A STUDY ON THE RESOURCE DEPENDENCE, HUMAN-WILDLIFE CONFLICT AND COMMUNITY PARTICIPATION IN FOREST MANAGEMENT IN ALAKNANDA BASIN, UTTARAKHAND

Thesis submitted to the

Saurashtra University, Rajkot (Gujarat)

For the award of the Degree of

DOCTOR OF PHILOSOPHY

IN

WILDLIFE SCIENCE

By

UPMA MANRAL

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Chandrabani, Dehradun

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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Under the Supervision of

Supervisor
DR. S.A. HUSSAIN

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March 2018



Earth and sky, woods and fields, lakes and rivers, the mountain and the sea, are excellent schoolmasters, and teach some of us more than we can ever learn from books.

-John Lubbock

DECLARATION

I hereby declare that the thesis **"A study on the resource dependence, human-wildlife conflict and community participation in forest management in Alaknanda Basin, Uttarakhand"** is original research conducted by me under the supervision of **Dr. S.A. Hussain** and **Dr. Ruchi Badola** of the Wildlife Institute of India. The thesis has been submitted to the **Saurashtra University, Rajkot (Gujarat)**, for the award of the degree of **Doctor of Philosophy in Wildlife Science** and has not formed the basis for the award of any other degree. It embodies my own work and observations, and in that respect the investigation appears to advance knowledge on the subject.

Date: 06.03.2018

Place: Dehradun

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CERTIFICATE

This is to certify that the thesis by **Ms. Upma Manral** entitled **"A study on the resource dependence, human-wildlife conflict and community participation in forest management in Alaknanda Basin, Uttarakhand"** is an original and independent research work submitted to the **Saurashtra University, Rajkot (Gujarat)**, for the award of the degree of **Doctor of Philosophy** in **Wildlife Science.**

Ms. Upma Manral has put in more than six terms of research work embodied in this thesis under our guidance and supervision. The work presented in this thesis has not been submitted for any degree of any other University or Institution.

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I also certify that the research work was appreciated by all who remain present and the comment made is incorporated in the thesis.

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Executive Summary

Himalayan mountains are highly dynamic systems with both natural and anthropogenic disturbances acting as integral drivers of natural system dynamics in the region. The consequent changes brought into the system determine ecosystem productivity and the flow of ecosystem services to the humans. Any degradation of ecosystem functions and services will increase both the environmental and socioeconomic vulnerability of mountain communities which are highly reliant on natural systems, particularly forests of the area. The loss and degradation of natural habitats of wildlife and proximity of human settlements to the forests due to land use changes have resulted in frequent human-wildlife interactions in the region. Such interactions often have associated economic costs due to loss of livelihood assets *viz.*, livestock and crop harvest. This does not deter local communities from working towards forests conservation and resource management in their surroundings. Locals in the region have had a tradition of harmonious relationship with surrounding forests, managing forests through social fencing and collective actions. The objectives of the study were to: a) quantify the extent of extraction of plant resources in different villages located at different elevations; b) assess the availability of major phyto-resources in and around the villages and surrounding forests along elevational gradient in the Alaknanda river basin; c) assess the extent of human-wildlife conflicts affecting the livelihood in the study area; and d) measure the contribution of community forest management practices in livelihoods of local communities. Four hypothesis were framed as: a) patterns of both availability and the extraction of forest resources in the study area

change along the elevational gradient; b) human–wildlife conflicts negatively impact livelihood generation of affected communities; c) community forest management practices play a role in augmenting livelihood of local communities in the area; and d) better managed forests in an area are the result of community participation in forest management.

The Alaknanda River basin is a highly diversified ecological region with wide elevational variations from 642 m to 7817 m. The river basin lies between 29°58' to 31°04' N latitude and 78°34' to 80°17' E longitude and drains an area of approximately 11,000 km^2. Like rest of the Himalaya, the basin is prone to slope failure and landslides and has seen many extreme weather events including the torrential rains in June 2013. There are three Protected Areas in the River basin including the Nanda Devi National Park and the Valley of Flowers National Park and the Kedarnath Wildlife Sanctuary. Intensive study was conducted in Madhmaheshwer and Kalimath valleys, which fall in Mandakini sub-watershed in the western part of Alaknanda basin and also form part of Kedarnath Wildlife Sanctuary (KWS) landscape. Studies have evidenced habitat destruction and successional changes in the forests of the region because of ongoing unsustainable harvesting, logging practices and infrastructure development activities. With a host of drivers of change such as changing land-use, weak political will towards conservation; the projected climatic variation might bring complex changes in social-ecological systems of the region which need to be addressed to ensure unremitting flow of ecosystem services and benefits from the forests of the region and guarantee their role in conservation of Himalayan biodiversity.

At first, a reconnaissance survey was conducted to gather information on major forest types, location and elevation of villages, general community characteristics, principal services available, primary livelihoods, primary crops and traded agricultural products, forest-resources collected and secondary data on demography and socio-economic indicators, cases of human-wildlife negative interactions was procured from government departments. The data collected from reconnaissance survey and from various departments and agencies was subjected to Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) to identify homogeneous groups of villages. Study villages selected after HCA were re-divided into three elevational categories *viz.,* high-elevation villages (HEV, villagers frequently access forest above 2000 m asl), mid-elevation villages (MEV) and low-elevation villages (LEV) to study the resource use patterns and phyto-resource availability within the landscape. A total of 418 household level surveys in 15 villages were conducted with semi-structured questionnaires having both open-ended and close-ended questions. Questions were asked on household characteristics and demography, forest resource use, livelihood strategies, incidence of negative interaction with wildlife and participation of household member in phyto-resource conservation activities. Entry point monitoring, at selected forest entry points, was done to identify preferred tree species used as fodder and fuelwood and to validate the data on biomass extraction obtained from questionnaire. To estimate the availability of key phyto-resources, sampling was done in forests (under forest department and community-managed) and agro-forestry systems (AFS). In forests, vegetation characteristics were enumerated by laying 10 and 5 m radii plots for

trees and regenerating individuals at 200 m interval along resource-use trail to examine the availability of phyto-resources. Within the villages, 30 m wide belt transects were laid along the trails and agricultural areas to enumerate fodder species and biomass availability. Already existing regression equations were used to estimate biomass of certain species while for rest (primarily multi-purpose species in AFS), ocular estimation was done. To estimate monetary loss due to Human wildlife interaction (HWI), questions were asked regarding incidents of wildlife attack on human and livestock and of crop raiding people's acceptability towards compensation schemes. Impacts of HWI was validated in select villages by noting down incidents of livestock depredation and through laying transects for crop damage along the agricultural fields before the harvesting period. For assessing the community participation in forest conservation, open-ended discussion with community, household based questionnaire survey and purposive questionnaire survey with representatives of local institutions involved in forest management were done.

