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Mountains Under Pressure: Evaluating Ecosystem Services and Livelihoods in the Upper Himalayan Region of Nepal

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ABSTRACT

Natural resource-based livelihoods in mountainous regions are subject to new types of development as well as climate related pressures and vulnerabilities. On one hand, the integrity of the mountainous landscape is under pressure from the melting of glaciers, changes in water availability, rainfall patterns, and soil degradation. On the other hand, as mountainous environments become increasingly more important in national growth strategies and development priorities, new avenues for livelihoods and vulnerabilities become more pronounced. Climate change effects are expected to be disproportionately higher in mountainous regions. There is therefore a critical urgency to better comprehend these changes shaping mountainous environments and to better assess future direct and indirect impacts on ecosystem services and livelihoods.

This article presents the results of an analysis of ecosystem services and livelihoods in the Upper Mustang region of Nepal. The region was selected for its particular trans-Himalayan location, development diversity, and climatic changes that have placed increasing pressure on local ecosystem services. We examine the central role of ecosystem services for remote mountain regions, particularly for the poor, the existing pressures on the key ecosystem services and local ways of adapting to climate-induced effect to ecosystem services and, cogeneration of the knowledge gaps and co-production of knowledge with communities to support local adaptation strategies. We adopted a combination of qualitative and quantitative analytical approaches. We found significant implications for local livelihoods and adaptation strategies with reference to water for farming, pasture productivity and livestock rearing, as well as tourism development. Additionally, we highlight knowledge gaps in assessing ecosystem services and opportunities for local monitoring that may close in on the gaps with an end goal of overcoming poverty.

Key Words : Water Scarcity; Poverty; Adaptation; Trans-Himalaya; Upper Mustang

INTRODUCTION

Mountain specificities both enable and constrain development (Jodha et al. 1992). The major constraining factors are remoteness, inaccessibility and fragility. These factors are counterbalanced by comparative advantages and diversity offering 'niches' that allow people to make their livelihoods. Yet, these livelihoods are challenged by climate change impacts on local environmental resources (Renske 2011) that vary in terms of temporal and spatial scale and have different manifestations in local livelihoods (ACAP 2012). From a regional perspective, warming rates and other climate change effects are expected to be disproportionately higher in mountainous regions (IPCC 2007). Global climate models predict a stronger warming potential at higher elevations (Bradley et al. 2009) which is in turn associated with a range of hydro-climatic uncertainties, impacts on water security, agriculture and livestock production (Gautam 2013, Immerzeel et al. 2010). There are also uncertainties associated with evaluating direct and indirect human impacts on mountainous natural resources and ecosystems. Human-induced changes to the landscape as a result of tourism expansion, road development and agricultural trade intensification can influence both livelihood dynamics and ecosystem behavior (Gonzalez et al. 2009). Species migration as well as important ecological gradients of temperature, humidity, soil properties and other abiotic drivers may also be directly or indirectly influenced by human activities (Thuilleret al. 2008). Changing weather extremes can further affect hill slope stability (Gruber and Haeberli 2007). In particular snow avalanches and fast meltdown of accumulated snow have been severe consequences for livelihoods, soil and fertility wasting, water quality, and sediment deposition (ICIMOD 2009).

The Upper Kali Gandaki Basin, located in the Mustang district of the trans-Himalayan region of Nepal which borders the Tibet Autonomous Region of China to the northeast, provides a suitable case study to address these current knowledge gaps. The basin lies in the rain shadow of the Annapurna massif and is valued for its vulnerable highland ecosystems and the services they provide (ICIMOD 2010). Major threats to ecosystem services (ESS) are interrelated with the melting of glaciers and soil degradation. Decreasing water availability and its consequence to ESS is major concern particularly in the Mustang region (NTNC 2008, Chapagain and Bhusal 2013, Renske 2011, Acharya 2006). The case description and empirical insights presented in this article are therefore aimed to improve current understanding of ESSs and livelihoods in light of increasing complexity and fragility in mountainous regions. This has significant implications for local livelihoods and adaptation strategies with reference to water for farming, pasture productivity and livestock rearing, as well as tourism development. Additionally, the paper highlights knowledge gaps in assessing ESS and opportunities for local monitoring that may help in overcoming the existing poverty.

