homegardens the Chagga use four vegetation layers. Under a tree layer, which provides shadow, fodder, medicines, firewood and formerly also construction wood bananas are grown and under the bananas coffee trees, and under these vegetables. This multilayer system maximizes the use of limited land. The area is irrigated by a network of canals fed by main furrows originating from the montane forest. Rough estimates give over one thousand furrows of varying lengths and capacities (Ramsay 1965). This farming system evolved over several centuries and did not change much over the last decades compared with the land uses in the lower zones. There is evidence that the first banana gardens and water canals existed already in the 12th century (Winter, pers. com.). This old land use system has formed the identity of the Chagga, who are of multiethnic origin, despite the fact that they belong to the Bantu people.

The agroforestry system of the Chagga homegardens is a unique feature of Kilimanjaro, stretching on the climatically most favourable zone of the southern and south-eastern slopes (Fig. 1) over an area of 1000 km². If one passes from north-east to the south-western end of this belt, one could drive for 120 km through a closed "banana forest" containing about 225 Million banana "trees" – if there was a continuous road. The same type of land use, however with a smaller extension, occurs on the Pare Mountains and Mt. Meru, which shows nearly exact the same floristic and structural composition.

In a recent study Hemp, A. (2006a) described natural flora, vegetation and structure of the Chagga homegardens and Hemp, C. (2005) investigated the function of the Chagga homegardens as a habitat of endangered and endemic grasshopper species. To highlight their function for biodiversity and as a refuge area for natural plants and animals the spe-

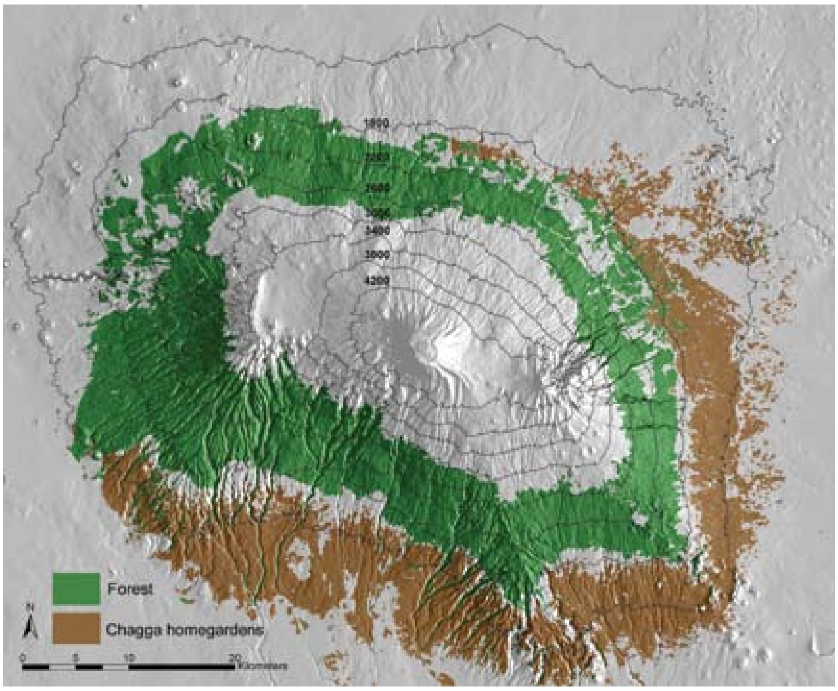


Photo Left: Mount Kilimanjaro; copyright Marc van der Chijs
Figure 1: Distribution of the Chagga homegardens on Kilimanjaro, based on a supervised classification of Landsat ETM images taken on 29 January and 21 February 2000 (source: USGS/UNEP-GRID-Sioux Falls) using the software IDRISI 3.2 and ArcInfo 8.3. Digital elevation model by Christian Lambrechts and Janet Akinyi Ong'injo, Nairobi, based on toposheets at scale1/1:50,000.

cies composition of this man-made habitat was compared with all vegetation formations of Mt. Kilimanjaro.

Vegetation structure of the homegardens

Fig. 2 shows a vegetation profile of a Chagga homegarden in the area of Kidia (Old Moshi) (ALL DATA FROM HEMP A. 2006A). Typical of the agrisilvicultural system of the Chagga homegardens is their multilayered vegetation structure similar to a tropical montane forest. Therefore the growth form spectrum (FIG. 3) displays beside herbs also trees, shrubs, lianas and epiphytes. Apart from some cultivated fruit trees, e.g. Avocado and Mango or introduced timber trees such as Grewillea robusta and Cupressus lusitanica, most of the 82 encountered tree species are remnants of the former forest cover. Most widespread are Albizia schimperiana, Rauvolfia caffra, Cordia africana, Commiphora eminii and Margaritaria discoidea. Nearly all banana fields are covered by at least some trees.

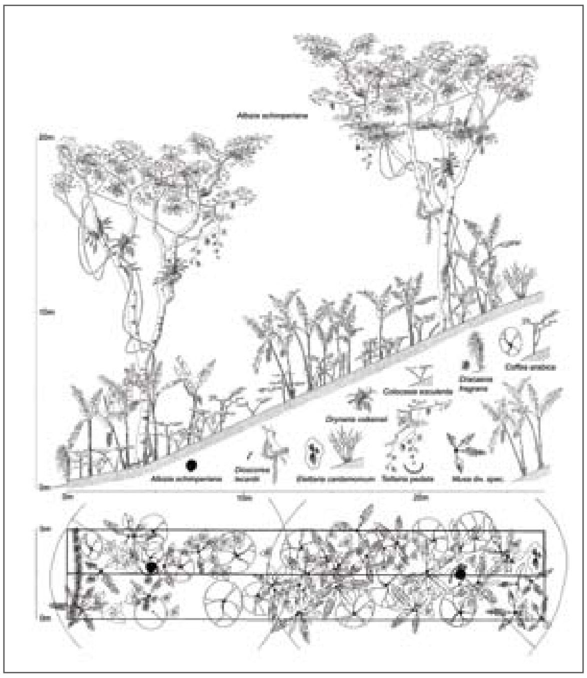
52 liana species were found in the plots. Eleven liana species were cultivated plants with important agricultural crop plants such as three Dioscorea and Passiflora species and the Cucurbitaceae Telphairia pedata belonging to this growth form.

Similar to the trees, epiphytes and lianas most of the shrubs in the Chagga homegardens were forest species. However, in the shrub layer the most important cultivated plants occurred: Different varieties of Musa x sapientium (dessert bananas) and M. x paradisiaca (cooking bananas) and Coffea arabica. Bananas form a dense (mean cover value 50%) upper shrub layer of about 4-6 m height and coffee trees a lower layer of 1,5-2 m.

Biodiversity of the homegardens

Flora

The Chagga homegardens maintain a high biodiversity with over 500 species including 400 not cultivated plants (ALL DATA FROM HEMP A. 2006). This is about three quarter of the species occurring in the ruderal vegetation formation (i.e. vegetation on road sides, waste places and fallow arable land) on Kilimanjaro. With over 700 species this formation holds rank three in respect of species richness after the forests and grasslands. Most areas of the submontane and lower mon-



From top to bottom

Figure 2: Profile (27 x 2,5 m) and ground plan (27 x 5 m; bold lines indicate the area used for the profile) of a typical Chagga homegarden in Kidia (Old Moshi) at 1400 m asl. Exposition: south west, inclination: 25 degree. An open light upper canopy is formed by Albizia schimperiana var. amaniensis, on which epiphytes such as the fern Drynaria volkensii and Telphairia pedata, a liana with oil-containing seeds, find habitats. Bananas form a dense upper shrub layer of 4-6 m height, coffee trees a lower shrub layer of 1,5-2 m, intermingled with 1-1,5 m high Coco Yam (Colocasia esculenta). The lower side of the banana field borders a path; here Dracaena fragrans is planted as a hedge.

Figure 4: Chagga homegardens in the area of Kibosho with an open tree canopy and a dense banana undergrowth.

Figure 7: Mixture of partly endemic Saltatoria species found within Chagga homegardens.

tane coffee-banana belt resemble woodland with a dense undergrowth of bananas (FIGS. 2 AND 4). Thus, over one third of the plants (193 species) occurring in the homegardens were forest inhabitants, species that need a forest-like habitat structure for surviving (FIG. 5). These are about 17% of the 1225 forest plants of Kilimanjaro (45% of the forest trees and 17% of the forest epiphytes). Some forest plants (e.g. Pilea tetraphylla) were only encountered in the banana plantations but in none of the about 600 forest plots established on the mountain, highlighting the important conserving function of the Chagga homegardens, which resemble in fact more “homeforests” than homegardens. Compared with large scale commercial coffee plantations this conserving function becomes evident: Four surveyed commercial plantations harboured only 6 forest species, and three quarter of the species were widespread ruderal or cultivated species.

These findings are in line with the fact that biodiversity in general on Kilimanjaro culminates at 1000-1300 m with over 900 vascular plant species inside the coffee-banana belt, the most densely populated region of the mountain. This is due to the high variety of (moderately) cultivated areas (the Chagga homegardens), forest patches, river gorges and grasslands at this altitude. This (mostly man-made) variety of habitats, the high beta-diversity, promotes alpha-diversity, allowing species from lower altitudes to climb up the mountain. A similar phenomenon was observed in the Saltatoria fauna of Kilimanjaro (HEMP & HEMP 2003, SEE BELOW).

Saltatoria

192 Saltatoria species (grasshoppers and bush crickets) were recorded for the whole of Mt. Kilimanjaro, the majority in grassland (130 species), followed by waste land (includes fallow arable land, roadsides and open disturbed places) with 83 species, forests with 38 species, and clearings with 47 species (FIG. 6). The Chagga home gardens form an important habitat in respect to biodiversity, with 52 species, about a quarter of the whole Saltatoria fauna. Comparatively few species were found in swamps (14 species) and only 6 Saltatoria species occur in the afro-alpine zone.

Over 70% of the Saltatoria species found in the Chagga home gardens originate from forest communities, the remainder are open land forms. The forest species come from the colline zone (12 species), the sub-montane zone (12 species) and montane zone (4 species). Ten forest species, mainly from colline savanna forest communities, were not found in the homegardens.

One hundred and fifty-four open land species are known; only 24 species (16%) were found in plantations; 8 are open land forms from the colline zone and 15 were found in the sub-montane zone. Only one species is an inhabitant of the montane zone.

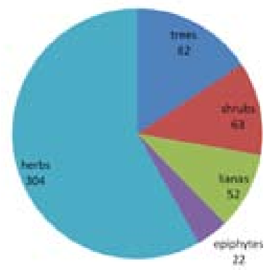
Thirty-two percent of the species in the Chagga home gardens are endemic. Endemism rate for the whole of Mount Kilimanjaro/ Meru area is 16 %. The Chagga home gardens provide habitat to more than half of the endemics occurring from the colline to the afro-alpine zone of Mt. Kilimanjaro. Two endemic species found in plantations originate from habitats of the colline zone, nine from sub-montane and five from montane habitats. 25% of all colline endemics also occur in plantations, as well as 75% of all sub-montane and 63% of all montane endemics of Mount Kilimanjaro.

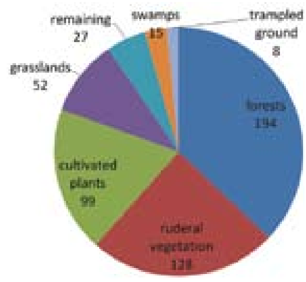
Although highly influenced by human habitation, the Chagga home gardens serve as important regional refuge for Saltatoria species, especially for forest species and endemics. The mixture of retained tree canopies and open patches appears to favour a mix of species typically not found together elsewhere (FIG. 7).

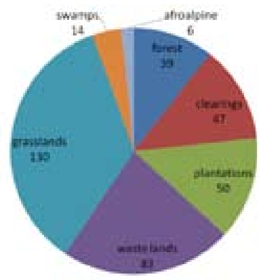
From top to bottom
Figure 3: Growth form spectrum of the Chagga homegardens showing species number of the respective stratum in the vegetation plots.

Figure 5: Floristic composition of the banana fields in respect of the different vegetation formations on Kilimanjaro.

Figure 6: Saltatoria species of different habitats on Mt. Kilimanjaro. Numbers are based on 192 species. Many species occur in more than one habitat.







The homegardens and global environmental change

The extinct natural forests of Kilimanjaro's lower slopes
Large-scale environmental change has a long history of over 2000 years on Kilimanjaro: The "banana forest" of the Chagga homegardens replace a natural forest, which covered the lower slopes of Kilimanjaro before human settlement. This lost forest resembled in many aspects the species- and endemic-rich submontane forests of the Pare and Usambara Mts. that belong to the biodiversity hotspot of the Eastern Arc Mts. Today, only the deepest valleys in the cultivated areas harbour forest relicts of that type suggesting a rich forest flora inhabited lower areas of the southern slopes of Mt. Kilimanjaro in former times. Since humans have continuously inhabited the lower slopes of Mt. Kilimanjaro for at least the last 2000 years (ODNER 1971), it can be assumed that many forest species were extirpated together with the forest cover. Thus, the lower degree of endemic forest plants of Kilimanjaro can be explained by wide destruction of the lower montane forests. This is corroborated by the fact that forest species such as members of the grasshopper group Saltatoria, who are affected less by forest devastation, have similar numbers of endemic forest species in the submontane and montane zone on Mt. Kilimanjaro (including Mt. Meru) and the East Usambara Mts. Many endemic grasshopper species have coped with the habitat change from forest to plantations (HEMP & HEMP, 2003; HEMP, C., 2005). Therefore, Kilimanjaro can serve as a striking example of the large and long-lasting anthropogenic influence on levels of diversity and endemism of African landscape (HEMP 2006B).

Recent changes
In the past few years changes in the management of commercial coffee plantations have been noted. Plantation ownership is changing and new coffee varieties that are less shade-demanding are being planted. There is, therefore, no need to retain a tree canopy layer, and where this has happened hundreds of trees have been removed, e.g. in the Mweka area of Kilimanjaro in 2003. High demand of wood, low coffee prizes on the world marked and the introduction of coffee varieties that are sun-tolerant also endanger the traditional homegardens. In some areas of the mountain (e.g. on the eastern slopes) the trees in the banana fields are very scattered or already missing. This has far reaching consequences for biodiversity, microclimate and soil fertility.

Scenarios of future environmental change: evidence from Saltatoria
To understand future processes on fauna and flora of an ecosystem with a changing environment the knowledge about the situation of the past is very valuable. In case of the insect group Saltatoria historical data from about 100 years ago are available (SJÖSTEDT 1909). Also the understanding of the

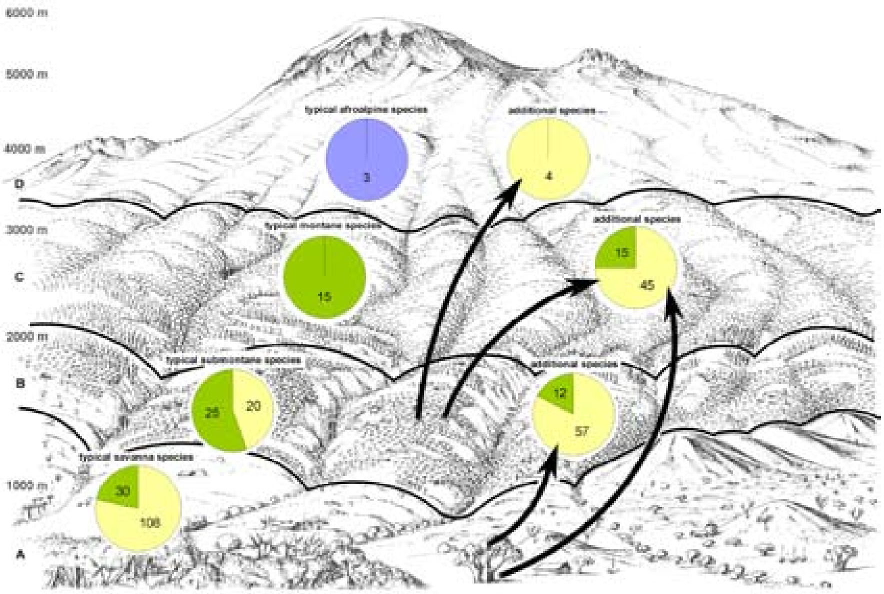


Figure 8: Upward migration of Saltatoria species from lower zones. Left circles giving numbers of species which are typical for this zone; right circles giving numbers of species that are additionally found to the typical species of the respective zone, arrows indicating area from which they migrated upwards. Yellow: openland forms, green: forest forms; blue: afroalpine forms. A: colline lowland savanna area, B: submontane and lower montane zone, C: montane zone, D: (sub)alpine zone.

ecological demands of species is necessary to make predictions of what will happen when the environment changes. In our studies we investigated the habitat demands of Saltatoria using a modified method of Braun-Blanquet (1964), usually applied in plant sociology. In parallel vegetation relevés and Saltatoria assemblages were recorded and united to a table (FOR FURTHER INFORMATION ON THIS METHODS SEE E.G. HEMP & HEMP 2003, HEMP C. 2005).

Thus comparing the historical data and using the information on habitat demands of stenoecious species it became clear that many Saltatoria species either "moved" uphill in the past 100 years or suffered from a dramatic population decrease e.g. Parepistaurus lindneri, which was found only in remnants of sub-montane forest, along riverine forest and in few plantations fringing rivers in the colline zone. The same stands for Horatosphaga montivaga (SJÖSTEDT 1909), which was recorded 100 years ago inside the banana belt. Today this species was not found at the type locality any more due to habitat loss. Typical submontane forest Saltatoria (e.g. Maura lurida (FABRICIUS 1781) and Anoedopoda lamellata (LINNÉ 1758)) today only occur in small forest relicts, mostly in deep inaccessible gorges. Thus, A. lamellata for example, seems to have been a common katydid during Sjöstedts expeditions (SJÖSTEDT, 1909) while today it was found only twice since 1996. Maura lurida (submontane forest, PHIPPS, 1970) was not recorded on Kilimanjaro again, since its first record.

A striking example for an upward movement is the endemic grasshopper Ixalidium sjostedti Kevan, 1950. Species of the genus Ixalidium are bound to litter of semishade situations preferably of submontane forests. Volkens (1897) reported that this forest type was still present on the lower slopes of Mt. Kilimanjaro 100 years ago and Sjöstedt (1909) reported that I. sjostedti occurred from the savanna to the cultivation belt on Mt. Kilimanjaro. Sjöstedt (1909) stated that this species preferably dwells among litter of the plantation belt. In our studies we found I. sjostedti beside in submontane plantations frequently also in higher located homegardens and even at the lower border of the montane rain forest and forest paths to elevations of over 1900 m. From the beginning of the last century to today the Chagga people multiplied 10 times and subsequently the cultivated area expanded. With the anthropogenic opening of the closed forest species such as I. sjostedti moved upwards now finding habitat also at higher elevations. Even today this species can still be found in riverine forest remains at 1000 m a.s.l. of the southern slopes of Kilimanjaro showing that it was once a species of colline and submontane forest habitats.

These processes in Saltatoria due to landcover changes can be observed in several stenoecious taxa on Mt. Kilimanjaro as well as on adjacent mountains (e.g. North and South Pare, West and East Usambara). Thus all those species are affected by landcover changes that show narrow habitat demands such as species from the genera Parepistaurus, Altiusambilla/Rhainopomma, Odontomelus, Gymnobothroides, Amytta, or Chromothericles. With increasing influence of humans, that means that more and more submontane forest was changed into agroforestry systems in the past 100 years, species of these genera coped and found habitat in the now anthropogenic influenced environment. Some of them even enlarged their area of occurrence since they now occur also in higher elevations while others (e.g. pure forest species) got extinct in the homegardens.

If the observed trend towards a drier and warmer climate on Mt. Kilimanjaro (SEE HEMP A. 2005) proceeds lower vegetation zones of Kilimanjaro will move up-wards and will get more and more fragmented. Savanna species will spread from lower altitudes to the submontane, montane and even afroalpine zone due to loss of forest and a warmer microclimate. Saltatoria species show this trend very clearly even today (FIG. 8). About 100 years ago the submontane zone was still partly covered by forest and comparatively few Chagga homegardens concentrated in favourable areas. 45 Saltatoria species are typical inhabitants of the submontane zone. Due to the dense human population many areas have been opened up creating habitat for openland species which are typical for savanna habitats. Thus, nowadays 69 savanna species are found on grasslands, pathways and fallow land of the submontane zone. Also the montane zone is affected by these changes. Beside 15 typical montane Saltatoria species, all of them forest species, 60 species originating from lower zones were recorded during our studies, e.g. on montane meadows, forest paths and clearings and also in the forest. And even the alpine zone is affected by these changes: originally harbouring 3 purely endemic species, 4 Saltatoria species from lower zones are found occasionally also in this habitat. With an ongoing fragmentation, especially of the montane forest zone will be affected most. From the lower edge in the densely populated cultivated zone the forest belt is opened up by fires, illegal logging and cattle grazing while wild fires of the afroalpine zone lead to a downshift of vegetation belts from the upper zone (see Hemp 2005). Highly endangered will be mainly endemic and stenoecious species of the forest belt that will suffer loss of habitat and even will get extinct in the near future if this trend continues as we recorded it for the past 15 years. The Chagga homegardens in its present form still offer habitat for some of the stenoecious species. However, depending on a steady water outflow from the forest belt the homegardens are already suffering from a reduced water yield of burnt cloud forests (Hemp 2005). If this sustainable agroforestry system is lost Mt. Kilimanjaro will loose most of its endemic inhabitants as studied in the group Saltatoria.

Conclusions

In summary, the Chagga homegardens maintain not only a high biodiversity, they are an old and very sustainable way of land use that meets several different demands. Beside crop production, the sparse tree layer provides people with firewood, fodder and timber. But the high demand of wood, low coffee prizes on the world marked and the introduction of coffee varieties that are sun-tolerant endanger this effective system. In order to reduce the pressure on the forest, it is necessary, to support the tree planting in the Chagga homegardens with their unique agroforestry system. Similar to environmental programs for farmers in the European Union (e.g. for the protection of wetlands or dry meadows), there should be a program that rewards farmers to have a certain share of their land covered by trees. It can be estimated that a homegarden supplies ¼ to ⅓ of the fuelwood requirements of a family (Fernandes et al. 1984). As the banana belt is nearly as extensive as the forest reserve, this will of course have major effects in terms of forest protection and the water balance. In combination with new marketing and farming strategies for growing organic coffee through traditional methods an advertising campaign should be started especially in European countries where the awareness of environmental problems is high.

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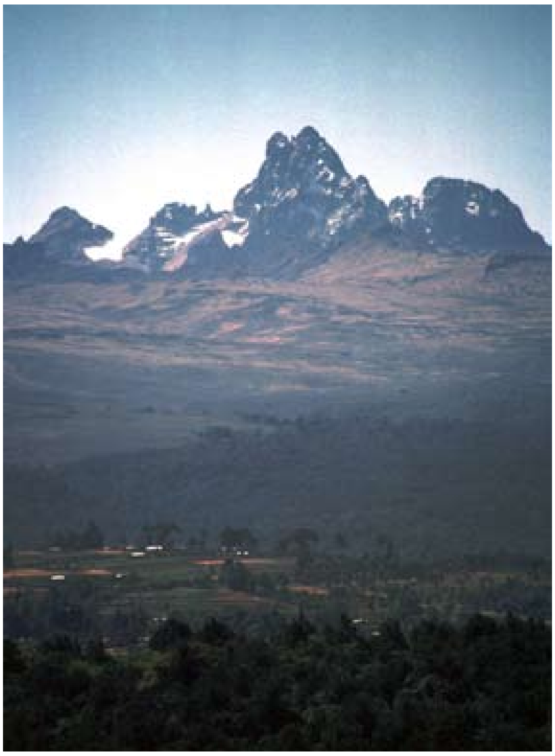

Photo 1: Mount Kenya seen from the North. The different altitudinal zones (farming, forest, and afro-alpine and nival zones) are clearly visible; copyright Hanspeter Liniger

Dimensions of Global Change in African Mountains: The Example of Mount Kenya

Boniface P. Kiteme, Hanspeter Liniger, Benedikt Notter, Urs Wiesmann, Thomas Kohler

This paper discusses the effects of global change in African mountains, with the example of Mount Kenya. The geographical focus is the northwestern, semi-arid foot zone of the mountain (Laikipia District). Over the past 50 years, this area has experienced rapid and profound transformation, the respective processes of which are all linked to global change. The main driving forces behind these processes have been political and economic in nature. To these an environmental change factor has been added in recent years – climate change.