Preliminary descriptive analysis (mean and standard deviation) was done for household's socio-economic variables, biomass consumption patterns, tree community structure and various forest characteristics including disturbance rank and regeneration status, plant resource availability (aboveground biomass) in forests and agro-forestry systems and monetary loss due to various human –wildlife negative interaction events. Box plots were used to visualize the difference in average annual fuelwood, fodder and leaf litter consumption along elevational gradient. In forests, the available ground tree biomass was calculated using already existing regression equations while for agro-

forestry system, fodder biomass was visually estimated and corrected for observer's biasness through a correction factor. Kruskal Wallis Test and pair-wise post-hoc comparisons were performed between different elevation categories of villages for amount of fodder, fuelwood consumed and leaf litter collected (kg per year per household) and for total above ground biomass and species-specific biomass available in the study area using the Statistical Package for Social Sciences (SPSS) PC version 21.0. One-way ANOVA was performed to test whether nearness to Sanctuary played any role in phyto-resource use patterns by households. To predict role of various independent variables in resource use patterns, Generalized linear modeling was performed using the package MuMIN in R3.2.4. Study plots were ranked for disturbance based on average lopping intensity, lopping proportion, grazing intensity and regeneration proportion. Mann Whitney U test was performed to see if community forest management practices play a role in augmenting livelihood of local communities and Kruskal Wallis test and Pair wise post-hoc comparisons were performed to see if status of forests varied under various management regimes.

High elevation villages included Ransi, Chilond, Chaumansi and Jaal Malla, mid-elevation villages included Gadgu, Gaundar, Raulek, Buruwa, Khonu, Kotma, Kaviltha and Kalimath and low elevation villages were Bedula (including Khetinadla), Bhatwari (including Sansari) and Mansoona (including Kunjalpur). The major plant-resources included fuel wood and leaf and grass fodder. Other forests resources were leaf litter, hill bamboo, edible plants and mushrooms, and dry grass for thatch roofs. There was a significant difference in the total fodder consumption and fodder

consumption from forest and agro-forestry systems along the elevation. The total annual fodder consumption per household was significantly higher (p value < 0.001) for HEV (14571.32 ± 4234.67 kg) than MEV (10563.45 ± 4076.03 kg) and LEV (9274.31 ± 3890.65 kg). The average annual fodder consumption from Sanctuary (or reserve) forests was also highest for HEV (12031.68 ± 4135 kg) followed by MEV (7792.63 ± 3564.49 kg) and LEV (4728.43 ± 2366.14 kg). Both the values were significantly higher for MEV than LEV (p values = 0.016 and < 0.001, respectively). In case of Agro-forestry system (AFS), LEV had highest values (3769.53 ± 3167.84 kg) that significantly varied (p values <0.001) from MEV (2456.33 ± 2483.03 kg) and HEV (1706.42 ± 1896.17 kg). Similar trends were noted in fuelwood consumption which was the most common and primary source of energy, used for cooking and space heating. High elevation villages had highest average fuelwood consumption per household per year (5899.47 ± 1926.06 kg) that varied significantly (p values < 0.001) from MEV (4323.40 ± 1839.01 kg) and LEV (3733.43 ± 1871.10 kg). It was significantly higher for MEV than LEV (p value = 0.017).

Results from generalized linear modeling showed that the total annual fodder consumption by a household was positively and strongly and precisely predicted by livestock numbers of the household, elevation, landholding size, number of grazing months and household size or number of family members and negatively but strongly and precisely predicted by distance of household from road. It was also positively predicted by number of sheep and goats but it was not precise. Total annual fuelwood consumption was positively predicted by household size, elevation, number of grazing

months, distance of household from road and livestock numbers of the household. Monthly LPG consumption of household predicted fuelwood consumption negatively and precisely.

Results from one-way ANOVA and Tukey post-hoc test revealed that the fodder consumption was statistically significantly higher for villages located inside the Sanctuary than fringe villages and distant villages. Similarly, fuelwood consumption was statistically significantly higher for villages located inside the Sanctuary and fringe villages compared to the distant villages. It was statistically significantly higher for Sanctuary villages than the fringe villages ($p < 0.001$). Study results are consistent with studies from similar social-ecological settings from other parts of Himalaya, supporting that forest plant resources are important for subsistence based rural economy of the region and resource use pattern vary significantly along the elevational gradient, strongly predicted by family size, distance from sanctuary, distance from road, use of alternatives, landholding size and livestock numbers. The forests resources formed important component of non-cash economy that forms the basis of human well being and sustenance in the rural Himalaya.

Thirty-nine species of trees were recorded from the forests of the study area, of which 15 were extracted as fodder and 17 as fuelwood. The above ground biomass (AGB) recorded in the forests of the Kedarnath Wildlife Sanctuary Landscape (164.16 t/ ha to 203.64 t/ha) was within the intermediate biomass category (150-300 t/ha) and lower than previously recorded from mixed broadleaved forests or mixed oak-pine forests at similar elevations in Western Himalaya. A hump-shaped relationship was

found for biomass along elevation as the highest biomass (per unit area) was recorded in mid-elevation forests. Total above ground tree biomass (203.64 ton/ ha) and total above ground biomass of fuelwood tree species (195.51 ton/ha) was highest in the mid elevation forest (MEF) followed by high (HEF; 164.18 ton/ ha and 156.49 ton/ ha) and low elevation forests (LEF; 164.16 ton/ ha and 137.76 ton/ ha). There was no significant difference in total AGB and available fuel wood AGB along the elevational gradient. However, it varied significantly for certain preferred species *viz.*, biomass for *Rhododendron arboreum* was significantly higher in MEF than LEF; for *Alnus nepalensis* it was significantly higher in HEF than MEF and LEF and higher from HEF to LEF for *Pinus roxburghii* and *Engelhardtia spicata*, while it varied significantly from MEF to LEF for *Q. glauca* and *E. spicata*. LEF had highest leaf biomass of select fodder tree species in forest (3.67 ton/ha) than MEF (2.87 ton/ ha) and HEF (2.32 ton/ ha). The total leaf biomass per hectare did not vary significantly along elevation; however, it was significantly higher for LEF from HEF for *Quercus glauca* and *E. spicata* and for MEF to LEF for *Alnus nepalensis*; and for LEF than MEF for *Q. glauca* and *E. spicata*.