CONCEPTUAL BACKGROUND

The conceptual framework lies in tracing relationships between livelihoods and ESS in remote mountain areas. The close dependency of human wellbeing on various ecosystem services has been emphasized in the Millennium Ecosystem Assessment report (MEA 2005). This defines ecosystem services as "benefits people obtain from ecosystems". Ecosystem services are perceived to be underpinning human health, economy and the quality of life. For example, the provision of water resources is one of the most fundamental ecosystem services for humanity. The integrity of the landscape is another major ecosystem service that benefits local development, for example through tourism. Both are subject to degradation due to melting glaciers, soil degradation, erosion (natural and human-made), use of fertilizers and solid wastes (Boseli et al. 2000, Gautamet et al. 2013). A better understanding of ESS has potential for protecting ecosystems and the services they provide (MEA 2005).

There is a typical association between ecosystem services and human well-being (Fisher et al. 2014). For instance, material well-being depends primarily on provisioning ESS and secondarily on supporting and regulating ESS. Thus, it is widely recognised that the concept needs to move beyond the mere notion of ecosystem services to address inter-linkages with people's livelihoods, particularly in poverty contexts and climatically vulnerable regions (Carpenter et al. 2009). In the context of remote mountain communities, people in poverty contexts crucially depend on the natural resource base and specifically on their proximity to and maintenance of continuous reliable access to ecosystem services (Carpenter et al. 2006). However, the precise ways in which poorer mountainous communities access ecosystem services and the particular means by which decisions are taken by people on ESS are not well understood. While thepoverty dynamics is essentially a multi-dimensional (Robeyns 2005), a research focus is on how the specific links between poverty and livelihoods might be re-cast in light of a better understanding of mountain ESSs in particular.

To effectively trace the interrelationship between ecosystem services and local livelihoods, the spatial relationship between ESS production and their flow pattern has to be better understood. Ecosystem services are spatially explicit, and their detailed understanding requires systematic mapping at appropriate scales. Therefore the evaluation presented here aimed towards a more contextual understanding of ESS and livelihood dynamics as these pertain to the Mustang and Nepalese experience of mountain local development. The evaluation of major hydrological ESS for example can be better estimated using spatial analytical methods, but the social and cultural dimensions of ESS may more appropriately be determined through tracing perceptual understandings of ESSs by communities that directly depend on them.

Hence traditional ecological knowledge of ecosystems and beliefs that condition ESS (Berkes 2009), understandings of ESS and associated management practices (Robertson and McGee 2003), and insights about ESS based on local perceptions derived from individual and collective experiences (Fazey et al. 2006) need to be emphasized. People's decisions and actions influence the use of resources directly and indirectly. ESS tend to have common pool resource characteristics (Ostrom et al. 1999). As a result, collective decision-making and governance arrangements also need to be considered. Both formal and informal decision making processes can influence priority uses of water for irrigation and hydrological regulation at upstream and downstream. Understanding the governance arrangements and individual and collective decisions making processes that shape decisions in mountains is therefore crucial.

METHODOLOGY

We used a combination of qualitative and quantitative research methods. In particular we sought to establish the centrality of ESS for remote mountain regions, particularly for the poor, the existing pressures on the key ecosystem services, local ways of adapting to climate-induced effect to ESS; cogeneration of the knowledge gaps and co-production of knowledge with communities to support local adaptation strategies. A systematic approach was undertaken using a situation analysis, starting with a more general scoping of the study site. Based on the situation analysis, two communities namely Dhakarjong and Phalyak were selected for the case study.Field data were collected using household survey, in depth interview, focus group discussion and observation. Out of total households (81), 36 households were selected randomly for questionnaire survey. The questions in the local language were asked covering the issues of total agricultural land, cultivated and abandoned land, irrigation water availability and changing situation, major crops grown, livestock, changes in crops and general trend of precipitation and temperature. Two focus group discussions were conducted, with local leaders, including the head of traditional institutions (Mukhiya), local farmers, elder and adult men and women participating. The discussion was mainly on climate variability particularly precipitation and temperature variability as they were experienced and their indicators, the impact of such variability on water and their farming, pasture land and ecosystems. Similarly, four in-depth interviews were conducted within and around the issues of climate variability and its impact on water, agriculture and pasture resources, cropping pattern and agriculture calendar and on newly coming tourism resources and its impact onlocal production systems. Furthermore, detail observation and mapping of irrigation cannels, abandoned land and agricultural practices were done. All fieldwork activities were completed in four field visits in 2014 and 2015. In addition, the available climate and demographic data were collected from secondary sources and analyzed.