After introducing the area of research, the paper presents three dimensions of global change that are manifested in the region and largely shape its development:

- Socio-political change: this refers to the 1960s, the decade that brought independence to large parts of Africa, certainly a change of global dimensions. One of the major effects of Kenya's independence in 1963 was land redistribution, which resulted in large-scale internal migration involving many regions of the country, particularly the regions northwest of Mount Kenya.
- Economic change: this refers to a period that began in the mid 1980s and which saw the increasing incorporation of Kenya, and the area northwest of Mount Kenya, into globalised food markets, with a focus on horticultural production for European markets.
- Environmental change: this refers to global climate change and hence looks back to the effects of changes that have already occurred, as well as anticipating changes that might occur in future. For the regions northwest of Mount Kenya, climate models predict important changes in rainfall distribution that will have a profound impact on freshwater availability and management.

The results presented here are based on research undertaken northwest of Mount Kenya within the framework of a series of long-term Kenyan-Swiss research programmes that began in the early 1980s. Funding was provided mainly by the Swiss National Science Foundation and the Swiss Agency for Development and Cooperation, with contributions from the Kenyan Government and a number of international donors such as the Rockefeller Foundation and others.

Mount Kenya – a water tower in a semiarid region

Mount Kenya is the second highest peak in Africa (5,199 m). It contains a World Heritage Site and a National Park in its upper zones. There are 12 remnant glaciers, all receding rapidly. With its glacier-clad rocky summits, Mount Kenya is one of the most impressive landscapes in East Africa

(PHOTO 1). Biodiversity is outstanding, owing to the succession of different bioecological zones at close range, extending from nival and afroalpine to forest and savannah. The summit area is a major destination for mountain tourism in Kenya, including trekking, mountaineering, and game watching. Differentiation within the densely populated foot slopes around the mountain is also high; land use includes such diverse forms as small-scale farming based on multicropping, as well as horticulture, ranching, and pastoralism. The mountain is regarded with great respect by local communities and many people still consider it a repository of spiritual power.

Mount Kenya is an island of resources in a dry environment. Specifically, it is a water tower providing water to over 7 million people living in its surroundings. All the major rivers in the region originate from Mount Kenya, with most of the water coming from the middle and upper zones of the mountain, especially in the dry season. These zones provided 73% of the dry season flow between 1985 and 1999, with forests and moorlands contributing 65%, and the Alpine zone, including the glaciers, 8%. From the point of view of water supply, therefore, the disappearance of the glaciers will have a negligible impact, which stands in marked contrast to the situation found in other mountain areas of the world.

The greater Mount Kenya region has experienced rapid and far-reaching change over the last 50-60 years. Population has increased manifold, both in rural and urban areas, and traditional subsistence farming has incorporated coffee and tea production, and most recently horticulture, which have all become major export earners for Kenya. These developments put increasing stress on natural resources, especially water, which is important not only for agriculture and the growing urban centres in the areas immediately adjacent to the mountain, but also for pastoralism and tourism (also a major foreign currency earner) which are located further downstream.

Political change – Kenya's independence and its effects northwest of Mount Kenya

Change and transition have been especially fundamental and far-reaching in Laikipia, the region located in the drier northwestern foreland of Mount Kenya. Following Kenya's independence in 1963, this region, which had formed part of the so-called "White Highlands", was opened up for African settlement. Many of the large-scale properties were sold and subdivided, and land use changed from ranching to small-scale mixed farming (PHOTO 2). This major transition was accompanied by a large influx of people who mainly immigrated from high-potential but densely populated Central Kenya. The population increased from 58,000 in 1962 to over 300,000 in 1999, which corresponds to an average annual growth rate of 4.7% compared to the national average of 3.3% for Kenya as a whole. Today, population densities are as high as 150 persons per square kilometer in what was a pastoral area before colonial times. Unfortunately, rainfall in the area is marginal for crop production; annual rainfall is low and highly unreliable in terms of amount and timing. Crop failures are frequent and widespread, especially for maize, Kenya's most important staple and the crop preferred by immigrant small-scale farmers. Food production in this sector covers about 65% of household needs in the less dry areas closer to the mountain, but only 5-10% in the drier areas further away from the mountain. As a consequence, food security is very low and poverty is widespread in the smallholder settlements in the area. Originally from high-potential areas, many of the small-scale farmers did not invest primarily in adapting rain-fed agriculture to semi-arid conditions, but turned to river water for irrigation in order to secure production. This has increased legal and, to a greater extent, illegal water abstractions from mountain rivers tremendously since the 1960s. For example, within the five-year period from 1997 to 2002 river water abstractions increased by 250 to 300 % for the different rivers.

Photo 2: Close neighbourhoods: large-scale and small-scale farming, northwestern foot zone of Mount Kenya; copyright Hanspeter Liniger

Economic change – the appearance of large-scale horticulture

Kenya has been integrated in global markets since colonial times, especially the coffee, tea and tourism markets. Since independence, coffee and tea have also been grown by smallholders, including those South and East of Mount Kenya, while tourism has been concentrated on the coast and in semi-arid areas. None of these global markets therefore made a noticeable impact in Laikipia. This changed with horticulture.

Large-scale irrigation horticultural production began to make its appearance in Laikipia, and elsewhere in Kenya, in the early 1980s (PHOTO 3). The sector has since experienced a boom. With a 20-fold increase in export value between 1983 and 2002 for the country as a whole, it is now second to tea and has surpassed coffee as an export commodity. This boom is reflected in developments in Laikipia. Between 1991 and 2003, 24 large horticultural firms were established there, with a total area of 1085 ha. Production of vegetables for national and international (mainly European) markets accounts for 94% of the output. Large-scale horticulture has become the single most important formal generator of employment and income in the rural areas north-west of Mount Kenya. Its total salary disbursements are equivalent to 10,000 Euros per day for a labour force of 4700 to 7400 persons. At the same time, the sector has become a major competitor for the scarce water resources originating from the Mountain.

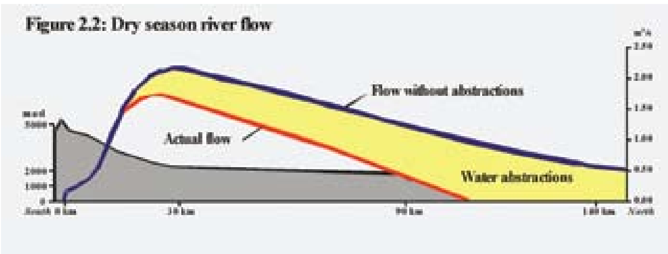

Figure 1: Dry season river flow, Northwest of Mount Kenya. In recent decades, water abstractions for smallscale farming and horticulture have grossly contracted the area where water is reliably available during dry seasons, cutting off most lowland areas and their main water users - pastoralism, safari tourism, and wildlife (Sources: Wiesmann et al 2000; Liniger et al 2007).

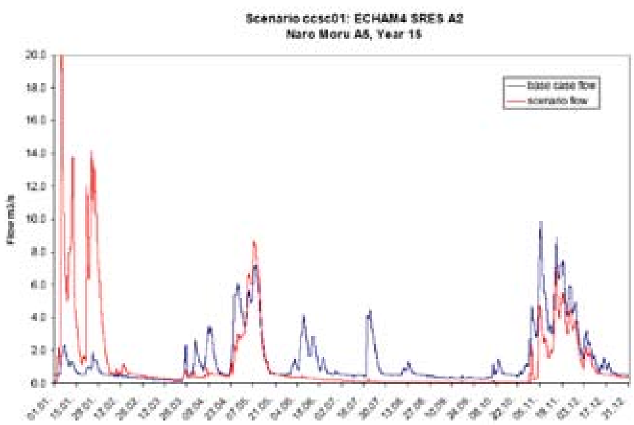

Figure 2: The graphs from Naro Moru River, one of the main water courses northwest of Mount Kenya, show that seasonality of runoff is projected to change drastically as a result of climate change. Long dry periods will become remarkably dryer, while short periods will experience extremely high flows that will be difficult to manage. (Base case flow: 1987 – 2001, measured values (river gauge recordings); Scenario flow: 2040 – 2069, based on climate change scenario ccsc1/ECHAM4 SRES A2). (Source: Notter et al 2007)

The legacy of change: water conflicts and conflict management

These developments – massive immigration, transition of land use from large-scale ranching to small-scale farming, and the booming horticulture sector – have put increasing pressure on regional water resources and resulted in growing competition and conflicts among the different user groups. Increasing demand from upstream users such as small-scale farmers and horticultural firms, as well as from growing urban areas and central places has virtually cut off supplies of water to downstream areas, especially in the dry season. In the arid lowlands north of Mount Kenya, for example, dry season flow dwindled from 9 m3 in the 1960s to less than 1 m3 per second in the late 1990s; in recent years the main rivers there have dried up completely for certain periods, at increasingly frequent intervals and increasingly closer to the mountain (FIGURE 1). The main users in these lowland areas – distant small-scale farm settlements, pastoralists, and the tourism industry with its lodges – are heavily affected. The very existence of pastoral communities is threatened by rivers drying up. But the future of tourism is also critically linked to rivers, as these are vital for the wildlife on which tourism in these areas depends. Moreover, wildlife has increasingly moved upstream in search of water in recent years, causing serious human-wildlife conflicts as manifested by frequent crop raids and, at times, loss of human life.

In a bid to control regional water management, the authorities followed the recommendations made by the research community and engaged in a series of initiatives, starting with multi-stakeholder campaigns focusing on the challenges of sustainable and equitable water use. The campaigns started in the mid 1980s (1984) and intensified in subsequent years, attracting major support from relevant government departments and various development programmes, including research programmes that provided key data on the region's water resources and socio-economy, based on long-term records and extensive field surveys. A

Photo 3: Horticultural fields with dam, Laikipia District; copyright Hanspeter Liniger

number of concrete initiatives resulted from these campaigns and from related work. Among the most successful were Water User Associations (WUAs), which include the main users along a river course. These associations have provided a platform for negotiating resource sharing arrangements and conflict resolution mechanisms with clearly defined rules and procedures of enforcement.

The Water User Associations (WUAs) have grown quite rapidly and have become effective grassroots structures for handling user conflicts in the area. The first WUA in Laikipia was formed in 1997, and by 2003 13 associations were in place, increasing to 32 in 2007. Large-scale horticultural firms are members of many of these associations; the firms have played a key role in the formation of some of the associations and have helped to sustain their operations. Out of the 52 cases of water-related conflicts that came before the authorities between 1997 and 2003, 48 were resolved by the WUAs, while 4 were referred to law courts. The work of the associations now extends beyond conflict resolution and includes resource mobilization through fund raising; environmental education and awareness creation; water conservation through better irrigation practices such as drip irrigation, rainwater harvesting, and improved river water storage; and catchment protection through afforestation, among other measures. Exchange visits serve as platforms for sharing experience between associations from within and outside the catchment.

Climate change and anticipated impacts

It should be noted that evidence available from research attributes the causes of dwindling water resources more to the socioeconomic changes discussed above than to the effects of climate change in the catchment. However, climate change is likely to further complicate the delicate situation in the region in future, especially with respect to water resources. A study recently completed on the Naro Moru River, one of the main rivers northwest of Mount Kenya, predicts an increase of 26% in the annual flow for the period 2040-2069 compared to the current flow (FIGURE 2). More importantly, though, seasonal distribution is projected to change dramatically. January and February, now the months with the lowest flows, are expected to show extreme flood peaks with up to 20 times the present flow. On the other hand, low flows will dominate for most of the rest of the year, reaching only about 1/10 of present values. Despite the uncertainties regarding climate modeling in Tropical Africa due to limited monitoring data and the lack of regional climate models, the study gives an initial indication of the magnitude and direction of future climate change. If these predictions come true, present water consumption levels and allocation arrangements are very unlikely to be sustainable, and water distribution will have to be fundamentally rethought. Destructive flood flows might present an additional challenge. As the local potential for adaptation relating to farming and livelihood strategies is severely limited by poverty and continued immigration, resource conflicts in the highland-lowland system of Mount Kenya will continue to increase and may erupt uncontrollably. Early anticipation of potential developments and a multi-stakeholder-based search for pathways to more sustainable water use, including water conservation and water distribution, are therefore a necessity in this delicate situation. Hence, monitoring and accompanying research are an essential component of this search.

Conclusions and challenges

- In the past 50-60 years, economic, political and social driving forces such as migration, population growth, changing land use, and global food markets have been the main drivers of change and resource conflict northwest of Mount Kenya. These driving forces will continue to be present in the years to come.
- In future, climate change and its consequences could have an impact similar to that of these other drivers. It should therefore be factored into plan-

ning and decision making dealing with regional and local development.

- In the complex highland-lowland system of Mount Kenya, endogenous or self-regulating solutions to the threats posed by these drivers cannot be expected without regulatory support from national and international agencies, and without a solid information base supporting negotiations focusing on sustainability.
- In the past, the research community has been an important partner in regional development discourse, both in formal and informal fora. The role of research as a broker will remain important in future, both in relation to sharing information with stakeholders and in helping negotiate lasting solutions for resource use and sustainable development.
- This will only be possible if potential donors acknowledge that this requires adequate funding, especially to maintain basic long-term monitoring networks and analyses. The areas concerned include socio-economy, land management, rainfall and water resources, in a research approach that aims to bridge the gap between local needs and the effects of global change.

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Photo 1: Cattle grazing maize straw in the Ethiopian Highlands. Crops often serve multiple purposes in the agricultural systems of Africa, and maize straw is a key dry-season feed resource for livestock in many places. The impacts of climate change may thus be felt in several different ways in such systems, in addition to its effects on food availability for the farmer's family and cash income for the household. Copyright, Dave Elsworth/ILRI.

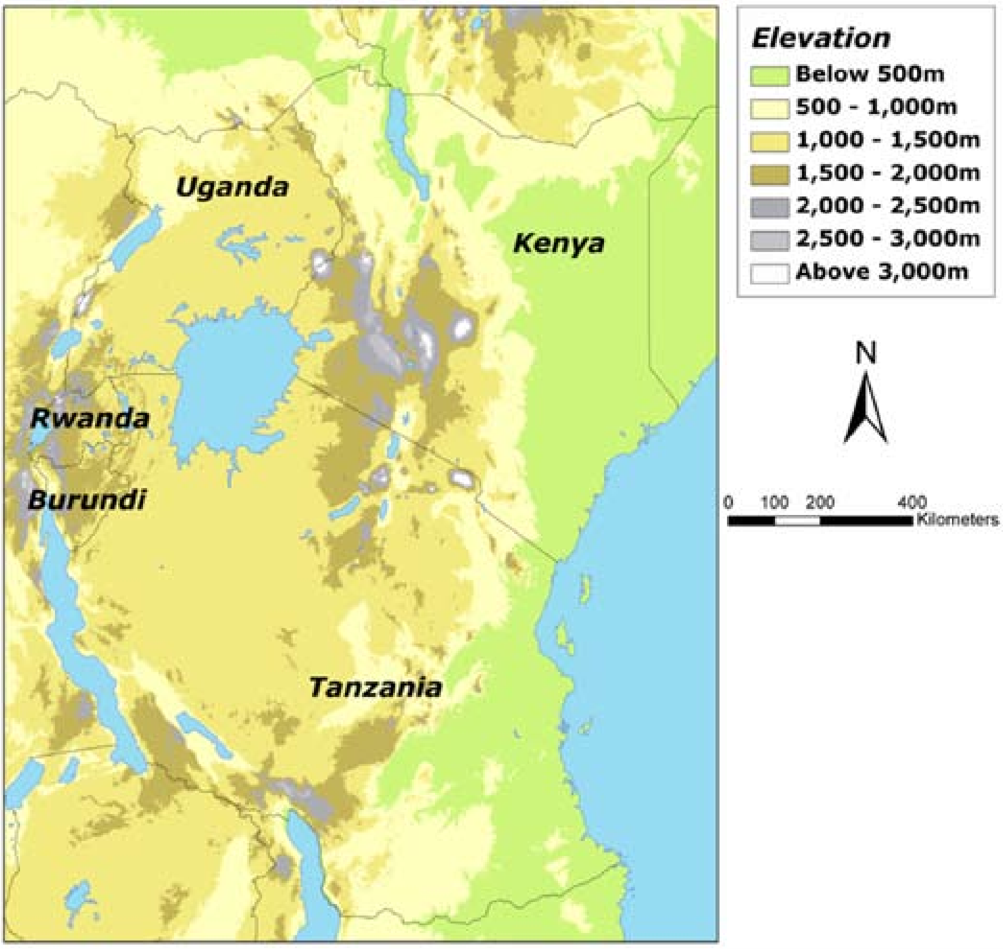
Crop Yield Response to Climate Change in East Africa: Comparing Highlands and Lowlands

Philip Thornton, Peter Jones, Andrew Farrow, Gopal Alagarswamy, Jeffrey Andresen

Climate change will have significant impacts on agriculture, particularly in East Africa where there is such variation in topography and climate. Modelling studies can help to show where these impacts may be largest, to help guide adaptations to ensure food security in the coming decades. Results suggest that crop yield reductions may be expected over 50% to 70% of the area simulated. At the same time, highland areas in parts of the region may see increases in yield potential, which could have a positive impact on householders' incomes and food security in these places.

The impacts of projected climate change during the first half of the current century will pose a serious problem for development in sub-Saharan Africa (SSA), and will add burdens to those who are already poor and vulnerable[1,2]. Many of these impacts will be felt in agriculture, which nevertheless will continue to play a crucial role in SSA through its direct and indirect impacts on poverty, as well as in providing an indispensable platform for wider economic growth that reduces poverty far beyond the rural and agricultural sectors[3].

There is much activity on the part of development agencies and governments to come to grips with these challenges, including the planning and implementation of appropriate adaptation strategies. Development agencies could greatly benefit from information that quantifies the impacts that may arise, so that development assistance can be targeted in appropriate places, depending on the development objectives that are being pursued. There are still knowledge gaps concerning the interacting and multiple stresses on the vulnerability of the poor in Africa, however. One of these is to understand more about how vulnerable households may be affected by increased climatic variability and climate change, to better understand the implications for poverty reduction as well as to be able to assess adaptation initiatives[4,5]. Coping with climate variability is certainly not a new problem for African farmers, but existing coping mechanisms may not be up to the challenges that are likely to be faced in the future[6].



Map 1: The study region, showing elevations. Elevation data source: Reuter, H. I., Nelson, A. and Jarvis, A., 2007. An evaluation of void-filling interpolation methods for SRTM data. International Journal of Geographical Information Science 21 (9), 983 – 1008.

A considerable amount of work has been done already on quantifying some of the agricultural impacts of projected changes in future climate, but most of it to date has been carried out at low spatial resolutions, such as the globe, region, and country[7,8,9]. Particularly for organisations that work with a "pro-poor" mandate in developing countries, in addition to the relatively broad-brush information that such studies provide, there is a need for more detailed information on the impacts of climate change on agricultural systems, so that effective adaptation options can be appropriately targeted.

Linkages between land use and climate change

The work outlined here is part of a larger research project called the Climate–LandInteraction Project (CLIP). This is designed to look at questions of how land-use change affects climate as well as how climate change affects land use. CLIP is quantifying the two-way interactions between land use and regional climate systems at multiple scales in East Africa, a region that is undergoing rapid land-use change. The linkages between land use/land cover and climate change are being examined through the modelling of agricultural systems, land-use driving forces and patterns, the physical properties of land cover, and the regional climate[10].

We have looked at possible impacts on crop yields in the region in some detail, building on previous work[11]. East Africa is very heterogeneous, in terms of topography and altitude. The study region is shown in (MAP 1), covering all of Kenya, Uganda, Tanzania, Rwanda and Burundi, and parts of Ethiopia, Congo, Malawi and Mozambique. Nearly 70% of this region is highland or mountains, lying at altitudes above 1000 m.

We ran two crop models, one for main-season maize[12] and one for secondary-season Phaseolus beans[13], with daily weather data that are characteristic of future climatic conditions in the region, as represented by a combination of two climate models and two contrasting greenhouse-gas emission scenarios. These crop models use a daily time step, and calculates crop phasic and morphological development using temperature, day length and genetic characteristics[14].

Development and growth processes are influenced by water and nitrogen balance submodels[15]. For the maize crop, we ran simulations using a short-season Kenyan variety as a proxy for a well-adapted generic maize variety, using typical current smallholder cultural practices such as little or no fertilizer and low planting densities. Bimodal rainfall patterns are common in the study region, and there are quite large areas where two growing seasons occur per year. For these areas, we simulated bean production also, by planting beans after the maize crop had been harvested. As for the maize runs, simulated cultural practices reflect regional management. Details of all the methods used are described elsewhere[11,16].

We first ran replicated (multiple-year) "baseline" simulations and produced maps that show average simulated maize yields when grown in the primary season under current climatic conditions, and average simulated bean yields in the secondary season, where this is feasible. We than ran the crop models again, but using daily data characteristic of possible future climatologies in 2050. We ran these simulations only for those areas of the study region where maize and secondary-season beans could potentially be grown, on the basis of soil and climatic suitability. Most of these areas lie at higher elevations. In comparing current and future production, we found that if all such areas were indeed cropped, then "regional production" would decline by 1-3% for the lower emission scenario, and by 11-15% for the higher-emission scenario used, depending on the climate model used.

There are many places in the study region where we found a statistically-significant increase or decrease in mean simulated yield compared with the baseline yield, for primary-season maize and secondary-season beans to 2050, using one of the climate models and the higher emission scenario. Maize yields are projected to be reduced (often by 20% or more) for large areas in the north-west of the study region (northern Uganda, southern Sudan) and for the more semi-arid areas of Kenya and Tanzania where maize cropping is possible. In contrast, maize yields are projected to increase in some of the highland areas of the region: in the southern Ethiopian highlands, the central and western highlands of Kenya, and the Great Lakes Region. Projected yield losses in secondary-season beans are rather more widespread, with many parts experiencing yield losses (sometimes of up to 350 kg per ha and more). Other areas, such as the western highlands of Kenya, the Great Lakes region, and northern Mozambique, are projected to see substantial increases in bean yields.

The results show that crop yield responses to the changing rainfall amounts and patterns and the generally increasing temperatures projected by climate models vary by crop type and by location. For the range of climate model-scenario combinations that we considered, the modest aggregate production decreases that are projected to 2050 hide a large amount of variability, and under the higher-emission scenario, substantial maize and bean yield reductions may be expected over 50% to 70% of the area simulated. At the same time, the highland areas in many parts of the region may see increases in yield potential, which could have a positive impact on householders' incomes and food security in these areas. We should point out that there are likely to be changes in the type, distribution and severity of crop diseases as a result of the changing climate. These are not taken into account in these model runs, but they may well affect the yields that can be obtained under relatively low-input conditions.

Temperature and yield response

We have done other analysis that shows that a substantial part of this heterogeneity in yield response can be explained by temperature effects. In maize, at high altitudes, yields may increase as temperatures increase, but at most lower elevations, yield changes also depend on water availability, and many places will see increasing water stress in the maize crop, all other things being equal. For secondary-season beans, temperature-driven yield increases will occur at higher elevations or up to average temperatures of about 20-22 °C. Beyond these temperatures, yields will tend to decline. These results suggest that there may be a future need for various adaptation options: more drought-tolerant maize varieties, for example, coupled with management practices that can make the most of available rainfall such as water harvesting. For bean production, a shift in bean cropping to higher elevations may be appropriate in some situations.

