ICIMOD

FOR MOUNTAINS AND PEOPLE

Climate Change Impacts and Adaptation in the Hindu Kush Himalaya:

Summaries of Selected Studies from the Himalayan Climate Change Adaptation Programme

CICERO
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About ICIMOD

The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

About HICAP

The Himalayan Climate Change Adaptation Programme (HICAP), one of the initiatives under ICIMOD's Regional Programme on Adaptation to Change, is a six-year research programme initiated in 2012. HICAP is supported by the Governments of Norway and Sweden and implemented jointly by ICIMOD, GRID-Arendal, and the Centre for International Climate and Environmental Research-Oslo (CICERO), in collaboration with local, regional, and international partners. HICAP carries out basic and applied research as well as policy engagement to contribute to enhanced resilience to change, particularly climate change, through improved understanding of vulnerabilities, opportunities, and potentials for adaptation. The programme focuses on four selected river sub-basins: upper Indus (Pakistan), Koshi (Nepal), Eastern Brahmaputra (India), and Upper Salween Mekong (China). For more information about the programme, please visit our website: www.icimod.org/hicap

All ten studies are part of the Himalayan Climate Change Adaptation Programme (HICAP). HICAP is implemented jointly by ICIMOD, CICERO, and GRID-Arendal in collaboration with local partners, and is funded by the governments of Norway and Sweden. All the publications can be found on www.icimod.org/hicap and www.icimod.org/himaldoc together with a wide range of knowledge products both from HICAP and other programmes and initiatives by ICIMOD and partners.

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Contents

Introduction

The Himalayan Climate Change Adaptation Programme (HICAP) is a six-year long basic and applied research programme initiated in 2012 in four major river basins of the Hindu Kush Himalaya (HKH): the Upper Indus (Pakistan), Koshi (Nepal), Upper Brahmaputra (India), and Salween-Mekong (China). The programme's main objective is to enhance the resilience and adaptive capacities of the people, especially women, living in the mountains of the HKH. Together with local partners in the four river basins, research was conducted to improve the understanding of vulnerabilities, opportunities, and potentials for adaptation by generating high quality scientific and evidence-based knowledge on climate change and its impacts on ecosystem services and the livelihoods of people living in the mountains. HICAP has been able to address the multiple dimensions of change and the understanding of adaptation by integrating different scientific disciplines, ranging from the physical and natural sciences, to the social and human sciences. In the process it has covered various topics and sectors such as climate change scenarios and projections, water availability and management, availability of ecosystem services, agriculture and food security, and gender, vulnerability and adaptation. This comprehensive approach ensures a holistic understanding of the interconnected and complex impacts of climate change and the multitude of risks and challenges these impacts impose on already vulnerable communities. Thus far, the programme's research results and findings have been published in more than 80 knowledge products and publications, such as peer-reviewed scientific journal articles, working papers, policy briefs, short videos, and flyers.

This publication is a collection of summaries of ten selected HICAP studies. The studies are published in scientific peer-reviewed journals or as working papers. The selected studies exemplify the scientific and thematic scope of HICAP's research and the various scales that HICAP's research has covered – the regional, basin, sub-basin, local, and household levels. The studies complement each other and provide coherent and comprehensive information and knowledge on climate change impacts as well as identify adaptation actions that are needed for enhancing adaptation in the HKH. They also reflect the initiative's methodological scope, ranging from mathematical climate modelling and remote sensing studies, to policy analysis, household surveys, and place-based ethnographic and participatory research methods.

The first study presented, (1) *Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation*, uses climate modelling and cryospheric-hydrological model outputs to analyse the likely impacts of climate change on future water availability in the four selected river basins. The second selected study, (2) *Projected changes in climate over the Indus River Basin using a high resolution regional climate model (PRECIS)*, makes projections for temperature and precipitation changes for the Upper Indus Basin in Pakistan. The model outputs have allowed for an assessment of future climate change impact on water resources and the livelihoods of people in the basin. The third study, (3) *Estimating water availability across the Upper Salween and Mekong river basins*, also addresses the uncertainty surrounding future water availability in the region. By comparing various methods for predicting water availability, the study identifies the most effective methods for projecting water availability without historical data and gauge stations. The fourth selected study, (4) *Grassland growth in response to climate variability in the Upper Indus Basin, Pakistan*, assesses the impact of climate change on grassland phenology and productivity growth in the Upper Indus Basin. Collectively these four studies provide valuable information on how the climate has changed, how it is likely to change in the future, and what impacts the changes can have on the availability of ecosystem services.

