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Understanding the Relationships in Nature-Human Systems to Improve Social-Ecological Resilience in the Hindu-Kush Himalayas

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ABSTRACT

Biodiversity provides vital ecosystem services that contribute to human societies and economies, as well as resilience of ecosystems to adjust to disturbances, such as fires, floods, climate change, etc. However, biodiversity is threatened by anthropogenic pressure and habitat loss. Life in the Hindu Kush Himalayas (HKH) is based on a fundamental principle of interdependence and mutual respect between Nature and humans, one of give and take. Deep understanding of the extent and magnitude of this dependence plays a critical role in strengthening of ecological and social resiliencies, which are critical for adaptation to changing natural resources, especially in the wake of global climate change. Based on the HKH region of Bhutan, we explore fundamentals of Nature and human systems and identify opportunities for sustaining interdependence to enhance ecological and social resilience. Our findings indicate that humans and Nature have a healthy interdependence in Bhutan. Rural communities are heavily dependent on Nature for agriculture, livestock, non-timber forest products, and religious celebrations. It is also evident that this close interface sometimes sparked heavy losses to farmers especially from livestock predation and crop damage, motivating retaliatory actions. In addition, stresses from climate change, forest fire, hydropower and other infrastructure projects are exacerbating environmental degradation as well as threatening human livelihoods. Despite these challenges, communities in Bhutan welcome biodiversity conservation because they are aware that their future depends on the health of their environment. This is manifested in Bhutan maintaining not only pristine, but fully functional ecosystems that are increasingly becoming rare in the world. We propose ecofriendly interventions to sustain this interdependence between Nature and humans in a highly vulnerable landscape.

Key words: Biodiversity, Hindu-Kush Himalayas, Bhutan, interdependence, resilience, climate change

INTRODUCTION

Biodiversity is the fabric of Earth. Its condition is the barometer of the health of ecosystems and, therefore, the wellbeing of our society. Biodiversity provides vital services, such as: provisioning services (e.g. food, water, and materials that contribute to society and economies), regulating services (e.g. climate, hydrology, pollination, etc.), medical discoveries that cure diseases; cultural services (e.g. tourism, spiritual/mental/physical health, recreation, etc.); supporting services (e.g. habitable areas, genetic diversity, etc.); and resilience of ecosystems to adjust to disturbances, such as fires, floods, climate change, etc. [1]. However, biodiversity is in a state of crisis putting these vital services in jeopardy, especially food, water, and energy (Result& Sharma, 2015) and the poor and underprivileged are the first to be impacted (Rasul & Sharma, 2015; Davies, *et al*., 2013; Alagh, 2010). These problems are further exacerbated by global climate change (Alagh, 2010; Eriksson, *et al*., 2009).

At the cross roads of the 21stcentury, the world is still grappling to find viable solutions to mitigate and adapt to an array of critical problems facing the Earth, including degrading ecosystems services, declining food productivity, and drying water sources, to name a few. This failure is largely due to an essential inability to understand that isolated projects will not produce sustainable solutions to these world problems. Infact, several studies (Lele, Klousia, & Goswami, 2009; Barnett & O'Neill, 2010; Urwin & Jordan, 2008) confirm that isolated adaptation strategies can increase vulnerability or undermine net resilience by decreasing capacity or increasing risks in another place or sector, resulting in maladaptation. These problems demand deep understanding and appreciation of the intricate relationship between Nature and humans and that biodiversity conservation alone can significantly minimize these problems, especially for those who are directly dependent on Nature.

The Hindu Kush Himalayan (HKH) region is a crucible of human civilization and a biological hotspot. Over 200 biodiversity hot spots (with more than 10,000 plants, 997 birds, 300 mammals, 270 fishes, 280 reptiles/amphibians species) are located in the region (Chettri, *et al*., 2010; Brooks, *et al*., 2006). About half of the world's poor reside in the 8 countries of the HKH region and about 500 million of them have no access to modern energy (Chettri & Sharma, 2016; Rasul & S Sharma, 2015). HKH also holds the world's largest fresh water reserve (referred to as the 3rd Pole) on which over 1.3 billion people directly depend (ICIMOD, 2010). Life in these mountains is based on fundamental

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relationships between Nature and humans and a critical dependency of humans on Nature. The mountains not only provide food, water, and energy, but they are also considered the abode of gods and deities and a sacred source of spirituality that shapes and dictates the terms of relationships between humans and Nature. The quality of these relationships dictates the strength of ecological and social resiliencies, which are critical for adaptation to changing natural resources, particularly in the wake of global climate change. For these predominantly agrarian communities, conserving biodiversity is the only viable chance to sustain their resilience and secure necessities, such as food, water, energy, materials, and spirituality. This dependency is vulnerable to imbalance by any abuse of this delicate relationship and climate change is emerging as one of its greatest threats. Limited funds and resources along with a growing population in the face of degrading ecosystem services compound this threat. Therefore, adaptation and mitigation demand urgent interventions to improve resilience.