These results should be interpreted with caution, as there are various sources of uncertainty associated with them. There are issues associated with downscaling the outputs of climate models, and results depend to some extent on the climate model used (they are all simplifications of highly complex processes) and on the emission scenario used (the future pathway of global development cannot be known with any certainty). Also, the yield simulations are subject to errors of data input and model specification. Nevertheless, this kind of analysis is useful as a first step in identifying possible "hotspots" in East Africa where cropping adaptations may need to be implemented. The results also highlight the need to assess impacts at the household level. Yield responses of maize and beans to climate change are different, but many smallholder systems in the region include a range of additional or different crop and livestock enterprises. Maize stover is a key dry-season feed resource for cattle in many places, for example, and any reductions in maize biomass for livestock may need to be made up in other ways. There are some locations in the study region where maize yield reductions may be able to be offset by increases in bean yields, but there are other places where both suffer yield reductions. In general, we do not know what the effects may be of these impacts and their interactions with other farm and non-farm livelihood strategies on household income and food security. Further work needs to be done to assess the likely system-level impacts of climate change in the region, to see where trade-offs are possible, where new opportunities present themselves, and where action is needed if adaptation is to be effective.

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Image 1: Signpost on main access road to the community forest.
Image 2: Oil palm producers in the community forest.
Image 3: Fish drying in Dikolo village Bimbia. Image 4: Timber from the community forest.
Image 5: Charcoal production in the community forest.

Forest Governance Challenges on Mount Cameroon

Emmanuel O. Nuesiri

Mt. Cameroon, part of the Cameroon Highlands ecoregion, is situated at 4" 13' N, and 9" 10' E. At 4100m, it is the highest peak in West/Central Africa and is an active volcano with major activity last occurring in 2000. The Cameroon Highlands is a biodiversity hotspot[1] and its fertile volcanic soil has also made it a hotspot for both subsistence and commercial agricultural activities since the late 19th century. Plantations on Mt. Cameroon supply the world market with cash crops such as tea, coffee, rubber and bananas. The indigenous inhabitants of the region, the Bakweri, constitute about 10% of the population[2] whereas the other 90% of the population is made up of people from other parts of Cameroon and other nearby countries including Nigeria and Benin.

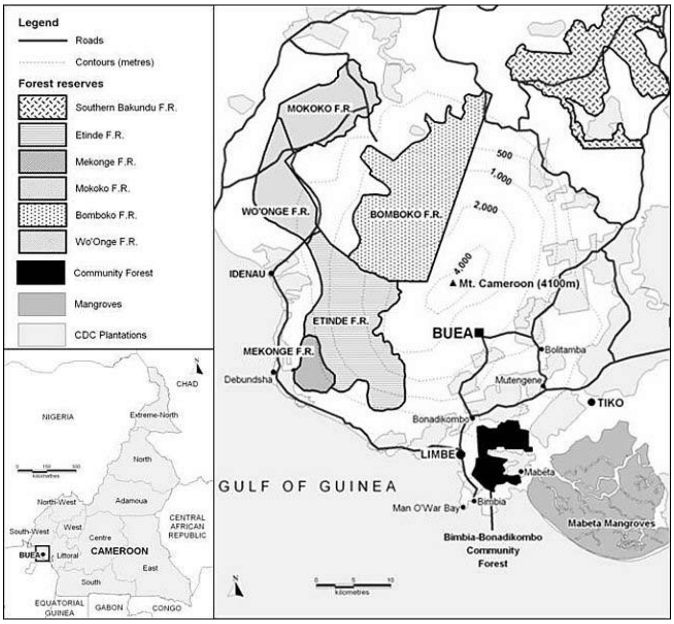
The inhabitants' dependence on farming and the heterogeneous population structure has posed great difficulties to the implementation of sustainable and participatory forest management on Mt. Cameroon. This article reflects on these challenges through a case study of the Bimbia-Bonadikombo community forest (BBCF), an on-going forest management initiative inspired by the Mount Cameroon Project (MCP), Limbe. This integrated conservation and development project was implemented from 1994 – 2002 with funding from the Department for International Development (DFID) of the British Government. This article proceeds with a brief review of the origins and adoption of community forests in Cameroon, emphasising the socio-political context under which it was adopted. It then shows the governance challenges of implementing community forestry on Mt. Cameroon and concludes with comments on the governance of Mt. Cameroon's forests.

Community forestry: Origins and adoption in Cameroon

The origin of community forestry discourse can be traced to participatory natural resource management movements[3]. Advocates argue that bringing local people into the decision making and management of forest resources has a positive impact on the sustainability of this resource. They further argue that by using the sustainable use paradigm, participatory forest management strategies help to alleviate local poverty, building the managerial capacity and skills of local people. Opponents argue that participatory forestry leads to continued forest loss[4]. However, the participatory forestry rhetoric was appealing to donors who co-opted it, making it one of the conditions for forest aid from rich developing countries[5].

Cameroon's deep economic recession of the late 1980s, brought about by a fall in commodity prices, forced the country to turn to the World Bank and IMF for aid. These institutions prescribed a structural adjustment package that included the lay-off of government workers and required that the government reform its forest sector. Thus, in 1994, the government enacted a new, decentralised forest law. Amongst other novelties, this new law allowed local people to obtain community forest status for forest land if they could prove their de facto traditional tenure rights[6]. The British government provided support to the forestry department to implement the community forest policy[7]. The policy states that the maximum size of forest area that can be applied for is 5000 hectares, which, if approved, will be under community management for a period of 25 years. Thus a community is mandated to submit a management plan for the forest on both an annual and 5-yearly basis along with its application file.

This management plan must informed by a socio-economic and an ecological survey conducted by the community. The community forest management team must also be a legally registered body complete with a clearly articulated organigramme, operational procedures and bylaws– requirements that are technically and financially beyond the capacity of local communities in Cameroon[8]. The policy also gives the forestry department the authority to halt a community's management rights if persuaded that the community is not adhering to the forest management plan. While some observers argue that the high cost associated with community forests in Cameroon exposes an agenda to ensure that control remains in government hands, others argue that policy shortcomings are due strictly to the novelty of the new policy[7]. It is under this socio-political context in 1998 that the MCP Limbe initiated the creation of the Bimbia-Bonadikombo community forest (BBCF).



Map 1: Land use pattern in the Mt. Cameroon region

Governance challenges to creating the BBCF on Mt. Cameroon

There are about 107 community forests in different parts of Cameroon covering 400,000 hectares of forest[9]. The Bimbia-Bonadikombo community forest (BBCF), the only approved entity in the Mt. Cameroon region, is situated in the Limbe sub-division of the Fako division of Cameroon's South West Province. It lies south of the Limbe-Douala highway, a key route for petrol tankers taking fuel from the Limbe refinery to Douala, Cameroon's commercial capital. The BBCF is surrounded by three cities that are within an hour's drive from its boundaries: Tiko to the east, Limbe to the west, and Mutengene to the north. There are also 11 other, smaller settlements and three agricultural plantation workers' camps within an hour's walk from the BBCF. The region is, without a doubt, an area facing extreme anthropogenic pressure, as shown in the map below.

The indigenous Bakweri are a literate and politically informed minority group, which have always held prominent governmental posts with both the past and present Prime Minister of Cameroon, who is also of Bakweri origin. Their prominence results from the fact that they had the first cash crop plantations in Cameroon and that education played an important role in their society from very early on, with the first school built in their region by missionaries in 1850. The Bakweri were thus among the first set of educated elites in the country, while the entrepreneurial elites profited from the plantation economy[10]. This exposure to the forces of 19th century globalisation led to rapid urbanisation in the Bakweri's land as well as the birth of a class of colonial elites under Bakweri leadership and an influx of migrants. While the traditional livelihood of the Bakweri is constituted by fishing and hunting, a high proportion of Bakweris now work in the civil service and private sector.

The indigenous Bakweri, as a group, are not as directly dependent on the forest for their livelihoods as is the migrant population. The Cameroonian migrant populations are heavily involved in farming, while the foreign migrants from Nigeria and Benin are more involved in fishing. The population's occupational structure shows two broad trends: farmers dominate village type settlements, while peri-urban settlements close to Limbe city have mixed populations of farmers, public, private and informal sector employees. This was the socio-economic context under which the MCP Limbe developed a participatory biodiversity conservation strategy (PBCS) for the Mt. Cameroon region[11]. The PBCS was developed through participatory consultations with indigenous peoples, migrants, government departments and the private sector in the Mt. Cameroon region.

The PBCS is currently implemented through the participatory land-use plan (PLUP), which maps out areas within the region, set aside for expansion of settlements, agriculture, community forests and biodiversity conservation. In order for the various actors to fulfil their roles in the smooth execution of the PLUP, the MCP Limbe carried out several workshops on capacity building for the forestry department and all other actors. MCP Limbe also worked with the local people in the Mt. Cameroon region towards the creation of four community forests. However, only the Bimbia-Bonadikombo community forest (BBCF) succeeded in gaining government approval before the MCP Limbe ended in 2002[12], and still remains the only approved community forest in the region.

The creation of the BBCF met with greater success than the other three initiatives, because Bimbia has been a main site of global-local exchange since the 19th century[10]. This meant that the BBCF application received greater attention from MCP Limbe and the forestry department than did the other three community forest applications. This historic and deep immersion of Bimbia into global processes and other socio-economic characteristics of the Mt. Cameroon region contributed to the challenges faced by the MCP Limbe during the creation of the BBCF. These include unresolved land tenure contestations, high use pressure in the Mt. Cameroon forest area, indigenous elite interest and gaps in the community forestry policy. Each of these is briefly explained in the paragraphs that follow below.

Unresolved land tenure contestations

Land tenure issues increased the difficulty of the Mt. Cameroon Project to achieve its objectives. Cameroon Land Ordinance No. 74-1 of July 6, 1974 maintains that the State is the guardian of all lands. However, traditional authorities continue to exercise de facto rights over land. In the Mt. Cameroon region, the indigenous Bakweris are locked in a legal battle against the Cameroonian government to reclaim the lands hosting the government-owned agricultural plantations[13]. These plantations were initially set up during colonial era by European entrepreneurs but were passed on to the government of Cameroon upon gaining independence. The Bakweris claim the land was expropriated from them without compensation, and they are thus demanding that this land be returned to them. Therefore, in the Bimbia-Bonadikombo area, the immigrants who depend substantially on the forest for their livelihoods cannot obtain de jure or de facto rights over the land. This precarious land tenure position makes the non-indigenes unable to fully embrace participatory forestry.

High use pressure in the Bimbia-Bonadikombo forest area

Botanic surveys of the forest area led by experts from the Royal Botanic Gardens in Kew, England, showed that the area was of high conservation value and they called for the forest to be designated a protected area. The high use pressure and the significance of this forest to the livelihoods of much of the population made it impossible for the government to give the forest this protected status[12]. This constraint, alongside government and donor pressure on the MCP Limbe to pilot the participatory ethos in the new forest policy of 1994, led to the decision to opt for community forestry instead.

Indigenous elite interest

The most challenging actors encountered by the MCP Limbe were the indigenous Bakweri elites, who articulated their position through two indigenously-controlled institutions, the Victoria Land and Forest Conservation Committee (VLFCC) and the Victoria Area Rainforest Common Interest Group (VARCIG). These institutions were used to defend the de facto traditional rights of the Bakweri over the forest against the de jure rights of the government and the use-rights of the non-indigenes. The project's objective of creating an inclusive and equitable management team for the community forest was strongly resisted by the indigenes and, therefore, 70% of the Bimbia-Bonadikombo Natural Resources Management Council (BBNRMC) managing the community forest is of indigenous origin2. The elite position is partly driven by a desire to protect the economic rents they receive from the non-indigenes using the forest as well as by a fear of being politically dominated by the more numerous non-indigenous population and forest users.

Failure of community forestry policy to define 'community'
The land tenure difficulties and indigenous elite recalcitrance to an inclusive management framework for the community forest is related to a significant gap in Cameroon's community forestry policy. The policy fails to clarify what constitutes a community, leaving this key socio-political concept to local interpretations, which tends to view community as a group bounded exclusively by ethnicity[14]. This exclusive stance undermines the inclusive ethos underlying participatory forestry discourse. Not defining community is not only a significant policy failure, but also a missed opportunity to address issues of equity and citizenship.

Forest governance on Mt. Cameroon

While decentralised and participatory forest management has the potential to win the hearts and minds of local people, guiding them towards sustainable forest management, in highly heterogeneous locales such as the Mt. Cameroon region, the multiplicity of actors and processes makes sustainable forestry a daunting challenge. This is linked to cultural ruptures in these societies, which manifest themselves in the 'indigene' and 'migrant' discourses readily observable in socio-political life at both the local and national scale. In this context, inclusive participatory processes sometimes aggravate ethnocentric passions, as dominant groups fear the loss of power and the socio-economic privileges that come with it. Participatory forestry has, however, given conservationists insight into the deep influence of ethnicity in socio-political relations in Cameroon across all spatial scales.

This knowledge bodes well for contemporary conservation efforts in the Mt. Cameroon region, such as the Cameroonian government's on-going programme to create the Mt. Cameroon National Park in partnership with the Worldwide Fund for Nature (WWF). Conservationists in the region now understand the social dynamics that could stand in the way of effective programme implementation and are more appreciative of the need for staff with the social know-how and skills required to negotiate sustainable solutions with the local populace. The experiences from Mt. Cameroon and other regions around the globe have brought about awareness that sustainable forest management in mountain regions has a better chance of succeeding when conservationists possess an understanding of the historic and social context.

The author is a member of MRI's Global Change Research Network in African Mountains

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Society, Desertification and Climate Change in the Argentinean Chilean Central Andes Region

Elena María Abraham and Ricardo Villalba

Desertification, the land degradation of drylands due to diverse factors including climate variations and human activities, is among the most serious environmental challenges facing the world today. Risk tremendously increases when desertification processes synergise with climate changes and new drivers are added to already degraded areas, leading to unknown situations. How will local societies cope with these environmental changes. This paper presents examples from the Central Andes, with special emphasis on irrigated viticulture and hydropower generation. It discusses some climate change scenarios and the desertification status in relation to ongoing processes affecting both the economy and the environment of the Andes and the settlements in their area of influence. Facing this changing scenario is essential to discussing and agreeing upon a proper development model for drylands. With this in mind, some different scenarios are presented.

Photo: Before dawn at Aconcagua Peak, Andes;

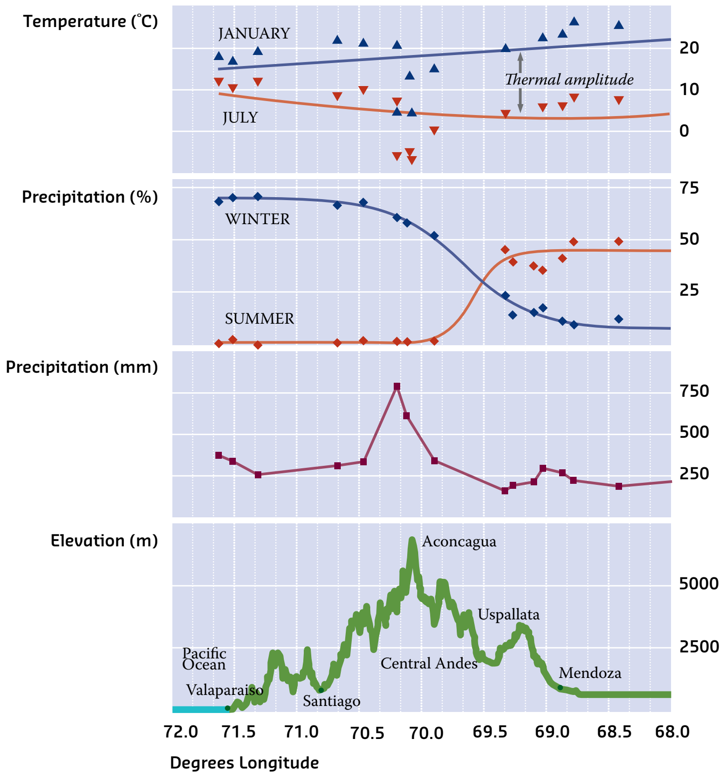

Figure 1:Transect across the Central Andes (32ºS), showing changes in mean January and July temperatures (upper), in seasonal (summer and winter) precipitation distribution (middle), and in total annual precipitation (lower) associated with topography (bottom). Locations of the meteorological stations are indicated by triangles in (upper), diamonds in (middle), and squares in (lower). Meteorological stations in the latitudinal band between 31º30'S and 32º30'S have been included in this transect (Villalba et al. 2003).

Table 1: (opposite page) Impacts of climate changes on ecosystem services across the Central Andes

A transect running at 32º S from Valparaíso on the Chilean coast to the Desaguadero river in Mendoza, Argentina (FIGURE 1), shows that both sides of the dry Andes face a similar problem: an increasing demand for water resources to sustain urban, agricultural and industrial development. In central Chile, the metropolitan, V, and VI regions contain ca. 8.4 million people or 55% of Chile's population. About 48% of the annual discharge of the Maipo River, Santiago's main water source, is withdrawn to meet these needs. Central Chile also accounts for about 45% of the total irrigated area of the country. On the eastern Argentinean side of the Central Andes the rivers serve a population of ca. 2.2 million people in the provinces of San Juan and Mendoza. With less than 200mm of precipitation per year, agriculture must rely on irrigation. Hydropower plants fed by cordilleran rivers generate 62% and 86% of the total domestic energy generation in Mendoza and San Juan, respectively. The vast eastern fluvial aeolian plains lying along the Argentinean eastern slope deserves special mention, as they constitute storage units for ground and surface water resources. In favoured sectors, the beneficial action of rivers has resulted in a Mesopotamian model on the wide alluvial fans. These are the "oases", where the presence of water and suitable soils has allowed for the creation of irrigated crop areas and the settlement of cities that articulate their irrigated space of influence in a viticulture agricultural model. Of special note among them is the northern Mendoza oasis in Argentina, where nearly 97% of the province's total population is concentrated in only 3% of the territory.

These are the places where systematised irrigation and joint use of ground and surface water resources are practiced, and where dams for water distribution have been built. These are also the places, however, where water use is more inefficient and land is more highly degraded. Beyond the isolated green island patches of the oases lies the non irrigated desert, with its immense range of different environments linked by dryness. The desert, practically uninhabited with less than half an inhabitant per square kilometre, has been neglected by politicians and is being subjected to accelerated processes of desertification due to the abusive use of resources.

Deserts show contrasting activities. On the one hand, subsistence pastoral activities such as goat breeding only for meat production have a strong impact on the fields due to overgrazing. On the other hand, the oil and mining industries extract riches from the substrate without improving the local territory, often polluting water resources in the process. People living there are mainly affected by the lack of water, in both amount and quality. The desert stores water at great depths, in many cases tainted with arsenic, and this makes it inaccessible to the few inhabitants living there, forcing them to make due with rudimentary wells and reser-

Ecosystem Component	Ecosystem Services	Impact of Climate Change	Implications
Glaciers and Snowfields	Provides freshwater to downstream ecosystems	• Reduction in annual stream flow	• Irrigation in the Central Andes • Hydropower generation in the Central Andes and northern Patagonia
	Enhances recreation opportunities & aesthetic values of landscapes	• Timing of snowmelt • Reduction in winter recreational opportunities • Loss of landscape icons	• Irrigation in the Central Andes • Hydropower generation in the Central Andes and northern Patagonia • Visitor satisfaction • Tourism revenues related to water-based recreation across the Andes
		• Summer stream flow	• Increasing "summer drought" in northern Patagonia • Salmon production in northern coastal Patagonia

voirs. One of the major desertification processes was the logging of the native woodland. Between a 5 and 15m depth, the water table feeds the dry open mesquite woodland consisting mainly of Prosopis spp., which deserves particular attention because of its importance to the population. Today this woodland has practically disappeared. Studies conducted on environmental history show the decline of the woodland in the desert. It was cut down and used to build the viticulture and wine-growing oasis. In a 35-year period during the railroad expansion that took place from 1901 to 1935, 992,748 metric tons of forestry products were cut down, equating to a total of 198,550 deforested hectares (Abraham & Prieto, 2000). This wood from the desert has been used in the oases as vineyard poles and props. Such studies are important when desert development policies are defined.

Drying of Desert Wetlands

Another important desertification process was the use of water in high and medium river watersheds for the irrigation of the oasis, which resulted in the drying of desert wetlands. Several important wetlands (one of them a RAMSAR site: "Lagunas de Guanacache") stretched along the margins of the low basin, supporting great biodiversity. The use of river water for irrigation has stopped their course, and now they are mere river beds of sand that no longer carry water, with the associated drying of the wetlands. In addition, actions for land recovery and control are scarce and insufficient. The main processes, deforestation, overgrazing, expansion of the agricultural border, urbanisation, salinisation, and water table rise in the oases, land desertion and poverty continue to worsen land degradation.

Facing the possibility of climate changes at global scale, the major problem confronted by the region is the uncertainty about climate behaviour in the long and medium term. Scientists warn that 70 years from now, current levels of precipitation in the subtropical plains of South America's middle latitudes might significantly increase, whereas a drastic decrease in snowfall will take place at same latitudes in the Andes Cordillera (Francou et al. 2005, Christensen et al., 2007, IPCC, 2007, Labraga, 2005). Summers will be rainier in the region's plains and as a result of global warming and a generally more dynamic atmosphere, summer precipitation will be linked to convective storms, with heavy rain and probably severe hail. Convective storms will affect crops and human settlements, also augmenting the possibility of floods and mudflows in the mountain and piedmont zones. Simultaneously, snow precipitation will diminish in the Cordillera during the winter (Table 1). The present day cordilleran precipitation mean is 250mm and, according to the scientists' projections, at the end of the century it will

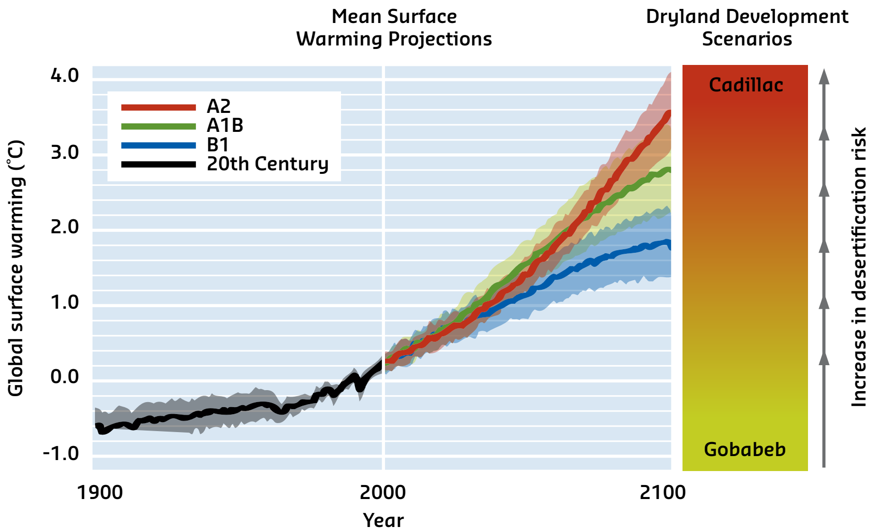

Figure 2: Scenarios of Global Warming and Desertification during the XXI century.

have been substantially reduced. Glaciers are particularly vulnerable in warmer climates, with many of them having already disappeared in several parts of the world during the last century. In many localities across the Andes, reduction in glacial area has been associated with negative trends in snowfall and river runoff from the Andes. Although in recent decades some basins in the tropical Andes have experienced an increase in runoff as a consequence of glacial retreat, in the long term, there will be a reduction in water supply as the glaciers shrink beyond critical limits (Jansson et al., 2003). Recent glacier recession has also been documented throughout the Central and Patagonian Andes (Leiva et al. 2007, Masiokas et al.2008). Temperature records (Figure 1) show significant warming, which has been concurrent with negative trends in regional precipitation and streamflows. These climate variations are largely responsible for the widespread glacier recession documented.