The following three studies deal with the direct or indirect impacts of climate change on natural systems and ecosystem services, and the consequences these impacts can have on mountain livelihoods. The fifth study, (5) *Ecosystem services and livelihoods in a changing climate: Understanding local adaptations in the Upper Koshi*, Nepal, documents local communities' perceptions of climate and environmental change and their adaptation strategies in a district in Nepal. This has allowed for an assessment of the local impacts of climate change on livelihoods and the availability of ecosystem services. The sixth study, (6) *Payment for ecosystem services: possible instrument for managing ecosystem services in Nepal*, assesses the applicability of 'payment for ecosystem services' (PES) schemes in Nepal as a way to adapt to climate change. PES is a sustainable conservation and management of ecosystem services model that seeks to ensure the continuing supply of these services and thus the livelihoods of the people who depend upon them. The seventh study, (7) *The last straw – Food security in the Hindu Kush Himalayas and the additional burden of climate change*, analyses the vulnerability of agriculture and food security to the impacts of climate change. The study recommends various actions for improving and ensuring food security in the HKH.

The last three studies examine the possible link between environmental change and migration, and the consequences of climate change on women's livelihoods. By reviewing existing research and knowledge, the eighth study, (8) *The changing Hindu Kush Himalayas: Environmental change and migration*, examines the link between environmental change and migration, and the extent to which remittances can enhance adaptation to environmental change. The ninth study, (9) *Migration as an adaptation strategy and its gendered implications: A case study from the Upper Indus Basin*, also examines the link between environmental change and migration. The study assesses the influence of environmental shocks on migration and the effects of remittances on the adaptive capacity of recipient households and on gender relations. The last study, (10) *Women's empowerment at the frontline of adaptation: Emerging issues, adaptive practices, and priorities in Nepal*, examines how climate change impacts women's lives and analyses gender differences in relation to adaptive capacity. The study identifies appropriate and sustainable adaptation strategies to ensure equitable access to resources, rights, and opportunities.

1. Consistent Increase in High Asia's Runoff Due To Increasing Glacier Melt and Precipitation

Lutz, A. F., Immerzeel, W.W., Shrestha, A.B., & Bierkens M. F. P. (2014). Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. *Nature Climate Change*, 4, 587-592.

www.nature.com/nclimate/journal/v4/n7/full/nclimate2237.html?foxtrotcallback=true

More than one and a half billion people living downstream of the Hindu Kush Himalaya (HKH) rely on the large river systems originating in the mountains. The climate across the HKH varies, as the east is influenced by the monsoon, causing most precipitation to fall from June to September, while precipitation in the west is more equally distributed throughout the year. The state of precipitation – snow, ice, or liquid – affects how it is stored and how it contributes to runoff. Variations in elevation and rainfall affect seasonal flow and stream flow contributions differently in each of the river basins. All of these variables determine a river basin's runoff composition and, to a large extent, its response to climate variability and change. However, the composition of the runoff that feeds the rivers in the HKH is still not well understood, impeding the assessments of climate change impact on the availability of water resources in High Asia.

High-resolution models that quantify meltwater already exist, however most of these studies have only focused on small-scale watersheds. Only by using a large-scale fully-distributed hydrological modelling approach incorporating short-term changes in climate, snow cover, glacier dynamics, and runoff, can appropriate adaptation and mitigation strategies be developed. To better understand the hydrology of the HKH, Lutz et al. (2014) applied a large-scale, high-resolution cryospheric–hydrological model to quantify the upstream hydrological regimes of the Indus, Ganges, Brahmaputra, Salween, and Mekong river basins. Spanning from 1998–2007, the model includes all major hydrological and cryospheric processes, allowing the scientists to quantify the contributions of glacier melt, snow melt, direct rainfall runoff, and base flow to the total flow. To estimate the future impacts of climate change on water availability by 2050, the model was forced with the latest set of climate models to show how runoff composition and total runoff volume are expected to change.

Despite large differences in how different sources contribute to the runoff between the five basins, the study projected an overall increase in river runoff in all the basins until 2050. An expected increase in precipitation for each basin, except for the Upper Indus Basin, is identified as the main cause for the increased runoff. The expected runoff increase in the Indus Basin is, by contrast, caused primarily by accelerated melting of glaciers, ice, and snow. However, as precipitation forecasts for the Indus Basin are inconsistent, water availability in this basin remains uncertain and warrants further research.

