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FORESTS, WATER AND CLIMATE CHANGE IN HIGH ALTITUDE AND HIGH LATITUDE WATERSHEDS

Summary

This draft background paper was prepared in view of the 26th EFC WP MMW Session (Oulu, Finland, 19 – 22 August 2008), whose theme is "Forests, water and climate change in high altitudes and high latitudes watersheds". It presents a number of entry points and aims at providing all the participants with a common base for articulating their interventions. On the basis of the currently available literature this document discusses the impacts of climate change on forests and water in high altitudes as well as high latitudes and presents two case studies, which validate the importance of the topic and make it a sensitive subject that needs more awareness and attention.

According to the Intergovernmental Panel on Climate Change (IPCC 2007) our planet has experienced an average increase in temperature of 0.74°C over the last century. Yet, this rise in temperature and its impacts are not evenly distributed, with high altitudes and high latitudes being particularly affected. Therefore, these regions can act as early indicators and should be closely monitored in order to find out about the different impacts of climate change.

The climate of high altitude and high latitude watersheds is characterized by seasonal cycles and the hydrometeorology is largely controlled by processes involving snow and ice. The impacts of climate change are easier to predict in high latitude than in high altitude watersheds where topography and microclimate are highly differentiated. However, the overall predicted trends are the same: more precipitation during the winter months, dryer summers, more extreme weather events and increased unpredictability as well as upwards-moving treelines and losses in biodiversity. In high latitudes, the changed hydrology can cause floods, droughts, more storms and pest diseases to trees, in high altitudes, the consequences of climate change can be much worse and may lead to glacier and permafrost hazards with disastrous consequences. These impacts of climate change can result in considerable human and economic losses, whereas the ability for mitigation and adaptation largely depends on a country's level of economic development. The strongest negative impacts will be experienced in mountain regions of developing countries which are particularly vulnerable.

Although the understanding of snow and ice processes has improved in recent years, there remain some fundamental issues to be addressed. There is a great need to better comprehend hydrometeorological processes, to strengthen good monitoring systems and to develop better and more reliable climate change models. Furthermore, with the increased potential for natural hazards there is a great need for more elaborated disaster risk management tools – also on a transnational basis.

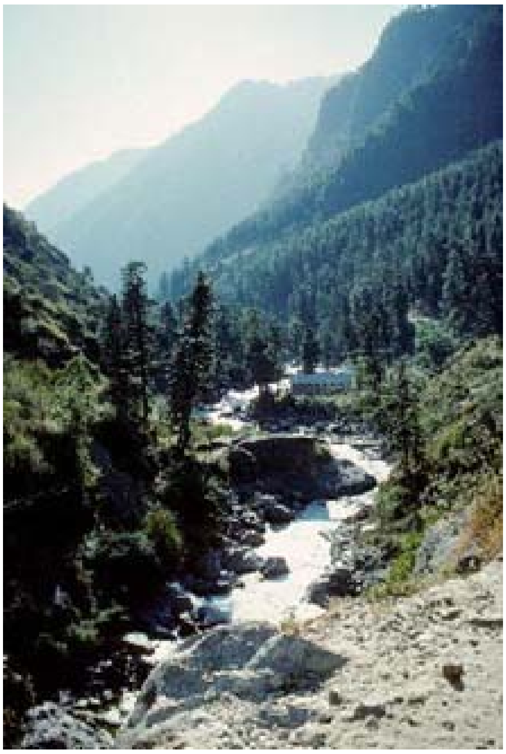
Table of contents **Page**

Section 1: High altitude and high latitude watersheds: overview, impacts and adaptation strategies to climate change

1.1 The situation in high altitude watersheds

Global importance

High altitude mountain watersheds are particularly vulnerable to climate change. This is of great relevance since mountains cover 25 % of the world's surface and are home to 12 % of the world's population. According to a FAO study on vulnerability in mountains, 245 million rural mountain people in developing and transition countries are at risk of, or actually experiencing, hunger and food insecurity (FAO, 2003). A significant part of human population is depending on freshwater resources originating in mountain areas and on the genetic diversity available in mountains. Mountainous areas are also important for recreational purposes and tourism. Climate change is affecting these vital mountain resources and accelerating their degradation. This in turn will negatively affect food security and the socio-economic situation of mountain communities and beyond.