Results indicate that the total available tree biomass per unit area (both fuelwood and leaf fodder; tons per ha) did not vary significantly along the elevational gradient; however a spatio-temporal variation in access to forests (both Sanctuary and/ or reserve forests and community forests) for resource collection was noted. Villages situated within the Sanctuary or along the boundary had access to greater extent of forests. However, low elevation villages were surrounded by other villages and rivers and were

situated at a distance of 2 or more kilometers from Sanctuary. This gave a spatial disadvantage to LEVs, as forests were less accessible for resource collection. All the LEVs had only community forests in close vicinity; which are opened only for a few days in winter for fodder collection or opened for livestock grazing during winter months.

65 species of both planted and naturally occurring trees were recorded in the agro-forestry systems (AFS) of villages. In MEV, 19 fodder tree species were recorded while in HEV and LEV, the species richness was 15 and 16, respectively. Availability of leaf fodder biomass in AFS varied along elevation with LEV having highest biomass (2.62 ton/ ha) followed by MEV (2.14 ton/ ha) and HEV (1.5 ton/ ha). However, total leaf fodder biomass in agro-forestry system did not vary significantly along elevation. It varied significantly between HEV and LEV for *Ficus neriifolia*, *F. subincisa*, *Litsea monopetala*, *Grewia optiva*, *Lyonia ovalifolia* and *Q. leucotrichophora*. Cultivated species including *Ficus* spp. dominated the AFS in LEV and many MEV. However, *Q. leucotrichophora* or Banj oak a slow growing climax species of region's forests dominated AFS in HEVs which might be remnants of encroached Banj oak forests by local communities.

To estimate the monetary loss to sampled households due to Human-Wildlife interactions, selected villages were re-categorized into three groups based on nearness to Kedarnath Wildlife Sanctuary *viz.*, villages inside the Sanctuary (SV), fringe villages (FV) and distant villages (DV; > 2 km).

Results indicate that the average economic loss per household was small compared to average annual income, however, loss was detrimental for households which were dependent largely on primary livelihood activities including agriculture and animal husbandry, particularly female-headed households. There were only three incidences of wild animal attack on humans in last two years, which included Common Leopard (*Panthera pardus*) attacks on a young child outside his house and on a shepherd closer to forest-village edge and an Asiatic black bear (*Ursus thibetanus*) attack on a man closer to his cowshed in village. None of the attacks resulted in death of the victim. In case of livestock depredation too, only these species were reported to be involved. Out of all the sampled households (418), only 46.89 % (196) reported livestock depredation. Attacks were most in Sanctuary villages (61.47 % of sampled households) followed by fringe village (41.67 %) and distant villages (41.12 %). The average monetary loss per household was INR 14500 ± 24472 in PA villages, INR 15566 ±29674 per household in fringe villages and INR 7814 ± 8581 per household in distant villages.

Crop raiding by wild animals was reported by almost 99% of the sampled households. The wild species held responsible for crop raiding included wild pig (*Sus scrofa*), Rhesus macaque (*Macaca mulatta*), Nepal Grey Langur (*Semnopithecus schistaceus*), Asiatic black bear, Indian crested porcupine (*Hystrix indica*) and birds including sparrows and red and green finches. The percentage of harvest loss by wild pig varied from 18 ± 9 % in DVs to 30 ± 14 % of harvest in SV; in case of Black bear, it was 14 ± 7 % in DVs to 28 ± 19 % in SVs. In case of Primates (macaque and langur),

the loss varied from 20 ± 8 % of harvest in SVs to 26 ± 12 % in FVs. The monetary loss to a crop per season per household varied INR 149.55 ± 68.99 (for potato) to INR 633.89 ± 431.34 (for paddy) in SV, INR 74.61 ± 27.69 (for potato) to INR 804.73 ± 686.90 (for paddy) in FEV and INR 74.12 ± 71.64 (for mustard) to INR 453.74 ± 264.02 (for paddy) in DV.

There were primarily two self-governing local institutions involved in community forest management in the area *viz., Gram Panchayat* or Village *Panchayat* (GP) and *Mahila Mangal Dal* or Women Welfare Groups (MMD). GP look after the community forest and regulated the resource (leaf and grass fodder) use by villagers resulting in a spatial-temporal barrier. These forests are closed for most part of the year and are opened early winters in a process called *Updhi*. In many of the villages, the forests regulated for resource use by GP included some part of sanctuary or reserved forests (Ransi, Chaumansi, Chilond, Gadgu, Jaal Malla, Bedula). MMD are groups of village women, registered with Block development office for various welfare schemes. MMD are created to organize women for activities such as cleaning of resource use trails in forest and forest streams, protests against local production of alcohol, chasing away rhesus macaques and grey langur that damage crops and extraction of forest resources sustainably. The study area had only two *Van Panchayat* (VP) *viz.,* Kalimath and Bhatwari (Bhatwari and Sansari) villages, registered under Kumaon Panchayat Forest Rules 1931. Many of the study villages including Raulek, Buruwa, Jaal Malla, Gadgu, Mansoona, Bedula, Chilond and Khonu had '*Bala Van panchayat'*.

The average number of fodder head loads per households in villages with open community forests (OCV; community forests opened for most part of winter either for fodder collection or for both fodder collection and livestock grazing) was 31.85 ± 27.67 (worth INR 9556.68 ± 8286.24) while it was 7.04 ± 8.12 head loads per households (worth INR 2111.80 ± 2436.24) in villages with closed community forests (community managed forests are opened for few days during winter). Mann Whitney U test showed that sampled households in OCV received significantly higher fodder than sampled households CCV (p value < 0.001). However, when it came to sustainable and equitable flow of benefits, 80 % of respondents in CCV said that there was an equal and sustainable resource use due to strict GP regulations and no or only a few sporadic events of violations. Both the institutions played a crucial role in local-level development planning as an aid to *Gram Sabha* in decision-making process and created and maintained social capital within the rural society where most important way of imposing regulations were by social fencing. Results for forests condition under different management regimes showed higher disturbance in both Open community and Sanctuary forests. There was a significant difference in the disturbance rank of plots, proportion of regenerating species, canopy cover and proportion of lopped trees between open community and closed community forests. Similarly, there was significant difference in all these parameters, except canopy cover between closed community and Sanctuary.