Improving the efficiency and effectiveness of resource use coupled with coordinated efforts to minimize tradeoffs and maximize synergies is a pre-requisite to creating resilient systems. However, many developing nations, especially in South Asia, follow an isolated approach that overlooks the interconnections and dependencies within and between human-Nature systems (Rasul & Sharma, 2015). Although Nature conservation and economic development have long been the development pillars of many governments, and improving the resilience of ecosystems and societies have become a recent priority to adapt to climate change, there has been little effort to understand the human-Nature interface from an interrelationship perspective. Our study, which is based in the Hindu-Kush Himalayan (HKH) region of Bhutan, explores and increases understanding of the relationships between human and natural systems and provides support for biodiversity conservation as a key to improving ecological and social resilience and to securing vital ecological services, including food, water, and energy. We further identify opportunities for sustaining a harmonious relationship between Nature and humans to secure ecosystem and social resilience.

MATERIALS AND METHODS

Study Area

We conducted our study in Bhutan, a HKH country widely known for its high levels of biodiversity resulting from exceedingly diverse habitat types along its enormous elevational gradient (97m – 7,570m ASL). Bhutan is also known for the Nature friendly lifestyle of its people, religious sentiments, and good political will. Despite its small size, Bhutan harbors numerous mega fauna of global conservation significance, including the endangered Bengal tiger (*Panthera tigris tigris*), snow leopard (*Panthera uncia*), red panda (*Alirus fulgens)*, golden langur *(Presbytis geei)*, white bellied heron *(Adrea signis)*, black-necked cranes (*Grus nigricollis*), etc. As result, Bhutan has 71% of its territory under forest cover with both people and Nature receiving good quality ecosystem services based on local communities' respect for The environment. To assure this outstanding relationship between Nature and humans into the future, the constitution of the Kingdom of Bhutan requires that the country maintain at least 60% of its territory under forest cover in perpetuity. This mandate is manifested by also designating 51% of the country as protected areas and biological corridors.

Our study covered 7 districts (Bhutan is composed of 20 districts and 205 blocks) and 25 blocks or sub-districts (locally known as *gewogs*), which also include one major national park (Jigme Singye Wangchuck National Park) and 3 biological corridors. At the time of this study, there were approximately 58,852 people living in the study area. The study area is biologically diverse with subtropical forests from 150mASL rising through alpine meadows to snow and glaciers at over 5000m ASL. These forests provide critical habitat for some of the most endangered and high profile wildlife in the world, including the endangered black-necked cranes, snow leopard and Bengal tiger, as well as the critically endangered white bellied heron (*Adrea signis*), among others. Overall, 40 species of mammals and at least 391 species of birds have been confirmed in the study area Ministry of Agriculture, 2008). The major habitat types represented in the study area range from permanent ice caps at the highest peaks and alpine tundra, meadows, scrub, and lakes to subalpine conifer forests, cool and warm broadleaf forests, and subtropical broadleaf forests in the south, adjacent to Royal Manas National Park. These diverse habitats have endowed the study area with high levels of biological diversity ensuring healthy ecosystem services and social and ecological resilience. In particular, one of the last untouched primary conifer forests that is highly threatened elsewhere in the Himalayas is located in the JigmeSingyeWangchuck National Park in the heart of this study area (Wang, Curtis, & Lassoie, 2006).

In addition, the study area has extensive ethnic and cultural diversity and is home for people of *Ngalop* (people of western origin concentrated in western and northern region), *Mangdeb* (people living along the Mangde river), *Kheng* (people of living in remote reaches in south central region), and *Lhotsamp* (people of people mainly concentrated in the southern region), backgrounds including many indigenous tribes, such as *Oleps* (people believed to be the original inhabitants of Bhutan and depend heavily on natural resources), yak herders who are known for their skills to produce cane and bamboo products. Irrespective of their location, people are settled along narrow river vallyers, wide glacier valleys, and mountain shoulders. Some of them have direct access to roads, while others have to travel by foot or on horseback for two or three days to the nearest road head. The villagers are primarily agro-pastoralists nomadic herders, and have been depending on natural resources for satisfying their needs including food, water, energy, grazing, spirituality, timber, etc.

Sampling Framework

To assure representative proportion of households from the 25 districts, we used stratified random sampling to select sub-districts for this study. Special care was taken

Table 1 . Demographic profile of respondents

Demographic variables (%)							
Gender		**Age**		**Education**			
Female	**Male**	**15-65**	**>65**	**High**	**Primary**	**NFE**	**None**
46.0	54.0	90.7	9.3	9.3	13.3	3.3	74.0

NFE: Non-Formal Education

to ensure that the design was sensitive to social and biophysical conditions to reduce redundancy, but ensure representation of all social and biophysical characteristics at a landscape level. Respondents from each of the sample blocks were selected randomly using taxpayers' lists (which has no alphabetical order). Using the list of taxpayers obtained from the local district office, 25-35 individual respondents were randomly selected for focus group discussions (FGD) and 15 respondents for interview from each district. Heads of 750 households attended the focus group discussions of which 375 household heads were interviewed using a structured questionnaire with both closed and open ended questions. In addition, 25 forestry and park officials were consulted and interviewed to ascertain their knowledge and experience on biodiversity conservation and policies in a human dominated landscape.