STUDY AREA

The district lies in the north-western part of the country and borders with China in the north.The Mustang district ranges from about 2000 m to 8137 m above sea level, while the study villages are located at >3000 m elevation (DDC 2008, 2011). It has high mountain arid climate where settlements with farmlands are mostly located along the Kali Gandaki River. The study area falls in the rain shadow of the Annapurna Range that acts as a barrier for orographic rainfall, resulting in average 250 mm annual rainfall. The area receives strong wind and intense sunlight, and winter temperatures fall below minus 20ºC. The annual average maximum and minimum temperatures of Jomsom for the period 1981-2012 were 17.7 ºC and 5.5 ºC respectively (DHM 2008, ACAP 2012).

Data presented here are derived from two settlements, Dhakarjong and Phalyak, in the Kagbeni Village Development Committee (VDC) of Mustang district. Geographically, the study site lies between 28°49' 23.7" N to 28°49' 32.1" N and 83°44' 21.4" E to 83°44' 49.2" E (Figure 1). The region is selected for its particular trans-Himalayan location, development diversity, and climatic changes that add pressure to local ecosystem services (ESS) (Mountain-EVO 2015).

RESULTS AND DISCUSSION

Major Ecosystem Services (ESS)

The major ESSs in the region are water, agriculture, pasture land, and tourism (Figure 2), which are all central to community livelihoods and poverty alleviation.

A) Water Availability Situation and Adaptation

Water is the lifeline of communities in upper Mustang and the study villages in particular where agriculture is a primary source of income. The availability of water is dependent upon the amount of precipitation and its storage as snow in the catchments. The infiltrated portion of precipitation is the source of groundwater and springs. Water flow in streams depends on snowfall accumulation over the watershed during winter. Respondents observed that water is sufficient during June to the first half of August due to monsoon precipitation, and river water is not required for irrigation during December to February if snowfall occurs frequently during these months. Past records indicate that ratio of winter precipitation to annual total is larger compared to other parts of Nepal. Monsoon and winter precipitation contribution in Lumle, the highest rainfall