The major recommendation from study include: i) Reducing resource dependency from forests through increasing biomass production within human systems

by planting fast-growing native grasses and multi-purpose native tree species on civil lands and along field boundaries, and through promotion of renewable-energy technologies to reduce reliance of local communities on forests biomass; ii) Offsetting economic loss to local communities incurred due to Human Wildlife Negative Interactions by financially equipping management authorities to compensate loss of local communities, demarcation of non-grazing areas within the highly fragile alpine regions of Sanctuary and awareness drives for local communities on relevant rules and regulations related to natural resource use, compensation schemes and other welfare programmes and workshops for ground staff on participatory approach and goodwill and relation building; iii) Livelihood improvement interventions through promoting value-added products and developing a niche market for these products, eco-development in and around major tourists sites to ensure sustainable livelihood for villagers and development of specialized payment initiatives under Payments for Ecosystem Services (PES) and REDD+ (Reducing Emissions from Deforestation and Forest Degradation) programmes within the community-managed forests; iv) Building partnership between management authorities and local communities to give a multi-stakeholder platform by creating horizontal and vertical linkages among the three types of institutions *viz.,* local institutions, civil society or non-government organizations, and government line agencies and management authorities; v) Future research frameworks that consider both the spatial scale and high heterogeneity within the social-ecological systems of the Himalayan landscape and focus on large scale sustainability of resource use and of development activities in the fragile Himalayan Mountains.



Chapter 1

Chapter 1

Introduction

1.1 People-Forest Interaction

Ecosystems provide a range of goods and services necessary for human well-being including direct services such as fertile soil, timber and non-timber products and an extensive range of environmental benefits such as climate regulation, watershed protection, conservation of biodiversity and other life supporting services (Shackleton et al., 2007; Shackleton and Shackleton, 2004). These services are fundamental for human health, livelihoods and survival (Ali et al., 2007; MEA, 2005) particularly for the forest-dependent communities across the globe. Therefore, forests and various forest resources are seen as wealth creating and livelihood supporting assets, particularly by rural people (Adedayo et al., 2010). In mountainous regions across the globe, rural communities living in isolation in remote areas, have developed a lifestyle that is intimately associated with the utilization and preservation of these natural resources. These communities derive a number of benefits from natural systems including forests which form the basis of their subsistence and livelihood.

In the Indian Himalayan Region (IHR), forests constitute an important natural capital stock providing a number of tangible and intangible ecosystem services to the local communities (Saxena et al., 2005; Singh and Singh, 1986; Singh and Singh, 1992). The IHR supports about 18,440 species of plants, of which 25.3% are endemic to the

region (Samant et al., 1998; Singh and Hajra, 1996). This high plant richness forms the foundation of culture, food security and health care system of local communities (Maikhuri et al., 2004). A major proportion of the total human population in the region lives in rural areas where very few livelihood options are available. Thus, forests form an important economic resource as well as an essential life support system for local communities. A significant diversity is found in the use of different plant species depending on the quality, accessibility and availability of the resources and also the human population of the adjoining villages (Singh and Singh, 1992).

1.2 Forest Degradation, Protected Areas and Dependent Community's Vulnerability

In the past, small populations with few requirements had little negative influence on the forest health; but increased human population and excessive extraction practices have taken their toll on forests in the recent decades (Awasthi et al., 2003). Forests are dwindling due to various reasons across the globe (FAO, 2015). Once, within the carrying capacity of surrounding forests, the extraction of biomass resources such as fuelwood, timber and fodder by local communities has now crossed this limit in many resource rich areas of the world (Reid et al., 1990). Extraction of forest resources and livestock grazing are widespread in developing countries and are considered to be a threat to global biodiversity (Daniels et al., 1995; Hegde and Enters, 2000; Murali et al., 1996). As early as 1923, Champion postulated that people drive the dynamics of forest development in the Himalaya. As early as 1920s, Troup (1921) and Champion (1923)

had reported chronic disturbance in the Himalaya caused by human activities. Large scale commercial exploitation of forest resources in recent decades, continuous unregulated extraction and damaging harvest practices accompanied by forest fires have degraded and fragmented these forests in most of the areas in the region. Forests in many parts have been transformed into cultivation and habitations with many remaining patches facing chronic stress (Singh and Rawat, 2011). This reduction in forest cover threatens the local biodiversity and ecological benefits from the Himalaya that include maintaining farm productivity, hydrological balance and prevention of soil erosion (Chipika and Kowero, 2000; Hurni, 1999; Ives and Messerli, 1989; Myers, 1990, Ramakrishnan et al., 1996). In such a scenario, Protected Areas (PAs) act as a cradle for the conservation of forest ecosystems and biodiversity. Their role in biodiversity conservation cannot be questioned (Bruner et al., 2001). Covering over 12.85% geographic area globally, PAs lay the foundation of ecosystem conservation and play a crucial role in achieving the Aichi biodiversity targets and the Sustainable Development Goals.

The basic approach of management in PAs involved restricting any kind of resource use from the region and protecting the area and its biodiversity by shielding it from people (Badola, 2012). However, PAs are no more considered the islands isolated from surrounding cultural landscapes and are increasingly identified as playing an integral part in social, economic, and cultural well-being of surrounding communities (Svancara et al., 2009). Failing to address the apprehensions of the public and interest groups, understanding their positions and need can result in mistrust against the

management authorities. This may contribute to public opposition to the PAs and conservation efforts. It should be recognized that the local communities incur the indirect and opportunity costs of PA creation which include diminished benefits or economic opportunities due to prohibited resource uses (Scherl and Emerton, 2008; West et al., 2006). These costs are aggravated from the damages caused to human life, crop or livestock by wildlife. These costs are often substantial, particularly for marginalized sections of society. Thus, the inclusion of a human dimension becomes the key to successful management and conservation programs.

1.3 Rationale of the Study

Like rest of the Indian Himalayan Region, local communities in the Alaknanda basin derive a number of benefits from forests in the form of fodder, fuelwood, timber, leaf litter, medicinal plants etc. (Dobriyal, 2015; Kittur et al., 2010; Misra et al., 2009; Sati, 2008; Silori, 2001; Singh et al., 2009). As a result of this intimate dependence on forests for survival, local communities have had a long tradition of managing natural resources through collective actions and encouraging agro-forestry in the villages. However, with time, the population, demand for natural resources and for infrastructure development has increased hugely in the region. This, along with frequent natural calamities, has resulted in loss and degradation of forests in the region (Nandy and Rao, 2001a; Negi, 2007; Thakur et al., 2011). The increasing proximity of human settlements to the forests have also resulted in human-wildlife conflict in the region resulting in loss of output from agro-pastoral system (Dobriyal, 2015; Rao et al., 2002).