Data Collection and Analysis

Given the multiple variables in our study, such as biodiversity, social, and management effectiveness, we employed several data collection methods. To adequately address our study objectives, existing data and information on biodiversity and socio-economic conditions in the study area were collected through literature review, respondent interviews, and focus group discussions (FGD). Interview questionnaires with both open and closed questions were used to interview respondents.

Literature Review: We conducted data and literature reviews to assess existing available information on biodiversity and social conditions in our study sites and the HKH region of Bhutan. We then used preliminary findings from our review to design field visits and interview questions. Our data and literature reviews included natural resource management plans, research and case studies, project documents, policy documents, and field reports. In particular, we focused our review on: i) collecting existing data and information on biodiversity and collating this with current biodiversity information, including the status of globally threatened species, endemic species, and representative ecosystem (s) and habitats; and ii) collecting existing data and information on socio-economic conditions in the region, including population size and structure, current land use, livelihoods, and poverty levels of the local communities that live in, and/or use natural resources from, the study area, and collating this with current socio-economic information, such as gender-disaggregated data and ethnic composition.

Field Visits: Our survey team visited all 25 sub-districts and consulted with relevant officials (e.g. Park Managers and Chief Forest Officers) and local community members to collect primary information on biodiversity and socio-economic conditions in the study area, ascertain key threats, local relationships with Nature, perceptions of forest and Nature conservation rules, and local recommendations to mitigate and adapt to these threats. This information was generated through FGD and key informant interviews using a questionnaire with open and closed -ended questions. Interview questions generated data on demographics, sources of livelihoods, sources of cash incomes, awareness levels about biodiversity, perception on biodiversity status, and threats.

Data analysis: Data collected from the field and from desktop were encoded into a Microsoft Excel database, cleaned and analyzed for ascertaining trends, extent, and magnitude of dependence as well as respondent's perceptions of biodiversity.

RESULTS

Demographic Characteristics

Forty-six percent(46%) of the respondents were women compared to 54% men (Table 1). A large majority of the respondents were between the ages of 15-65 indicating a high productive human workforce in the communities. Over 74% of the respondents had not received any form of formal education.

Human Dependence on Biodiversity: Livelihood-Biodiversity Linkages

Sources of livelihoods

Agriculture and livestock herding were the major sources of livelihood for farmers across the study area. Results showed that both were heavily dependent on biodiversity and ecosystem services for water, pollination, fodder, grazing lands, and leaf litter. In addition, our results indicated that agriculture also needed additional land and energy. The least popular source of livelihood was business and trade with about 12% of the respondents reporting activities away from the farm as a source of livelihood.

Our results indicated that traditional farming was not complete without livestock. Livestock were shown to be sources of milk, butter, and meat as well as manure for enriching soil and increasing the yield of crops and draught power to plough fields. This importance is reflected by almost all of the respondents (92.7%) stating

they own livestock with an average ownership of at least 1 cow for 2 households. However, the livestock sector was also heavily dependent on Nature for grazing land, fodder, and water. Feeding preferences in the open landscape indicated that threats of predation and competition with native species were notable with at least 50% of the respondents reporting that their livestock were both stall-fed and forest grazed (Figure 1). A large proportion of the farmers (46%) reported practicing stall-feeding only, which provides potential to scale up this feeding method to reduce stray grazing in forests. Only 4% practiced 100% forest grazing.

Insufficient grazing land was a major problem faced by the livestock sector with 56% of the respondents reporting it as their top constraint. This was followed by wildlife predation (42%) on livestock. This is of special interest as it not only invokes retaliatory killing of high profile predators, such as tigers and leopards, but also generates anti-conservation sentiments among the otherwise God-fearing Nature loving farmers.