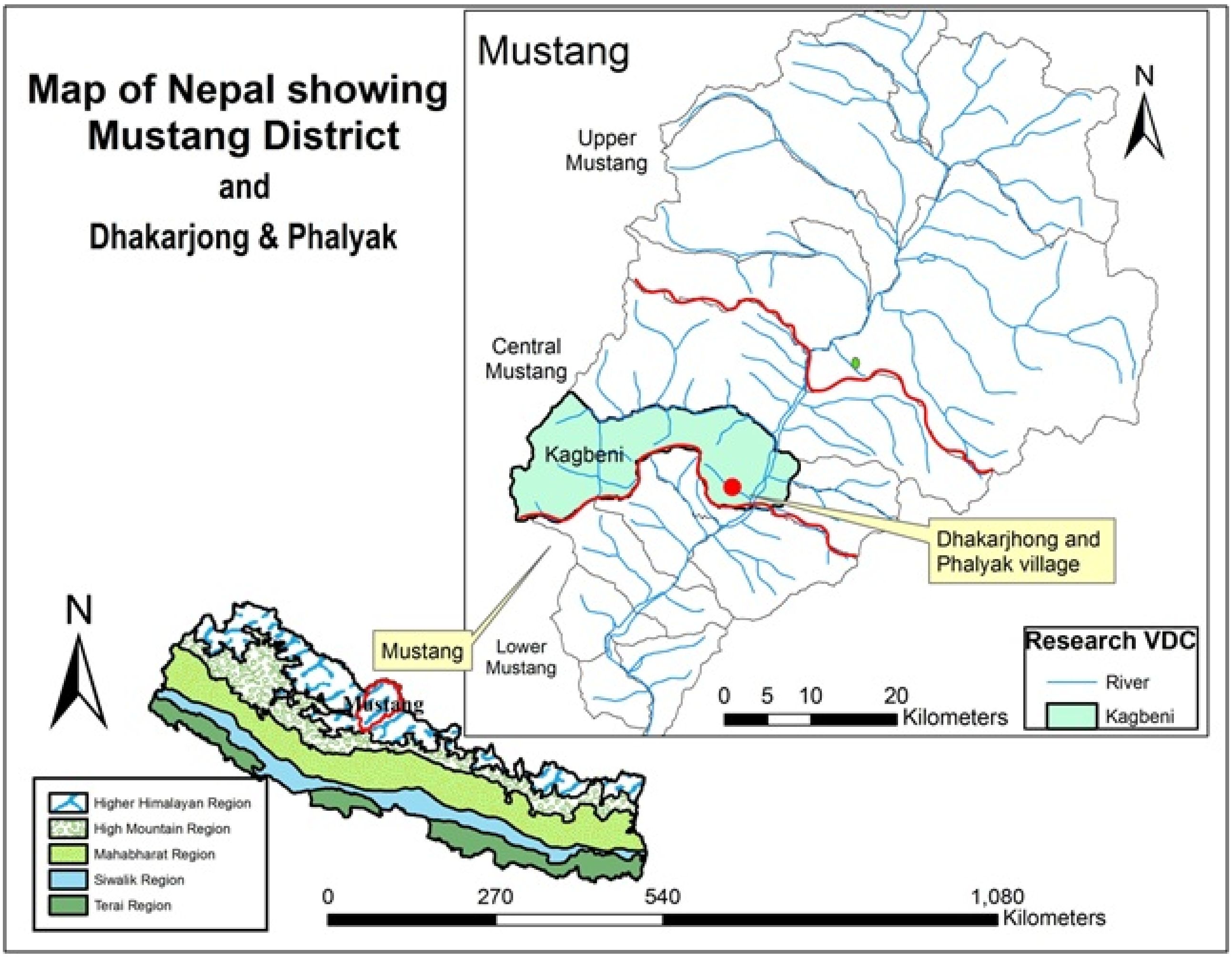

Figure 1: Location map of the study sites,Dhakarjong and Phalyak in Mustang district of Nepal.

location of Nepal, is 85% and 15% respectively whereas it is 55% and 45% in Jomsom, located just a few kilometres lower than the study sites. Thus, there is low contribution of monsoon and higher influence of westerly disturbance.

Local people have rich knowledge and experience and also have their own interpretation of the local climate situation. They have perceived increasing warming, sharp seasonal variation such as very cold winter and warm summer, increasing amount of frost instead of snow, and increasing wind speed. 73% of households surveyed responded that they perceive a decreasing amount of irrigation water by a quarter, whereas 25 % households spoke a decrease by a half. They also noted that 15-20 yr ago, they used to receive heavy snowfall that accumulated up to 90 cm and gradually melting over three weeks. Now, there is very little snow and it melts away within 2 to 3 days. Very little snow accumulates in the upper catchment of the Lumbuk River. This sort of climate variability posed uncertainty to local farmers.

This local perception of a changing climate is supported by analysis of data from the nearest station in the south at Jomsom, Mustang (DHM 2008, ACAP 2012), which showed that annual precipitation has been increasing whereas winter precipitation has been decreasing (Figure 3). Primarily, winter precipitation as snow plays a significant role in river flow in summer, when water is needed for irrigation. Additionally, data show that the temperature in the region is increasing (Figure 4).

Figure 2. Photos showing major ESS in Mustang

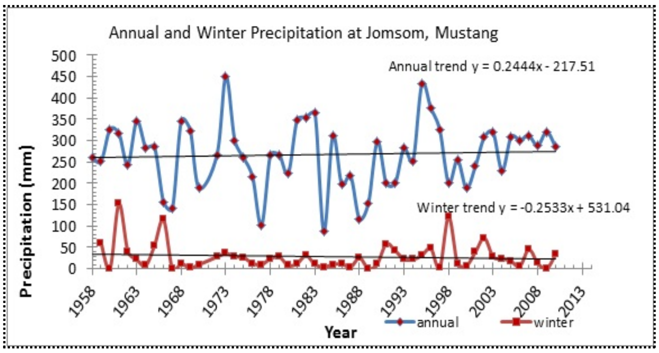

Figure 3. Precipitation trend at Jomsom (1958-2013), Mustang

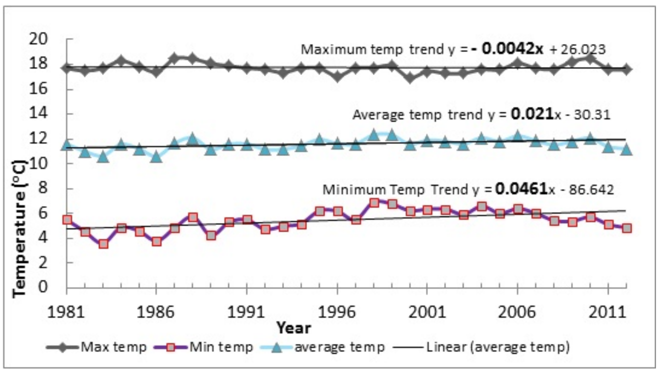

Figure 4. Temperature trend at Jomsom (1981-2012), Mustang

Historically, irrigation practices in both villages have been changing in accordance to water availability. People adapted water sharing practices using wooden weir with five openings for five shares in the early period. As the wooden system did not work for long, people are sharing water-day turn in current practices. Water conflict is usually settled through the traditional 'mukhiya' institution which is unanimously selected from the certain clan in the village. Mukhiya works in close collaboration with local government and plays a vital role in making decisions related to village level activities and management systems.