The basin has three Protected Areas *viz.*, the Nanda Devi National Park, the Valley of Flower National Park and the Kedarnath Wildlife Sanctuary. Even the protected area landscapes are not untouched of anthropogenic pressure, as many villages are located within or in the fringes of these. The Kedarnath Wildlife Sanctuary (KWS) in the Mandakini sub-watershed in Western Himalaya has 12 villages located inside the Sanctuary while 161 are situated along the southern boundary. Some 88 woody species (54 trees and 34 shrubs) and over 146 plant species are used for fuelwood and fodder by the local people in the KWS landscape (Singh et al., 2010). Fringe forests of the sanctuary and community forests within villages are crucial for meeting households' consumption requirements as they extract wood (timber and firewood) and non-wood (fodder, leaf litter, etc.) forest products. Despite the protected status, the Sanctuary forest face several challenges in terms of wildlife offences, encroachment, irresponsible activities of tourists, infrastructure development, pressure from unsustainable harvesting of resources and lack of livelihood opportunities in the area and a continuous change in regeneration patterns in forest stands (Misra et al., 2009; Thakur et al., 2011). The expanding human settlements along with overgrazing in and around the wildlife habitats has resulted in increased negative interactions between wildlife and local communities for limited resources, which might further compromise with the conservation goals.

Therefore, it is imperative to understand the resource use pattern and biomass extracted by local communities and the threats posed to livelihood of the locals by negative consequences of human-wildlife interactions. This will provide a rational basis

for planning and management decisions without which forest conservation would be difficult. There is a need to understand the perspectives of resource user groups and the socio-economic underpinnings that drive the forest use (Makino, 2009). As forests are the most important natural assets of the people living in and around the forest area (Ali et al., 2007), they come forward to perform different activities collectively to manage forests based on their needs (Pretty and Ward, 2001). Therefore, the participation of local community in forest and natural resource conservation, impacts of such activities on the forest status and livelihood of locals have also been studied.

1.4 Review of Literature

1.4.1 People-forest interaction: Resource dependence on forests and major driving factors

The forest ecosystems are important in sustaining life on earth and their importance for human health and well-being is well documented in the literature (MEA, 2005). Local communities living in the forest fringes; predominantly the marginalized sections depend on various forest resources for their day-to-day consumption requirements and income generation (Das, 2011). Rural communities in almost all developing nations extract fuel, fodder, timber, and other products from forests as these products lay the foundation of their culture and food security (FAO, 2008; Kaimowitz, 2003; Mamo et al., 2007; Sunderlin et al., 2005). These resources are 'the hidden harvest' or 'invisible capital' which lays the foundation of human survival (Campbell and Luckert, 2002; Cavendish, 2000). In such a scenario, it becomes imperative to

quantify the contribution of these resources to a household's well-being and total income for understanding the livelihood strategies, the determinants of poverty and inequality, the implications of the degradation of these resources on rural economy and for designing effective conservation and development strategies which are supported by forest-dependent communities (Angelsen and Wunder, 2003; Herrold-Menzies, 2006; Jagger et al., 2012; Oksanen and Mersmann, 2003; Saxena et al., 2005; Vedeld et al., 2004).

All across Africa, Asia, and Latin America, forests make substantial contributions to livelihood outcomes in rural settings. Angelsen et al. (2014) estimated contribution of forest income in rural household's income portfolio to be 27.5% globally. It ranged from 28.6% of average household income in Latin America to 20.1% and 21.4%, respectively in Asia and Africa which highlights the overall importance of forests and other natural systems to rural livelihoods. Studies in rural communities of Malawi (Fisher, 2004), Bolivian lowlands and Eastern Honduras (Godoy et al., 2002) and Western Ethiopia (Mamo et al., 2007) estimated the contribution of forest income in a household's total income to be 30%, 17–45% and 39%, respectively.

In India, forests provide tangible goods worth more than USD 10,000 million annually with fuelwood and fodder contributing USD 7500 million together (Bahuguna, 2000). In the Indian Himalayan Region, the high plant richness of forests constitutes source of food, medicine, oil, fiber, fuel, housing and construction materials and forms the basis for the livelihood security of the rural poor (Maikhuri and Ramakrishnan, 1992; Samant et al., 1998; Singh and Hajra, 1996; Singh and Singh, 1986; Singh and

Singh, 1992). The marginal agriculture-based economy of the Himalayan states like Uttarakhand is heavily dependent on the forest and its products, primarily for subsistence income (Farooquee and Maikhuri, 2007). A household in the rural Himalaya gains livelihood security in many ways such as through ownership of land, livestock and trees; rights to grazing, fishing and gathering; through stable employment with adequate remuneration and varied repertoires of activities. Various phyto-resources are collected from the wild by these households and sold in order to increase household income (Olsen and Bhattarai, 2005; Olsen and Larsen, 2003; Silori and Badola, 2000). Communities depend to a large extent on forest-dependent subsistence farming, with many traditional societies utilizing natural resources based on their perceptions, experience and response to patterns of resource uses by others (Joshi and Negi, 2011). Biomass is the main source of energy in the villages and many rural populations of the Himalaya have been using firewood as the only source of energy for generations (Bhatt and Sachan, 2004). Sharma et al. (2009) noted that over 75% of fodder and fuelwood requirement of household was met from the forests in Garhwal Himalaya. Other studies from region estimated the fuelwood consumption per household to be 6.52 to 15 kg per day (Awasthi et al., 2003; Dhanai et al., 2015). Similar was the condition for fodder with households extracting 43.96 kg household^{-1} day^{-1} from forest in Kedarnath region in Uttarakhand (Malik et al., 2014).