The findings from this study can be used to assess the consequences of the changing climate in the basins. With runoff expected to increase until 2050, more emphasis should be placed on coping with extreme events and adapting to changing water availability. The increased runoff could lead to an increase in the occurrence of floods and landslides, while shifting water availability could have negative consequences for regional food security, as flow peaks and growing seasons are no longer in sync. These consequences should directly impact climate change policies, where a transition towards coping with intra-annual shifts in water availability is desirable.

2. Projected Changes in Climate over the Indus River Basin Using a High Resolution Regional Climate Model (Precis)

Rajbhandari, R., Shrestha, A. B., Kulkarni, A., Patwardhan, S. K., & Bajracharya, S. R. (2015). Projected changes in climate over the Indus river basin using a high resolution regional climate model (PRECIS). Climate Dynamics, 44, 339–357.
https://link.springer.com/article/10.1007/s00382-014-2183-8

In terms of human dependence, the Indus River Basin ranks among one of the most important river basins in the world, as around 215 million people's livelihoods directly or indirectly depend on the river. The 1.1 million square kilometre area of the Indus Basin is shared by four countries: Afghanistan, China, India, and Pakistan, with more than half in Pakistan and more than a third in India. The Upper Indus Basin consists of mountainous terrain, and includes parts of the Hindu Kush, Karakoram, and Himalayan mountain ranges; the Lower Indus Basin comprises the southern plains. The Indus River is the primary source of water for the downstream part of the basin, which is home to one of the world's largest irrigation systems. However, climate change could have a marked adverse effect on the water resources, livelihoods, and industries of the basin.

Precipitation in the Hindu Kush Himalaya (HKH) varies widely from east to west. In the eastern part of the region, the monsoon contributes more than 80% of the annual precipitation, while in the western part, in northern Pakistan and Afghanistan, the monsoon contributes less than 30% of the annual precipitation. Studies have shown that the runoff in the river basins in the east depends more on the monsoon, whereas runoff in the west of the region, such as the Indus, relies more on melting snow and glaciers. Such differences in the source of the runoff suggest that potential impacts of climate change on the river basins in the east and in the west will be different from one another.

In order to project the future impacts that climate change might have on the water resources and livelihoods of the people in the basins, climate change scenarios need to have a high resolution and be developed for river basins instead of over sub-continental or national domains. This study attempts exactly this for the Indus Basin by examining the projected future climate change in the basin using outputs from the 'Providing Regional Climates for Impact Studies' (PRECIS) regional climate modelling system. The study examined the future changes in rainfall and temperature for three time slices representing the near (2011–2040), the medium (2041–2070), and the distant (2071–2098) future for three different lateral boundary conditions (LBC) using the IPCC Special Report on Emission Scenarios (SRES) A1B scenarios.

The PRECIS model showed good skill in capturing the surface climate scenario over the Indus Basin for both rainfall and temperatures. The model simulations show overall changes in precipitation, with an increase in the Upper Indus and a decrease in the Lower Indus, and little change in the border area between the Upper and Lower Indus Basins. In the winter season, the results indicated an increase in precipitation over the Upper Indus Basin and a decrease over the Lower Indus Basin. The Indus Basin is projected to warm significantly and progressively over all three-time periods, with greater warming in the Upper Basin, and greater warming in winter. Such a warming tendency could have widespread consequences for the glaciers and ice in the mountains and impact the water resources of the whole basin.

3. Estimating Water Availability across the Upper Salween and Mekong River Basins

Liu, S., Ding, W., Liu, C., Liu, L., Bajracharya, S., Shrestha, A., & Pradhan, N. S. (2015). Estimating water availability across the Upper Salween and Mekong river basins. *Proceedings of the International Association of Hydrological Sciences*, 368, 343-349.

www.proc-iahs.net/368/343/2015/

The Upper Salween and Mekong River Basins (USMRB) in southwest China are very similar to each other. Water availability in the basins is dominated by the monsoon, with a dry and a wet season. Both the Salween and the Mekong Rivers are over 2,000 kilometres long, have similar elevation differences of more than 4,500 meters, and have an average gradient of 2‰. Predicting and knowing the availability of water in the future is important for regional planning and water resource management. In order to project future water availability, it is important to know the water availability and hydrological patterns of the past. However, projecting water availability in the USMRB is challenging since there is a lack of historical data and an absence of discharge gauge stations.