How will local societies and economies cope with these environmental changes? The water from snowmelt will diminish while summer precipitation will increase, posing deep changes in the management of natural resources. Water will need to be extracted more efficiently from the Cordillera, as flows will tend to diminish with time. The unfavourable effects resulting from future increases in summer precipitation will have to be mitigated. These changes could lead to a change in the regional productive activities and possibly, to a change in the traditional culture of water management in many regions in South America. If the generalised desertification processes taking place in practically every ecosystem is added to this changing climatic scenario, vulnerability increases even more. In a changing world where humid places will be subject to progressive dryness and vice versa, the map of desertification is likely to change. The need will thus arise for experts on the changes that desertification processes entail to transfer their experiences and knowledge to all those unaware of the consequences of land degradation. It is vital to link the experience generated by the UNCCD to concrete and practical measures in order to prevent and combat desertification, aided by the important scientific findings of the Global Change Convention. Thus, the lessons learnt from experiences on Sustainable Land Management are of key value. In this sense, it is essential to discuss and agree upon the development model that is best for drylands. What are the options?

The inherent fragility of drylands and the high risk to which they are exposed under conditions of global change can only be overcome with knowledge, planning, political will and investment achieved through a consensus on the development style to be implemented. This may change among different scenarios and models, fluctuating between the extremes. There are those who propose huge transformations in the natural conditions of desert areas with major investments in capital and infrastructure. These developments completely separate society from nature and are known as "Cadillac" (Ezcurra ed. 2006), with Las Vegas or the megacities of the Gulf being prime examples. Then there exists the opposite extreme, those who want to "leave everything as it is", not modifying anything in the ecosystem. This last position is supported by groups of radical "ecologists" who are opposed to any kind of intervention. Midway between these extremes is the view of a sustainable development of drylands, directed towards territorial balance and social equity. This so-called "development in patches" is based on a deep knowledge of the potentials and restrictions of drylands and of the demands and needs of the population. It represents an attempt to develop desert environments with few restrictions and optimal conditions for settlements and production (corridors, wadis, oases, terraces, sand dune bases), while restoring and preserving the rest of the territory. Called the "Gobabeb model" in the Global Deserts Outlook (EZCURRA ED., 2006), this model is named after the homonymous locality in the Namibia desert where these experiences have been successfully developed. Whichever model is chosen, the consequences are quite predictable. The inherent fragility of degraded lands can only be overcome with the proper knowledge, planning, political will, investment, and agreed upon equitable development models that are directed towards territorial balance, social equity and sustainable development.

The development styles adopted and the effects of these models can be linked to the worldwide climate change scenarios developed by global climate change experts (FIGURE 2). Whatever the development model selected, it must be implemented within the frame of a planning and management process in which the generation of knowledge to monitor changes can be given a hierarchy and gain importance. The measurement of the status, pressure, impacts and responses, incorporated into an integrated assessment and follow-up system, must be part of a new attitude that values the contributions of science and technology as a guide for decision making. If, in addition, this can be achieved through a participative process of knowledge construction (ABRAHAM ET AL. 2006), we would be able to advance with more certainty in the road of sustainability, with a more equitable society in harmony with dry environments.

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Central Andean Foothill Farmers Facing Global Environmental Change

Elma Montaña

Mendoza, a modern hydraulic society

In Andes of central western Argentina, the Mendoza River follows a quite spread out path. It originates in the snow-crested mountain range and flows toward the lower plains, providing water for the irrigation of oases developed on the foothills. This scheme develops in two opposing landscapes: on the one hand lies a green oasis with neat rows of grapevines, tree-bordered roads and streets, and irrigation channels and drains. This is the powerful oasis where human work celebrates having conquered a hostile nature. On the other hand, non-irrigated lands are a "no-man's land" and subordinate spaces perceived as empty and void of interest. Whereas the oasis concentrates the dynamism of Mendoza city's one million inhabitants and export viticulture-based economy, the scattered population of unirrigated lands barely survives on out-of-market economic activities, devastated by poverty and desertification processes (MONTAÑA ET AL., 2005).

Under this light, Mendoza River basin communities could be considered modern hydraulic societies, in which the social tissue is strongly associated with a comprehensive and intensive water resource manipulation within an order imposed to control a hostile environment (WORSTER, 1985:7). As power distributions are associated with water management, water would have the capacity to express, and also model, the hegemonic and subordinate social relations of a hierarchical system.

As links between water and community are very strong in the Mendoza River basin, scenarios in which climate change and water scarcity will intensify could cause not only spatial changes, but also affect social processes while influencing the existing relationships between nature and culture.

Water, climate and its scenarios

As in other dry lands, in the Mendoza River basin, water is a limiting factor for human settlement and agriculture. The intensive viticulture and horticulture of the area are only possible if tied to water management, making use of surface water distributed by the irrigation network or by pumping groundwater. Climate, however, also imposes it conditions, as frost and hail cause crop losses annually.

The Global Environmental Change (GEC) scenarios (2020-2030) built for the Mendoza River basin (BONINSEGNA AND VILLALBA, 2007) forecast a rise of 1.5°C in mean temperature, a decline of over 100mm in precipitation and a 150m rise of the 0°C isotherm, reducing the snow pack and increasing ablation surfaces. As a result of these changes, the flow volume of the Mendoza River is expected to dimin-

Harvesting tomatoes (Figure 3, opposite page) and grapes (Figure 4, above) on a horticultural farm in the Northern Mendoza; copyright Elma Montaña.

ish between 7 and 13%. The hydrogram of this nival regime river would also be affected. The peak discharge would be advanced by one month, increasing spring flows (October and November) and lowering summer outflows (January, February and March). This poses threats to agricultural and livestock activities already restricted by water scarcity, affecting not only farmers, but also the entire agricultural-based regional economy.

Farmers facing global environmental change

The research has focussed on the situations to be faced by farmers in three representative productive systems of the basin. Two of these systems consist of agricultural activities developed within the oasis irrigation system: one permanent (viticulture) and the other annual (horticulture, mostly olericulture). The third, goat husbandry, is an extensive livestock activity taking place mainly for subsistence purposes in non-irrigated areas upstream and especially at the tail of the basin.

Research has advanced in terms of exposure analysis while adaptive capacities are still under study. Nevertheless, some insights about the farmers' vulnerabilities can be anticipated. These can be illustrated by four main points:

a) Nature of the productive system: Oasis agriculture vs. non-irrigated extensive goat husbandry

A preliminary analysis must differentiate the agricultural systems (viticulture and horticulture) relying on irrigation from the goat husbandry extensively developed in non-irrigated zones. Diminishing precipitation will not affect the former but will decrease the natural vegetation of the desert, affecting goat husbandry and intensifying the desertification processes already in place. Drought periods strongly impact this activity, putting it at its survival limits and compromising alimentary security of its domestic production units. The extreme poverty of this area's population could raise a paradoxical situation in terms of vulnerability. The benefits of goat husbandry are so scarce that the incomes of these domestic production units must be complemented with others coming from temporary agricultural or urban activities and State subsidies. Therefore, these producers would need to become more diversified than those devoted exclusively to agriculture and would be more likely to adopt a wider range of adaptive strategies. Leaving theoretical arguments aside, their extreme poverty is closely related to their vulnerability.

The diminishing river runoff will be harder on agricultural farmers who rely on the surface irrigation network. In the context of a system that allocates water proportionally to the plot surface independent of whether the land is being used and the crop type grown, viticulture farmers will be favored over horticulture producers because of the vineyards' lower water consumption and higher resistance to water stress. On the other hand, the annual cycle of horticulture makes adaptive strategies such as moving to better locations easier in terms of climate and water risks.

Agricultural farmers will see adaptation to hydrogram alterations facilitated by the operation of the Potrerillos dam, position just before the river reaches the oasis. Ecological flows are not being considered in the dam operation though, so the river regulation favoring water consumption in the oasis prevents water surpluses from reaching the tail of the basin. It is in this area that desert communities receive less and less water as the rural and urban oasis upstream continues its development. This subordinate position in the hydraulic society explains a good deal of the vulnerabilities of the desert communities.

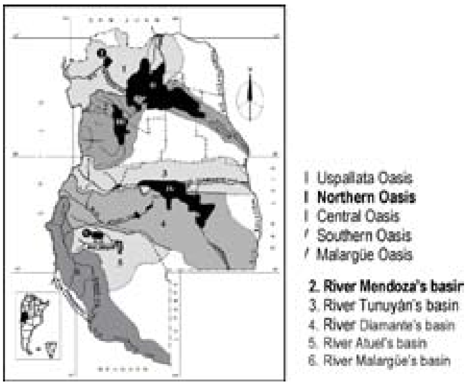

Figure 1: Mendoza Province, basins and irrigation oases, Source: Garduño, 2003

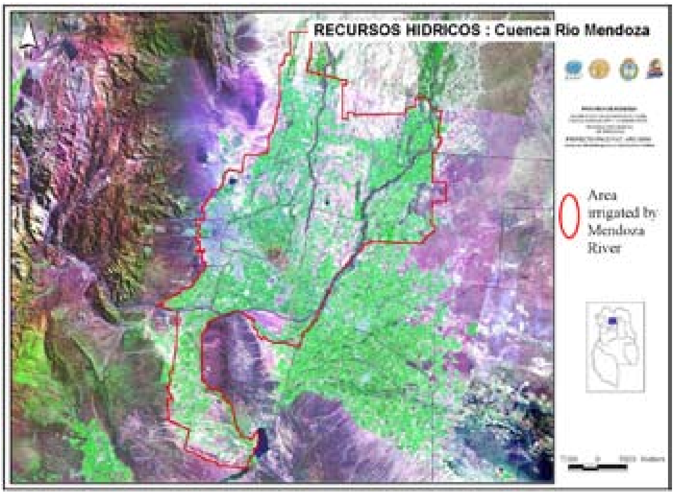

Figure 2: Northern Mendoza Oasis, Source: Proyecto PNUD-FAO/ARG/00/008, 2006.

b) Structure of the productive chain and the farmers' position in it

Mendoza's river basin horticulture is an atomised agricultural sector formed by a great number of heterogeneous producers. The distribution channels are also varied in the context of a weakly regulated sector in which the informal economy plays an important part. The complicated and unstable decision making processes with which horticultural farmers must deal does not encourage investments that would reduce exposure. This structure will also set hurdles to the implementation of institutional measures that would help the most disadvantaged producers to face GEC scenarios.

In contrast, viticulture shows a clear structure with horizontal and vertical integration, as well as regulations set by formal institutional arrangements. Adaptive measures could be fostered here not only from the State but also by the existent farmers' organisations. As integrated and organised as this structure is, the farmers universe is quite polarised between the producers who make wine and are directly involved in the wine export circuit and small and medium scale farmers whose participation in the chain highlights their subordinate position. Are State institutions likely to be co-opted by the most powerful agents? This takes us to another issue.

c) Farmer typology

Faamer typology ("large/small", "capital intensive/traditional", "export/domestic" or any other showing power quotas) is directly related to vulnerability, in goat husbandry as well as in the oasis agricultural systems. The economic wealth of big farmers allows them to overcome reduced surface water allocation by pumping groundwater. In the context of loosely regulated groundwater management, they can even become independent from the "democratic" but tedious water users' organisation mechanisms and just turn on the pump whenever it fits their irrigational needs, obtaining water volumes only restricted by affordable and subsidised energy prices. In the same way, these farmers are in a better position to adopt other vulnerability reducing measures such as pressurised irrigation, which makes for a more efficient water use, or hail net protection. Unlike the more disadvantaged farmers, they can move to better locations, an adaptive strategy that is currently being seen not only with horticulture farmers that rent the land for their annual crops but also with big winemakers who buy land and build wineries in upstream foothill locations.

d) Location in the basin

Finally, the position in the basin appears to be a vulnerability factor. More successful agricultural farmers, especially

Figure 5: The facilities of a "seat" of a non-irrigated area. In the background, the natural vegetation; copyright Elma Montaña.

those integrated with the export sector, gradually climb the foothills to settle in the upper oasis lands, looking for lower temperatures, better standards of water rights that are less likely to be cut back in a drought situation as well as better water quality and less pollution. In some cases, such farmers push the agricultural border upstream by means of groundwater pumping. These are capital-intensive properties relatively protected from climate and water risks. On the other hand, those farmers who cannot afford such prime locations must resign themselves to the less attractive traditional locations of the oasis, leaving them with fewer resources to reduce their exposure and work out adaptive strategies. These farmers will be in greater need of institutional support to cope with the expected effects of GEC.

Conclusions

It is obvious that the vulnerability of Mendoza River basin farmers depends upon the nature of their activities, as some of them are more water and climate sensitive to GEC scenarios than others. Preliminary research findings show that even within the same productive system, other factors also affect a farmer's vulnerability, in terms of exposure as well as adaptive capacity. Some of these factors seem to be related to power relationships and to equity issues of this hydraulic society. Being wealthy and successful in the wine and food markets, having access to technology such as irrigation, being vertically and horizontally integrated and being privileged by the use of better and more expensive lands upstream are all shielding factors and indicators of a broader availability of adaptive resources.

Factors and mechanisms that could make farmers more or less vulnerable in GEC scenarios have shown a significant similarity to those which explain the performance seen while facing the challenges of the globalised agrifood markets during the 90s. At that time, the weakest producers, those who couldn't keep pace with the new rules of the game, were negatively affected or even thrown out of business, while a concentration process took place in favour of the more powerful agents. It seems that GEC effects will impact Mendoza River basin farmers in an analogous way, this time adding its effects to the ones already produced by globalisation.

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Responding to the Collapse of Mountain Ecosystem Health and Natural Resource Management Institutions in Peru

Gabriela López Sotomayor

This paper explores land-use planning strategies and tools for rural development under conditions of extreme social and geographical fragmentation, historical conditions worsened by two decades of neo-liberal policies that aim to foster the comparative advantages of the Peruvian economy at a global scale.[1]

The neo-liberal development model established in South America considers rural and agrarian communities to be elements marginal to modernity. Mountain areas in general, lacking roads to markets and highly unpredictable environments, were seen as marginal areas for competitive agriculture and thus considered by state and economic elites as sources of natural resources at best. Over the last two decades, neo-liberal policies for mountain rural areas focussed on humanitarian help for the "marginal" or "unviable"[2], a state and public perspective that devalued rural societies and their cultural heritage as well as ecological services, local knowledge and the contributions of rural communities to the nurturing of rural landscapes.

In recent years, increasing understanding of the critical role of rural economies to the overall health of Andean nations has prompted legislation to promote territorial planning mechanisms. In Peru there is new legislation covering, for instance, Planes de Ordenamiento Territorial, or land-use planning tools for regional and provincial territories at district scales. However, all of these land-use procedures lack methodologies that really involve local actors in the generation of the "territorial ordering as a political process", mentioned in official legislation and regulations. Though not clearly defined, this language reflects an intention to transfer land management to localities.

A relevant issue concerning the political context in which land-use planning takes place in Peru is the notorious fragmentation of environmental controls across various economic sectors. So as to favour competitiveness in the global economy, environmental controls in Peru are entrusted to the different production sectors under a so-called "one window policy". This means, for instance, that a mining project is regulated and controlled only by one window, in this case, the Ministry of Energy and Mines, itself in charge of promoting investments in the sector and policing companies.[3]

Planning land-use from a central government perspective

Between 1984 and 2005, the Peruvian state developed diverse legislation with regard to ordenamiento territorial or land-use planning, using much terminology that was never properly defined. In 2003, The Peruvian Congress approved the new law of municipalities called the Ley Orgánica de Municipalidades, defining the responsibilities of provincial or district level municipalities. Thus, municipalities are mandated to promote integral, sustainable and harmonious development within their political boundaries, with the help of a local planning process that must be integral, permanent and participatory, coordinated with the regional and national levels of government. A variety of sectoral and multisectoral plans are required regularly from municipalities. Multi-sectoral plans include the Plan de Desarrollo [Development Plan] as well as the Plan Urbano Rural [Rural Urban Plan] for districts, and the Plan de Acondicionamiento Territorial [Territorial Land Use Plan] for provinces. Each year, municipalities have to plan their budget through a participatory process, resulting in the mandate to allocate a percentage of their budget through local participation ("presupuesto participativo") to develop investments that have been collectively agreed upon.

In 2006, the National Environment Council (CONAM), Peru's central environmental authority, defined Ordenamiento Territorial as "an instrument that is a part of sustainable development state policies. Is a decision that this policy process has to involve social, economical, political and technical actors for an ordered and sustainable use of the territory"?[4]

Thus, the official document elaborated by CONAM indicates that the process is fundamentally participatory and that it must be planed for a long-term horizon, using the tools and processes stipulated by the Ecological and Economical Zoning (EEZ) regulations. The EEZ, a preliminary tool to identify the comparative advantages of different territorial units in the area subject to planning, focuses on biophysical and economic parameters. These parameters are used to establish the potential use of the land, eventually seeking a balance between prospective alternatives.

Contrasting with these regulations, however, in highland regions, land tenure is not clearly registered and documented for individual smallholders and even less so for many rural communities, creating tenure insecurity. This lack of titles and registration of land ownership, among other factors, limits the capacity that communities have to properly manage their territories or seek investments with a long-term vision, most notably, forestry plantations. Without this basic and necessary condition, planning is systematically blocked.

Another factor that limits effective land-use planning in the highlands of Peru is the fact that the lowest level of government is the district municipal level. It is peasant communities that have real control of the territory, however, while municipal governments represent the interests of urban areas in the highlands. A gap therefore exists between those with the resources and responsibilities to plan, the municipalities, and the entities that hold actual control of the territory, the communities. "Peasant Community" legislation indicates the equality of rights and obligations, defense of the common good, participation, internal reciprocity as well as "defense of ecological equilibrium, preservation and rational use of natural resources" as founding principles for these social entities (3rd Article Law 24656). However, in spite of legal recognition, public support to fulfill these functions has rarely materialised. As a consequence, peasant communities are socially and politically weak. Their elected authorities typically cannot even complete short, one to two year office terms due to internal conflicts, there are no national programmes to support the technical capacities of elected community leaders and, as indicated above, communities are not part of the political structure of the state and therefore have no direct access to public funds. Even in areas of Peru without a tradition of peasant communities, rondas campesinas [peasant police patrols] have substituted the lacking state services in these remote locations[5] and are recognised by legislation (Law N° 27908). Peasant and other rural communities that are key to effective territorial planning have little or no support in the legislative framework to fulfill their role in land planning.

In summary, district and provincial level municipalities, the lowest, most decentralised government levels charged with land-use planning in mountainous regions, are historically and structurally disconnected from the rural communities that are the institutions actually controlling both access and the ways in which land in highland Peru is used.

Using the land from a community perspective

Awareness of the broader socio-economic and political context in which rural, local level land-use planning takes place in Peru raises the issue of the necessity to engage in developing regional-level stakeholder platforms. This becomes particularly relevant when taking into account the fragmentation of state controls into separate sectors[i] and the relegation of communities to a political and economic blind spot in the vision of the central state.

Above, note was taken of the fact that rural communities are associated with extreme poverty and structural incapacity to be competitive in the existing development model of Peru. It is therefore assumed that any external investment or alternative uses of the land (dams, mining, or industrial forestry, tourism) are necessarily better than current agricultural uses.

Fragmentation is prominent at all levels, occurring within regions, as well as across regions (formerly known as "departamentos"), and between regions and the central government. This is exemplified by the fact that many of the 52 coastal watersheds extend across two regions. As a result conflict over water control has erupted between Huancavelica (highlands) and Ica (coastal), and between Ancash (highland) and la Libertad (coastal). Fragmentation also takes place within regions between coastal and highland populations. For instance in Piura, amongst the richest agrarian regions of Peru and an area where coastal farming entirely depends on mountain runoff, there is no awareness, interest, or knowledge, and therefore no actions to properly integrate remote mountain communities into land-use planning. In addition to the aforementioned fragmentation, there are also active policies limiting the legal capacities of rural communities to control investment within their territories (e.g. agreements to use community land by external third parties like mining projects require absolute majority of registered members to become legal).

It is in this context that the need to promote multiple stakeholder platforms becomes critical in order to link highland with lowland communities.

The Rio Santa watershed illustrates the issue of fragmentation and the need to promote multiple stakeholder

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platforms to create a better environment for local planning. With over 12,000 km^2 in area, the watershed is a huge and topographically complex mountainous territory equaling about one-third of the size of Switzerland. This watershed has 21 tributaries descending from the glaciers of Cordillera Blanca in Huascaran National Park. This national park is a protected area created over alpine grasslands, it was expropriated by Peru's Agrarian Reform of 1969 from haciendas, but was in fact used extensively by local rural residents. Two of the rivers of the watershed come from the drier Cordillera Negra, which has no glaciers. The region has some of the largest gold and copper mining operations of the country, and three hydroelectric plants. Irrigation schemes in the coastal desert, using water from Rio Santa, have planned investments for approximately 200,000 hectares of land over the next years. Glaciers providing the bulk of water during the dry season have already lost nearly 25% of their mass in the last 30 years.[6]

It is against this backdrop that the districts of this territory, comprising over fifty rural villages and communities, are required to produce land-use plans that should theoretically become "territorial ordering as a political process". Therefore, this level of social, political and economic fragmentation requires a methodology to help mediate stakeholders' understanding of each other's interests.

Participatory experiences

From micro scale to medium scale: the Participatory Action Research Committees (PARC) and Participatory Management Plan (PMP)

The PARC and PMP processes

At the Mountain Institute Andean Program we have developed specific methodological processes for different landscape scales, from the local to the watershed. Since 1999 various participatory action research projects have been developed with rural families. For example, the Participatory Management Plan (PMP), a process that was conceived for a medium scale area, comprising the territories of several communities. We define the PMP as a strategy to locally generate the best ideas to manage natural resources in a geographical area, taking into account the current situation, and past experiences. This occurs as a learning process and implies an exchange among "colleagues"[ii] (local and external) of the "best ideas" to manage a particular ecosystem. This process is based on the women and men's vision of their future, and takes into account socio-cultural differences such as the variety of age groups, who define their own actions and strategies to conserve and to manage the ecosystem, reducing the threats and negative impact of certain activities, and taking advantage of the opportunities and potential resources to achieve sustainable development of the ecosystem.

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At both scales (a protected area or a localized ecosystem like the Paramo), the final objectives pursued are:

- To reinforce the rural communities institutions and their technical capacities for sustainable development, through conservation strategies and a reasonable use of natural resources.
- To develop a common view of the future they seek for their landscape.
- To contribute to the emergence of local leadership and to reinforce or to develop coalitions.
- To promote a participatory management in order to develop funds for productive investment.
- To help rural communities improve their standard of living, while conserving the rural environment.
- To generate sustainable alliances for conservation with local actors, by discovering more appropriate incentives to conserve their natural resources and corresponding environmental services.

The PMP and PARC are territorial planning tools, which promote the development of collective mobilization, improve learning and foster decision making processes from a local perspective.[7]

These outcomes are essential building blocks and local capacities that will be required by all the ordenameinto territorial tools established in the Peruvian legislation for districts, provinces and regions. Strengthening local capacity for innovation is as important as technologies themselves.[8]

"Camino del Agua": connecting stakeholders

This activity was organized in Rio Santa watershed. It requires the identification of a core group willing to invest time and resources over a medium term to create stakeholder knowledge of the diverse perspectives they have on resources and the environment. Once a year, three transects across the watershed are organized (in the case of Rio Santa in the upper, middle and lower sections of the watershed). To the furthest extent possible, members of rural communities representing a cross section of local society organize the walk and invite a diversity of stakeholders. Participatory mapping and focal group discussions guided by key questions take place in the field as people walk through their landscapes. This is followed by a one-day workshop where representatives from all three walks gather to exchange information and conduct a joint analysis. Finally, this is followed by public presentations to a wider audience in order to expose information from the individual walks and the results of analysis. The outcome of these exercises is dialogue, increased mutual knowledge and above all public positioning of the local communities' perspectives. Repetition of the exercise aims to institutionalize dialogue and create public awareness of the central role that rural communities must have to promote effective land-use planning at a regional scale. Thus, repeated "caminos del agua" generate information about the region, improve knowledge of different values or objectives among stakeholders, create a political environment that is favorable to marginal rural communities and therefore increase the chances to develop shared visions and more consistent local and regional planning results.