Forest resource extraction can be extremely heterogeneous, even at local levels. A number of factors such as socioeconomic and demographic conditions, values, beliefs, market influence, season or preferences bring variability in an individual's,

household's or a community's dependence on natural resources (Adhikari et al., 2004; Angelsen et al., 2014; Baral and Heinen, 2007; Gavin and Anderson, 2007; Gunatilake, 1998; Jumbe and Angelsen, 2007; Maskey et al., 2006). Poor households with less alternative incomes tend to be more dependent on natural resources (Baral and Heinen, 2007; Dev et al., 2003; Reddy and Chakravarty, 1999). However, this might not be the case always as few workers have concluded that wealthier households which can afford large initial investments, *e.g.* improved technology for timber extraction or acquiring large amount of livestock tend to consume more forest resources to enhance their incomes (Adhikari et al., 2004; Agrawal and Gupta, 2005; Herrold-Menzies, 2006; Narain et al., 2008). Teshome et al. (2015) found a positive influence of family size, being a member of forest-resource based cooperative while a negative influence of distance to forest resources on forest income in Ethiopia. Davidar et al. (2008), in a study done in Southern Western Ghats of India, found that poor households tend to collect more fuelwood to be sold while wealthier households tend to extract more green leaves for manure. In the Himalayas, elevation plays a significant role in fuelwood consumption with households situated at higher elevations extracting more fuelwood, particularly during prolonged winters when a large amount of wood is used for space heating (Awasthi et al., 2003; Dhanai et al., 2015; Malik et al., 2014). Sharma et al. (2009) found a positive relationship of income with livestock numbers and fodder consumption from forest and a negative relationship of income and fuelwood use from forest. They argued that households with higher livestock numbers had higher income

due to dairy farming while poorer households tend to extract more fuelwood as a free source of energy.

1.4.2 Phyto-resource availability along elevation

The demand for forest resources by the local communities changes with time; increasing with increase in population or decreasing with increased availability of alternatives (Bahuguna, 2000). In any of the cases, it is important to study the availability of resources in the source system and general trends in availability across various environmental and anthropocentric gradients. A number of factors are believed to impact the distribution patterns of plant species and their biomass including climatic, topographical and habitat heterogeneity (Bryant et al., 2008; Khan et al., 2011; Kikvidze et al., 2005; Kreft and Jetz, 2007; Lee and Roi, 1979; Odland and Birks, 1999; Paudel and Vetaas, 2014; Vazquez and Givnish, 1998; Zhang et al., 2013).

The Himalayan forests are among Earth's most multifaceted and diverse ecosystems, characterized by a highly variable climate, a strong degree of seasonality and a high diversity of both plant communities and species. However, this richness is not distributed uniformly and a number of factors including elevation, drive plant community structure in the area giving a comparative ecological advantage to villages in terms of availability of resources (Rao et al., 2003). With sharp environmental gradients, the diversity in vegetation is astonishing across Himalaya (Chawla et al., 2008; Dutta and Agrawal, 2005; Kala and Mathur, 2002; Oommen and Shanker, 2005). Elevation is one such factor that drives the plant diversity in Himalaya (Anthwal et al.,

2008; Bhattarai and Vetaas, 2006; Grytnes and Vetaas, 2002; Ren et al., 2006; Vetaas and Grytnes, 2002; Wang et al., 2003) with studies concluding that species diversity peaks closer to the mid-elevational range (Rahbek, 1995, 1997). Bhattarai and Vetaas (2003) interpreted the elevation gradient as a climate-energy gradient that affected the diversity of various life forms along elevational gradient. In a study done in Pakistan, Khan et al. (2013) concluded that vegetation changes with elevation from moist-cool temperate communities to alpine herbaceous communities with an optimal plant species diversity at middle altitudes (2800–3400 m). Correlated with elevation, they found that diversity is reduced at lower elevation due to anthropogenic impacts while at higher elevation shallow soils and high summer grazing pressure reduce the diversity.

The phytomass or plant biomass is a key component of the global carbon cycle that influences the distribution and abundance of herbivores and the resource use pattern by humans (Olff et al., 2002). Therefore, it becomes imperative to study the phytomass or plant biomass patterns in forests which support wildlife and surrounding human population. Phytomass, particularly tree biomass differs with forest types, stand age, site conditions, species composition, size class of trees, edaphic factors, rainfall pattern, and elevation (Cao et al., 2012; Gairola et al., 2011; Peichl and Arain, 2006; Terakunpisut et al., 2007; Zhao et al., 2014). The phytomass pattern along an elevational gradient is not well studied compared to pattern of phytodiversity (Namgail et al., 2012). Whittaker and Niering (1975) studied 15 communities along the elevation gradient in the Santa Catalina Mountains, Arizona and found a reduction in aboveground biomass with elevation. Singh et al. (1994) reported first an increase up to

2600 m above sea level (asl) elevation and then a drop sharply above 3100 m in Central Himalaya. In a study conducted in temperate forests of Kashmir Himalaya, Dar and Sundarapandian (2015) observed higher biomass values in coniferous forest dominated by *Abies pindrow* between an elevation of 2300–2800 m asl and then reported a decline in broad-leaved *Betula utilis* forest which is at a higher elevation of 2800 – 3250 m asl. Namgail et al. (2012) observed a hump-shaped relationship between aboveground phytomass and elevation in the alpine steppes of Ladakh, India. They argued that a lower biomass at lower elevation could be due to trampling and overgrazing of plant resources by domestic livestock.

1.4.3 Human-Wildlife Interaction: Implications for livelihood of local communities

'Human-wildlife conflict involves interaction between humans and wildlife where negative consequences, whether perceived or real, exists for one or both the parties' (Decker et al., 2002). It usually suggests opposition of interests of group/s to those of conservation values. This conflict arises due to competition for limited resources and have existed since long, but an increase in the hostile encounters in recent years has been recorded as a result of expansion of human settlements and their activities into and around wildlife habitats or success of various measures taken for conservation of wildlife and their habitat in a human dominated landscape (Gubbi, 2012; Nyhus and Tilson, 2004; Sawarkar, 1986; Vijayan and Patil, 2002). The resultant conflict jeopardizes conservation goals and human well-being. In the current scenario of increasing human population, resource scarcity and economic imbalance, the

conservation goals and ecosystem sustenance are threatened and might escalate the negative impacts of human-wildlife interactions (Limenh, 2007). Human settlements expand into and around wildlife habitats that results in transformation of wildlife habitats into urban and sub-urban areas and agrarian ecosystems (Nyhus and Tilson, 2004) and shrinking of species population into marginal habitat patches (Siex and Struhsaker, 1999), while overgrazing by livestock in the wildlife habitats results in decline or local extinction of wild herbivore populations (Mishra et al., 2003). Recovery of declining populations of many large mammals, due to efficient wildlife management and large network of protected areas worldwide has also lead to increased conflicts (Fall and Jackson, 2002; Saberwal et al., 1994; Vijayan and Patil, 2002; Woodroffe et al., 2005a).