The amount of irrigation water that each farmer is able to access is also changing. In the past, each household had a specified number of hours of water right, which is allocated in proportion to their land size. Large farm owners and farmers with land farther from the irrigation pond severely suffered due to the decreasing amount of water. As a coping mechanism to scarce water, communities of Phalyak and Dhakarjong have been adopting water storage during night by making ponds at the top of the farmland. However, large areas of cultivable land remain barren due to water deficiency. Each household abandoned about 0.4 ha of farmland within the last 15 years.

There is a lack of knowledge about how much water each crop requires in the growing period and what is the total demand in two villages. Equally,how much water is supplied from available sources was unknown. Consequently this study attempted to cogenerate scientific knowledge to fulfill this gap that may help to understand the uncertainties and help people in better utilization and management of the environmental resources so that the local livelihood is enhanced (Figure 5). A flow monitoring equipment is installed at Lumbak stream after extensive dialogue with the communities regarding issues such as the selection of monitoring sites, most urgent priorities from the community perspective in terms of measurement and; also information visualisation options for best communication of information back to the water users in the long term. Rainfall and temperature measurement data of the area and measured discharged at canal of each village, assessed the capacity and situation of traditional water storage pond and canal situation (Buytaert et al. 2014).

The information related to precipitation and streamflow is very useful to the farmer to prepare the irrigation plan. The analysis on temperature has multi-dimensional impact on biological and physical state of the nature. For example the type of crop, its growth rate and production depends on the temperature of that place. Similarly temperature plays a significant role to manipulate the nature of precipitation, rate of snow melt and consequently fluctuation of water level in the river. These phenomena are directly or indirectly linked with available ecosystem services of the particular place. The delivery of ecosystem services and the consumption capacity of the people are hence affected by temperature and precipitation. This effort greatly helped local farmers in understanding the amount of water available for critical period and also make them aware.how to be more adaptable in the event of water scarcity.

B) Agricultural Land

Mustang's land resource consists of abundant grassland and shrub species in slopes and river valleys which favours livestock farming. Grassland occupies 42% area (Table 1) followed by barren land (42%). Snow (glaciers and ice) covers about 8% of the total area of Mustang.

Figure 5. Cogeneration of knowledge on water availability and requirement

Forest and agriculture cover 4% and 2% of the total area. Based on the data for the period 1994-2014, published in the district profile of Mustang (DDC 2011, 2013), the natural forest is decreasing by 0.77% whereas agricultural land is increasing by 0.86% per year.The productivity of grassland depends on precipitation and affects livestock rearing. Agricultural land is limited in the district, mostly found as isolated patches on the mountain slopes and along the valley. In the study villages, the total agricultural land is approximately 117 ha (39 ha in Dhakarjong and 78 ha in Phalyak village, in Kagbeni VDC (Mountain EVO 2015). The average land holding size is about one hectare. The irrigation facility throughout the year is available to 45% of the agricultural land in Dhakarjong and to 41% agricultural lands in Phalyak village. Four hectares of agricultural land in Dhakarjong and 20 ha in Phalyak is irrigated only during the monsoon. Out of the total cultivable area in both communities, 33% are left barren or abandoned primarily due to lack of irrigation during winter.

Table 1. Area and population by VDC in Upper Mustang

VDC	Population		Area		Pasture land		Irrigated
	Total	%	km^2	% of total	km^2	% of total	land, %
Chhoser	529	7.5	347.2	11	221.16	7	0.0008
Chonhup	801	11.4	99	3	72.44	2	0.0010
Lomanthang	569	8.1	284.2	9	140.67	4	0.0013
Surkhang	360	5.1	800.4	25	305.75	10	0.0007
Charang	452	6.4	324.6	10	66.28	2	0.0008
Ghami	611	8.7	220.6	7	86.54	3	0.0007
Chhusang	512	7.3	489	16	184.43	6	0.0011
Kagbeni	937	13.3	283.7	9	104.65	3	0.0007
Jhong	253	3.6	50.9	2	30	1	0.0009
Muktinath	628	8.9	59.6	2	31.67	1	0.0008
Jomsom	1370	19.5	185.2	6	71.54	2	0.0011
Total	7022	3144	1315.13	42			

Agricultural land is also a scarce resource in the study villages. It is distributed on the southern slope of the mountains and along the banks of the Kaligandaki River. The available land is devoted to cultivate limited crops such as potato, barley, what, and buckwheat. Field data shows that large farmers have bigger holding size and have abandoned more land compared to medium and small holders (Table 2).