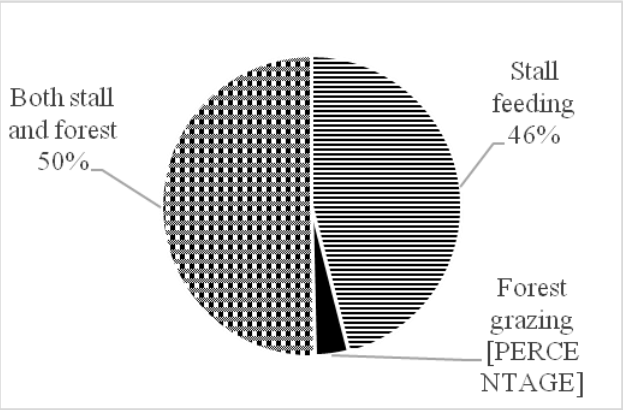

Figure 1. Feeding preferences as reported by those who owned livestock

Depth of Dependence on Biodiversity

Agriculture and livestock were inseparable as the top sources of cash income for farmers in rural HKH [11]. Both are also Nature-dependent. A total of 46% of the respondents indicated agriculture as their top source of income followed by 36.3% relying primarily on livestock. Overall, the farmers earned a combined US$184,741 in the last 12 months (1US$ = 68 Bhutanese Ngultrums), of which US$110,353 was from agriculture, and averaging about US$1,232 per household.

In addition, farmers in the HKH region of Bhutan also depended heavily on forest and non-timber forest products (NTFP), including lumber, firewood, cane, bamboo, edible fruits, medicinal plants, and wild orchids. Findings from our study indicated that farmers collected mushrooms, fern tops, and fodder almost daily during their season (Table 2). Both males and females were almost equally involved in collection of mushrooms; collection of fern tops was largely by females (56%) with fodder collection restricted to just women (100%). Of the products collected, 50% of mushroom and 40% of fern tops were sold to earn extra cash income.

Communities in the HKH region also collected and used wood as a source of fuel to heat, light, and cook. Almost all our respondents reported collection of fuel wood with each household spending on average about 7-days/year collecting fuel wood mainly from the surrounding forests. We found that 62% of the respondents reported that fire wood collection was largely a joint effort by both females and males, while males predominantly carried out transportation of firewood.

Human Understanding of Biodiversity

Community Perception on Status of Biodiversity

Most respondents indicated that biodiversity in the study area had undergone some level of deterioration, with 48% of the respondents stating that biodiversity needs improvement. By comparison, 46% reported that biodiversity was in good condition five years prior to the study (Table 3). In contrast, 38% of the respondents stated that biodiversity had improved in the previous 5 years. There did not appear to be a difference in the perception of biodiversity status between different age groups, gender, and education. Respondents attributed this improvement to community forests, government effort for protection of biodiversity, and community participation. On the other hand, reasons cited for needing improvement in biodiversity included human wildlife conflict, an increase in human population, and hydropower projects in some areas.

Table 2 .Type, Amount, and Gender Roles in Collection of Forest Products

Type of forest product collected	Total collected	Collected by	
		Female %	Male %
Mushroom (Kgs)	326	45.8	54.2
Fern tops (bundles)	1085	56.1	43.9
Fodder (backloads)	200	100.0	0.0

Table 3. Farmer Perception of Biodiversity Status (%)

Condition of biodiversity					
5 years ago			Today		
Excellent	Good	Fair	Improved	Stable	Needs improvement
14.0	46.0	40.0	38.7	12.7	48

Table 4. Support for wildlife conservation policy

Yes %	No %	Top three species that should be protected	Reasons
86.7	13.3	Tiger, leopard, wild dog	Tiger and leopard are precious and endangered; sambar is important prey; wild dog is a predator for wild pig

In contrast to the majority reporting the need for biodiversity improvement, respondents consistently reported an increasing trend in their sightings of both predator and prey species (Figure 2). The reported increase is higher for prey as compared to predators like tiger and leopard. This may be due to fewer sightings of predators or their signs as they are rarer and live in more remote areas while prey species occupy areas closer to settlements, including sometimes for feeding on agricultural crops. Studies in other regions support the premise that if there is sufficient healthy critical habitat and robust populations of predators and prey, then there is generally lower crop damage and depredation on livestock. Our findings indicated that both depredation and crop damage were on the increase suggesting a correlation with deterioration in biodiversity as observed by a majority of the respondents, but further scientific investigation is required, particularly ecological and population studies.

Community Awareness Level about Biodiversity, Ecosystems, and Support for Wildlife

Our findings indicated a high level of awareness with 89.3% of the respondents reporting they were aware of the importance of biodiversity conservation. Respondents (27%) reported that they already had or they would like to take up community forestry as a step toward conserving biodiversity.

Over 73% of the respondents favored wildlife protection, citing predators like tigers and leopards are endangered and culturally precious. Farmer support for sambar deer, which is a primary crop damaging species, comes from the understanding that they are also key prey for predators that kill their livestock. Those who do not support wildlife protection (26.3%), based their arguments on crop damage, livestock loss, and consider wildlife as a threat to their livelihood. There was also no evidence of differences among the tribal groups and the wider population in their support for wildlife conservation and wildlife protective policies.

A large proportion of the respondents (86.7%) supported the existing wildlife conservation policy that it is beneficial to have wildlife in the surrounding ecosystem (Table 4). A notable portion (41%) of respondents reasoned their support was because the policy allows for monitoring of illegal activities, which increases their access to forest resources, while 16% stated it protects wildlife, which they feel are precious.