However, there are various projection methods available for estimating water availability that, in different ways, compensate for the lack of data and gauging stations. This study compares and combines three such methods to find the most efficient and practical method of determining water availability in the USMRB. The 'borrowing method' applies discharge data from the nearest or similar station to an ungauged station and is the simplest and most widely used method. The 'substitute method' assumes that stream flow in the sub-basins of one basin is always similar. The stream flow of the ungauged basin can be estimated by knowing the contributing area of the gauged basin. With the 'generated method', hydrological models are used to simulate the lacking discharge data based on input information (such as meteorology, land cover, soil, and vegetation). Each method was explored and different combinations of the methods were tested, with the intention of identifying the best method offering the highest efficiency rate to determine long-term water availability for the USMRB.

The results show that better estimates are obtained by borrowing data from the nearest station with hydrological similarity, even if it belongs to another basin, than by borrowing discharge data from downstream or upstream within the same basin. Two stations that belong to the same basin but are far apart do not necessarily have similar seasonal variation patterns. Similarities in seasonal variation patterns between two stations are a more important requirement when identifying hydrological similarity, since this leads to the highest possible accuracy when using the borrowing method. The accuracy was shown to be highest at a monthly scale and lowest at a yearly scale. For ungauged stations, hydrological similarity might be difficult to determine. In such cases, the study showed that upstream stations with shorter geographical distance may be more hydrologically similar than stations much further downstream.

4. Grassland Growth in Response to Climate Variability in the Upper Indus Basin, Pakistan

Abbas, S., Qamer, F. M., Murthy, M. S. R., Tripathi, N. K., Ning, W., Sharma, E., & Ali, G. (2015). Grassland Growth in Response to Climate Variability in the Upper Indus Basin, Pakistan. *Climate*, 3, 697–714.

www.mdpi.com/2225-1154/3/3/697

In the Upper Indus Basin (UIB), animal husbandry is the predominant means of income generation. Hence, the availability of healthy grasslands for cattle, sheep, horses, and goats on which to graze is critical. Occupying around half of the HKH, grasslands are not as healthy as they should be. Grasslands are declining due to overgrazing, agriculture, and invasive species, and are further threatened by potential long-term variations in the climate. Ultimately, these pressures on the grasslands are affecting the productivity and the livelihoods of the people in the basin.

The UIB experiences high climatic variability on a relatively small scale. Due to the high susceptibility of high altitude grasslands to climate change, the UIB is a complex area where it is necessary for farmers to adapt their grazing practices to a changing phenology and productivity. In order to be able to devise appropriate policies for management of the grasslands and adaptation solutions, a systematic assessment of how the climate impacts the grassland dynamics in the UIB is needed. This study carried out such an assessment, using satellite-based information in the absence of ground-based climate and vegetation data. This method allowed researchers to understand the spatial patterns of seasonal and annual difference in rainfall and temperature in four bioclimatic regions: humid subtropical, temperate, sub-alpine and alpine, and analyse ongoing climatic conditions and their impact on grassland growth dynamics in the UIB.

Analysing 11 years of data (2001–2011), the study was able to establish some significant relationships between climatic patterns and grassland phenology. Spring temperature, for example, was the major trigger starting the growing season in the alpine and sub-alpine regions. The length of seasons was primarily determined by annual temperature across all of the bioclimatic regions. Productivity was mainly influenced by summer temperature and annual rainfall in the humid subtropical region, by spring temperature in the alpine and sub-alpine regions, and by both temperature and rainfall in the temperate region. It was further shown that annual mean temperature has a greater influence than annual precipitation on the grassland dynamics in the study area.

The study results provide a basis for discussing the development of local climate-vegetation models, which can be used in the management of grasslands, and for sustainably regulating grazing and herd movement across zones and meeting their grazing needs.


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5. Ecosystem Services and Livelihoods in a Changing Climate: Understanding Local Adaptations in the Upper Koshi, Nepal

Bhatta, L.D., van Oort, B. E. H., Stork, N. E., & Baral, H. (2015). Ecosystem services and livelihoods in a changing climate: Understanding local adaptations in the Upper Koshi, Nepal. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 11(2), 145–155.

www.tandfonline.com/doi/full/10.1080/21513732.2015.1027793

Ecosystem services (ES), the uses humans gain from their surrounding natural environment, are vital to rural livelihoods. The ecosystems of the HKH provide agricultural products such as food and fibre, and help store carbon and protect biodiversity, water, and the landscape. However, global climatic changes, coupled with other stressors, are affecting the mountain ecosystems' abilities to continue providing the quality and quantity of ES required for sustaining rural livelihoods. Degradation of mountain ecosystems has adverse impacts on rural and poor populations, due to the direct connection between their livelihoods and ES, their limited capacities to adapt to changes, and their high vulnerability. Understanding and documenting how rural communities experience climate and environmental change, and how they react to changes and cope with shocks are important for efficient planning and implementation of adaptation policies.