Recently people are motivated towards apple planting in their land to replace cereal crops. District Agriculture Statistics (1997-2012) show that the number of apple trees distributed increased from 4039 in 1997 to 31540 in 2012 in Kagbeni VDC. Because of the increased temperature, the area has become more favorable for apple farming. An apple tree starts fruiting only after 4/5 years and it takes about a decade to become mature; until then, farmers also grow other cereal crops simultaneously. Household survey shows that about one third of the total land is now covered by apple planation. Large size farm holders have devoted about 40% of their land to apple plantation followed by medium (24%) and small holders (7%). The small holder has still subsistence risk and focused to grow cereal crops rather than perennial crops (Table 3).

Table 2. Land holding size by household (area in ropani)

Farm size category	HH	Total land	% land	Average holfing	cultivated land	barren land*	average cultivated area /HH
Small	13	71.7	10.01	5.52	69.64	2.05	5.36
Medium	11	184.5	25.76	16.77	168.76	15.7	15.34
Large	12	473.0	66.04	39.42	383.93	89.07	31.99
Over all	36	716.2	100	19.89	609.33	106.82	16.93

Source: Field Survey, 2014. +: One hectare equals 19.65 ropani.
*Note: The figure extrapolated from farmers total registered land. However, farmers have also cultivated unregistered land that are called as *partijagga* in national legal terms, mostly around their registered land. Chiefly such unregistered land is abandoned first.

Table 3. Apple plantation area by farm category based on 2015 field survey

Farm size category	Area under plantation	% of area
Small	4.92	7.06
Medium	40.97	24.28
Large	147.1	38.31
Total	192.99	31.67

Local people claim that both water scarcity and migration of young people out of the village are possible factors for land abandonment and apple farming. Further, young people are more motivated to get involved in off-farm activities, such as tourist guide, and porter.

C) Landscape, Culture and Tourism

The Mustang region is famous for its aesthetic and unique nature as well as religious and cultural heritage. Dhaulagiri (8167m), Nilgiri, Tilicho and other mountain peaks and the whole Annapurna Range lie to the south of the study area. In addition, the Buddhist and Hindu culture along with highland landscape are at the centre of attraction (DDC 2011). Muktinath, one of the four forms of the Lord Shiva where the Hindus are supposed to visit at least once in their life, temple is also there.

The landscape beauty of the region is unique. The assemblage of the Himalayas ranges, the mountain peaks, beautiful glaciers, forest land, agriculture patches and settlements together with Buddhist Gumbas and monks have made the region highly attractive to tourism. Trekking starts from about 1000 meters and ascends up to the world's highest pass, the Thorong la Pass at 5516 meters, and descends to Kagbeni 3000 meter via Muktinath (3800 m). The Annapurna Trekking Circuit (ATC) is famous worldwide where numbersof tourists increased from 15,013 in 2004 to 113,213 in 2013. Upper Mustang is not within the ATC and trekkers require special permission to visit there. Despite high trekking fees, the numbers of trekkers have increased from 661 in 2005 to 3883 in 2014(Mountain EVO 2015, MoCTCA 2015). On one hand, increased tourism has created job and business opportunities for young people but on the other it has increased the demand for local products such as milk, vegetables and cereals. Local people are attracted to the potential opportunities of increased tourism and this seems to be gradually changing their perception towards the landscape and its role in their future livelihoods from neutral to very positive.

CONCLUSION

The study confirmed that the region is water scarce. Water is highly contested resources between individuals, communities, and social groups within the basin. Disputes over water are related to domestic water use, water sharing, and the control of water sources. Locally, water , agricultural production, the attractive landscape and culture heritage are seen as the major ESS. Local people have considerable uncertainty over the changing nature of ESS production due to climate unpredictability that has affected their livelihood. Coworking with local people enabled them to assess the ESS in the context of climate change, helped them to prioritise their utilization of water, agricultural land and labour.The livelihood of mountain people is highly dependent on natural resources. Economic activities and income sources are highly concentrated on agriculture and livestock. As a result, ecosystem services are likely to continue to play a vital role in safeguarding mountainous livelihoods.