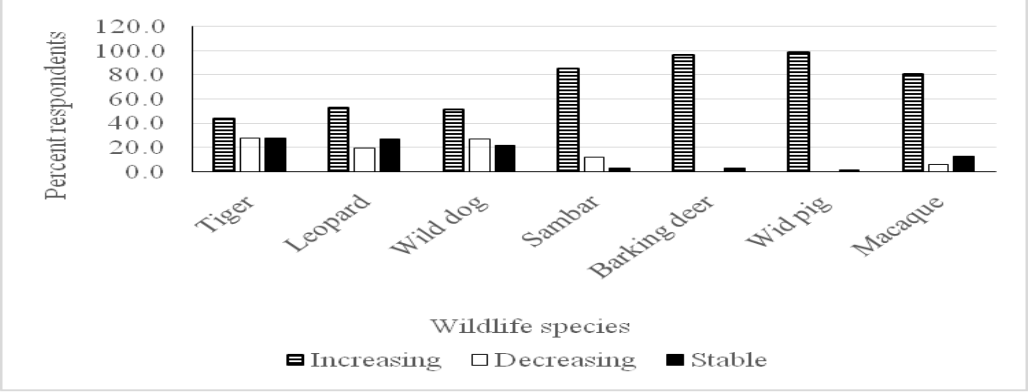

Figure 2. Farmer perception of population status of key wildlife species (%)

Cost of dependence: Assessment of Threats

Human-Wildlife Conflict

Human-wildlife conflicts come in the form of livestock depredation, crop damage, property loss or retaliatory killing of wildlife, or illegal harvesting of natural resources, which depletes habitats. Respondents reported that 72 cattle and 1 mule were killed by tigers while 12 cattle were killed by Himalayan black bears. There are also many unreported cases of other wildlife depredations. It is important to note, however, that forensic studies clearly show in many cases that it is difficult to draw definitive conclusions that livestock were actually killed by predators and did not die of other causes and the predators later scavenged the remains. According to forest officials 2 tigers, 4 sambar deer, 1 wild pig, and 1 Himalayan black bear were killed in retaliation in the previous year. The overwhelming majority of the respondents (88%) in this study indicated that they were facing livestock depredation. Respondents ranked the common leopard as the top predator of livestock, followed by wild dog and tiger (Figure 3). Retaliatory killings were also reported by park officials.

Every respondent (100%) from across the study area reported crop losses. Overall, wild pig, sambar, and barking deer were the main causes (Figure 4). In addition, crop damage by smaller animals, such as porcupines, was reported to be increasing. Crop damage by monkeys and birds was also reported and was the most difficult to deal with as fences do not stop them. As with past studies and findings, the top wildlife responsible for crop damage was the wild pig followed by barking deer and sambar deer with 100%, 67.3%, and 52.3% of the respondents reporting damages from these animals respectively.

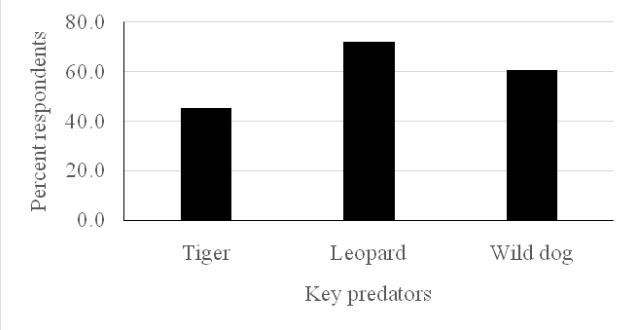

Figure 3. Key wildlife responsible for livestock predation

Poaching and Illegal Trade in Plants, Wildlife and Their Parts

In the study area, our results showed that main wildlife species poached were, leopard (*Panthera pardus*) for skin, musk deer (*Moschus chrysogaster*) musk pod), red panda (*Alirusfulgens*) for fur, and bear (*Ursus thibetanus*) for bile, skin, and claws. Tigers were killed very rarely. Because of the tiger's rarity and low population, any loss via poaching, retaliation, or management control may have a negative effect on the population. People living along the northern border who set traps in the high-altitude area poached musk deer. Forest rangers patrol these areas, but because of the rugged terrain and small staff numbers, respondents noted that it was difficult to apprehend poachers. A summary of recent cases of illegal poaching available from the forest authorities in the study area is given in Table 5.