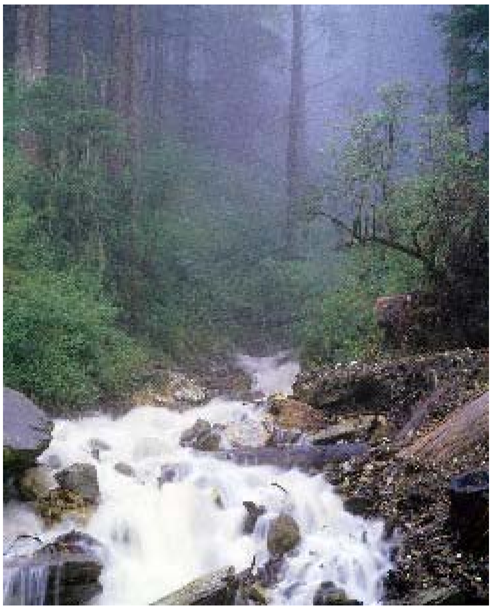
Mountains are the water towers of the world.
A Forested mountain watershed in the Indian Himalaya.
Picture by Thomas Hofer.

Hydrology

To conduct an assessment of the impacts of climate change on mountain watersheds is very challenging. Mountain river systems are characterized by extremely variable morphology and topography and by strong variations in vegetation and soil characteristics (Gurtz, et al. 2005). The mountain climates are characterized by marked diurnal and seasonal cycles, with high variability at spatial and temporal scales. Mountain climates are difficult to describe, let alone project climatic changes in the future because of this variability. Even very small changes in the location of measurement sites can result in considerable changes in the data collected. In addition, there is a lack of global climate data sets for mountain areas over an adequately long time period (Price & Haslett, 1995).

Climate change, with locally and regionally differentiated impacts on temperature, precipitation, snow cover and glacier storage, is likely to alter discharge characteristics from mountain-dominated regions. This will affect timing, volume and variability of mountain discharge and hence also show influence on runoff characteristics in the lowlands (Viviroli and Weingartner 2006). Hydrological model scenarios up to the year 2050 in the pre-alpine and alpine sub catchments in the north eastern part of Switzerland predict distinct changes in precipitation seasonality in the study region, with higher winter and lower summer precipitation (Grabs 1997, cited by Gurtz et al. 2005). Furthermore, model predictions indicate an increase of temperature, wind speed and global radiation over the whole year. Moreover, climate change is expected to increase evapotranspiration and decrease runoff generation from snowmelt. These changes are connected with increased amounts of liquid precipitation and an upwards shift of the snow line, with largest relative changes occurring in alpine catchments. In addition, model simulations show increased seasonal and month-to-month variability of runoff in both pre-alpine and alpine sub catchments. With the exception of some winter months, there is a distinct decrease of high, mean and low discharge in the pre-alpine catchments. In the alpine catchments, model scenarios suggest a strong increase of high, mean and low discharge in winter and spring and a clear decrease in summer and autumn (Grabs 1997, cited by Gurtz et al. 2005). Model predictions also show a distinct impact of climate change on snow-cover. The mean number of days per year with snow coverage exceeding 50 mm of snow water equivalent in the study river basin is reduced by about 30 days in the altitudinal range between 1000 and 2500 m asl (Grabs 1997, cited by Gurtz et al. 2005).

Considering these scenarios, it is obviously very difficult to make generalizations about how climate change is affecting runoff globally in mountainous regions because of high variability even within one region of study at different elevations. However, in general, most projections predict more precipitation in the winter and drier summers leading to changes in river discharge patterns, including an increase in the frequency and intensity of floods and droughts as well as more uncertainty in the predictions.



Climate change will change the existing hydrological patterns in mountain watersheds.
Picture from Bhutan by Masakazu Kashio.

Hazards

In addition to extreme weather events, there are specific hazards related especially to climate change and mountain areas caused by changes in temperatures and precipitation patterns. Because of the warming, the glacier and permafrost- related hazards are becoming more frequent. These hazards are a continuous threat to human lives and infrastructure in high mountain regions and they are perhaps the most visible sign of climate change. Related disasters can kill hundreds or even thousands of people at once and cause damage with a global sum on the order of 108 Euro annually (Kääb et al. 2005).
Glacier and permafrost hazards in high mountains are outbursts of glacier lakes (causing floods and debris flow, see next paragraph), ice break-offs and subsequent ice avalanches from steep glaciers, glacier length variations, destabilisation of frozen or unfrozen debris slopes, destabilisation of rock walls and combinations or chain reactions of these processes (Kääb, et al.2005).

Because of climate change, most glaciers are retreating and there is even a potential for extinction of mountain glaciers (Dyurgerov 2005). As a result, the formation of glacier lakes could lead to glacier floods, which have highest potential for disasters and damages (up to 3 km3 flood volume, and, in exceptional cases, up to 40 000 m3/s runoff and over 1200 km run-out distances) (Kääb, et al. 2005). These outbursts can turn out to be “mountain tsunamis” with devastating consequences. Ice avalanches often affect smaller areas and are generally restricted to sparsely populated high-mountain areas. However, in combination with other glacier hazards, ice avalanches have the potential for far-reaching disasters (Kääb, 2005). The prediction of glacier length variations is complicated. Advancing and retreating glaciers can pose a direct risk, especially to mountain infrastructure (Kääb 2005).