Conclusions

Local level land-use planning based on participatory processes has strategic value to achieve the objectives of ordenamiento territorial as "political process". Local participatory planning encourages actors to understand the systematic nature of society and its environment, to realize how the groups they belong to are nested in larger groups, and for local leaders to understand which other systems are components that they must coordinate with. It encourages them to reflect on their long-term goals, how their goals fit within those of the regional and national systems of which they are part, and if a larger sense of regional territorial identity emerges, how their goals contribute to shared goals in the larger society.

In fragmented rural societies, fostering dialogue mechanisms which are designed to improve mutual knowledge of stakeholders and their shared territory, and highlight the perspective of marginal rural groups, must be sustained over a long period of time before a common vision at the regional scale can be obtained.

These experiences (similar to Inter-American Institute for Cooperation on Agriculture *IICA* experience in Brazil) have left many valuable lessons, including the recognition that social capital and social organization are fundamental elements in conceptualizing and delimiting a territory.[9] The inhabitants understand their territory not only through its climatic, geographic and demographic characteristics, but also through the confidence that is created as a result of their associations, cooperation and networks. Sustainable development of a rural territory can be recognized as the consolidation of social cohesion and territorial cohesion, an expression of rural communities and national societies, which are integrated by social equity. This kind of territorial cohesion means that the resources, economies, societies, and spaces are interlinked, giving inhabitants the sensation that they belong to the territory, and encouraging their auto-definition as cultural, political and social integrated entities.

We emphasize that the need to plan is more than an administrative requirement, participatory planning is an effective tool for informed decision making, and is a key to alleviate poverty in the developing world.

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NOTES

i. Peru's Ministry of Environment was created during preparation of this document. The new ministry was hastily established as a requisite of the free trade agreement signed with the United States.
ii. In this case "colleagues" means that local population and external professionals are developing horizontal relationships.

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Some Guidelines for Helping Natural Resources Adapt to Climate Change

Jill S. Baron, Susan Herrod Julius, Jordan M. West, Linda A. Joyce, Geoffrey Blate, Charles H. Peterson, Margaret Palmer, Brian D. Keller, Peter Kareiva, J. Michael Scott and Brad Griffith

Flexibility in management approaches will be critical to maintaining ecological resilience in mountains and other ecosystems in a changing climate

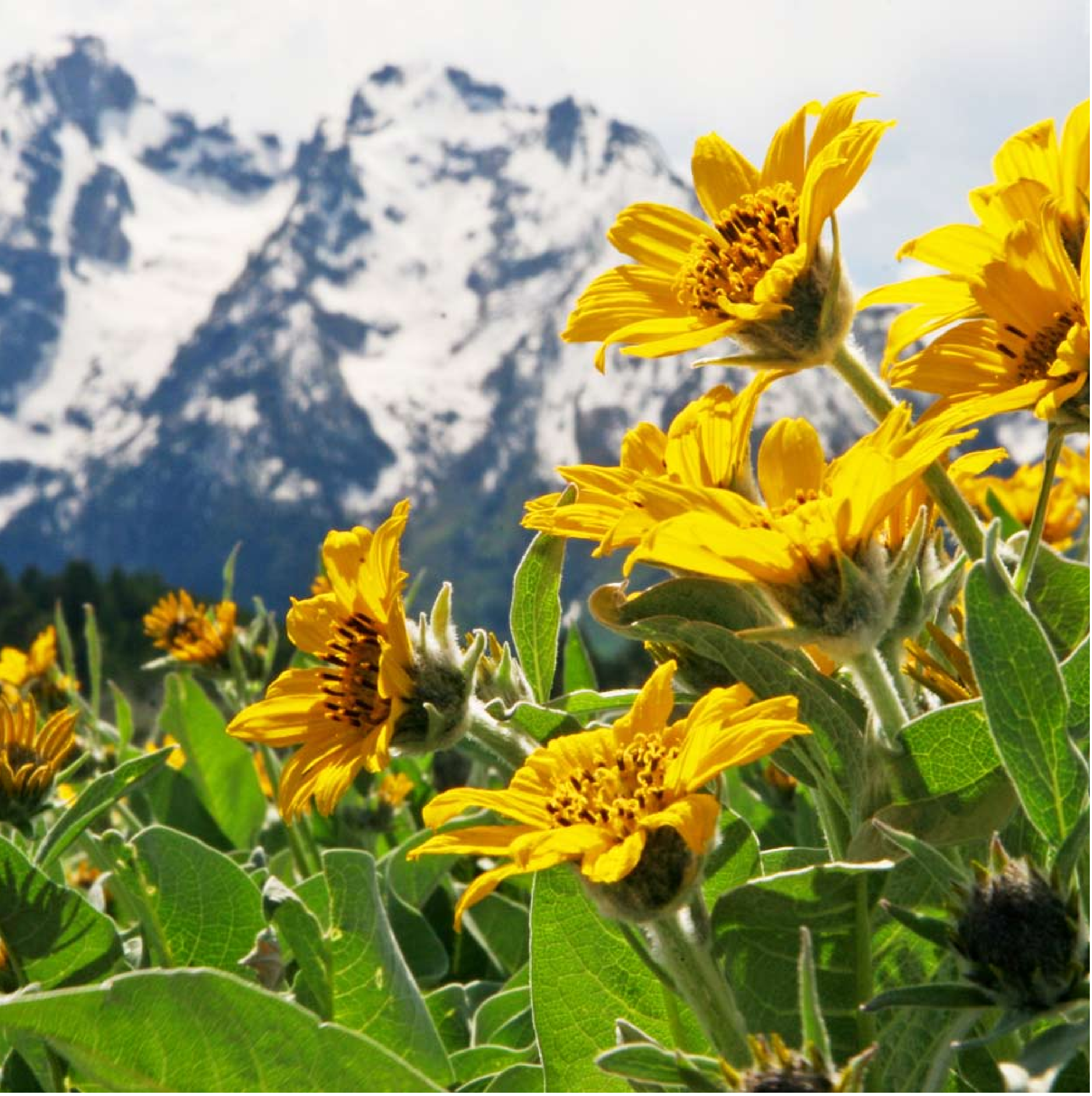
Photo: Grand Tetons National Park, USA ; copyright, Matt Hintsa.

The changes occurring in mountain regions are an epitome of climate change. The dramatic shrinkage of major glaciers over the past century – and especially in the last 30 years – is one of several iconic images that have come to symbolize climate change.

Climate creates the context for ecosystems, and climate variables strongly influence the structure, composition, and processes that characterize distinct ecosystems. Climate change, therefore, is having direct and indirect effects on species attributes, ecological interactions, and ecosystem processes. Because changes in the climate system will continue regardless of emissions mitigation, management strategies to enhance the resilience of ecosystems will become increasingly important. It is essential that management responses to climate change proceed using the best available science despite uncertainties associated with the future path of climate change, the response of ecosystems to climate effects, and the effects of management. Given these uncertainties, management adaptation will require flexibility to reflect our growing understanding of climate change impacts and management effectiveness[1].

A recently released report by the US Climate Change Science Program: Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources identifies adaptation strategies for US national forests, national parks, wildlife refuges, wild and scenic rivers, estuaries and marine sanctuaries[2]. Fully one third of the world's legally protected areas, including many US national parks and forests, are in mountains[3]. Elevation and climatic gradients make mountains especially vulnerable to climate change, thus management approaches that encourage natural processes and populations to adapt to changing climates will become increasingly important.

Starting with the management goals of each of these systems, scientists identified approaches that could increase



the short-term resilience (over perhaps the next several decades) of ecosystems, resilience being defined as the amount of change or disturbance an ecosystem can absorb before it enters a fundamentally different state. As climate continues to change, however, resilience thresholds will likely be exceeded. Thus, longer-term adaptation approaches will require flexibility, managing for changing conditions instead of fixed goals, and management approaches that acknowledge uncertainty (TABLE 1). Case studies, although certainly not definitive, were used to begin to apply principles of adaptation to specific US public lands (BOX AND MAP).

Successful adaptation of natural resource management to climate change begins by identifying resources and processes at risk from climate change, defining thresholds and reference conditions, establishing monitoring and assessment programs, and engaging in management actions that increase the resilience of these resources. Adaptation strategies include scenario planning; adaptive management, including an increased capacity to learn rapidly from man-

Case study summary

The authors of Synthesis and Assessment Products: Adaptation Options for Climate-Sensitive Ecosystems and Resources (SAP) 4.4 explored opportunities to adapt to climate change in 13 case studies encompassing the range of ecosystems and types of federally managed systems covered in the report (see map). In general, these ecosystems will face warmer temperatures, more frequent and prolonged droughts, and more precipitation falling in intense storms. Moreover, many of the cases examined will face limits in water availability due to a combination of decreased snowpack, earlier spring snowmelt, and increased evaporation and runoff. Mountain ecosystems will likely suffer more severe insect and disease outbreaks, longer fire seasons and more severe fires, and shifts in biotic communities (e.g., cold-water dependent fishes) due to warmer air and water temperatures.

Although the specific adaptation options varied by management context, some common themes emerged from across the case studies. For example, many case studies emphasized the need to capitalize on the flexibility in current planning processes and to explicitly incorporate climate change considerations in management plans. Another key theme was the importance of implementing better monitoring systems to provide salient information for improved decisions for climate change adaptations. Similarly, most of the case studies emphasized the need for education (of management staff and the public) about the science of climate change and its implications. Engaging landowners to manage vegetation near buildings and dwellings, for example, would help the US Forest Service minimize risks to property and lives from the expected increase in wildfires within the landscape mosaic of National Forests. Finally, several case studies highlighted the need for a strong science-management partnership to develop and implement adaptations. The Olympic National Forest case study, for example, noted that collaboration with other agencies and organizations helped develop innovative climate change adaptations for the benefit of many stakeholders.

agement successes and failures; and examining and responding to the multiple scales at which species and processes function. The latter most certainly will require regional to international partnerships and a shared vision among multiple organizations. Science-based management principles will become more critical because past experience may not serve as a guide for novel future conditions. Preparing for and adapting to climate change is as much a cultural and intellectual challenge as an ecological challenge[4].

Table 1

Steps to implementing adaptations to climate change for park and reserve managers

1. Identify resources and processes at risk from climate change
2. Establish reference conditions, identify thresholds, and monitor for change
3. Assess, plan, and manage at multiple scales, letting the issues define the appropriate scales of time and space
4. Form partnerships with other resource management entities
5. Increase reliance on adaptive management and scenario-based planning
6. Use best management practices to reduce other human-caused stresses to park and reserve ecosystems
7. Reward managers who adopt approaches that increase understanding and accelerate the pace of learning

Identifying resources and processes at risk from climate change

Systematic characterization of potential climate changes on resources can be accomplished through summaries of the literature, guided research, gatherings of experts, and workshops where scientists, managers, and the public discuss risks to resources. We caution against the tendency to insist on high-resolution climate forecasts before undertaking this exercise. While detailed and site-specific climate forecasts may be helpful for specific applications, general projections may be sufficient for the initial stages of risk assessment. Subsequent iterations of the exercise can explore resource risk in more detail. It may be useful to rank susceptibility of resources and processes based on the speed of expected response, the role that species or processes play in the ecosystem, the importance of the species or resources to meeting management goals, and the ecological and socioeconomic potential for adaptation. Assessment of risk requires explicit consideration of how crossing thresholds will affect valued species, communities, ecosystem processes, and their interactions. Climate change provides the impetus to identify not only acceptable versus unacceptable change, but controllable versus uncontrollable change.

Establishing reference conditions, identifying thresholds, and monitoring for change.

Climate changes may cause ecological thresholds to be exceeded, leading to abrupt shifts in the structure of ecosystems. Threshold changes in ecosystems have profound implications for management because such changes may be unexpected, large, and difficult to reverse. Understanding where thresholds have been exceeded in the past and where (and how likely) they may be exceeded in the future allows managers to plan accordingly and avoid tipping points where possible. Activities taken to prevent threshold changes include establishing reference conditions, modeling a range of possible climate changes and system responses, monitoring to identify relevant ecological changes, and responding by implementing adaptation actions at appropriate scales and times.

Reference conditions determined partly by observations and data from the past, including paleoenvironmental records, help managers and scientists identify ecological states or regimes, and hence guide management activities. But reference conditions are also value statements; what a set of individuals identify as important. With uncertain future climates, managing to return to a reference condition may no longer be the appropriate goal[5]. Knowledge of the ecological and physical setting that produced the reference condition is still useful, however. If the reference condition would incur greater resilience to human-caused disturbance, including climate change, than current conditions, it provides a goal for protection or restoration. Alternatively, if the reference condition is highly dependent on past climate conditions, it identifies the need for adaptation to new conditions. Scientific evidence that past and highly valued conditions are no longer attainable may provide the incentive to plan for ecosystems that are sustainable under future conditions[6].

Table 2
Some Adaptation Approaches for Climate Sensitive Ecosystems

1. **Reduce anthropogenic stresses**: minimize localized human-caused disturbances (e.g., pollution, fragmentation) that hinder the ability of species or ecosystems to withstand climatic events.
2. **Protect key ecosystem features**: manage to maintain structural characteristics, organisms, or areas that support the overall system.
3. **Maintain representation**: protect variant forms of a species or ecosystem so that, as climate changes, there may be populations that survive and provide a source for recovery.
4. **Replicate**: maintain or establish more than one example of each ecosystem or population within a management system, such that if one area is affected by a disturbance, replicates in another area may reduce risk of extinction and provide a source for recolonization.
5. **Restore**: rehabilitate ecosystems that have been lost or compromised.
6. **Identify refugia**: use areas that are less affected by climate change than other areas as sources for recovery or as destinations for climate-sensitive migrants.
7. **Relocate**: transplant organisms from one location to another in order to bypass a barrier (e.g., urban area).

Managing at multiple scales:

Complex ecological systems operate and change at multiple spatial and temporal scales. The scales at which ecological processes operate often will dictate the appropriate scales at which management institutions should be developed. Migratory bird management, for instance, requires international collaboration; ungulates and carnivores with large home ranges call for regional collaboration; marine preserves require cooperation among many stakeholders; all are examples where managers cannot be effective working solely within park or reserve boundaries. Similarly, preparation for rapid events such as floods will be managed quite differently than responses to climate impacts that occur over decades. Species may be able to move to favorable climates and habitats over time if there is appropriate and connected habitat.

Increasing reliance on adaptive management and scenario planning.

Ecosystems that provide societal goods and services are complex systems within a complex landscape. Doak and others[7] suggest complexity and surprises reinforce the need for management plans that are highly precautionary, rather than plans that assume specific management actions will have specific outcomes. The two major factors that influence selection of strategies for managing complex systems are the degree (and type) of uncertainty and the extent to which key ecological processes can be controlled. Most current approaches toward resource management are appropriate when uncertainty is low and specific activities are likely to achieve a clear outcome. But the changes to ecosystems that will result from interactions of natural dynamics, anthropogenic change, and novel climates will increasingly negate the ability to manage for specific outcomes. Adaptive management, which is a process that integrates learning with management actions, is applicable to circumstances where there is ability to influence an ecological process, but uncertainty as to the best methods [8,9,10]. By treating management activities as hypotheses, adjustments are made in decisions as outcomes from management actions and other events are better understood. This method supports managers in taking action today using the best available information while also providing the possibility of ongoing future refinements through an iterative learning process. Scenario-based planning provides a way of envisioning a range of quantitative or qualitative plausible futures[11]. Adaptation responses can then be developed for the range of plausible futures; this approach is more robust to uncertainties than managing for any single projection of the future.

Adaptation Approaches

The report identified seven resource management approaches that might confer short-term resilience to ecosystems and highly valued species (TABLE 2). Protecting key ecosystem features involves focusing management protections on structural characteristics, organisms, or areas that represent important "underpinnings" or "keystones" of the overall system. Reducing anthropogenic stresses is the approach of minimizing localized human stressors (e.g., pollution, fragmentation) that hinder the ability of species or ecosystems to withstand climatic events. Maintaining representation refers to protecting a portfolio of variant forms of a species or ecosystem so that, regardless of the climatic changes that occur, there will be areas that survive and provide a source for recovery. Replicating centers on maintaining more than one example of each ecosystem or population such that if one area is affected by a disturbance, replicates in another area provide insurance against extinction and a source for recolonization of affected areas. Restoring is the practice of rehabilitating ecosystems that have been lost or compromised. Identifying refugia refers to taking advantage of areas that are less affected by climate change than other areas and as sources of "seed" for recovery or as destinations for climate-sensitive migrants. Relocating refers to human-facilitated transplantation of organisms from one location to another in order to bypass a barrier (e.g., urban area)[1,2].

We estimated confidence in the ability of each of the seven approaches to provide resilience by quantifying the amount of available evidence to support the determination that the effectiveness of a given adaptation approach is well-studied, understood, and agreed upon throughout the scientific community. The resulting confidence estimates varied both across approaches and across management systems. Reducing anthropogenic stresses was the one approach for which there was considerable scientific confidence in its ability to promote resilience for virtually any situation. Confidence in the other approaches—including protecting key ecosystem features, representation, replication, restoration, identifying refuges, and especially relocation—was much more variable.

Many existing management practices can be applied to protect ecosystems from some aspects of climate change. Changes in temperature, precipitation, sea level, storm intensity and other climate-related factors can exacerbate problems that are already of concern to managers. Fortunately, many existing management practices also can address these climate change interactions. For example, reducing the delivery of pollutants to estuaries may enhance physiological resistance of many estuarine species to elevated water temperature. Another existing approach, use of riparian buffer strips, is effective at limiting nutrient and sediment loadings from agricultural lands into rivers under a wide range of current climates, suggesting that it will be effective under future climates as well. However, this does not mean that managers should only continue or intensify existing practices; they also need to explore key adjustments in the timing, spatial extent, and location of their practices to ensure greatest effectiveness given climate change.

The importance of communication, trust, and scientist-manager-public partnerships

Even highly reasoned actions have some potential to go awry, especially as climate changes. Although clearly not desired, failures provide opportunities for learning. Continued and expanded public education about the complexity of resource management, transparency in the decision-making process, frequent public updates on progress or setbacks, and internal agency efforts that promote trust and respect for professionals within the agency are all important methods for promoting more nuanced management efforts. Partnerships among managers, scientists, educators, and the public can go a long way toward efficiently closing information gaps. With good communication and coordination, scientists can target their research to better inform management challenges, resource managers can share data and better design monitoring to test scientific hypotheses, and outreach specialists can better engage the public in understanding and supporting adaptation activities.

Photo: Buffalo at Yellowstone National Park, USA; copyright Matt Hintsa

Managing for change

Adapting to climate change may require more than simply changing management practices—it could require changing management goals. In other words, when climate change has such strong impacts that original management goals are untenable, the prudent course may be to alter the goals. At such a point, it will be necessary to manage for and embrace change. Climate change requires new patterns of thinking and greater agility in management planning and activities in order to respond to the inherent uncertainty of the challenge. There are no clear answers yet for how exactly to proceed, but a critical dialog among engaged stakeholders including scientists, managers, and the public may help chart the way forward.

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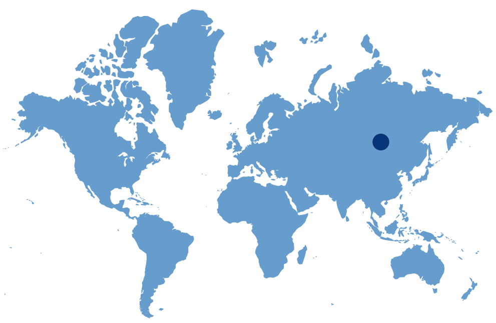
Climate Change Adaptation Strategies for Pastoral Communities of Mongolia's Central Mountainous Region

Chuluun Togtokh



Nomadic pastoral systems are dissipative structure-functions (Nicolis and Prigogine, 1977, 1989) immersed in arid ecosystems of great temporal and spatial heterogeneity (Chuluun, 2000). Historically, traditional pastoral networks emerged in drylands with scarce natural resources, subsequently evolving to increase human adaptive capacity in coping with climate variability and extreme climatic events such as drought and zud, a winter condition that can prove devastating for livestock. A large geographical landscape was critical in order to offset climate variability, as traditional pastoral networks used certain landscapes primarily for forage and water. There was thus a strong coupling between traditional pastoral groups and the landscapes they used. Traditional pastoral communities and their cultural landscapes, consisting of four seasonal land types in addition to reserve areas, otor pastures and haylands, provides a prime example of a coupled social-ecological system or human-environmental system (Global Land Project: Science Plan and Implementation Strategy, 2005). These traditional pastoral social-ecological systems were sustainable for centuries.

The Mongolian cultural landscapes, however, were fragmented with the administrative-territorial division reform of the last century (Ojima & Chuluun, 2007). Now almost half of all sums or sub-provinces lack one or two seasonal pastures. Interestingly, there wasn't much change

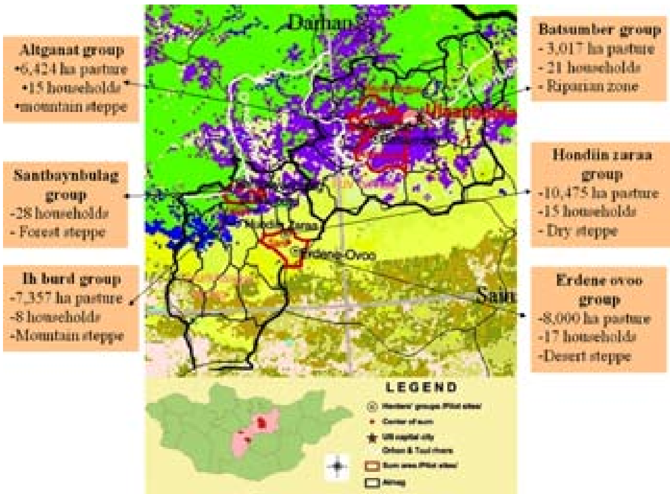


Figure 1: Map of Pilot Study Sites

in terms of cultural landscape use during the socialist period, although there were large changes in pastoral social-ecological systems during the socialist period between late 1950s and 1990. More complex dynamic changes in pastoral social-ecological systems have occurred since 1990 in the transition to a market economy. The number of herders has more than doubled since the early 1990s as a result of the economic migration spurred by livestock privatisation. Traditional pastoral networks at the lowest level (hot ail) re-emerged and re-organised themselves during this period of time, as some younger and more inexperienced herders started to follow their parents or relatives, who had more herding experience. These pastoralists continued to use traditional cultural landscapes under the leadership of experienced herders. Some new herders started to live near the settlements and water sources, causing overgrazing as a result of their low mobility. Due to a rise in the price of cashmere, goat numbers more than tripled from 5.1 million in 1990 to 18.3 million in 2007 since the transition to open market economy (MONGOLIAN STATISTICAL YEARBOOK, 2008).

In addition to economic and social factors, global warming is becoming a slow but critical variable, affecting the reduction of water and food resources. Over the last 60 years, surface air temperature in Mongolia has increased by 1.940C, which, along with its socio-economic vulnerability, makes Mongolia one Earth's hot spots. Spring is also becoming increasingly dry as a result of warmer temperatures and decreased precipitation.

This research aims to investigate change and transformation of open pastoral social-ecological systems (GALLOPIN, 2006) and develop climate change adaptation options for pastoral communities with participation of herders, local and national governmental officers and scientists (VOGEL ET AL., 2007). A social survey among herders on local climate change observation and its impact on pastoral systems was conducted and participatory workshops with pastoral communities. These workshops aimed to communicate the current and future risks of climate change, land use changes and rangeland assessment techniques, as well as the socio-economic vulnerability of the herders to climate change.