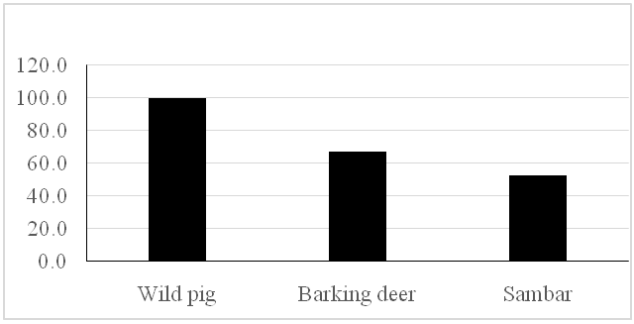

Figure 4. Key wildlife responsible for crop damage

Forest Fires

Available records indicated that forest fires damaged a total of 26,644 acres of forest in the study area during the previous 5 years (Table 6). Most fires took place in conifer zones.

Climate Change Risks

Socially, about 81% of the respondents reported that they observed an annual temperature shift, with an overall increase in temperature in the summer leading to drought. No respondents reported a decrease in temperature leading to drought. A majority of respondents (75%) indicated that the coldest month in their districts shifted to a later period, from November, December, and January to December and January, indicating an overall shift in temperature with warmer Decembers. Previously, the hottest months of the year were July and August, but at the time of our study, this had extended into September. People in the higher altitudes also experienced warming with a decrease in the coldest period from five months (November through March) to three months (November, December and January). The hottest period in the highlands occurred from May to August, while previously it lasted from July to August. These findings indicate that, overall, warmer periods appear to have increased with a decrease in cold months over the previous five years.

Onset of rainy seasons also shifted with over 74.4% of the respondents reporting delayed rainfall. They reported that the rainfall patterns had become unpredictable with either no rains when needed or too much rains when not needed. People across the landscape (77%) were seriously concerned about decreasing water quantity and drying water sources affecting agricultural activities and productivity. They communicated that water shortage is the greatest threat to their food security.

Incidences of pests and disease had also affected the farm economy in the study area with 87% of the respondents reporting crop and vegetable loss due to pests and disease (Table 7). Overall, 70% of the respondents reported that they experienced some form of extreme weather events in the last 5 years. Drought, wind and hailstorms, delayed rains, pests, and diseases were the major extreme weather events that farmers experienced

Table 5. Frequency and type of wildlife poaching

Species poached	Detection frequency	Comments
Illegal fishing	6	Rivers and streams
Sambar deer *(Cervus unicolor)*	1	In agriculture field
Musk Deer (*Moschus chrysogaster)*	1	3 musk deer killed
Monal Pheasant ((*Lophophorus impejanus*)	1	2 Monals killed

Note: Wildlife killed in retaliation are not included here.

Table 6. Frequency of forest fire and magnitude of damage in the study area

Year	2011	2012	2013	2015
Area damaged (acres)	271	645	1547 8	9650.29
Frequency	2	2	6	5

Source: Department of Forest and Park Services, 2016

Table 7. Percent of respondents who experienced extreme weather events and associated losses.

Extreme weather events	Total	Losses
Drought	58	Crops
Flood	2	Land + crops
Land slides	6.7	land + crops
Soil erosion	8	land + crops
Wind/hail storms	90	Crops + roof
Forest fires	23	none
Early onset of rain	35	crops
Delayed onset of rain	75	crops + vegetables
Prolonged rain	49	Crops + vegetables
Pests and disease	87	Crops + vegetables

leading to a decline in crop yields, loss of vegetables, and lifting of roofs. Our study also revealed that farmers need awareness training on climate change impacts and adaptation strategies as only 8% of the respondents received such opportunity in the past.

DISCUSSION

Human Dependence on Biodiversity: Livelihood Biodiversity Linkages

The Hindu-Kush Himalayas are a center of human civilization and are endowed with highly diverse human communities practicing a range of religious, cultural, and livelihood system (s). This diversity affords resilience as well as protects the resilience of the very ecosystem that they depend on. In Bhutan, livelihoods of the local communities are embedded in their social and religious cultures, such that they render a very pro Nature lifestyle. Our findings indicated a high proportion of the communities had not received formal education and their predominant source of livelihood was mainly from agriculture and livestock. Agriculture and livestock were not only the top source of food, but also cash incomes for these communities.

Agriculture is constrained by several factors, including inequitable distribution of land ownership, which causes shortages. Across the HKH, land is a scarce resource that is often inequitably distributed with the rich owning more land. A previous study[15] reported that in some areas of Bhutan, almost 90% of the rural communities depended on 15% of the land, with the remaining land concentrated in the hands of a few property owners. This means that poor people, who are the large majority of the population, are forced to depend more heavily on biodiversity. Similar studies in South Asia found people to be highly dependent on biodiversity (Jha, 2009; Narian, Gupta, Van't Veld, 2008; Jodha, 1992). This then exposes vulnerable groups to the brunt of natural disasters and disappearing ecosystem services.