Permafrost is decaying because of warming. This causes slope instability and increased frequency of natural hazards, such as rock fall and landslides. Especially on steep mountain slopes, the physical stability is highly sensitive to thermal changes, since thawing reduces the strength of both ice-rich sediments and frozen jointed bedrock. Ice-rich soils undergo thaw consolidation during melting, resulting in elevated pore water pressures, so that formerly frozen sediment-mantled slopes become unstable (Morgenstern and Nixon 1971). Especially in the low altitudes mountains, where permafrost temperatures are only a few degrees below zero, even a slight change in temperature may cause a significant increase in the depth of the summer thawing and in consequence, widespread permafrost degradation (Harris 2005).

All of these hazards can occur and be disastrous on an individual basis. Nevertheless, combinations and interactions between these or other types are of similar or even greater importance. For example, if ice and/or rock avalanches enter natural or artificial reservoirs, they are able to trigger flood waves and, as consequence, can lead to overflowing and breaching of dams with corresponding flood and debris flow disasters (Kääb 2005).

It is predicted that both the number and size of glacier lakes will increase as a result of climate change. Coupled with intensified rural development, the vulnerability of mountain communities to outburst floods is growing rapidly. Furthermore, for those rivers fed largely by ice melt, reduction in glacier volumes will have a particularly strong impact on dry-season river flows, and on the provision of downstream water for various uses (agricultural, domestic, industrial, hydropower). Will climate change affect glacier runoff differently in different climatic regions? Hagg and Braun (2003, cited by Hock et al., 2005) compared the situation in the Alps and the continental mountain ranges of the Tien Shan, Central Asia, and showed that the effects of a doubling of CO_2 in the atmosphere on glacier runoff are similar in both areas. However, since the melt water from the glaciers is the only source for water during dry season in the continental areas of Central Asia, loss of glaciers will affect lowland areas even more drastically in those regions than, for example, in Central Europe (Hock 2005); disappearance of glaciers will lead to the disappearance of the main source of fresh water causing extensive droughts and water shortage in mountains as well as downstream.

The assessment of glacier and permafrost hazards requires systematic and integrative approaches. Presently, the most successful strategy is based on the combination of remote sensing, modelling with Geographical Information Systems (GIS), geophysical soundings and other local field surveys (Richardson and Reynolds, 2000, cited by Kääb 2005).

Climate change is causing the disappearance of the glaciers.
Also this longest and largest glacier (glacier of Aletsch) in the Alps is under threat of disappearing because of climate change.
Picture by Thomas Hofer.

Ecological processes

Forest ecosystems in mountains are influenced by climate change mainly in two ways: first by the increased concentrations of CO2 available for photosynthesis (the physiological response) and second, by the actual change in climate (physical responses) (Price and Haslett 1995).

The physiological responses include changes in photosynthesis, respiration, water use efficiency, reproduction, growth rate, shape, nutritional quality and seed production (Strain and Cure 1985, cited in Price and Haslett 1995). The most evident physical response is migration. Rising temperature can induce upward migration of early-responding, early-succession pioneer species and may disadvantage slower-responding, late-successional species or populations trapped on low mountain tops (Grabherr et al. 1994). In the long run, a warmer climate should cause an advance of the treeline upslope since the growing season temperature is the single most important determinant of treeline position, irrespective of season length (Körner 1998). The overall concern is that rates of change in temperature may be greater than the ability of species to adapt or migrate (Price and Haslett 1995). The mountains are centres of biodiversity, but the species are already under significant natural climatic pressure, and therefore, threatened (Price 2008). Consequently, species may become extinct and the ecotypes and genetic variation may be lost. However, some species may become abundant and speciation may occur in response to new conditions (Smith and Tirpak 1989).

Not only temperature, but also the water availability is a critical factor for species, especially in arid areas. For example, in Mediterranean-type ecosystems the summer drought is a major factor constraining establishment of seedlings (Castro et al. 2005). According to studies made in the Sierra Nevada National Park of Spain, the different response of species to summer drought (in terms of seedling establishment) could shift community composition in Mediterranean mountain forests due to the predicted increased aridity and irregular precipitation resulting from climate change (Mendoza et al 2006). The spatial differentiation of mountain environments will significantly influence the ways in which mountain ecosystems respond to climate change. However, the potential spatial complexity of ecosystems responses continues to be underestimated (Shafer et al 2005).