Livestock depredation is globally the most common form of human–wildlife conflict and can involve a variety of taxa including felids, canids, ursids and raptors (Thirgood et al., 2005). Almost all large carnivore species specialize in ungulate predation and attack domesticated ungulates whenever an opportunity arises (Karanth et al., 1999). The problem is alike across the globe and involves livestock depredation by tiger, leopard, snow leopard and wolves in Asia**,** by puma and jaguar in South America, wolf and bear in North America and Europe and a number of felids and canids in Africa (Butler, 2000; Conforti et al., 2003; Jackson and Wangchuk, 2001; Kaczensky, 1999; Madhusudan, 2003; Mishra, 1997; Nowell and Jackson, 1996; Treves and Karanth, 2003).

Besides livestock predation, crop damage is another form of human-wildlife conflict. Agricultural crops and fruit orchards are often damaged by wild ungulates, primates and granivores and frugivores birds. A number of ungulate species including white-tailed deer, wild boar, nilgai, barking deer, wild ass etc. cause damage to both food crops and young shoots of other crops and plantations (Dave, 2010; Jhala, 1993; Linkie et al., 2007; Sekhar, 1998; Sillero-Zubiri and Switzer, 2001). Elephants are known to cause large scale damage to crops and human lives across their range in sub-Saharan Africa, South-East Asia, and the Indian sub-continent, and are the most studied crop-raiders among all (Gubbi, 2012; O'Connell-Rodwell et al., 2000; Sitati et al., 2003; Sukumar, 1993; Zhang and Wang, 2003). Primates are also nuisance species when it comes to damage to any food plant including fruit trees, grains, peanuts, pulses etc. (Linkie et al., 2007; Naughton-Treves et al., 1998; Sillero-Zubiri and Switzer, 2001).

The research on HWC has primarily been focused around natural science with a resultant well-understood ecology of some conflicts (Woodroffe et al., 2005b). However, it involves people, and it is very essential to understand attitudes, beliefs and values of stakeholders to mitigate conflicts (Ogra, 2008; Redpath et al., 2004). In rural areas where livestock holdings and agriculture are an important part of household's livelihood and incomes, competition between local communities and wild animals for the use of natural resources is intense thus escalating conflict (Mishra et al., 2003). The intensity of loss and resulting retaliation among the local communities against the wild mammals is high in tropics and developing countries (Distefano, 2005).

The losses incurred by the local communities have monetary as well as psychological implications (Ogra, 2008). The economic costs attributed to such losses amount from 12% of the household income for livestock predation in Zimbabwe (Butler, 2000) to 30% of household income due to livestock depredation and crop loss in Karnataka, India (Madhusudan, 2003). In two cattle ranches adjacent to boundary of the Tsavo East National Park in Kenya; attacks of lions, spotted hyenas and cheetahs resulted in loss of 2.4% of total herd per annum amounting to US$ 8,749, while in Annapurna conservation area of Nepal, locals lost almost a quarter of the average annual national per capita income to livestock depredation by snow leopard (Oli et al., 1994). Karanth and Nepal (2011) noted that 90% of the households were affected by losses in all the PAs in India and Nepal. In Chitwan National Park, Nepal, 90% of the households reported crop losses due to the wildlife (Spiteri and Nepal, 2008). In the Jigme Singye Wangchuck National Park, Bhutan, 21.2% of households lost 2.3% of their livestock per annum, which amounted to 17% of their total per-capita cash income. In the region of Xishuang Banna Nature Reserve, China, large-scale crop and property damage by elephants resulted in loss of 28% - 48% of the annual income of locals, with a total loss of US$ 314,600 between 1996 and 1999 (Zhang and Wang, 2003). In the Caprivi region of Namibia, elephant crop damage and lion depredation resulted in an economic loss of US$ 39,200 (1991-1995) and US$ 70,570 (1991-1994), respectively (O'Connell-Rodwell et al., 2000). Weladji and Tchamba (2003) recorded a loss of 31% of crop and 18% of livestock incomes with a significant variation among communities in and around Benoue Wildlife Conservation Area, Cameroon. People living inside the

northern border of Tambopata - Candamo Reserve in Peru experience conflict with wildlife with an annual loss of US$ 45 and US$ 145 for crop and livestock damage respectively (Naughton-Treves et al., 2003).

Locals living adjacent to Bhadra Tiger Reserve, India lost an approximate 11% of their grain production to elephants and 12% of their livestock holding to large cats annually (Madhusudan, 2003). Similar is the case of Sariska Tiger Reserve where agriculture and livestock rearing are main economic activity of 117 villages situated in and around the reserve. Damage to crops of chickpeas, maize, mustard, wheat etc. from wild ungulates was 6 - 27% of total crop yield per ha. The total economic loss from crop damage and livestock depredation by tiger and leopard was INR 2500 to 3500 per household (Sekhar, 1998). A small population of blackbuck around two villages in Gujarat caused loss of 48,600 kg of *Sorghum* crop in a single season accounting for economic loss of INR 29,000 (Jhala, 1993). In Kibber Wildlife Sanctuary, India, pastoralist communities incurred a loss of 18% of their livestock holdings to snow leopard and wolf attacks, an economic loss equaled to 25% of annual income per household (Mishra, 1997). Similarly, around Hemis National Park, India, snow leopard and wolf killed 492 animals within a period of 14 months valued at US$ 23,500 (Jackson and Wangchuk, 2001). Rao et al. (2002) in the western Himalaya, India, found that crop damage varied from 18% to 60% depending on location of the field with respect to the forested area. On the other hand, One-horned rhinoceros in the vicinity of Chitwan National Park, Nepal, caused loss of 10-100% of crops putting considerable monetary burden on villagers (Mishra, 1982). In Nanda Devi Biosphere Reserve, more

than 40% area was damaged for all crops with an average monetary loss of INR 2590 per household, annually. In Rajaji National Park, crop damage due to wild animals ranged from 20-50% of total harvest (Ogra and Badola, 2008).

Such financial losses are particularly damaging if occurring in regions with underdeveloped economies (Mishra et al., 2003). The relative impact of damage caused on household's income varies greatly according to the economic dependence on agriculture and livestock and for households with subsistence economies, even small losses can be significant (Oli et al., 1994; Sukumar, 1993; Thirgood et al., 2005). Costs are escalated if investments are made in fencing or damage limiting measures or if the conflict is severe, families abandon cultivation of otherwise profitable land (Naughton-Treves et al., 1998; Schumann et al., 2006).