Our study also confirmed that traditional agriculture was not complete without livestock. Livestock was not only critical for providing energy in the form of draught power and transportation, manure to fertilize soils, and food in the form of meat, butter, and cheese, but also generated income for these cash deprived communities. However, the success of the livestock sector was also heavily dependent on Nature for grazing land, fodder, and water. Already farmers were in short supply of

grazing lands, which in part, is due to a Government policy that nationalizes grazing lands across the country (Center for Bhutan Studies and GNH, 2013). The down side of this agriculture-livestock-biodiversity linkage is the threat it presents for grazing, especially in deep forests where it not only competes with key prey species, but also makes encounters with predators more likely. Studies (Wang & Macdonald, 2006) reported that livestock grazing in deep forest competes with wild herbivores and drives the latter species to the marginal habitats along fields where they damage crops and get into conflict with farmers. Simultaneously, stray grazing also invites increased predation by predators (Wang & Macdonald, 2009). Both crop damage and livestock predation by wildlife sparks retaliatory killings and negative attitudes towards wildlife (Wang, 2010; Wang & Macdonald, 2006).If the livestock sector fails, it is predicted that the agricultural industry will collapse and the poor will starve. Consequently, it is critical for both managers and local farmers to understand herd management dynamics and develop innovative strategies to keep this important sector alive without significantly hurting biodiversity. Such strategies could include scaling up stall-feeding of livestock or allocation of dedicated grazing lands that can reduce unwanted interactions between wildlife and humans.

In addition to agriculture and livestock, farmers in the HKH region of Bhutan also depended heavily on forest and non-timber forest products (NTFP), including lumber, firewood, cane, bamboo, edible fruits, medicinal plants, and wild orchids almost on a daily basis (Chettri & Sharma, 2016; Chettri & Sharma, 2002).Some of these products were collected both for self-consumption as well as for selling in local markets to generate cash income. Past studies have shown that households in South Asia derive 48.7% (Bahuguna, 2000) and 14-23% (Jodha, 1995) of their households' income from forests. Similar findings have also been reported elsewhere in Southern Africa (Cavendish, 2000), Latin America (Coomes, Barhman, & Takasaki, 2004), and Southeast Asia (Viet Quang & Nam Anh, 2006).However, it has been shown throughout the world that excessive and unsustainable collection for self-consumption and sale of these NTFPs results in forest degradation and critical habitat loss for wildlife.

Human Understanding of Biodiversity

Historical records showed generally positive relationships in the Hindu-Kush Himalayas. The relationship here is one based on local community dependence on and trust and respect for Nature. This is why countries like Bhutan in the HKH region have been able to harbor not just pristine, but fully functional living ecosystems. In strict scientific terms, this relationship is not quantifiable and increasing local people's awareness and understanding of the functionality of ecosystems and the value of ecosystem services, especially of these illiterate communities in HKH region, remains difficult without informed intervention, education, and training. For example, local communities in the study area of Bhutan appear to display high levels of awareness about the importance of biodiversity conservation, including support for Community forestry, conservation policy, and curbing illegal poaching of wildlife and plants. This can be attributed to the Government's proactive conservation policies and strong extension activities in the field. Other studies, (Thinley *et al*., 2011) from Bhutan also reported that proactive extension and awareness programs helped boost community's awareness and knowledge about the importance of biodiversity for human wellbeing.

Some communities from the study area reported that the perceived qualities of biodiversity and ecosystems had improved during the previous five years and attributed such improvements to expanding community forests, government effort for protection of biodiversity, and community participation in resource management. Importantly, these communities were in full support of protecting Nature, including wildlife that damage their livelihoods and despite the difficulties of living with Nature and subsequent personal losses. In addition, there was growing resentment toward hydropower plants destroying natural resources and problem animals.

Cost of dependence: Assessment of Threats

The relationship between humans and Nature has always been marred by conflicts (Wang, 2010b; Conover, 2002). While this is a natural phenomenon Conover, 2002), the extent and magnitude of conflicts have risen steadily due to increased human populations exerting excessive demands on, and intensifying competition for, resources Chettri & Sharma, 2016; Wang, 2008). Crop damage, livestock predation, habitat degradation and loss, excessive grazing, unsustainable collection of forest products, poaching and trade, forest fires, encroachment, fragmentation, and land use are some of the emerging issues that threaten ecosystem and social resilience and render them more vulnerable to the impacts of climate change and natural disasters (Chettri & Sharma, Davies, *et al*., 2013; IIED, 2010). Our results revealed that major sources of current habitat degradation were from free-ranging livestock grazing in forests, frequent wild fires that are often set by people (fires are set to burn agricultural debris or to regenerate fresh grasses for livestock), and unsustainable collection of non-timber forest products by a growing population to meet commercial market demands. Naturally, this increases critical habitat loss for wildlife with consequent increases in wildlife encounters (including sightings), crop damage, and livestock depredations.