In as much as forest ecosystems in mountains are affected by these different ecological processes related to climate change, these processes also influence the role of the forests in providing different ecosystems services, e.g. regulating water quantity and quality. Also the role of forests in disaster risk mitigation can change. However, there is still considerable uncertainty about how this role is actually changing. In the past, there was an assumption that forest is always the best land cover to maximise water yield, regulate seasonal flows, ensure high water quality and prevent floods downstream. It is scientifically confirmed that forests do play a significant role in maintaining water quality. The role of upstream forests in ensuring water availability and in regulating water flows downstream is much less clear. The impacts of forest removal are evident at the micro level and with short-duration and low-intensity rainfall events. As rainfall duration or intensity increase, or as distance of the rainfall area from the watershed increases, the influence of tree cover on flow regulation decreases (information summarized by Calder et al 2007). Based on these findings forests can be expected to play a major role in mitigating the effects of climate change (e.g. high frequency of floods or droughts) in smaller watersheds, but much less in large river basins.

Finally, upwards movement of tree line as a result of climate change may reduce river flow due to higher water demand of the "new" forest stands and due to increased evapotranspiration.

Integrated watershed management

The International Expert Meeting on Forests and Water, held in Shiga, Japan in November 2002, highlighted the need for more holistic consideration of interactions between water, forest, other land uses and socio-economic factors in complex watershed ecosystems.

Practical experience has evidenced that the adaptation to climate change can be more effective if it is based on integrated watershed management approaches. Impacts of climate change will not just be felt in regions where rainfall decreases, where evapotranspiration increases, where the treeline moves upwards or where glacial lake outbursts occur, but will have an impact on natural and socio-economic systems downstream. Forested upper watersheds provide important environmental services such as stabilization of water flows and improving water quality, erosion control, landslide protection or providing timber and fuelwood. Accordingly, the adaptation strategies need to be looked at in a holistic way serving both upstream and downstream inhabitants.

Forests protecting downstream housing and people in the Alps. Picture by Thomas Hofer.

Policy actions must address climate change issues at local, national and global levels. Mountain regions are particularly important in this respect since in addition to being strongly impacted by climate change they are under significant anthropogenic pressure caused by land use practises, unsustainable use of natural resources including tourism, infrastructure development and soil and water pollution.

In order to minimize these stresses, mitigation and adaptation measures should be embedded in all policy areas in an integrated manner. Because poorer communities in developing countries are most affected by these changes, the capacity must be developed and strengthened to cope with impacts of and adapt to climate change through conservation of natural resources, diversification of livelihood options and reduction of disaster risks associated with climate change.

1.2 The situation in high latitude watersheds

Global importance

High latitude watersheds are characterized by the boreal coniferous tree zone, which lies in a circumpolar belt (typically between 50 ◦N and 70 ◦N). Boreal forests cover globally large area (17 % of terrestrial surface) and this area is not highly fragmented. Considering the vast extent of boreal forests, the human impact on boreal forests has been relatively minor on a global scale (WCMC 1999). Globally these forests play a very important role in mitigating climate change, because of their capacity to absorb $CO2$. As long as the amount of wood removed during harvesting is less than total forest growth, forests serve as net carbon sinks. Also, densely forested watersheds are important in regulating fresh water quantity and preserving water quality. In high elevation areas, such as Lapland, the multiple use of forests and water is important. The demand for nature tourism and recreation is increasing.

Hydrology

The climate in high latitude watersheds is characterized by seasonal cycles and the hydrometeorology is largely controlled by processes involving snow and ice. Probably the most important effect of climate change on hydrological regimes is the change in seasonal distribution of runoff.

In northern high latitudes the temperature increase is greater than the global average. Between the 1970s and the 2050s, the five climate models indicate a mean rise of 4.0 ◦C in winter temperatures in boreal forest regions. This is the largest temperature change predicted for any forest biome (WCMC 1999). There are regional variations between predictions, e.g. in Finland the average temperature could rise by 4-6 ◦C (MAF 2005). The warming is greatest in late autumn and winter because of the late formation of sea ice, whereas the influence of ice is much reduced in summer, when the mean summer temperatures is expected to rise by 2.5 to 3.0 ◦C by the 2050s (WCMC 1999).

According to model predictions, the most important rainfall increase will occur in high latitudes. An average of 10 % increase of precipitation is expected in boreal zones. Their increase is generally spread throughout the year, is greatest in winter (WCMC 1999) and slight in summer (Jylhä et al. 2004). The boreal soils are close to saturation in winter and the excess water may be lost as run-off, whereas the summer soil moisture content is predicted to reduce, because of little change in precipitation but enhanced evapotranspiration (WCMC 1999). The excess water from snowmelt and rainfall can cause winter floods. Changes in water quantity will affect many sectors of society, like water supply, energy production, industry, water traffic, construction, fishing, recreational use and agriculture. However, changes in water quantities are not expected to have any significant impact on the growth of forests, except that the probability of extended dry periods could hinder the growth of trees in habitats which are most sensitive to aridity (MAF 2005). Changes in rainfall will also affect water quality. Floods and more abundant rains will increase the drainage and the potential inflow of nutrients and harmful substances into surface and groundwater bodies. Drought will also lead to oxygen depletion in shallow lakes.