In the changed context, these activities are facing multiple problems such as less water available for irrigation, knowledge gaps on use of advance tools and technology, and little information on weather conditions and climatic variability. Improved agricultural practices might play a crucial role in poverty alleviation. Apple farming is becoming a booming business as a measure of crop diversification strategy in response to changing climate and migration dynamics. The increasing in tourism and trade, has opened new avenues of livelihood of the people. Due to fast growing tourists and trekking business and road connectivity, values of ecosystem services are increased. As the study aims to address the knowledge gap, local people have been eager to involve and address their information gap and uncertainties to get out of the poverty

Natural resource-based livelihoods in mountainous regions are subject to new types of development as well as climate related pressures and vulnerabilities. On the one hand, the integrity of the mountainous landscape is under pressure from the melting of glaciers, changes in water availability, rainfall patterns, and soil degradation. On the other, however, as mountainous environments become increasingly more important in national growth strategies and development imperatives, new avenues for livelihoods and new sources of vulnerabilities have become more pronounced. There is therefore a critical urgency to better comprehend these changes shaping mountainous environments and to better assess future direct and indirect impacts on ecosystem services and livelihoods.

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REFERENCES

ACAP. 2012. Climate Change Impact on Livelihood and Natural Resources of Upper Mustang. National Trust for Natures Conservation (NTNC), Lalitpur, Kathmandu. 31 pages.

Acharya, R. 2006. Status of Himalayan Griffon (*Gyps himalayensis* Hume, 1869) and Ethno-Vulture Relationship in Upper Mustang. School of Environmental Management and Sustainable Development (SchEMS), Kathmandu. 34 pages.

Berkes, F. 2009. Evolution of co-management: role of knowledge generation, bridging organisations and social learning. Journal of Environmental Management 90(5): 1692-1702.

Bhusal, J. K. and Subedi, B.P. 2014. Climate change induced water conflict in the Himalayas: A case study from Mustang, Nepal. Ecopersia 2(2): 585-595.

Bradley, R.S.; Keimig, F.T.; Diaz, H.F. and Hardy, D.R. 2009. Recent changes in freezing level heights in the tropics with implications for the deglacierization of high mountain regions. Geophysical Research Letters 36: L17701. doi:10.1029/2009GL037712.

Buytaert, W.; Zulkafi, Z.; Grainger, S.; Acosta, L.; Alemie, TC.; Bastiaensen, J.; Bevere, B.D.; Bhusal, J.; Clark, J.; Foggin, M.; Hannah, D.M.; Hergarten, C.; Isaeva, A.; Karpouzoglou, T.; Pandeya, B.; Paudel, D.; Sharma, K.; Steenhuis, T.; Tilahun, S.; Hecken, GV. and Zhumanova, M. 2014. Citizen science in hydrology and water resources:. Opportunities for knowledge generation, ecosystem service management, and sustainable development. Earth Sciencegarten C. : DOI 10.3389/feart 2014.00026.

Carpenter, S.R.; Bennett, E.M. and Peterson, G.D. 2006. Scenarios for ecosystem services: an overview. Ecology and Society 11(1), 29. http://www.ecologyandsociety.org/vol11/iss1/art29

Chapagain, P. S. and Bhusal, J. K. 2013. Changing water regime and adaptation strategies in Upper Mustang Valley of Upper Kaligandaki Basin in Nepal. Sciences in Cold and Arid Regions 5 (1): 0133–0139.

Chapagain, P.S. 2012. Effects of climate change on agro-pastoral system in the Upper Mustang Valley, Nepal. The Geographic Base 4: 21-27.

DDC. 2013. Mustang District Profile. District Development Committee, Mustang. 71 pages.

DDC. 2011. District Climate and Energy Plan- Mustang district. District Development Committee, Mustang. 19 pages. Cited in: Report on detailed situation analysis of the research site Phalyak and Dhakarjung Village of Kagbeni VDC, Mustang. Mountain-EVO/SOHAM-Nepal, 2015.

DDC. 2013. Mustang Tourism Master Plan. Mustang: District Development Committee, Mustang. 129 pages.

DHM. 2008. Stream flow summary (1962-2006). Kathmandu: Department of Hydrology and Meteorology (DHM). His Majesty's Government, Nepal. 396 pages.