Study Sites for Pastoral Social-Ecological Systems

Two out of six study sites for pastoral social-ecological systems were selected in the buffer zone of the Khustai Nuruu National Park, where wild horses known as tahi were re-introduced. These social-ecological systems in the buffer zone were selected so as to increase knowledge on the interaction between conservation and pastoral land systems, especially those in close proximity to the city of Ulaanbaatar. Four other sites were selected along ecological transects: forest steppe, mountain steppe, dry steppe and desert steppe. Prior to socialism, three of the sums along this gradient used to make up one administrative-territorial unit. One old herder from Sant sum said that this parents used to spend summer in mountains of Khijist sum. This confirms that there was free pastoral movement between mountains and steppe within the old administrative unit and old administrative-territorial divisions were primarily based on cultural landscape principles.

Hondiin Zaraa and Erdene-Ovoo, herders' groups at Sant sum, and Ih Burd at Hijirt sum, were led or guided by the old experienced herders who had lived in these areas for generations. Thus, traditional indigenous knowledge was basis for grazing management in these pastoral communities, and they followed their nomadic cultural legacy better than other herders' groups. Interestingly, the zuds of 1999-2002 prompted an increase in the formation of herders' groups due to several reasons such as legacy of cooperation and social learning, as well as government and donors support. Generally, relatively poor herders tended to form herders' groups, exemplified by Batsumber and Santbayanbulag herders' groups along the Tuul and

Orhon rivers. These groups were not led by an experienced herder, but by a former administrative worker or teacher. These group leaders were intelligent people, quickly learning the advantage of cooperation for relatively poor households.

Migration from the rural areas to the big cities of the central area started to increase in mid-1990s. The migration from the rural areas was a result of environmental change, following summer droughts and intensifying after the 1999-2002 zuds. The herders who had lost their livestock during these disasterous climatic events were forced to leave the area and can be referred to as environmental refugees. The Batumber and Altganat herders are examples of the migration of herders from the rural to the central region of Mongolia. In addition, the Khustai Nuruu National Park probably attracted herders due to its beneficial buffer zone management programmes. Thus both the Batsumber and Altganat herders' groups have the shortest local ecological knowledge as only one household in each community was native, with the rest of the herders having migrated from the western Aimags. The Tuul river valley served as a market pathway for the transfer of animals from the western Aimags to Ulaanbaatar city, and it was kept free of grazing by local herders during socialism. State agricultural farms existed in the region north of the Hustai Nuruu National Park between the late 1950s and 1990, but the farmers have since moved out of the area. The fields, abandoned after the transition to a market economy in 1990, have still not recovered from server soil erosion caused by the farming of these drylands.

Both the central region close to Ulaanbaatar, the capital city, and the Khustai Nuruu National Park were attracting people from remote areas of Mongolia. Thus, the majority of herders living in the buffer zones of the park are migrants, mainly from the western Mongolia. They enjoy double economic benefits from being closer to the market of Ulaanbaatar and the support from the park (SEE TABLE 1 for their income level compared to herders from other regions). Interactions of the herders living in park buffer zone are mutually beneficial. The herders assist in conservation of the park and they benefit from the park's assistance in building fences around springs, or in constructing wells. The herders are allowed to use park pasture during zuds. However, their impact on the ecosystems outside of the park is large, as overgrazing from their herds has led to ecosystem degradation. Herders living along the Tuul river developed a more sedentary lifestyle, moving only twice a year and covering only short, two to three kilometre distances. This has greatly concerned the Altanbulag sum government, which has passed regulations prohibiting grazing alongside river during between late June and late August. The herders, however, do not obey this regulation.

Research findings

Some research findings are summarised in Table 1. Livestock per capita is well correlated with income per capita due to the fact that the herders' main income for comes from livestock. The Batsumber and Altganat pastoral communities have the highest income. Four other communities, those of the forest steppe, the mountain steppe, the dry steppe and

Photo: Herders in the outskirts of Ulaanbaatar, Mongolia; copyright Nozomiiqel

Table 1: Studied pastoral communities

Name	Sum & Aimag	Ecosystem Type	Number of Households	Livestock per capita, sheep unit	Income pser capita, USD	Cultural landscape index	Socio-economic vulnerability
Batsumber	Altanbulag Tov	Riparian/ forest steppe	21	100	1,200	4/7	2.3
Altganat	Argalant Tov	Forest steppe	15	181	1,877	5/7	2
Santbayan bulag	Hujirt Ovorhangai	Riparian/ forest steppe	8	41	547	4/7	3.3
Ihburd	Hujirt Ovorhangai	Mountain steppe	8	49	618	5/7	3.2
Hondlin Zaraa	Sant Ovorhangai	Dry steppe	15	83	827	6/7	3.4
Erdene-Ovoo	Sant Ovorhangai	Desert steppe	17	79	972	6/7	3.5

the desert steppe, live along transect. In the herders' group, the livestock per household as well as the income per capita and overall richness of the cultural landscape has increased along this transect. In terms of cultural landscape, Batumber and Santbayanbulag herders living in the riparian zones during the summer and fall lack three pasture types out of seven (4/7). Thus most ecosystem degradation was observed in the riparian zones where herders have become more sedentary. Cultural landscape is better conserved in Sant (6/7) as compared to Hujirt. As a consequence, the ecological condition in Hujirt is worse than in Sant, and it seems that this is already affecting the incomes of the herders (SEE TABLE 1). There are signs that this trend may continue unless the proper measures are taken. The environment and poverty is interlinked. The socio-economic vulnerability of each community was calculated based on its proximity to the market, its income, the loss of animals during the 1999-2002 zud and the level of economic diversification. The pastoral communities of Tov aimag showed less socio-economic vulnerability due to higher income and shorter distance to the markets of Ulaanbaatar city.

The herders were very sensitive to water availability during both the warm and cold seasons and there was also ecosystem degradation as a result of overgrazing around the wells and the few remaining springs that had not already shrunk due to climate change impact. The herders were very sensitive to snow cover change as well. For instance, Nogoon Suuri, a herder of Hujurt sum, indicated that 6 springs had disappeared and that only a single watering point remained for 14 households with 3,000 livestock. This only remaining spring was prone to freezing, leaving these households without water in early December 2006 (SEE PHOTO AT LEFT). As there is usually snow on the ground duing this time of year, the herders dispersed, moving away from their winter camps so that they could use the snow as winter water source.

Photo right: Copyright M. Altanbagana, 2007

Photo Below: Herders in the outskirts of Ulaanbaatar, Mongolia; copyright Nozomiiqel.

Discussion

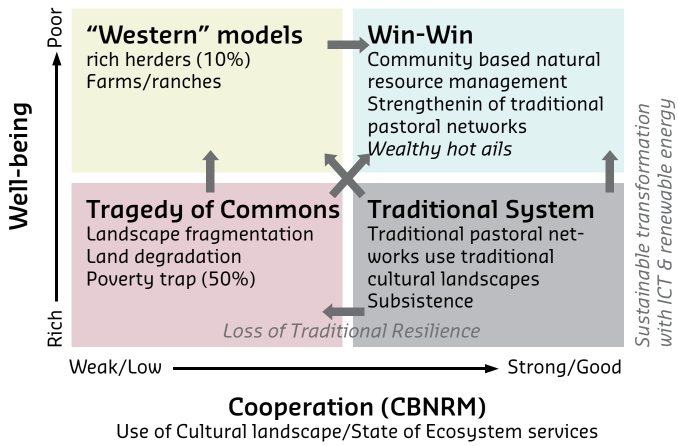
Livestock density exceeds carrying capacity in central Mongolia. The herders' economic well-being has generally improved with increased livestock numbers. Do to a rise in the price of cashmere, goat numbers have tripled since 1990. Water and foraging sources are becoming depleted due climate change in central Mongolia and the depletion has been amplified due to increasing land use intensity. Herders complain that goats further ecosystem degradation because they dig out the roots of young plants in the spring. Plant species composition is shifting with a decreasing number of edible plant species. Plant biomass may have already been reduced in non-linear fashion due to the interaction between climate change and overgrazing in central Mongolia. Spring drying trends have delayed the onset of plant growth in Gobidry steppe boundary area (ELLIS ET AL. 2002) and plant biomass decreased in central Mongolia during the 1990s, primarily due to climate change (OJIMA ET AL. 2004). Livestock numbers have increased since the early 1990s causing increased overgrazing effects with a reduction of dominant plant species known by the herders as Mongolian grasses. Observations of grassland ecosystem conditions in inner Mongolia, China and in Ovorhangai Aimag taken in 2002 and 2007 indicate that central Mongolia may be headed towards ecosystem degradation and desertification problems of the type already experienced in inner Mongolia.

In the central Mongolia study sites, small stream, lake and spring disappearance was also observed. Decreases in snowfall, increased tree cutting, the melting of permafrost, intensifying drying trends, destruction of riparian zone shrubs and swamps, and overgrazing all interacted in a nonlinear way, resulting in the disappearance of water sources. Regional climate may be affected due to the albedo change that comes with land and snow cover changes. Last summer, large floods in Hujirt sum territory due to both heavy rainstorms and drought conditions were observed. Riparian ecosystems appear to have keystone value in coupled pastoral social-ecological systems. The collapse of these critical ecosystems' ability to provide water would greatly impact the pastoral community, as water is the most valuable resource for both people and animals in drylands.

The complexities of coupled social-ecological systems increased with Mongolia's transition to a market economy and there are three general categories of herders and communities that are affected to different degrees. A wealthy class of herders with more than 500 livestock per household is emerging, making up only about 5% of herder households. A middle class with 200-500 livestock per household now makes up almost 20% of all herder households, and this group of herders has more choices to increase their resilience and adaptive capacity. Herders with less than 200 animals per household will have the advantage if they join formal herders' groups such as NGOs or informal traditional networks, as well-organised cooperation will give opportunities for economic, social, ecological, technological and cultural benefits. More than half of herders are considered poor with less than 100 animals per household. These poorer herders typically live near the cities and along the rivers and the link between environmental degradation and poverty is notable among this group. Some would benefit from re-training and the institution of sustainable farming systems with the introduction of productive livestock breeds and the diversification of their economy to include pigs, chickens and vegetables as sources of income.

Climate change adaptation options for cultural landscape restoration suggested in participatory community workshops included the introduction of community based conservation and sustainable use of natural resources, the addition and protection of water points for additional pastureland, the agreement between neighbouring sums for communal use of otor and reserve pastures, and the enlargement of administrative-territorial units, for instance, by combining several sums into one unit in order to restore cultural landscapes. For pastoral communities living in the riparian zones, diversification of the economy and intensification of the livestock industry through ecotourism and farming, the prevention of riparian ecosystems from degradation and desertification and taking animals to otor pastureland during the summer period were suggested options. Protection of springs from degradation by livestock was critical for communities living in the mountain and forest steppe.

Figure 2. Models for pastoral social-ecological systems



Research findings and thoughts for future adaptation strategies for pastoral social-ecological systems can be summarised in the scenarios diagram in figure 2.

Traditional system. Cooperation within traditional pastoral networks serves as a mechanism enhancing resilience to climatic disasters. Communal disaster relief mechanisms, assisting the most affected herders in many different ways, were in place. Traditional pastoral communities used cultural landscapes to cope with climate variability and climatic extremes. Due to proper management, rangeland ecosystems used for traditional grazing and ecosystem services were in good condition.

Tragedy of the commons. The rangelands are still State owned in Mongolia although livestock has been privatised. This has been the main reason for the increased overgrazing and ecosystem degradation near both settlements and water sources under capitalism. Poor herders especially have tended to become less mobile, living near towns, infrastructures and water sources as a result causing dryland fragmentation. Generally, herders have not cooperated and have competed more for resources in this scenario. Many herders in this model have lost their traditional resilience mechanisms to cope with climate variability and extremes, and potentially 50% of herders live in poverty. Deterioration of the social-ecological system with ecosystem degradation and increasing poverty happens in this model.

"Western models". Only 5-10% of herders became wealthier through the transition to a market economy. Generally, these rich herders don't cooperate with a larger pastoral community. They often take advantage of the current State ownership of pasture, often causing more damage to ecosystem services. Some of herders have small communities and use traditional cultural landscapes. Thus, some of the traditional networks that use cultural landscapes in sustainable ways can be included in the win-win model, with social and ecological benefits. This group of herders needs to be encouraged through proper pasture and culture landscape ownership mechanisms.

Win-win model. In the win-win scenario, the majority of herders must be transformed. The most desirable pathway for pastoral systems would be direct transformation from a traditional system to a win-win state, strengthening traditional pastoral communities with modern technologies such as renewable energy and communication information technology. High levels of literacy among the Mongolian herders (98%) and the suitability of the nomadic culture in concert with wireless communication make such a sustainable transformation very attractive. There is a great opportunity to conserve natural, cultural and social capital in order to maintain the adaptive capacity and resilience of Mongolian pastoral social-ecological systems to climate change and globalization. Teaching sustainable farming techniques to herders living near settlements and water points would be another pathway to reach a win-win situation and escape the tragedy of the commons state. A reform of administrative-territorial divisions that restores cultural landscapes appears to be the best, most cost effective adaptation option in order to promote the sustainability of coupled social-ecological systems with increased adaptive capacity and resilience to climate change at supra-pastoral community scales..

Conclusion

Pastoral land systems central Mongolia are becoming very vulnerable to climate change. Water and forage availability is changing due to global warming. Land use change, especially since Mongolia's transition to a market economy in 1990, have become a critical factor in the vulnerability of pastoral social-ecological systems. The traditional coping mechanisms enhancing the resilience of pastoral communities in the face of climate variability will be lost in Mongolia as in the surrounding countries of Central Asia, China and Russia unless alternative development agendas are taken. The opportunity of using the existing cultural landscape at community and cross-administrative boundary scales in Mongolia appears to be the most cost-effective resilience option for climate change adaptation in pastoral communities. Many international projects on pastoral development, poverty reduction or nature conservation in the Mongolia only consider parts of the problem. More holistic approaches are need to achieve win-win scenarios. Strengthening traditional pastoral networks with modern technologies to enhance social wellbeing as well as legal framework development for cultural landscapes at community and administrative unit scales for ecosystem service conservation are required to promote sustainability in pastoral social-ecological systems.

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Implications of Rangeland Enclosure Policy on the Tibetan Plateau

Grant Davidson, R.H. Behnke and C. Kerven

Fundamental, policy-driven changes are transforming China's rangelands in response to a perceived threat of environmental degradation. Having transferred livestock property from state to private ownership over the past two decades, government policy is now encouraging pastoralists to privatise parts of the natural resource, in the form of fenced enclosures. In other areas, the government has asserted its ultimate rights of land ownership and is excluding grazing entirely. These reforms are presented as packages that include incentives for pastoralists to fence pastures, cease moving their animals seasonally, build permanent settlements on the ranges, or emigrate to towns.

Photos previous spread, at right and above: Sheep herding on the Tibetan Plateau; copyright, Ernie Reyes.

Underpinning these policies is the presumption that extensive mobile pastoralism based on communal pasture use is backward and inefficient, and has led to land degradation1,2,3,4. Using a "Tragedy of the Commons" analysis[5], it is also argued that livestock-owners will take better care of the grazing land if it is privately controlled[6,7], or that pastures are so abused that grazing must be banned altogether[8].

Severe land degradation and desertification on the Tibetan Plateau has been widely noted by Chinese scientists, with overgrazing by livestock usually identified as the principal human factor causing degradation[9,10,11,12]. Many millions of hectares are classified as desertified to varying degrees, with 20.5 million ha. in the Tibetan Autonomous Region alone categorised in this way9. Some Chinese and international scientists have nonetheless questioned the usefulness of enclosure and exclusion as remedies for degradation[3,8,13,14,15].

An international, interdisciplinary research project, Range Enclosure on the Tibetan Plateau of China: Impacts on Pastoral Livelihoods, Marketing, Livestock Productivity and Rangeland Biodiversity (RETPEC), is currently investigating the biophysical and socio-economic impacts of policy-driven land use change in China's semi-arid regions by examining both the consequences and reasons for the implementation of this land reform process on the Tibetan Plateau.

The reforms that are the focus of RETPEC affect vast areas and millions of people. As a geographical feature, the plateau stretches across the Tibet Autonomous Region of China (TAR) and parts of four adjoining provinces (Qinghai, Gansu, Sichuan and Yunnan). The plateau covers 1.65 million sq. km, by far the most expansive area of alpine grassland in the world, containing diverse vegetation types from desert steppe in the west to moist alpine meadow in the east, across a rainfall gradient from about 100mm to 700mm of average annual precipitation. The plateau accounts for roughly half of China's rangeland and supports about five million ethnic Tibetan pastoralists and agropastoralists, predominately from China's minority groups representing some of the nation's poorest people.

Informing Policymakers

Rangeland reform to address the apparent crisis of overgrazing is being rapidly implemented on the plateau. Scientific research that would inform this process must operate at a

scale that reflects the geographical scope at which administrators and policy makers operate. This research should also provide information in a form useful to policymakers who may not have a technical background, but are nonetheless making decisions with long-term implications regarding the protection and management of rangeland ecosystems and the welfare of millions of people.

RETPEC was designed to meet these practical demands through a combination of interdisciplinary, field-based research, syntheses of existing research findings, and participatory work with pastoral communities, local administrations and NGOs. The project will inform public policy by assessing whether land degradation is ameliorated by the new land tenure and grazing regimes. By investigating the effects of situations in which pastoralists are forced to settle in rural areas or are obliged to leave the rangelands altogether and seek scarce alternative livelihoods in towns, thus creating a rural-to-urban population shift, it will also measure the consequences of sedentarisation on pastoralists' social and economic welfare[15,16,17,18,19]. The overall purpose of the research is to identify the immediate and long-term environmental, social and economic impacts of policies now being put into practice.

Specifically, RETPEC is investigating the biophysical and socio-economic effects of fenced versus open range grazing management across several major ecological zones in the Tibetan Plateau. The plateau provides a coherent ethnic, historical and geographical entity for comparative research. Across the plateau, enclosure and exclusion are being implemented unevenly, with largely unmeasured consequences[8,15]. Study areas in Hongyuan County of the Sichuan Province, Machin County of the Qinghai Province, Tienzhou County of the Gansu Province and Nyima County in the Tibet Autonomous Region have been selected to represent four main environmental conditions that characterise the plateau as a whole, namely high vegetation productivity in montane and peatland rangelands, high frigid meadows with medium vegetation productivity and lastly, high arid grassland with low vegetation productivity. Each of the selected sites will contain both enclosed and open range grazing management systems, or hybrid systems that combine elements of enclosure and open access.

Encouraging plurality and site-specific adaptations

The central hypothesis of RETPEC is that enclosure will be more prevalent and popular among pastoralists who have good access to markets and use rangelands that are intrinsically more productive. A corollary of this hypothesis is that no single system of grazing management and rangeland tenure is likely to be optimal under all conditions. Instead, it is likely that an array of different management systems will be appropriate to specific market and ecological conditions. RETPEC will therefore investigate the possibility that the most effective way to minimise rangeland degradation is to promote policies that encourage plurality and permit localised, site-specific adaptations.

RETPEC also hypothesises that grazing exclosures, or strictly enforced grazing bans, will be more prevalent in areas that have national rather than regional environmental significance, either because these areas represent unique conservation habitats or the upstream sources of nationally-important river systems, including the Yangtze and Yellow Rivers11,12. A corollary of this hypothesis is the possibility that the extent of exclosure is correlated with the perceived off-site importance of a resource, and has little to do with on-site rates of resource degradation. To investigate this possibility, we will estimate the severity of degradation at sites that are subject to varying degrees of enforced grazing exclusion.

In testing these hypotheses with RETPEC, we are pursuing three primary scientific and technical objectives:

Firstly, we will compare the extent and type of rangeland degradation, including biodiversity indicators for both flora and fauna, between four major ecological systems within which both enclosed and open-range grazing management is practised. This comparative analysis will establish the conditions under which enclosure and exclosure leads or does not lead to rehabilitated rangeland.

Secondly, we will explore innovative approaches for rangeland rehabilitation and improved pastoral livelihoods under various systems of grazing enclosure and exclosure. The identification of these approaches will involve the participation of local pastoral communities, administrations, NGOs and other stakeholders in the study areas. Assessments of alternative management arrangements will also be informed by new data from field studies undertaken by the project, published in Chinese and multiple European languages.

Thirdly, we will evaluate the social, cultural and economic repercussions of changing land tenure and grazing regimes on the pastoralists concerned. Interdisciplinary field studies will compare the incomes and livelihoods of pastoralist communities that are rapidly adopting new grazing regimes that require sedentarisation, with those communities that remain engaged in semi-nomadic livestock husbandry. Through participatory methods, the project will gauge the impact of settlement on livelihoods in terms of household labour and gender roles, access to markets, employment and social services and lastly, the effects of new living situations on the pastoralists' cultural identity.

RETPEC is managed by The Macaulay Institute, UK. Other partners are the Chengdu Institute of Biology, Chinese Academy of Science, PRC, the College of Pastoral Agriculture Science and Technology, Lanzhou University, PRC, the Qinghai Academy of Animal and Veterinary Science, PRC, the Tibet Academy of Agricultural and Animal Sciences, PRC, Queen Elizabeth House, University of Oxford, UK and the University of Tromsø, Norway. RETPEC is funded by the European Commission's INCO DEV 6th Framework Programme. The project began in 2007 and is anticipated to finish in 2011/2012.

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The range enclosure on the Tibetan plateau of china: Impacts on Pastoral Livelihoods, Marketing, Livestock Productivity and Rangeland Biodiversity (RETPEC) Project is endorsed by the Global Land Project

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Redeveloping Mountain Landscapes as Cultural Cradles of Biodiversity

P.S. Ramakrishnan

Photo 1: Apatani plateau of Arunachal Pradesh in unique cultural landscape – A unique traditional ecological knowledge (TEK)-based natural cultural landscape with a highly evolved traditional agricultural system; the 3-layered forestry systems (bamboo, pine and mixed forest systems) in the background is an unique example of community-managed production forestry with biodiversity concerns.

With much of the biodiversity located in the larger plains of the globe depleted as a result of the struggle, in addition to the needs of industrial development and the accompanying urbanisation that humans have witnessed over more than a century, much of the remaining biodiversity is now largely confined to the mountainous regions, especially those of the developing tropics. Realising that: (i) societies living in the mountains still try to relate and identify themselves with a 'natural cultural landscape' that they have carved out for themselves; (ii) these mountain landscapes, in the contemporary context, form the last outposts of biodiversity 'hotspots'; (iii) conserving and sustainably managing this biodiversity is critical to addressing the rapidly emerging environmental uncertainties, not only of the mountain people but of humanity at large; and (iv) that sustainable management of 'natural cultural landscapes' is an effective route towards conservation of biological diversity, whether at the sub-species, species, ecosystem or landscape level, efforts should be directed towards sustainable management of mountainous cultural landscapes. We have shown, based on work done over the last four decades, that this can be effectively achieved only by building bridges between 'knowledge systems', including both 'formal' and 'traditional' ecological knowledge, so as to ensure participation of all stakeholders. In this context, this article deals with the unavoidable steps that the scientific community at large will have to take to ensure that stakeholders such as policy planners, developmental agencies and, more importantly, the mountain communities themselves, move towards effective management of natural, cultural mountainous landscapes.[1,2]

What is unique about the Mountains?

Mountain societies in general, and those from the developing tropics in particular, are very 'traditional' in the sense that they are still closely connected with nature and the natural resources around them. Highly heterogeneous mountain environments also introduce a whole set of diverse, socio-ecological systems that often change over very short distances. This is often further complicated be the rich ethnic diversity typically found amongst mountain people. Dealing with mountain issues, therefore, demands an interdisciplinary socio-ecological systems approach. This has been a major challenge as interdisciplinary studies in ecology have only recently come to the fore. Indeed, a critical mass of interdisciplinary ecological research on mountain systems, even today, has not yet been achieved, for much of what is currently being done holds tightly to narrow, disciplinary lines.