Ecological processes

The boreal forests regions will be more strongly affected by global warming than any other forest region. Warming is greatest in this region because of the strong ice-albedo effect. Snow and ice cover substantially increase the reflectivity of the earth’s surface; as rising temperatures cause a retreat in ice-cover, the darkening land surface will absorb more solar energy and reflect less, which in turn further increases surface temperatures. The northward spread of boreal forests into previous tundra regions would also enhance this ice-albedo effect: snow tends to fall off tree branches onto the soil below, and these snowy forest areas are much darker than snowy open areas (WCMC 1999).

Boreal areas are relatively low in biodiversity and are dominated by approximately 15 tree species only. The growth is limited in the north by low temperatures and in the south by competition (WCMC 1999). Fire plays also an important role in boreal forests through releasing of litter and soil nutrients, stimulating production and species turnover, and limiting biomass. Every year, about 1 to 2 million hectares of boreal forests are burned in Canada, and between 1.4 and 10 million hectares in Russia. Insect outbreaks are another important feature at least in some countries. It is estimated that in Canada, for example, the damage caused by insect outbreaks accounts for one third of the annual harvest volume.

Finnish lakes are usually surrounded by large forested areas. Nearly all of Finland belongs to the boreal coniferous forest zone, which is characterised by a short growing season and a limited number of tree species.
Due to the Gulf Stream, however, conditions in Finland are more favourable than in other sites on the same latitude.
Picture by Eero Kubin.

Climate change may in the near future have a strong impact on the growth and regeneration of high-elevation forests and their environments. In high altitudes the treelines are primarily thermally controlled and the increase in temperature should result in their upslope expansion (Moen 2006). On the other hand, the southern limit of the boreal forest will retreat and this process is only partly driven by temperature increase but mainly because of increased competition from rapidly growing temperate species (WCMC 1999). It is estimated that climate zones will shift northward at a rate of about 5 km/year. This will favour the spread of species with fast dispersal rates over those with slow rates. In fact, for many tree species the natural rate of migration is only from 40 to 500 m/year. Trees face also many constraints considering the seed dispersal distances, establishment of seedlings and time required to reach reproductive maturity. In the case of the upper tree line expanding into tundra, the migration is further slowed by the adaptation of the soil (WCMC 1999). Furthermore, the biotic factors play also a crucial role, e.g. in fennoscandia, treeline is grazed by reindeer, and grazing may affect both the position and the structure of the treeline. The grazers have the ability to slow, or even halt the upward spread of the treeline by feeding on seedlings and saplings already weakened by adverse climatic conditions from field layer plants (Moen 2006).

The timberline in Northern Ostrobothnia region in Finland can be located at altitudes of 340 – 410 m asl, where the annual mean temperature sum ranges between 590 and 650 d.d. Picture by Eero Kubin.

The slowness and other constraining factors in these transition zones may cause extinction of species. However, the global extinction of boreal tree species will probably be low because of the low diversity and wide distribution of species. Even though the low biodiversity does not imply a good capability to adapt to changing conditions, the northern ecosystems have already a good adaptation capacity, because they need to survive in highly variable conditions in terms of temperature and humidity all the time.

One of the positive impacts of climate change on high latitude watersheds is the extension of the growing season. Carter (1998) calculated changes in the duration of the growing season in nine sites in Nordic region. Under three scenarios, representing the range of estimated greenhouse gas-induced warming by the 2050s, the growing season is expected to lengthen at all sites. The greatest lengthening is computed for southern and western Scandinavia (7-8 weeks) with smaller changes in Finland (4 weeks) and Iceland (3 weeks). In addition to this, the climate change speeds up decomposition of the soil in high latitudes leading to better nutrient intake of trees and other plants. In conclusion, the combined effect of the lengthening of growing season together with the better nutrient intake and expansion of the treeline into tundra regions in the north is expected to increase productivity and growth as well as structural change in the boreal forests.

Warming in winter leads to reduced snow cover in the Northern Hemisphere which in turn will have an indirect impact on ground frost. Ground frost depends on several factors including winter temperatures, thickness of snow cover and the length of the snow-covered period (MAF 2005). By the end of the century, it is estimated that the annual maximum depth of ground frost on snow-free surfaces will decrease by 30-50 % in southern and central Finland and by 50-70 % in northern Finland by the end of the century (Venäläinen et al. 2001). At present in certain areas in high latitudes the insulating snow cover significantly restricts ground frost and the decrease in snow cover is counterbalancing the impact of increased temperature on ground frost. However, in case the increase in temperature will be significant, the ground frost will clearly decrease when snow cover is becoming thinner (Venäläinen et al. 2001). Reduced ground frost will impede forest harvesting in the winter and weaken the anchoring of trees in the soil, exposing forests to storm damage (MAF 2005).