Human-wildlife conflict is a traditional and universal issue that continues to confound conservation efforts Wang, 2010b; Wang, 2008; Conover, 2002). Human-wildlife conflicts come in the form of livestock depredation, crop damage, property loss, retaliatory killing of wildlife, and illegal harvesting of natural resources. Communities in this study appear to be bearing major losses for living in Nature and for supporting conservation policies. Our results showed that, either crop damage, livestock depredation, or both affected almost every household. Livestock is a prized asset in these villages and can cost as much as US$700 per cow or bull, which is triple their per capita income. A study in 2006(Wang & Macdonald, 2006) showed that farmers lost as much as 81% of their per capita income just in livestock depredation

alone. Such losses motivate them to kill predators in retaliation. High profile predators and prey species, such as the endangered tiger, leopard, and wild dog, are involved and as such, their protection from retaliatory killing is necessary. It is critical to continue to implement innovative programs to reduce such conflicts either through stall-feeding or diversified income sources.

Forest fires continue to present uncertain threats to biodiversity and human livelihoods. Fires not only destroy large tracts of forests (reducing carbon sinks), emit GHGs, reduce ecosystem services, and diminish local livelihoods, but also increase the vulnerability of the land to impacts of climate change, including heavy rains leading to landslides and erosion (Chettri & Sharma, 2002).

Infrastructure development inevitably results in forest loss and fragmentation, especially during the building phase (IIED, 2010). A substantial threat in this study area is presented by the presence of 3 mega hydropower projects that are under construction. Primary broadleaf and mixed conifer forests that have taken millions of years to establish a complex functional ecosystem have been cleared to give way for construction of dams, housing colonies, powerhouses and road networks. The presence and continued development of the hydropower plants will intensify forest loss and fragmentation, especially during the building phase. Subsequent ribbon settlements along roads will increase loss of ecological connectivity. The temperate and subtropical forests in the HKH are particularly at risk from these threats. Loss and fragmentation of these forests will affect several conservation target species in the study area, including tiger, clouded leopard, golden langur, wild dogs, White-bellied herons, and hornbills and will almost certainly increase human-wildlife conflicts.

An assessment of the potential impacts of climate change on the biodiversity, human livelihoods, and water resources in the landscape based on interviews and literature review revealed that impacts were being felt across the landscape. Socially, communities in the study area were experiencing shifts in annual temperature, with an overall increase in temperatures over longer periods in the summer leading to drought and zero respondents reporting a decrease in temperature. Studies by other researchers elsewhere in the HKH show an overall warming over the last 100 years (Lui & Chen, 2000) and a prediction that this warming will continue into the future (Rupa, *et al*., 2006; Shi, 2001). On the precipitation front, HKH exhibits an inconsistent and varied trend (Bhutiyani, Kale & Pawr, 2010). Our findings indicated that rainy seasons were shifting with early rains and late monsoon withdrawals bringing in more rains when not required. All of these latter effects have serious implications for decreasing water quantity and drying of water sources, which impacts agricultural activities and productivity (Aggarwal, 2008). Such changes would require shifts in the way agriculture is usually practiced costing farmers untold hardship. Changes in temperature and precipitation also affect biodiversity and ecosystem services (Singh, *et al*., 2011). Studies have indicated that climate could trigger an upslope movement of broadleaf and subalpine forests (Forrest, *et al*., 2012), with loss of most of the alpine and subalpine habitat (Wang, 2008; Arthur, Pech & Jiebu, 2007). Loss of these important ecosystems will result in losing high altitude fauna and flora and the functionality of the ecosystem at high altitude (Chettri & Tenzin, 2012). Some conifer and subalpine forests will remain in the northern regions of the landscape. This could increase the habitat for tigers but with an equal if not increased retreat of habitat for its sister cat, the snow leopard.

CONCLUSION

Biodiversity is continuously degraded by anthropogenic pressure resulting from inequitable consumption by a fast growing world population and indiscriminate destruction of habitats. Deforestation and habitat fragmentation resulting from logging, agricultural intensification, excessive harvesting of natural resources and economic development are driving extinction and loss of biodiversity. Pollution from burning fossil fuels and dumping of waste is disrupting the functioning of ecosystems and affecting human health. Climate change is exacerbating both ecosystem degradation and biodiversity loss. The complexity of factors causing biodiversity and ecosystem degradation requires an integrated multidisciplinary approach that is embedded in deep understanding of the dynamics of human-Nature interactions. Our findings indicate that while humans are heavily dependent on Nature, the long-term persistence of both and their effective management cannot be achieved in isolation of either. Ecological diversity and biodiversity conservation are critical to ensure ecosystem services that are key to survival of humans and biodiversity. To assure that this relationship is resilient in the face of threats and vulnerabilities from climate change, ecological, cultural, and livelihood diversity must be preserved and promoted. Below we suggest local practical recommendations such as decreasing grazing pressure, strict monitoring of illegal poaching and trade, implementation of innovative approaches to reduce crop damages, etc., to reduce impacts on ecosystems and livelihoods and strengthen the coherence of the relationship between humans and Nature.

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