The impacts of climate change in the mountains of Nepal, such as water scarcity and droughts, and floods and soil erosion, affect the livelihoods of the rural communities, primarily through negative impact on agriculture, forestry, and pasture resources. To further examine and understand the impacts and consequences of climate and environmental change in Nepal, this study used participatory research with survey data from the Poverty and Vulnerability Assessment to document and analyse local impacts of climate change on ES and livelihoods, and to assess current adaptation strategies, knowledge, and perceptions of change of the communities in the natural resource rich Dolakha district, Nepal. Finally, historical meteorological data from a local weather station were compared with local perceptions of change.

The perceptions and experiences of the communities in Dolakha, supported by the meteorological data, reveal that changes in the climate are negatively impacting the availability of ES and livelihoods. Erratic rainfall, snowfall, and prolonged drought are the major identified climatic hazards. The communities have experienced water scarcity, and commercial forest products and livestock rearing are under threat. Some farmers are practicing a range of immediate and reactive strategies to recover from shocks, as well as more planned and proactive strategies to cope with the changes. The majority of farmers have resorted to borrowing money to cope. Others are shifting agricultural practices from cereal crops to vegetables and introducing new varieties of agricultural crops. To increase resilience and enhance the adaptive capacities of the communities, local climate change adaptation should focus on (1) increasing provision of agriculture services, including access to financial institutions, (2) making alternative crops and livestock a viable option, (3) securing land tenure and increased access to livelihood resources, including forest resources, and (4) strengthening the capacity of local governments such as Village Development Committees and District Development Committees, and associated local institutions to reduce the vulnerability and increase the adaptive capacity of local communities.

6. Payment for Ecosystem Services: Possible Instrument for Managing Ecosystem Services in Nepal

Bhatta, L.D., van Oort, B. E. H., Rucevska, L., and Baral, H. (2014). Payment for ecosystem services: possible instrument for managing ecosystem services in Nepal. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 10(4), 289-299.

www.tandfonline.com/doi/abs/10.1080/21513732.2014.973908

Communities that share ecosystems can sustain both their natural environment and local livelihoods if they share the costs and stewardship of their common resources. Payment for ecosystem services (PES), a free-market based approach to conservation and resource management, is a scheme in which ecosystem services (ES) users pay producers (or managers) to adopt (or maintain) environment-friendly practices, ensuring long-term supply of those services. Participants are guaranteed a continuous supply of ES thus boosting their own livelihoods without compromising the environment.

There are various ongoing PES schemes at work financing ecosystem management in Nepal, but PES experience in the country remains limited and the absence of solid policy and a legislative framework in Nepal makes implementation of PES at the community level problematic. This paper explores whether the models of existing PES mechanisms in Nepal can be adopted as part of a long-term and sustainable strategy that will minimize impacts on ecosystems.

For example, the Kulekhani hydropower facility in Nepal is a pioneer government PES initiative, giving 12% of its generated revenue to the Makwanpur District Development Committee (DDC). The DDC invests part of that revenue in upstream watershed conservation. Royalties are evenly distributed between the upstream and downstream communities, but controversy over the division of benefits is ongoing, with the upstream beneficiaries arguing that they should receive more as service providers and sustainers of the watershed. The downstream community wants distribution to remain 50/50.

Another example of PES is Reducing Emissions from Deforestation and Forest Degradation (REDD+), where communities are offered financial incentives to reduce emissions from forested lands and invest in low-carbon alternatives. In Nepal, a pilot PES scheme was set up in Dolakha, Chitwan, and Gorkha districts. In collaboration with local community groups, a REDD+ benefit-sharing agreement was developed to encourage communities to conserve forest lands. A Forest Carbon Trust Fund was established with clear guidelines on benefit sharing from carbon sequestration.

For a PES scheme to be successful, a number of criteria are necessary: it must be (1) a voluntary transaction, in which (2) a well-defined land use likely to secure that service is (3) bought by a (minimum of one) ES buyer from (4) a (minimum of one) ES provider if (5) the ES provider secures ES provision (conditionality). In the case of Kulekhani, the benefit sharing process and the lack of an institutional framework called for a more transparent negotiation in advance of the scheme's implementation so that all parties would have been clear on policy, benefit sharing, and the conditionality of the scheme. However, despite the controversy, the initiative is still considered to be a good PES scheme as it maintains water flow to the reservoir. Continued monitoring and evaluation of pilot sites such as Kulekhani and the REDD+ site will help feed policy dialogue and encourage further debate on the implementation of PES for sustainable ecosystem management.