Well-managed forest creates favourable conditions for adaptation to climate change. Both natural and artificial forest regeneration have their advantages in terms of adaptation to climate change. Natural regeneration creates opportunities for utilising the natural genetic potential of the tree species for adaptation to climate change. On the other hand, selection of the origin of artificial regeneration material and the use of improved material will allow a more efficient response to climate change. A shorter rotation of forest and regular forest management will improve adaptation by accelerating the spreading of new, genetically better adapted populations and reducing the risk of pest damage (MAF 2005).

1.3 The situation in high altitude and high latitude watersheds: a comparison

The climates in high altitude as well as high latitude watersheds are characterized by seasonal cycles and the hydrometeorology is largely controlled by processes involving snow and ice. In high altitudes, the diurnal cycles are also important factors.

The impacts of climate change are easier to predict in high latitude than in high altitude watersheds where the topography and microclimate are highly differentiated. However, the overall predicted trends are the same in high latitudes and high altitudes: more precipitation in winter, dryer summers, more extreme weather events and increased unpredictability. Although in high latitudes, the changed hydrology can cause floods, droughts, more storms and pest diseases to trees, in high altitudes, the consequences of climate change can be much worse and may lead to hazards with disastrous consequences.

The high altitude mountain forests and high latitude boreal forests are both among the threatened regions. Many boreal species have broad distribution and they are not likely to be threatened with total extinction. Many mountain species have narrow distribution because of fragmentation, are endemic or are located near the top of the mountains with nowhere to migrate. However, climate change is threatening particularly the biodiversity of high altitude forests.
Similar processes drive the treeline to go upwards both in high altitudes and high latitudes. In high altitudes, the process is leaving less space for ecosystems above treelines whereas in high latitudes the treeline has “more space” to evade. However, the ability of species to adapt or migrate may be easier in mountain regions, where species may only have to move a relatively short distance upslope, rather than longer distances, as would be the case in flatter areas (Boer and de Groot 1990). Still, in mountainous regions, because of the the spatial variability in the environment the species may also move horizontally and the impacts are more difficult to predict than in high altitudes.

The impacts of climate change can result in human and economic losses in high altitude as well as high latitude areas because of extreme weather events and hazards. However, the costs of adaptation will crucially depend on economic development and the ability to mitigate and adapt to climate change. In general, high latitude areas are located in prosperous countries whereas high altitude regions can be located either in the developed or in the developing world. For certain sectors climate change can even be an advantage in high latitudes, e.g. the increase in productivity or the possibilities to participate in clean development mechanisms. On the other hand, the results are often negative in mountainous areas of developing countries because these areas are directly dependant on mountain resources. Thus, even if the temperature increase is predicted to be more substantial in higher latitudes, the strongest negative impacts will be experienced in mountain regions of developing countries which are particularly vulnerable.

High latitude and high altitude watersheds will be affected by climate change in a different way as a result of the difference in the intensity of human activities: In high latitudes, forests often extend over huge areas, human impact is low and forests are sustainably managed. In some mountainous areas, particularly in developing countries, forests are often degraded and the forest cover is decreasing because of deforestation. In such situations, climate change may lead to increased threats to already diminishing forests.

In both high altitude and high latitude watersheds integrated watershed management is a sound strategy for the adaptation to climate change. Improved techniques for natural resources management and the provision of alternative livelihood options to reduce pressure on natural resources are important elements. Socio-economic interventions require awareness raising and capacity building at all levels.

Adaptation to climate change has economic and social costs. Therefore the developed countries in high latitudes and mountainous areas in the developed world have bigger adaptation capacity than the high altitude areas in developing countries. The communities in mountain watersheds of least developed countries are more vulnerable due to already existing pressures on natural resources caused by population growth and food insecurity. These areas need eternal support to enable them to adapt to climate change and to recover from damages caused by climate change.

Section 2: National/regional approaches and case studies

2.1 Climate change – Common concern – Successful regional co-operation in the European Alps

Case study based on ClimChAlp – Climate Change, Impacts and Adaptation Strategies in the Alpine Space. Strategic Interreg III B Alpine Space Project (www.climchalp.org).

Administration authorities, researchers and experts from seven Alpine countries (Austria, France, Germany, Italy, Liechtenstein, Slovenia and Switzerland) worked together closely to analyse and highlight the impacts of climate change in the Alpine space and to elaborate the basis for adaptation strategies. The strategic ClimChAlp project "Climate Change, Impacts and Adaptation Strategies in the Alpine Space" was carried out in the framework of the community initiative INTERREG IIIB co-financed by the European Union. The project ran from March 2006 to March 2008. The project aimed at supporting the political decisions regarding protection and natural disasters prevention due to climate change in the Alps. The main objective was to develop transnational adaptation strategies and measures in the fields of natural hazards, risk prevention, spatial development and economy with a longer term aim of finding ways for the communities in the Alpine space to cope successfully with the impacts of climate change whilst ensuring sustainable development in the area.