Natural science paradigms have evolved independently from those of the social sciences, and a socio-ecological systems approach thus demands adaptive methodologies that build bridges between these two streams. The rich traditional ecological knowledge (TEK) available with mountain societies provides an effective tool that allows movement between the social dimensions of the ecological, and teasing out relevant issues at all its scalar dimensions (FIG. 1).

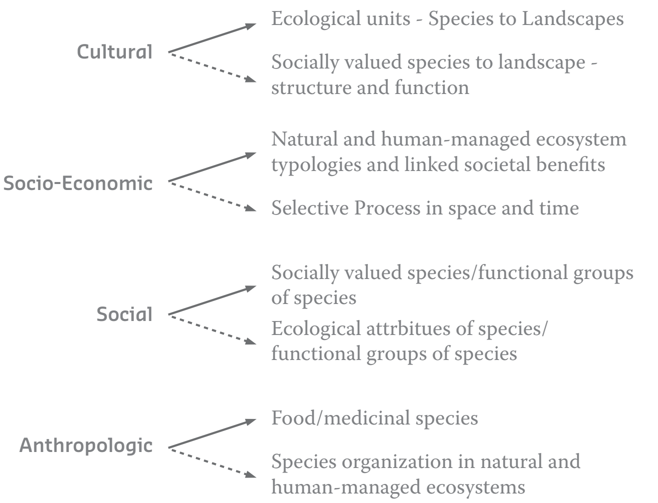

Figure 1: Descriptive and process linked TEK at the ecosystem/landscape level understanding of the anthroplogical, social, socio-economic and cultural dimensions of ecological functions.

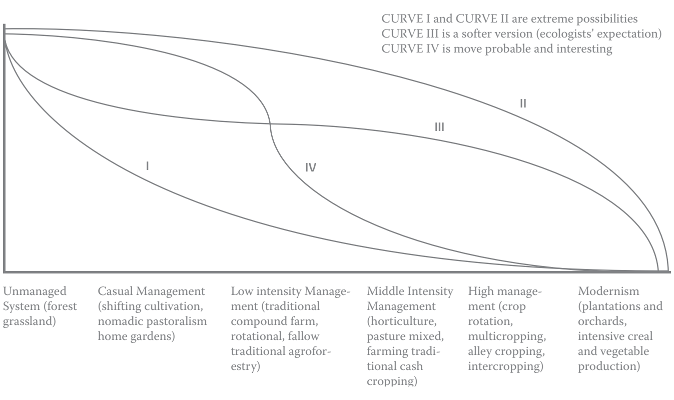

Figure 2: Biodiversity changes (four patterns) as related to agroecosystem types and intensity of management. Curve I and Curve II represent two extreme possibilities that seem to be unlikely. Curve III is a softer version the ecologists' expectations, whilst Curve IV seems to be more likely and is the most interesting from the point of view of biodiversity conservation (from: Swift, et. al. 1996).

It is important to recognise that traditional mountain societies, with all their natural and human-managed ecosystems, still remain attached to the 'natural cultural landscapes' that they have carved out of the natural resources around them. They also perceive human-created artefacts that may take a variety of different forms and shapes such as sculptures, temples and monasteries, as an integral component of the carved-out cultural landscape unit. Thus, these societies remain closely linked with biodiversity in all its scalar dimensions, taking a take a holistic view of nature and culture, which they intimately link through their 'knowledge systems' and their TEK in particular, with all its rich, intangible dimensions in the form of music, dance forms, poetry, folk-tales and religious rituals. These intangibles often have real tangible implications for human well-being.[3,4]

Knowledge systems: The Basis for Sustainable Mountain Cultural Landscape Management

Well endowed with rich biodiversity, both natural and human-managed,[5,6] conservation-linked sustainable development of mountain systems is critical in order to address sustainability concerns, not only of the mountain systems themselves, but also in finding solutions to global concerns. With rapidly emerging environmental uncertainties arising from environmental global change and economic globalisation, societies living in fragile mountain environments are no doubt more vulnerable to biodiversity loss. However, the adverse impacts arising from the mountains will also be felt what happens to with implications for human wellbeing within the mountain region and elsewhere outside too. This is the context in which biodiversity within the landscape (natural and human-managed ecosystems) context which is closely linked with TEK assumes global significance

In terms of today's understanding of TEK, direct ecological-economic benefits are important on the tangible level. In a sense, the mountain communities perceive these benefits as intangible, though, and it is up to scientists to put meaning to the intangibles, converting them to the tangibles[4] as indicated here: (a) Economic - traditional crop varieties cultivated, lesser-known plants and animals of food value as well as medicinal plants harvested from the wild are of direct economic benefit for mountain societies and can buffer periods of food scarcity; (b) Socio-ecological – the way in which mountain societies conserve and manipulate biodiversity contributes to ecosystem resilience and strengthens people's ability to cope with environmental change, to conserve soil water regimes and hydrology, and to manage soil fertility through the enhancement of soil biological processes;[7,8] the economic and socio-ecological dimensions invariably have a third dimension, linked with the two above: (c) Socio-cultural – cultural, spiritual and religious belief systems cherished by the inhabitants of mountainous communities, which are centred around the concepts of 'sacred species', 'sacred groves' and 'sacred landscapes' and can play an important role in biodiversity conservation[7]. All three of these components of TEK, interestingly enough, touch upon all disciplinary dimensions (FIG. 1). This implies that interdisciplinary approaches towards mountain research are called for, in order to conduct studies that guide community participatory policies for mountain development.

Photo 1b (above): a view of the Ganga sacred river based mega-cultural landscape of the central Himalayan region – revered by a vast majority of population of Indian origin

Photo 2 (right):A well protected 'sacred grove' placed in an otherwise highly human-impacted and desertified landscape (grassy cover in the foreground) in Meghalaya, in the northeastern hill region of India.

What is also to be noted at this point is that the concept of TEK extends to encompass traditional institutional arrangements too; thus, for e.g., in the Indian Himalayan mountain context, mountain societies have had as many different ways of traditional institution building as there are ethnic groups, which runs into a few hundreds, though some of those are still surviving. This implies that whilst relating science to address societal concerns in the area of conservation-linked sustainable development, right kind of institutional arrangements could play a key role towards ensuring community participation.

With highly diversified socio-ecological systems that are operating in highly fragile environmental situations, one of the important concerns is linked with food security. With the placement of agro-ecosystems in the context of a larger forested landscape, managing forestry has to be seen both within the context of agriculture or agroforestry and outside it in the larger landscape context. This becomes significant particularly in that mountain-system specific self-sufficiency in food security is often emphasised for socio-political reasons. Further, the rich agro-biodiversity that remains conserved in the tropical mountain systems has implications for global food security as well. Therefore, the following discussion on socio-ecological system management tends to place equal emphasis upon management of both agro-biodiversity and natural forest biodiversity in the larger mountain landscape context.

Managing Agro-Biodiversity for Food Security

Particularly in the mountains of the tropics as in the Himalayas, there exist a wide range of complex agro-ecosystem typologies with biodiversity comparable to that of the natural ecosystems.[9] Classifying these complex systems and relating them to a gradient in management intensification is a difficult task. A grouping based loosely on the intensity of land-use and management, however, provides a useful framework for discussion on the relationship between agro-ecosystem complexity and function (FIG. 2). Some of these agro-ecosystems are casually managed, as in the Northeastern hill region of India[8]; , or are managed at varied intensity levels, as elsewhere in the Himalayan and the Western Ghat regions of India[6] and the developed world in general.

Whilst most ecologists have assumed that Curve I, with its continual loss in biodiversity and increasing management intensities, is the most likely pattern, others have assumed other patterns as illustrated by Curves II and III, wherein there is an initial loss in biodiversity followed by sharp decline setting in only under extremely high intensities of management. Curve IV, however, in which biodiversity decline sets in at middle intensities of management and remains consistently low at higher intensities, is most probable and quite interesting from the managing agro-ecosystem complexity for stability with resilience perspective.[10] It is thus crucial to have a level of management that is closer to this critical area in order to sustain biodiversity in agriculture as well as to optimise production at the same time.

Pathways for Agricultural Development

If we consider high input modern agriculture as only one of the possible pathways for agricultural development, at least two additional pathways for sustainable agriculture also exist: (a) evolution by incremental change, (b) restoration through the contour pathway, as separate from the auto-route symbolising modern agriculture.[10] What these pathways imply in real terms is best illustrated through some specific examples, given below:

Incremental pathway
At one extreme, landscapes managed 'casually' or at 'very low-intensity' levels, largely through TEK, by traditional mountain societies of the developing world. Those systems, generally speaking, are amenable for step by step development, largely based on the rich TEK already present, bringing in formal knowledge-based inputs only minimally to achieve a redeveloped agriculture.

Redeveloping shifting agricultural systems, as in India's North-Eastern region through the 'Nagaland Environmental Protection and Development' (NRPED) initiative which was funded by the India-Canada Environmental Facility, is the best example illustrating this pathway. Briefly put, this was an attempt at sustainable tree fallow management using tree species identified through TEK and available within the local communities.[11] This initiative used socially-valued species that invariably have ecological keystone value as the basis for forest fallow regeneration, rather than allowing for natural forest re-growth, which is often not possible due to large-scale land degradation.[8]

It is important to emphasise that traditional societies often do have traditional ways of institution building. In the Nagaland context, with over 35 socio-culturally distinct ethnic groups, there are that many different ways of institution-building. The Nagaland Government, in their wisdom, allowed these groups to keep traditional ways of institution-building, supplemented with modern ways elective processes. In the contemporary context, such 'hybrid' institutions, linking the traditional with the modern, have helped foster immediate community involvement in the developmental processes.[6]

Contour pathway
This pathway emphasises adaptive management of agricultural systems, through models that are constructed to fit into the given ecological contours. A whole variety of agroforestry and alley cropping systems fall under this category, wherein model construction may often have a larger component of formal knowledge-based inputs, with TEK-based inputs supplementing this only to the extent necessary. The Sloping Agricultural Land Technology (SALT) developed for mountain agriculture in the Philippines falls under this category. With an emphasis on terracing the hill slopes, planting annual and perennial crops in 3-5 bands between double rows of nitrogen-fixing trees and shrubs planted on contours for soil conservation, all inputs based on formal knowledge. The objective here is to establish a stable ecosystem that would check soil erosion, ameliorate the chemical and physical properties of the soil and lead to increased income for farmers. Though it may be in harmony with the existing socio-ecological contours in the Philippine context, attempts to extend this technology to other situations in Asia, for example, in the Himalayas (Pratap), has been disappointing for many reasons: (i) farmers with uncertain land tenure were unable to accept the technology, a common problem with tree planting in many parts of the tropics; (ii) the land holdings often are too small and fragmented to make it compatible with this technology; (iii) few farmers could afford the heavy investment involved in site preparation and management; and (iv) significantly, traditional farmers were not yet attuned to accepting heavier formal knowledge-based inputs.

By investigating such limitations in the Central Himalayan context, we have been able to convince the farmers to accept redeveloped agro-foresty system models on a pilot scale, without making drastic departures from their traditional management practices. Here too efforts were made to strengthen their traditional agro-forestry models using tree species that they value socially and that have ecological keystone value, without making drastic departures from their traditional rotational farming practices.[7]

The Auto-route
This pathway involves use of the chemical energy subsidies that the larger agricultural scientific community has championed in order to sustain the system. An appropriate meta-

phor for this pathway is that of what an engineer would do to cut through a mountain and arrive at the other side, drilling a tunnel for a road by drawing a straight line from place to place on a map, regardless of physical impediments.[10]

Making such an artificial entity, standing apart the rest of the landscape, sustainable demands the building 'buffering mechanisms' within the soil system to counter the ill-effects arising from excessive use of chemicals, since such artificially-managed systems tend to be detrimental to soil health in the long run. This was achieved through sustainable organic residue management. This style of management called for enhanced biodiversity at the above and below ground levels through forestry/agro-forestry practices that made minimal use of TEK-based inputs, with a view to reduce external energy subsidies to the extent desirable in order to sustain productivity on the land. The 'FBO' (Fertilisation Bio-organique Dans les Plantations or the 'Bioorganic Fertilisation for Plantations'), developed by a group of Indian and French scientists under the leadership of Professors B. Senapati and Patrick Lavelle as part of an ongoing international initiative on tropical soil biology and fertility (TSBF), has enabled sustainable soil health.[12] The steps taken towards sustainable management of soil health through organic residue management had lead to a 30-50% reduction in fertiliser inputs.[13] What was developed in the context of the tea gardens in the Western Ghat mountains of southern India, has now reached Chinese shores. Many of the species often selected as a source for organic residues are also socially valued species with ecological keystone value. This was the certainly case when soil health was monitored with the help of earthworm species of ecological keystone value, already present in the soil sub-system.

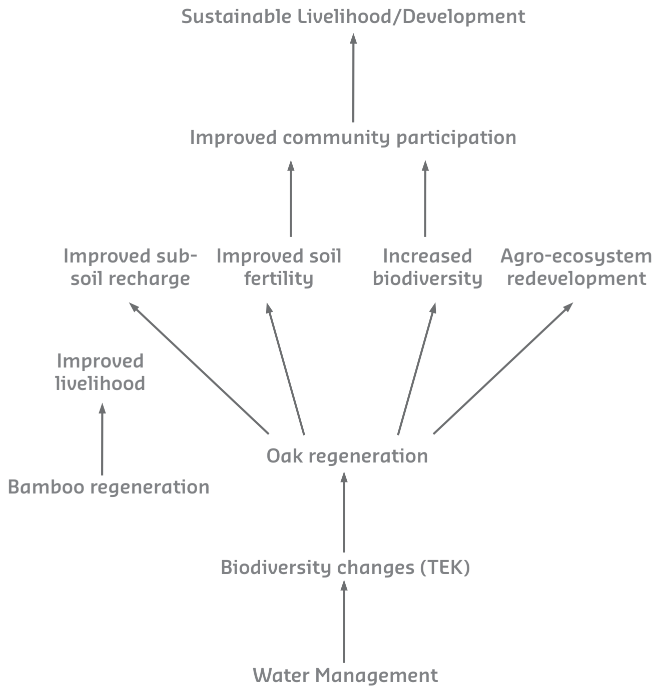

Figure 3: Water as a trigger along with biodiversity linked TEK, for rehabilitation of degraded mountain ecosystems across the Himalayan region. Provision of water triggers soil biological activities, leading to improved soil fertility. This in turn triggers community participation in rehabilitation of natural and human-managed ecosystems.

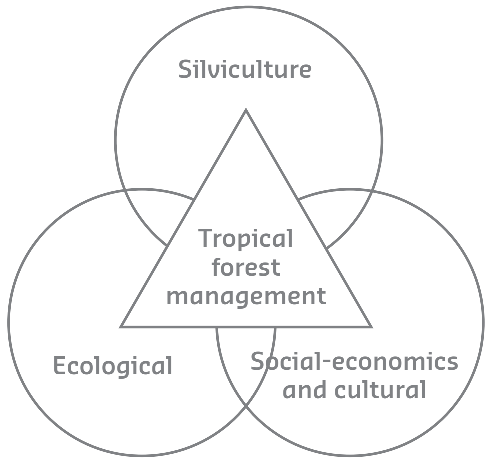

Figure 4: Interdisciplinary interactions called for in tropical forest management and conservation.

Sustainable Forestry in the Mountain Landscape

Foresters have long managed forests exclusively based on textbook-based sylvicultural knowledge, though in recent times, community participatory approaches are gaining ground due to sustainability concerns.[14,5] For example, a new initiative of the International Union of Forest Research Organisations (IUFRO) is now utilising traditional forest knowledge (TFK). Similarly, IHDP's emerging initiative on 'Knowledge Systems, Societal Learning and Sustainability' is equally significant in terms of coping with the environmental uncertainties arising from global change.

Forest dwellers are dependent upon forests for both tangible and intangible benefits.[5,7] In the context of TFK, the fact that socially-valued species such as Nepalese Alder (Alnus nepalensis) as well as many bamboo species have keystone value in the northeastern Himalayan regional context is significant for community participatory restoration ecology in general and sustainable forestry management in particular.[2,7] Similarly, in the central Himalayan context, a few late-successional species of oak (Quercus spp.), locally known as 'Bhanj', have ecological keystone values and are also valued on a socio-cultural basis, illustrated by the songs, folk dances, poetry and folk tales woven around them. This TEK-based concept enables sustainable soil fertility man-

Plate 1a: Rice varieties being planted by Apatani women which is related to nutrient gradient within the landscape

agement. If this technological input is integrated with water availability in the soil profile during the extended dry season as is the case in the monsoonal climate of India, the impact is magnified many-fold from both sustainable forestry and biodiversity viewpoints (FIG. 3). This has implications for food security and the availability of fodder, fuel wood and a whole range of non-timber forest products (NTFPs).

Unfortunately, these few oak species with multipurpose value have been systematically removed by timber extractors from mid to high elevation regions and replaced with pine plantations by foresters in the Central Himalayan context from the colonial period right up to the present. Such large-scale conversions are the underlying cause for the 'chipko' (tree-hugging) movement that has shaken the region in recent times and has gained global attention.[6,7] In many situations where landscape is already degraded to a very large extent, socially protected 'sacred groves' as relict ecosystems form the basis for ecosystem restoration (PHOTO 2).

What does all this imply? We need to take a broader perspective of our forestry practices and conservation issues, in which we effectively integrate sylvicultural issues with ecological and socio-cultural considerations[14] with the aim of sustainable forestry (FIG. 4).

Conclusions

The problems facing the mountain people of both the developing world and the developed world are in many ways quite similar, and yet, at the same time, somewhat different. Those living in the developing world, following the path towards the gradual destruction of their remaining cultural landscapes, are now keen to restore and conserve what they still have.[15,16] Thus, in the Indian Himlayan context, attempts at conservation-linked sustainable management of many of the Himalayan cultural landscape units is on going, as in the sacred Ganga River system, centred in the rather diffused cultural landscape of the Central Himalayan Garhwal region.[17] Similarly, conservation of the 'Demajong' cultural landscape of West Sikkim became a major issue after the failed attempt to build a hydroelectric dam over the sacred Ra Thong Chu river resulted in serious conflict between different sectors of the Sikkimese society.[18] The Apatani plateau cultural landscape, as well, with its unique and highly energy efficient agricultural system, boasts a productivity comparable to that of most modern agricultural systems receiving subsidised energy[19] and incorporates traditional, community-managed sylvicultural systems in the landscape (PHOTO 1). Interestingly enough, the developed world, having lost what much of their own cultural landscapes as, for example, in the European Alps, are now trying to rediscover and appropriately reconstruct what they have already lost.[20,21]

With external pressures leading to rapid deforestation and land degradation,[22] and with modern societies trying to impose a developmental pathway that is often alien to traditional value systems, conflicting situations are emerging in many parts of the world and cultural landscapes are drastically being altered. In other words, the use of TEK-linked developmental pathways are fundamental to conserving the cultural landscapes of the communities. Such a focus also ensures human security, an upland-lowland conflict issue which is rapidly gaining momentum in many parts of the world.[23] There is every possibility that these conflicts will be exacerbated through global change in general and rapidly emerging climate change in particular. The predicted food security issues linked to economic globalisation[24] will be most critical for the most traditional and marginalised sections of the upland societies in the developing world,[25] a problem that is increasingly becoming a global reality.

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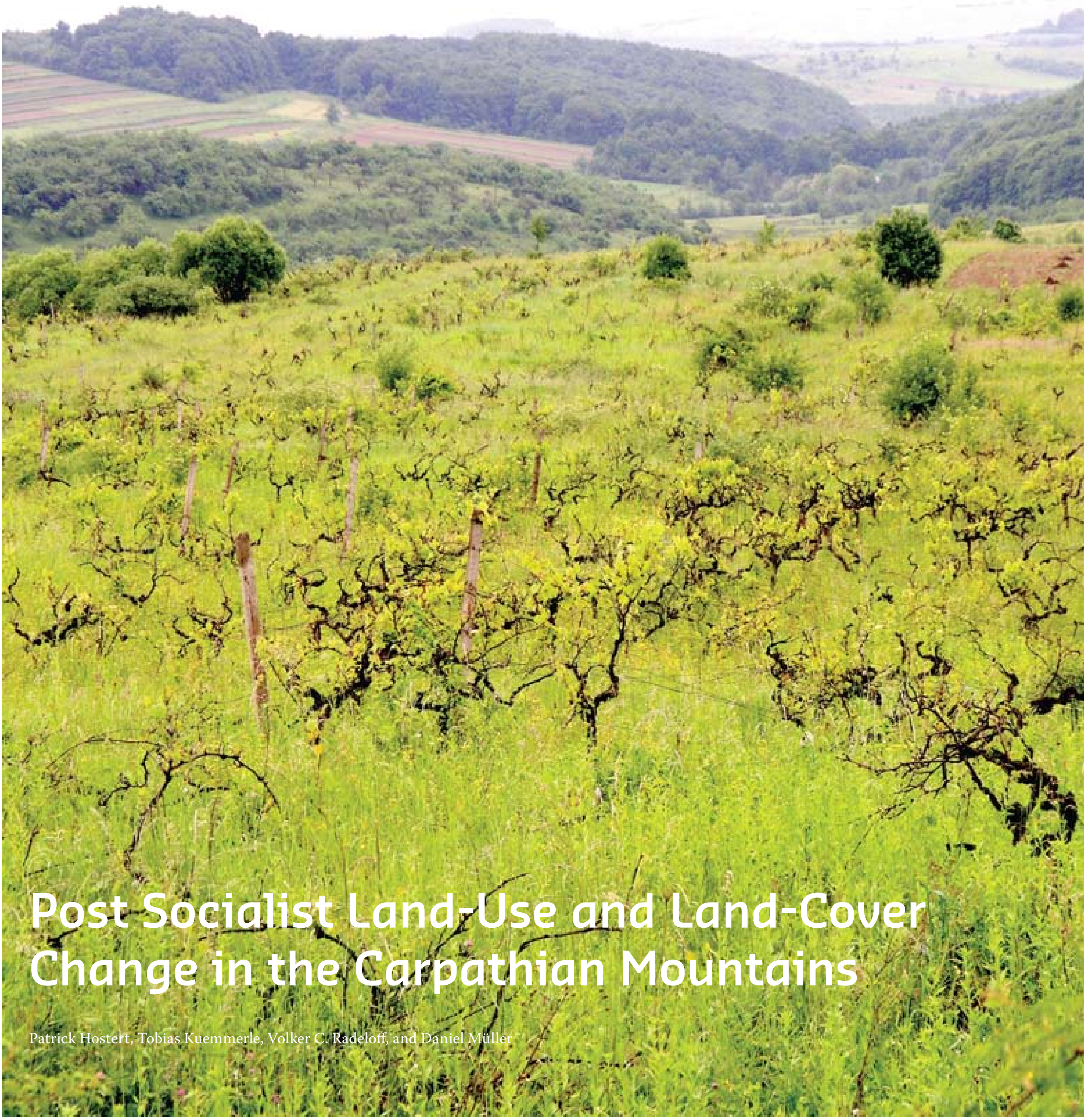
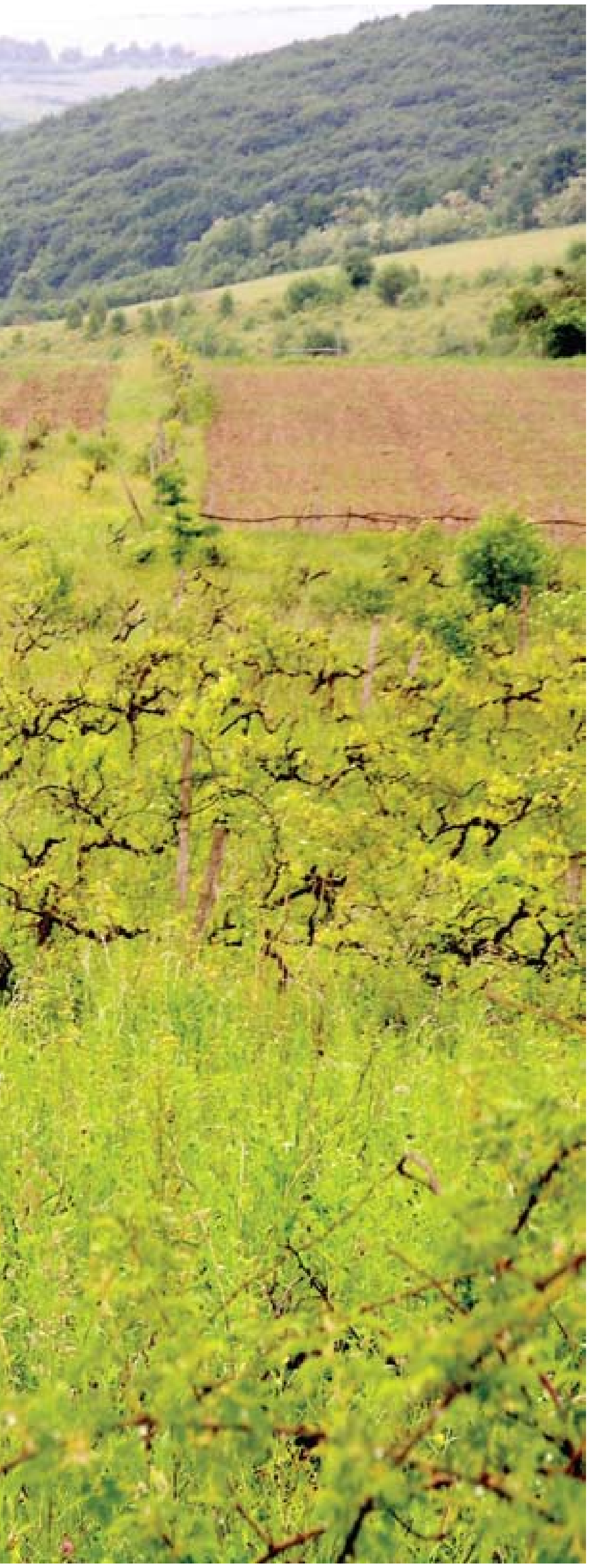


Post Socialist Land-Use and Land-Cover Change in the Carpathian Mountains

Patrick Hostert, Tobias Kuemmerle, Volker C. Radeloff, and Daniel Müller

Abandoned vineyards giving way to natural succession in the Ukrainian Carpathians,
© Geomatics Lab, Humboldt-Universität zu Berlin



The Carpathian Mountains, stretching across seven countries (Czech Republic, Hungary, Poland, Romania, Serbia, Slovakia, and Ukraine), represent Europe's largest continuous temperate forest ecosystem and are sometimes referred to as "Europe's Green Backbone". The mountain range is a biodiversity hotspot, providing important ecosystem services such as carbon storage and freshwater supplies, and is still rich in the traditional cultural landscapes that have largely disappeared elsewhere.