7. The Last Straw – Food Security in the Hindu Kush Himalayas and the Additional Burden of Climate Change

Kurvits, T., Kalternborn, B., Nischalke, S., Karky, B., Jurek, M., & Aase, T. H. (2014). *The Last Straw - Food security in the Hindu Kush Himalayas and the additional burden of climate change*. ICIMOD, GRID-Arendal and CICERO.

http://lib.icimod.org/record/29810/files/TheLastStraw.pdf

Climate change and increasing global food prices make future supplies of food to feed a growing world population questionable. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report identifies food insecurity as one of the key risks of climate change, potentially affecting all aspects of food security.

This HICAP publication deals with climate change and its impacts on food security in the HKH. Food insecurity in the HKH is a longstanding issue. Harsh climate, rough terrain, poor soils, and short growing seasons often lead to low agricultural productivity and food shortages. The region is thought to be a climate change hotspot where extreme weather events like floods and droughts are expected to impact food security more than in other areas. The effects of climate change are compounded here due to: high levels of poverty and high proportions of undernourished people; a high dependence on local agricultural productivity and depleted natural resources; vulnerable supply lines and complicated logistics to external markets; and poor infrastructure.

Vulnerability assessments has shown that over forty percent of HKH mountain households are facing decreasing productivity in their most important crops because of floods, droughts, frost, hail, and disease. As a result, many farmers are changing farming practices, including delayed sowing and harvesting, re-sowing, changing crop varieties, and abandoning staple crops and livestock varieties. These new production patterns are also creating problems related to improper soil and water management, and a lower diversity in production is leading to less diverse diets and more vulnerable food security.

While the number of undernourished people globally has been declining over the last two decades, the change has been disproportionately slower in the HKH countries. Outmigration is a great social challenge to farming in the region, with more than fifty percent of households engaged in off-farm employment in Nepal. While outmigration can be financially beneficial, it results in frequent labor shortages on farms.

Climate change is projected to affect food security in a number of ways. Conditions for food production and livelihoods in general will depend greatly on the balance through the seasons between glacial melting and rainfall. Most projections suggest that more extreme weather events and increasing rainfall variability will lower agricultural productivity. Food insecurity has the greatest impact on people who are socially, culturally, economically, or otherwise marginalized. Achieving improved food security in the face of climate change will require:

- More research on the local food production systems.
- More involvement of youth in farming.
- Supporting greater diversity in small-scale farming.
- Developing more gender-sensitive farming approaches.
- Securing more education and better networks for information sharing.
- Integrating food security development goals in policies addressing climate change adaptation.
- Mainstreaming mountain-related issues into the current discussions on the post-2015 process and Sustainable Development Goals.

8. The Changing Hindu Kush Himalayas: Environmental Change and Migration

Banerjee, S., Black, R., Kniveton, D., & Kollmair, M. (2014). The Changing Hindu Kush Himalayas: Environmental Change and Migration. In E. Piguer & F. Laczko (eds.), *People on the Move in a Changing Climate* (pp. 205-227). Global Migration Issues 2.

https://link.springer.com/chapter/10.1007%2F978-94-007-6985-4_9

People living in the mountains of the HKH have long adjusted to living in a fragile and marginal mountain environment. Their particular vulnerability to climate change has caused many mountain people to seek alternative and more reliable livelihoods beyond the rural mountains through outmigration.

This study reviewed current research to examine the link between environmental change and migration, the potential patterns of future change, and the extent to which migrant remittances can enhance adaptation to environmental change. Studying the relationship between environmental change and migration in a mountain context is crucial to improve our understanding of potential future migration patterns and their role in climate change adaptation.

The study found that environmental stressors influence migration decisions, but not in isolation from non-environmental drivers, such as social, economic and political factors. Livelihood options in the mountains are typically limited, and the awareness of the prospects beyond the mountains is rising. A high expectation of a life away from the mountains is a driver for migration. These prospects and expectations are also linked to people's social networks and the improved availability of educational opportunities in the cities. Finally, policies, legislation, political unrest and structural change can affect migration patterns, diminishing the need either for people to migrate or for becoming drivers of migration.

One of the reviewed studies concludes that communities exposed to rapid onset of water hazards (i.e. flood and flash flood) are more likely to migrate for work than those exposed to a slow onset of water hazards (i.e. drought). The degree of exposure and the degree of damage on agricultural production were also shown to influence the likelihood of labour migration.

The study reveals that the implications from migration in the context of adaptation such as the role of financial and social remittances and the influence of social networks, have received little research attention. With a growing need to enhance resilience and adaptation to climate change, there is thus a pressing need for more research on migration and for filling in this knowledge gap.