Fazey, I.; Fazey, J.A; Salisbury, G; Lindenmayer, D.B. and Dovers, S. 2006. The nature and role of experiential knowledge for environmental conservation. Environmental Conservation 3:1–10. DOI: http://dx.doi.org/10.1017/S037689290600275X.

Fisher, J.A.; Patenaude, G.; Gir, K.; Lewis, K.; Meir, P.; Pinho, P.; Rounsevell, MDA. and Williams, M. 2014. Understanding the relationships between ecosystem services and poverty alleviation: A conceptual framework. Ecosystem Services 7: 34–45.

Gautam, M.R.; Timilsina, G.R. and Acharya, K. 2013. Climate Change in the Himalayas: Current State of Knowledge. Policy Research Working Paper 6516. Environment and Energy Team, World Bank, Washingtpn, DC. 64 pages.

Gonzalez, A.; Mouquet, N. and Loreau, M. 2009. Biodiversity as spatial insurance: The effects of habitat fragmentation and dispersal on ecosystem functioning. Pages 134-146, In: Naeem, S.; Bunker, D.E.; Hector, A.; Loreau, M. and Perrings, C. (Editors) Biodiversity, Ecosystem Functioning, and Human Wellbeing: An Ecological and Economic Perspective. Oxford University Press, Oxford.

Gruber, S. and Haeberli, W. 2007. Permafrost in steep bedrock slopes and its temperature-related destabilization following climate change. Journal of Geophysical Research 112: 1–10.

ICIMOD. 2009. The Changing Himalayas- Impact of Climate Change on Water Resources and Livelihoods in the Greater Himalayas. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu. 17 pages.

ICIMOD. 2010. Mountains of the World: Seizing Opportunities-meeting Challenges. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu. 18 pages.

Immerzeel, W.W.; Van Beek, L.P.H. and Bierkens, M.F.P. 2010. Climate change will affect the Asian water towers. Science 328: 1382–1385.

IPCC. 2007. Climate Change 2007: Synthesis Report , Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Core Writing Team, Pachauri, R.K. and Reisinger, A. (Editors) IPCC, Geneva, Switzerland. 104 pages.

Jodha, N.S.; Banskota, M. and Partap, T. (Editors) .1992. Sustainable Mountain Agriculture, Volume I. Perspectives and Issues. Practical Action Publishing, Warwickshire, U.K. 796 pages

MEA (Millennium Ecosystem Assessment). 2005. Ecosystems and Human Wellbeing: Current State and Trends. Volume 1. Iceland Press, London. 901 pages.

MoCTCA. 2015. Nepal Tourism Statistics 2014. Ministry of Culture Tourism and Civil Aviation, Government of Nepal, Kathmandu. 126 pages.

Mountain-EVO, 2015. A Report on Detail Situation Analysis of the Research Site 'Phalyak and Dhakarjung Village of Kagbeni VDC, Mustang. SOHAM-Nepal, 19 pages.

National Research Council. 2012. Himalayan Glaciers: Climate Change, Water Resources, and Water Security. The National Academies Press, Washington, DC. 156 pages.

NTNC. 2013. Sustainable Development Plan Mustang (2008-2013). National Trust for Nature Conservation, Lalitpur, Nepal. 206 pages.

Ostrom, E.;Burger, J.; Field, C.B.; Norgaard, R.B. and Policansky, D.1999. Revisiting the Commons: Local lessons, global challenges. Science 284: 278–282.

Renske, D. 2011. Vulnerability of livelihood in Kagbeni, Mustang District, Nepal. Utrecht University, Utrecht. 140 pages.

Robertson, H.A and McGee, TK. 2003. Applying local knowledge: the contribution of oral history to wetland rehabilitation at

Kanyapella Basin. Australia. Journal of Environmental Management 69: 275–287.

Robeyns, I. 2005. The Capability Approach: a theoretical survey. Journal of Human Development 6: 93–117.

Thuiller, W.; Albert, C.; Araújo M.B.; Berry, P.M.; Cabeza, M.; Guisan, A.; Hickler,T.; Midgley, G.F.; Paterson, J.; Schurr, F.M.; Sykes, M.T. and Zimmermann, N.E. 2008. Predicting global change impacts on plant species' distributions: Future challenges. Perspectives in Plant Ecology, Evolution and Systematics 9: 137–152. doi:10.1016/j.ppees.2007.09.004

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