The fall of the Iron Curtain in 1989 resulted in rapid and drastic changes in Eastern Europe's political, societal and economic structures. Centralised planning economies shifted towards free-market systems, institutional regimes were altered and rapid demographic change occurred. The socioeconomic and political changes, in turn, affected land use, with an increasing influence of market forces in shaping rural landscapes. One result was that large areas of farmland were abandoned.

Concurrently, logging increased in parts of the Carpathians and land-use patterns were affected by the post socialist land reforms that led to stronger parcelisation of farmland. While these trends are acknowledged at a general level, the rates and spatial patterns at which they are happening are not well understood. Also, more recent trends in land-use due to the accession of some Carpathian countries to the European Union and its subsidy system as well as to surging food and energy prices remain largely unclear.

In addition to their ecological importance, the Carpathians offer unique opportunities to better understand the effects of broad-scale socio-economic factors on land-use change and human-environment systems in general. Studying land-use change in countries where abrupt political, socioeconomic and institutional changes have occurred provides a "natural experiment". In addition, the seven countries that comprise the Carpathians allow for the comparison of the rates and spatial patterns of land-use change across borders in an environmentally homogeneous region. Differences in land-use change during and after socialism, as well as among neighboring countries, can thereby be directly linked to policies, socioeconomic conditions, governance, culture and institutions.

Despite the unique opportunities that the Carpathians offer for land-use science, little is known about the rates and spatial patterns of land-use change that have occurred since 1989. The underlying causes of regional land-use change and its consequences for ecosystem services and biodiversity remain poorly understood. Our research goals have thus been to:

(1) reveal how rapid political, socioeconomic and institutional changes have affected land use,

Photo above: Traditional cultural landscape in the Western Ukraine, © Geomatics Lab, Humboldt-Universität zu Berlin
Photo left: Clear cut in the Slovak Carpathians, © Geomatics Lab, Humboldt-Universität zu Berlin

(2) assess the relative importance of the underlying drivers of land-use change via cross-border comparisons,
(3) quantify the effects of land-use change on ecosystem services and biodiversity.

Within the framework of IGBP and IHDP's joint Global Land Project (GLP), our research thus strives to contribute to a better understanding of the Dynamics of Land Systems (Theme 1) as well as the Consequences of Land System Change (Theme 2)[1].

Due to the limited availability and quality of official land-use statistics, we have relied heavily on satellite imagery. Landsat or SPOT images covering the entire Carpathians since the 1980s were primarily used. Detailed case studies, spatial statistics and simulation models elucidate underlying drivers and identify areas that are likely to change under different future land-use scenarios. Our case studies provide a better understanding of land-use decision making during political and socio-economic transitions.

Preliminary Results

Our preliminary results showed that land-use change was widespread during the transition, but that the rates and spatial patterns of these changes differed markedly in time and among countries. For example, forest disturbance rates generally increased right after the system change in almost all Carpathian countries, but disturbances in Slovakia and Ukraine were far more widespread as compared to Poland[2,3,4]. Likewise, forest fragmentation[5] and the effectiveness of protecting areas[2] differed among Carpathian countries. For instance, forest harvesting rates dropped in Slovakia after protected areas were designated, but in Ukraine forest harvesting rates inside and outside protected areas did not differ appreciably[2]. Illegal logging during the early transition years may have also been particularly widespread in Ukraine[4].

About 15-20% of the cropland used in socialist times was abandoned after the system change in all Carpathian countries[3,6], likely as a response to the decreasing profitability of agriculture after 1989. Topography, the accessibility of farmland and land-use patterns strongly determined the spatial pattern of abandonment[6&7]. Different land ownership regimes during socialism and various land reforms after 1989 also had a strong effect on post-socialist land-use change. For example, the land-use pattern and field size differed strongly among countries with different ownership regimes[8]. Cropland abandonment rates in Poland were twice as high on previously collectivised land as they were in areas that remained private during socialism[6]. Similarly, forest disturbance rates in Poland were five times higher in private forests than on public lands[9]. Yet, no ownership regime was clearly better in protecting forests[2&8], and, contrary to initial concerns, changes in ownership did not necessarily result in large-scale harvesting[3]. Overall, this suggests that the qual-

ity of institutions may be more important than the ownership regime itself.

Future research will focus on analysing land-use changes for the whole Carpathian Ecoregion[10], on developing stronger empirical evidence to explain and model the drivers of change, and on creating scenarios that allow for the assessment of land-use effects on ecosystem services and biodiversity in the Carpathians. These objectives require novel approaches to mapping land-use change and its effects over large areas, as well as to linking the observed changes to underlying drivers at a sufficiently specific scale. Most of all, however, these goals depend on input from different scientific communities related to land change and sustainability science, on bridging gaps between Eastern and Western scientists, and on integrating stakeholders from local to regional scales. The first steps in this direction have recently been taken with the launch of the Science for the Carpathians (S4C) Network[11], under the umbrella of the Mountain Research Initiative and a forthcoming workshop targeting land change science in the Carpathians[12].

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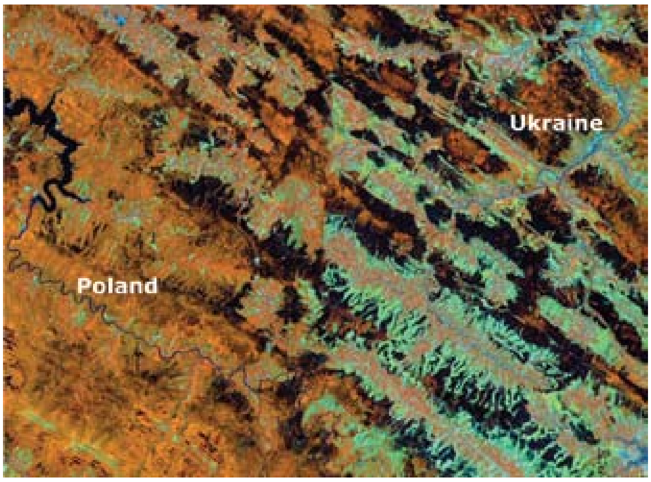

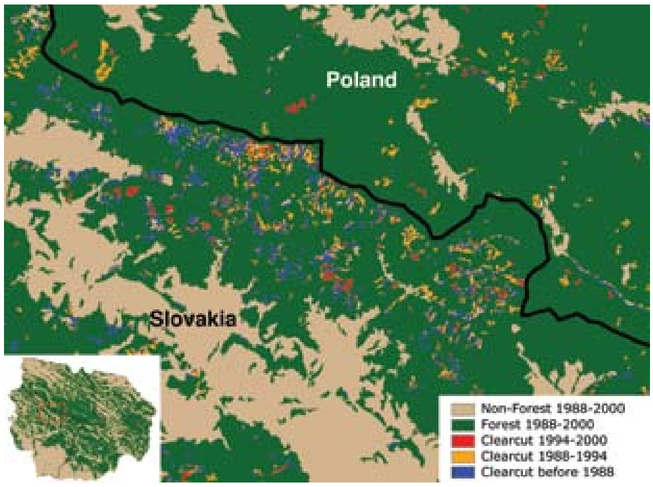

Figure 1: (upper) Landsat Thematic Mapper image from June 6, 2000 (false color composite): Differences in population density, land management, and nature conservation policies create diverging land-use patterns in the Polish-Ukrainian border region.© Geomatics Lab, Humboldt-Universität zu Berlin
Figure 2: (lower) Differences in the spatial pattern of forest harvesting along the Polish-Slovak border. © Geomatics Lab, Humboldt-Universität zu Berlin

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Strengthening Decision-Making Tools for Disaster Risk Reduction: An Example of an Integrative Approach from Northern Pakistan

Karen Sudmeier-Rieux, M. Jaboyedoff, A. Breguet, J. Dubois, P. Peduzzi, R. Qureshi, R. Jaubert

This article presents a case study of an interdisciplinary post-disaster assessment conducted in Kashmir, Pakistan following the 2005 earthquake and ensuing landslides. We explored an integrated methodology to understanding causes of the massive landslides and possible remedial solutions based on community risk perceptions, and locally adapted methods to landslide stabilisation. Although our methodology has been developed for a post-disaster assessment, we believe its principles can be modified to assessing climate change impacts and adaptation, which greatly parallel disasters.

The number and frequency of "natural disasters" is affecting greater numbers of vulnerable populations, especially in coastal- and mountain areas (ISDR 2004). More people are living in exposed areas, and the frequency of climate change related extreme events is on the rise. The use of "natural" to describe disasters is now widely considered a misnomer (HEWITT, 1983; ABRAMOVITZ ET AL., 2002). Rather, disasters should be seen as crossed thresholds caused by a breakdown in social systems, i.e. lack of emergency preparedness, early warning, failed dike systems; or ecological systems, i.e. drained wetlands, constructed flood plains, deforested hillsides. Severe disaster is when thresholds in both ecological and social systems have been crossed. Disasters are also often the symptom of "creeping environmental degradation" that has accumulated over a number of years (GLANTZ, 1994). Therefore, any effective strategy for mitigating this complex cause and effect between ecosystems and social systems must be interdisciplinary, especially in rural societies heavily dependent on natural resources for their livelihoods.

Post-disaster hazard assessments have typically been approached piecemeal: vulnerability assessments by humanitarian agencies; risk mapping by disaster management authorities; economic losses by development agencies; and rarely, the protective roles of ecosystems to reducing disaster impact. Disasters create the need for immediate, short-term reaction but effective disaster management requires long-term, integrated and multi-scalar solutions, combining both bottom-up and top-down methodologies. Tools, guidelines and capacity-building mechanisms need to be created which take into account both community level vulnerability and representations of risk, but also larger scale "expert" understanding of risk via remote sensing and GIS techniques; hazard mapping which also includes pre-existing vegetation and land use; economic losses; and land tenure patterns.

Photo: Damage following the earthquake and landslides in Kashmir, Pakistan 2005; copyright Zaz_Bj

As hazards are most often the result of the social, ecological and bio-physical spheres, all three need to be surveyed in order to prioritise remedial actions after a hazard event, promote long-term recovery and preventive measures (SUDMEIER-RIEUX, ET AL. 2006). Risk, conventionally expressed as a function of both hazards and vulnerability also needs to be assessed in order to prioritise mitigation and prevention measures (ISDR, 2004). However, risk perceptions are influenced by culture, context, and previous exposure to risk and are highly affected by other human security concerns. A society's perception of risk is likely to determine the extent to which mitigation actions are prioritised, alongside other societal concerns (PATON AND JOHNSTON, 2001).

Details of study area, study goals and methodology

The October 8, 2005 earthquake, measuring 7.6 on the Richter scale caused an estimated 75,000 casualties and triggered several thousand landslides affecting a large number of communities in surrounding steep mountain valleys. Landslides remain a great threat to communities, especially during heavy rainfall and July/August monsoon rains. The study area, lower Neelum river valley, was chosen due to its proximity to Muzaffarabad, (pop. 100,000) its very distinctly forested north-facing left bank, and its south-facing, largely degraded right bank. The study area, lower Neelum River Valley comprises approximately (19 x 20 km) 381 km² at 73°24'19 E, 34°30'7.2N (top left corner) and 73°36'43 E, 34°30'16N (bottom right corner) (FIG. 1). Land degradation is mainly due to grazing pressure by goats, upon which a large proportion of the population is dependent. The left bank has fewer villages, is to a greater extent state-owned, with fewer private and communal lands, or shamilat. Neelum river valley is a steep, v-shaped valley with estimated slope range from 35-65° and average width of 15 km between 800m–3,000 m altitude. It is located in Pakistan Kashmir, or Azad Jammu and Kashmir (AJK), a semi-autonomous state, with its own elected government and budget, approximately 180 km northeast of Islamabad.

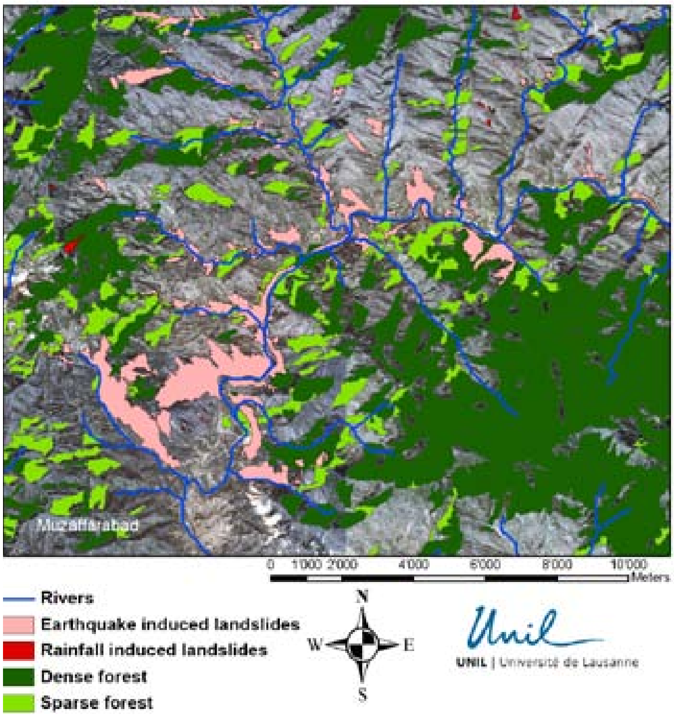
The fundamental research question of the study was what role did land use factors, especially vegetative cover, roads, terraces, and ownership play in the occurrence of landslides in the study area? Our conclusion was that land use, especially vegetative cover and road construction significantly impacted the occurrence of landslides in this region.

Secondly, we questioned how socio-economic data: land use, land tenure, risk perceptions could be incorporated in addition to geological information, for improving decision-making tools for disaster risk reduction in mountainous regions.

The interdisciplinary study involved several components and set out to explore the causes and locations of landslides at multiple scales and sources;

Information needs and available data:
Over 30 interviews were conducted with national and local decision-makers, humanitarian- and development agencies and NGOs.

Hazard assessment:
i. Landslide susceptibility model and map were developed by P. Peduzzi (UNEP/GRID-Europe) (PEDUZZI, IN PREP).
ii. Remote sensing analysis. The field study was greatly assisted by the purchase of a high resolution Quickbird satellite image (0.6m), used for remote sensing of landslides within the study area.



Biophysical assessment:
A landslide assessment (i.e. lithology, landslide type, slope gradient, location) was conducted on 100 landslides triggered by the 2005 earthquake, and 24 landslides triggered by subsequent rains, through July 2007. We combined this assessment with an expanded survey to include pre-existing land use (grazing, forested, terraces, gravel excavation, road, trails, habitation, etc.) vegetation type, economic assessment of the damage (forest land, agricultural land, habitations) ownership, and casualties. We divided each landslide into four quadrants: NW, NE, SW, SE and noted pre-existing land use characteristics on a 200m strip of land surrounding each landslide (grazing, forested, terraces, gravel excavation, road, trails, habitation, etc.) vegetation type; as well as an economic assessment of the damage (forest land, agricultural land, habitations) ownership, and casualties. Data from Neelum valley's right bank and left bank were compared.

Socio-economic assessment:
In addition to the land use, economic data assessment and land tenure data that were collected during the field study, we conducted an exploratory socio-economic survey of two villages, Saidpur and Kohori in Neelum Valley, to understand land use strategies and coping mechanisms of communities. Focus group discussions were facilitated by a close-up photo of the selected villages, (from the high resolution Quickbird image), providing a "participatory mapping exercise" to determine land use activities and changes caused by the earthquake, land ownership, risk perceptions and coping mechanisms for the village case study.

Risk assessment:
Risk needs to be defined based on specific assessments of vulnerability, value of objects at risk and probability of exposure. For this assessment, we chose one of our study villages, Saidpur village. For estimating risk to buildings, one should typically gather data on location, value, number of persons in buildings (permanent and temporary), construction types, vulnerability to a hazard event and probability of occurrence. As we did not have all these elements available, we simplified our calculations based on the number of persons per building, and the type of danger to each building. A similar risk assessment was conducted for road segments and main trails in Saidpur.

Prioritise interventions:
The next and critical step is to determine acceptable levels of risk, mitigation actions, risk communications and prevention, in accordance with stakeholders. This step requires a certain level of commitment from local government authorities, donors, or NGO's able to implement physical interventions such as locally adapted soil stabilisation measures, or securing evacuation routes; secondly, social capacity building, such as community awareness about risk reduction, or

Figure 1: (opposite page) Lower Neelum Valley vegetation cover, 2001 based on data obtained from UNEP-GRID-EUROPE/DEWA. Quickbird image from October 22, 2005 obtained by UNIL-IGAR. Landslides are depicted based on satellite image and field verification.
Photo: (above) Earthquake relief in Pakistan 2005, copyright Lacajablanca

early warning; thirdly, where appropriate, investing in reducing land degradation. As discussed previously, the definition of risk and tolerable levels of risk is a societal question. Prioritising interventions is a logical next step in the disaster risk assessment and reduction process; however, it fell outside the scope of this pilot study.

Results: An integrated approach provides more holistic understanding of landslides

According to our data, a majority of landslides (56%) were caused by human-induced factors, especially grazing and conversion of forest land, poor terracing, habitations located on exposed slopes and road construction. The remainder was related to proximity to rivers, steep slopes and geological features. These findings corroborate results from the landslide susceptibility model (PEDUZZI, IN PREP). The left bank, with geology type and aspects (Murree formation: sandstone, siltstone and clay) similar to that of the right bank, was subject to significantly fewer landslides due to greater vegetation cover: the number of landslides was significantly higher on the right bank (n= 84), compared to (n=16) on the left bank (FIGURE 1). The surface area of landslides triggered by the earthquake was also significantly higher on the right bank, estimated at 13.45 km^2 versus 3.57 km^2 on the left bank. For rainfall-induced landslides, there were 22 landslides on the LB, or 0.42 km^2, versus 2 landslides on the LB, or 0.092 km^2. A majority of landslides on the Murree formation were shallow, except for several large landslides near Muzaffarabad occurring on the Abbottabad formation.

The study shows that landslide occurrence is also highly dependent on land ownership and management regimes, with significant policy implications. Deforestation/grazing and landslides are most common on private lands or state-owned lands managed by private owners. The cost incurred by the landslides in our study area (381 km^2) is estimated at $ 3.6 million USD (including damage to the power supply) and can be compared with the annual public works budget of AJK for 2005 (13,297 km^2) of $1 million USD (AJK PLANNING AND DEVELOPMENT DEPARTMENT, 2005). This constitutes a significant economic setback to the region and could have possibly been reduced significantly with improved natural resources management. The relative cost of maintaining protective forest cover should be taken into account in forest management plans and private owners should be strongly encouraged and provided with incentives to maintain forest cover.

Discussion: trade-offs to an integrated approach to disaster risk reduction

This paper presented an integrated approach to assessing and responding to disaster risk reduction, using both top-down (remote sensing analysis) and bottom-up (village-level survey) information gathering techniques; GIS and field survey of land use factors. Its main constraints included lack of data for more accurate risk analysis, limited time in the field and lack of baseline data. One of the main benefits of this broader, interdisciplinary approach was to build on key stakeholder's information needs to ensure maximum utilisation and its relatively low budget. The methodology is straightforward, simple and useable in a data poor environment. The socio-economic data proved highly useful in parallel to the biophysical and hazard assessment in highlighting underlying causes of landslides, ownership, land use issues and potential policy implications for addressing the omnipresent landslide problem.

Mountain populations around the world have always lived with risk, including drought, flash floods, extreme temperature variations, difficult access to markets, health care and employment (MESSERLI AND IVES, 1987; HEWITT, 1987). Mountain livelihoods have evolved to high risk areas through various risk minimising strategies which have increased their social and biophysical buffering, or coping capacities (CHAMBERS, 1983; OLIVER-SMITH, 2001; DEKENS, 2007). An event such as the Kashmir earthquake and the enormous scale of ensuing landslides, which had not occurred in this region since human memory, caught the population and authorities unprepared. In such a crisis situation, information tools such as satellite images can provide quick overviews of the extent and scale of a hazard event. However, hazard and risk maps need to be drawn at a local scale in order to provide sufficient accuracy. One should question to what extent such maps alone are useful in societies where other human security concerns, such as unsafe roads, food insecurity, lack of winterised housing may outweigh the risk posed by hazard events, and where zoning is rarely enforced.

One of the most important conclusions we draw from this study is the importance of community-based disaster risk management strategies: early warning systems and monitoring of cracks created from earthquake movement, landslides and flood areas. These systems can be simple. One can, for example, establish a stick and string method for monitoring cracks, and work with the local religious leader to announce imminent threat via the town or village mosque. A community awareness outreach programme on locally adapted soil stabilisation techniques (such as placing vegetative mesh combined with soil stabilising plants), drainage schemes, the link between vegetative cover and landslides, in addition to emergency preparedness measures, would provide a more comprehensive approach to disaster risk reduction. For this, an integrated and multi-scalar approach to assessing, responding to - and preparing for – climate change and hazard events in mountain regions is necessary.

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http://www.iucn.pk/wp-content/uploads/2007/10/GIAN_Study.pdf
http://www.mtnforum.org/oldocs/1208.pdf

K Sudmeier-Rieux is a member of the Global Land Project and of MRI's Global Change Research Network in European Mountains (MRI Europe)

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