9. Migration as an Adaptation Strategy and its Gendered Implications: A Case Study from the Upper Indus Basin

Gioli, G., Khan, T., Bisht, S., & Scheffran, J. (2014). Migration as an Adaptation Strategy and its Gendered Implications: A Case Study From the Upper Indus Basin. *Mountain Research and Development*, 34(3), 255-265.

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Remote mountain communities dependent on natural resources are vulnerable to climatic and environmental stresses like floods and landslides. To ensure reliable household income, households often engage in circular labour migration to improve and diversify their livelihoods. This study in the Upper Indus Basin in Pakistan assesses the influence of environmental shocks on migration and the effects of remittances on the adaptive capacity of households and on gender relations.

When a disaster occurs, communities seem to benefit from labour migration through social and financial remittances. However, most studies conducted on remittances and adaptation have not taken gender differences in these benefits into account. In this study, researchers focused on the Yasin and Hunza valleys of Gilgit-Baltistan province, areas that have a high rate of labour migration, and are partially reliant on agriculture. Yasin valley faced severe floods in 2010 and Hunza suffered recurrent landslides that blocked the Hunza River and created a lake in which houses, farmland, and infrastructure were submerged.

The local communities are increasingly shifting from farming and raising livestock only to combining these activities with other income-generating opportunities, like labour migration, trade, and tourism. The study found that household members engage in circular labour migration in response to environmental pressures, both as a proactive measure against expected crop failure, and as a response to environmental events, such as natural disasters. In the study area, labour migration is not considered a viable option for women and, as a result, migration is gender differentiated: men are more likely to migrate for work, while women remain behind to run the household and the farm. Dependence on male relatives still hampers women's access to, and control over, assets and resources with significant consequences for women's abilities and capacities to adapt to climate change.

Therefore, it is necessary to enhance women's agricultural skills and knowledge, and strengthen their access to and control over assets and resources. This will not only alleviate their workload but also improve the entire household's ability to adapt. Women's work as caregivers and farmers is highly valuable, warranting regulation and protection as part of the formal economy. Disaster preparedness training and climate-change related projects should target women as crucial agents of adaptation. Finally, it is of paramount importance to invest in women's financial literacy, to enhance their bargaining and decision-making power. However, these gender transformational processes are more likely to be intergenerational than immediately and directly driven by migration.

10. Women's Empowerment at the Frontline of Adaptation: Emerging Issues, Adaptive Practices, and Priorities in Nepal

Gurung, D.D. & Bisht, S. (2014). *Women's Empowerment at the Frontline of Adaptation: Emerging Issues, Adaptive Practices, and Priorities in Nepal* (ICIMOD Working Paper 2014/3). Kathmandu, Nepal. ICIMOD

http://lib.icimod.org/record/29811/files/WE_14.pdf

Women are a driving force for rural development in Nepal. Agriculture dominates Nepal's economy and is a means of income for two-thirds of its population and 78% of all women in Nepal. In areas where most Nepali men migrate in search of employment, women have become the backbone of rural development. However, Nepal is one of the countries most vulnerable to climate risks and is characterized by high levels of poverty, high population density, and high exposure to climate-related hazards. Climate change is threatening the livelihoods of those directly dependent on agriculture and natural resources. Rural women are especially vulnerable to climate change because of traditional social roles, poor economic and social positions, and their disproportionately high engagement in the agriculture sector.

Lack of knowledge of how climate change specifically impacts women's lives often translates into policies and practices that perpetuate unequal access to resources and women's marginalization from development processes, policymaking, and initiatives. This study addresses this knowledge gap and identifies differences in impact and adaptive capacity between and among women and men in Nepal. It also identifies appropriate and sustainable adaptation strategies to ensure equitable access to resources, rights, and opportunities for marginalized, minority and indigenous people. The results are based on multi-level consultations involving grassroots women leaders, international non-governmental organizations (INGOs), national-level government and non-governmental organizations (NGOs), and district-level NGOs.

The findings reveal that decreasing water supplies have caused women to travel longer to collect water. Coupled with hardening of soils and the emergence of new pests and crop diseases, women's workloads are increasing, forcing them to spend more time on farming activities, resulting in less time available for childcare and taking care of the house. The increased workload negatively affects women's health, income, safety, nutrition, susceptibility to violence, and ultimately their social, economic, and political empowerment.