Some of the activities in Alpine space included the analysis of historical processes, assessment of the currently available global and regional climate projections, small scale hydrological modelling in selected river basins, studies of scenarios on forest biodiversity and land use as well as of natural hazards. A broad variety of observations and recommendations were listed.

It was demonstrated during the project that the Alpine Space is one of the areas most sensitive to climate change in Europe. It is also the area where the highest uncertainties remain because of specific difficulties in monitoring and modelling arising from topography. From the geological point of view, the Alps are a young mountain range which is still rising up, because of the land-forming processes. Most natural slopes are not in full equilibrium and climatic factors play a major role in this. Any change in these factors has the potential to shift this sensitive balance. Especially, an increase in different forms of landslides is expected triggered by climate change. The ClimChAlp project showed that slope monitoring is a very important prevention tool. Project compared and assessed different present slope monitoring techniques and their application in vulnerable areas. A compilation of best practise examples was generated underlining the benefits and possibilities of current monitoring methods. As a basis for long-term co-operation, an international expert network on slope monitoring was established as well as a new database providing background information on monitoring methods and corresponding experiences. The database also includes contact details of concerned authorities and experts.

The Alps are one of the most sensitive areas to climate change in Europe.
Picture by Thomas Hofer.

Also, the qualitative model region scenarios were created for the year 2030 and beyond, based on available climate projections and further input like expert interviews and stakeholder workshops. In order to check whether policy, administration, enterprises and stakeholders take the expected climate change impacts adequately into account, the current strategies and instruments of spatial planning and economic sectors were reviewed against the background of the scenarios. This cross-check revealed the need for a broad range of actions and led to a variety of proposals for adjusting spatial planning, tourism, forestry and agriculture in the model regions as well as in the entire Alpine Space.

The ClimChAlps project produced a very valuable methodological basis and recommendations for adaptation to climate change and for more effective transnational cooperation. The ways climate change manifests itself in Alpine space is as heterogeneous as the region itself. Therefore the results and recommendations elaborated in the project should in future be implemented step by step above all within local and regional adaptation strategies.

2.2 Climate change impacts on Indigenous peoples of the Russian North

The arctic indigenous people across the high latitudes are facing tremendous challenges with climate change. In Northern Russia the impacts of climate change on indigenous people is being assessed. The work is ongoing by the Russian Association of Indigenous Peoples of the North (RAIPON), together with the NorthSet project of the Institute of Geography at the Russian Academy of Sciences. The information for this case study is mainly based on the article in Encyclopedia of Earth 2008. Some information (when indicated) of the general impact of climate change and adaptation options is collected from Finland's National Strategy for Adaptation to Climate Change (MAF 2005).

The indigenous peoples of the Russian North comprise a mere 2 % of the entire northern Russian population and number approximately 200 000 individuals belonging to forty different peoples. The most numerous are the Nenets, who comprise around 35,000 persons; the least numerous are the Enets with about 209 and the Orok with 109. The subsistence area of the indigenous peoples is about 60 % of the overall territory of the Russian Federation and their traditional subsistence activities include reindeer herding, hunting, fishing, gathering wildplants and to a certain degree, craftmaking and traditional art. The specific activities of the different peoples very significantly from region to region.

In this project the impacts of climate change were assessed within the context of broader social, economic, and political changes and the results are still preliminary. Human impacts and environmental transformation in the Russian Arctic have intensified over the last few decades, for example the transition to a market economy in post-Soviet Russia has brought sharp changes to the economic and social conditions of the indigenous people of the north. The negative impacts of climate change combined with those of industrial development are threatening the livelihoods of indigenous people. In this changing social and economic climate, indigenous systems of traditional resource use are under threat. Traditional land use areas are mainly located within zones of political interest, particularly those concerning oil, mineral and timber production as well as military complexes with nuclear test sites. From the initial results of the research being conducted by RAIPON, a majority of indigenous people consider poaching, forest fires, industrial logging and clearing of forests for firewood to be some of the most significant issues that affect the physical environments and well-being of their communities.