Some of the already existing community-level adaptive practices identified in the study were: using mobile phones to share information and new adaptation technologies; using local networks to mobilize technical and financial resources for adaptation; gaining men's support for household and community work; use of plastic greenhouses to protect seedlings from heavy rain, frost, and blight; and rainwater harvesting. Given the vital role of women as primary actors in natural resource management and agriculture, adaptation strategies and solutions need to be gender-sensitive, inclusive of, and focused on women. The study recommends various actions needed to secure this, such as: target and sensitize men to support women's leadership; increase women's engagement in local-level climate change planning and implementation processes; allocate separate resources to support women's adaptation; and promote time-saving, appropriate, and gender-friendly alternative technologies, among others.

Concluding Remarks

As this collection of summaries illustrates, HICAP has conducted a wide, comprehensive range of climate change and impact studies as well as vulnerability and adaptation assessments. Linking the studies with one another provides an understanding of the complex relationships and interfaces between climate change, water availability, the availability and management of ecosystem services, food productions, food security, livelihood options, gender relations, vulnerability, adaptation, and resilience.

The results and findings from these studies have been used for assessing the impact of climate change on the availability of ecosystem services in order to examine the consequences that climate change is likely to have on both natural and human systems. The projections for the climate and water availability provide an insight into which changes and impacts the HKH mountain communities might have to cope with and adapt to. The results from studies (1) and (2) indicate that communities in many of the HKH river basins may face greater risk from flooding and landslides due to the projected increases in runoff and precipitation in those regions. In addition to managing disaster risks, these communities will also need to cope with reductions in grassland productivity as well as ecosystem services, as indicated by studies (4) and (5) respectively. These studies show that changing temperature and precipitation patterns are impacting these natural resources and services that mountain communities rely on for their livelihoods.

As shown in study (7), in addition to coping with the impacts of environmental and climate change, residents of the HKH also face many other challenges, including poor infrastructure, inaccessibility of markets, poverty, and myriad social barriers. Some of these unique mountain challenges, along with pressures created by climate change, are driving the widespread phenomenon of outmigration, as described in studies (8) and (9). Labour migration is one strategy that many households have adopted as a way to cope with the many challenges facing the HKH. Communities are also developing other strategies for adaptation, both at the household level and at the community level—through ecosystem management, for example, as described in studies (5) and (6) respectively. However, the success of adaptation strategies is limited at the moment by gender imbalances. As shown in studies (9) and (10), outmigration of men and impacts of socio-economic and climate change are resulting in greater responsibilities and workload for women. Therefore, adaptation strategies need to be developed with a particular focus on building the capacity of and empowering women to be the drivers of adaptation solutions.

Though these studies provide a relatively cohesive view of the overall impacts of and responses to climate change in the HKH, there are also clear gaps within and between the studies, which highlight the need for further research and assessments to provide an enhanced understanding of the links between climate change, vulnerability, and adaptation. There is, for example, a need for improved understanding on how different forms of vulnerability interact, the impacts of reduced water availability, and the consequences of adaptation practices taken by the people in the mountains (when farmers change production

patterns, for example, by shifting to better selling but more water demanding crops, it might provide a temporarily increased income but further deplete water resources, and thus in fact result in maladaptation).

The results from these selected studies and the rest of HICAP research have nevertheless contributed to a better understanding of risks, changes, impacts, vulnerabilities, and opportunities, which together comprise a comprehensive understanding for building adaptation and enhancing resilience in the HKH. As HICAP has sought to have policy impact and enhance adaptation on the ground, its research findings and results have been further developed in various action research and pilot projects. These projects have trialled and highlighted possible adaptation solutions and options, and functioned as go-to sites for policy- and decision-makers. The programme has furthermore synthesized, shared, and disseminated findings and results in knowledge forums, workshops, conferences, and other events. A series of synthesis products named "Adaptation Solution Briefs" examine particular topics and highlight the existing options for policy makers to promote adaptation to climate change (Adaptation Solutions Brief No 1 (2017) http://lib.icimod.org/record/32584/files/icimodASB.pdf).

Although the ten selected studies represent only a small part of the research carried out under HICAP, they show the strength of a comprehensive approach with integrated studies, as this ensures a holistic understanding of the interconnected and complex impacts of climate change and the multitude of risks and challenges these impacts impose. Such a holistic approach is necessary in order to produce evidence-based knowledge appropriate for influencing policymaking and informing decision-making processes. Lessons from HICAP further highlight the importance of having an integrated approach to climate change adaptation by creating cooperation between departments and sectors working with agriculture, forestry, environment, climate change, development, gender, and women's issues to effectively address the impacts of climate change and enhance adaptation and resilience.

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