The destruction of traditional activities, especially reindeer herding, - the most important activity for many indigenous groups - has continued in full speed.
One of the causes of the decrease in reindeer numbers is the degradation of the treeline (taiga-tundra) winter reindeer pastures. The reasons are mainly industrial forestry, clearing of forests for firewood and industrial pollution. The traditional ways of life of indigenous peoples are characterized by high adaptability to seasonal as well as to spatial differences in the physical environment. Climate change may interfere with the human-nature cycle of reindeer herding, where herders follow the paths of reindeer between summer grazing lands in the tundra and mountains and winter grazing lands in the treeline. Winter pastures are of great importance for reindeer herding. During the long arctic winter, reindeer depend upon access to pastures which are rich ground lichens - their basic food. In autumn, reindeer start to move to forested areas that provide layers of soft snow that they can dig through to find the ground lichens. Epiphytic lichens on old trees are important reserve fodder when the ground lichens can not be reached due to ice layers on or within the snow. Climate change will have significant ecological impacts, especially on the population dynamics of the reindeer (MAF 2005). Also, as a result of increased precipitation and higher temperature snow may become thicker which makes access to food for reindeer more difficult. It has been shown that climate change and responding forest management will have both positive and negative impacts on reindeer pastures. Climate change is likely to boost forest growth and the growth of forests may increase forest activities, which in turn may complicate the use of pastures. On the other hand, increased forest growth could provide the opportunity to develop forest management methods causing less harm to reindeer herding (MAF 2005). In Northern Russia, it is within extremely complex socio-economic and changing ecological situation that indigenous peoples have to deal with climate change issues. The work of the project on climate change impacts suggests an important way forward: indigenous observations of climate change must be examined together with greater emphasis on the concerns of indigenous peoples in terms of environmental degradation and habitat loss due to other factors. A broader understanding of change and discussions on how to deal with this must be included in environmental impact assessments, in environmental policy and in the elaboration of local programs for sustainable development.

This ongoing work in northern Russia evidences the struggles that indigenous peoples face in the era of climate change. This is particularly pronounced in the case of communities which mainly depend on reindeer herding. This livelihood strongly depends on pastures, the survival of which is strongly intertwined with the effects of climate change on forestry and watershed hydrology.

Section 3: Gaps and priorities

The development of this background paper with the task to compare high altitude and high latitude watersheds in terms of their ecology and their reaction to climate change has been a very interesting process which has revealed a significant number of information and experience gaps.

Although the understanding of snow and ice processes has improved in recent years, there remain some fundamental issues to be addressed. This is very urgent since watersheds in high altitudes and high latitudes are characterized by seasonal cycles and the hydrometeorology is largely controlled by processes involving snow and ice which are both very much affected by climate change.

There is a great need to quantify the role of snow cover in the existing and in the future states of the surface energy and water budgets and to better comprehend hydrometeorological processes in high altitude and high latitude areas. Also, there seems to be a lack of reliable model data when it comes to larger regions, where the data should be homogeneous. Monitoring networks need thus to be strengthened. Finally, there is a need of developing better and more reliable climate change models.

Disaster risk management is getting increasing attention in the context of climate change. The large potential for hazard assessment based on remote sensing and numerical modelling has to be fully exploited, and knowledge has to be transferred to affected regions. Scientifically objective criteria need to be developed to assess the hazard potential of glacial lakes and periglacial hazards. Scientists should work towards a greater transfer of information and improved communication between the scientific and political communities to raise the awareness and willingness of the responsible authorities to use the available information and knowledge basis on glacial and periglacial hazards. The impacts of environmental change on hazard potential need to be continually monitored and a rapid transfer of this information is critical for the successful mitigation of hazards in highly sensitive mountain environments. Also, many of the largest known glacier or permafrost are characterized by hazard combinations or process chains. These system interactions in high mountains clearly show the urgent need for integrated hazard assessment to account for a variety of relevant processes and their linkages on different timescales (Kääb 2005).

The ClimChAlp project showed that there is a clear need for transnational collaboration and exchange of information, especially regarding experiences made with new methods and successful adaptation strategies. Raising awareness, transdisciplinary and transnational communication and cooperation were identified as key factors for successful climate change adaptation. To be effective, those processes have to involve policy-makers, administration, researchers, associations, enterprises as well as the public. Thus, risk communication as well as spreading of information on possible impacts of climate change has to be improved substantially on the public and political level. Further case studies on regional, local and sub-local level are needed to improve the knowledge of climate change impacts on spatial development and economy and to transfer new findings into adequate and applicable adaptation measures. (ClimChAlp) These recommendations are not only valid in the Alps, but they can be applied globally both in transboundary high altitude and high latitude watersheds.

The ongoing project in northern Russia shows that there is a lot of work to be done with regard to the survival of the indigenous people in the era of climate change. This is particularly the case in areas which are in transition and which already face social, economic and environmental challenges. There is a need to develop special strategies for these areas taking into consideration the special relationship of indigenous people to natural resources as their main livelihood as well as the indigenous knowledge in monitoring climate change.

There is a large number of projections and scenarios about the impacts of climate change on forests and water in high altitude and high latitude watersheds. However, concrete examples or case studies which are actually able to identify, monitor and document such impacts are very few. For instance, are there any sites, where the treeline has already moved from one place to another because of warming? Are there any examples of successful adaptation strategies to new situations which are the result of climate change? There is a vast field of unanswered questions and it is hoped that the session on “forests, water and climate change in high altitude and high latitude watersheds” during the 26th session of the EFC Working Party on the Management of Mountain Watersheds will be able to raise awareness about these issues and trigger new initiatives in these fields.

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