1.4.4 Community participation in forest conservation

Despite the proposition that natural resources need protection from the destructive yet apparently rational actions of people, communities have shown that they can work together for long-term resource management (Pretty, 2003). Communities have long been known to manage common resources such as forest and grazing lands effectively over long periods without external help (Ostrom, 1990) and a number of local groups act effectively in resource management with good knowledge of local resources, appropriate institutional, social and economic conditions (O'Riordan and Kleeman, 2002). A number of workers have studied variations in resource governance and conditions through resource economics (Lise, 2000), common property (Ostrom,

1990), rural sociology (Goldman and Schurman, 2000) and environmental politics (Gibson and Marks, 1995) while some others have acknowledged the importance of communal institutional forms (Campbell et al., 2001; Ribot and Peluso, 2003). Many workers argue that involving local communities in decision making regarding conservation and resource management within surrounding lands or buffer zones result in more effective protected areas (DeFries et al., 2007; Hansen and DeFries, 2007) and that the protected areas alone do not guarantee effective conservation, and areas and programs which integrate human populations as management actors are needed for ensuring conservation (Nepstad et al., 2006). Studies have found that the participatory forest management (PFM) or involvement of community in forest management contributes significantly towards forest conservation (Blomley et al., 2008; Takahashi and Todo, 2012; Thoms, 2008). The community-based ecosystem management works best with the conviction that healthy ecosystems and community wellbeing are interdependent and recognizes that communities are key to sustainability and that to be sustainable, it must work with other communities on ecological, social, and economic aspects (Gray et al., 2008). The underlying premise here is that the sustainable forest management will most likely occur only when local communities get access to direct benefits from participating in forest management (Agrawal and Ostrom, 2001; Ostrom, 1990) with the objectives of enhancing forest conservation, reducing poverty, and achieving village level development (Agrawal and Gibson, 1999; Agrawal et al., 2008; Andersson et al., 2004; Ribot et al., 2006; Somanathan et al., 2009).

In Mexico, over half of the forests were given to local communities through 290–479 community forest enterprises which resulted in important gains in both social and economic justice, good forest management and biodiversity protection in the area (Bray et al., 2003). In Ethiopia, Ameha et al. (2014) found that when PFM members had economic incentives in the form of both subsistence and cash incomes, the program was successful in halting 3% annual deforestation reported in the area. In Nepal, Yadav et al. (2003) found that after the introduction of community forestry, the forests at all the sites improved which were deteriorating before the program. Adhikari et al. (2007) found that the number of trees on private land and supply of forest products from them improved after the introduction of community forestry, leading to improved forests. In the mid-hills of Nepal, Dev et al. (2003) found that community forestry based on 'Forest User Groups' with controlled extraction and grazing resulted in improved and more sustainable forest product and benefit flows to local communities.

In India, common pool resources have been estimated to contribute some US$5 billion per year to the income of the rural poor (Beck and Nesmith, 2001). The traditional state-owned and run systems of forest management have failed drastically in curtailing the depletion of India's forest resources against growing anthropogenic pressures. It has been increasingly recognized that the incessant forest degeneration can be restrained through establishing environmental governance mechanism that involves partnerships between the forest department and forest-dependent communities when ecological and economic benefits for the community are ensured (Paul and Chakrabarti, 2011). Realizing the need of involving local communities in forest management, Joint

Forest Management (JFM) was started in 1990 in India. There are nearly 106,482 villages covering an area of 22 million ha of forestland in 28 states and 1 union territory in our country under JFM (Pai and Dutta, 2006) which has resulted in rehabilitation of forestland, sustainable human development, income generation, decentralization of resources and rural empowerment (Prasad and Kant, 2003). However, the program suffered at many places because of fragile institutional arrangement, inappropriate conflict resolution mechanism, inefficient accountability mechanism and poor collaboration between the participating partners (Bhattacharya et al., 2010). Nayak and Berkes (2008) in a study in Orissa found that villager's participation in forest management and the bundle of rights held by them declined after the initiation of JFM along with more politicized environmental governance. Thus, they argue that the JFM should be built upon the existing strengths of community-based management.

Various communities globally are involved in management of common pool resources such as forests, through traditional ways and institutions (Berkes et al., 2000). Soltani et al. (2014) found in Zagros region of Iran that the traditional institutional arrangements of local community were successful in preserving forest resources without any state control. In India, there are many noteworthy instances of protection of natural resources by people that include protection of *Khejri* trees and Black buck by Bishnois of Rajasthan, *Chipko* movement of Uttarakhand and protection of sacred groves, sacred trees and sacred ponds throughout the country (Bhattacharya, 1995; Gadgil and Chandran, 1992; Gadgil and Vartak, 1976; Malhotra and Poffenberger, 1989). There are a number of projects in the Indian Himalayan Region that involve local communities

and encourage sustainable livelihood generation and biodiversity conservation in the area *viz.* Growers Forum (Rastogi, 2004), the Biodiversity Conservation and Rural Livelihoods Improvement Project (BCRLIP) and Rural Technology Demonstration and Training Centre (RTDTC) (Maikhuri et al., 2010).

In many rural communities of Uttarakhand, economic structure and social organizations are built around the primary relationships with the natural resources. The villagers have had a strong tradition of harmonious relationships with surrounding forests with many activities and management of grazing grounds and fuelwood and fodder reserves (Kandari and Gusain, 2001). Extraction of forest produce is undertaken in groups during periods fixed by the consensus of the community so as to reduce the risks of over-exploitation by individuals (Rao et al., 2003). Van panchayats (VPs) in the hills of Uttarakhand originated before independence from British rule and the state allows for the creation of forest councils by villagers since 1931 (Lise, 2000). Currently, there are 12,089 forest panchayats managing 5449 km^2 of forests which accounts for over 15% of total forest land in the state of Uttarakhand. These VPs decide on how to use the forest and give permission for collection of resources such as fuelwood, fodder and timber from the forests. However, despite their ability to protect and manage the forests better than alternative systems such as reserved or civil forests, VPs are constantly plagued by conflicts resulting in difficulty in maintaining the proprietary rights (Ballabh et al., 2002).

1.5. Objectives, Key Questions and Hypotheses

The objectives of this study are as follows:

1. To quantify the extent of extraction of plant resources in different villages located at different elevations.
2. To assess the availability of major phyto-resources in and around the villages and surrounding forests along elevational gradient in the Alaknanda river basin.
3. To assess the extent of human-wildlife conflicts affecting the livelihood in the study area.
4. To measure the contribution of community forest management practices in livelihoods of local communities.

The key questions framed for the study are as follows:

1. What is the diversity and status (availability) of major phyto-resources in the study area?
2. What are the key factors that influence the use of major phyto-resources in different villages?
3. How and to what extent does the extraction of resources change along the elevational gradient?
4. To what extent is the livelihood affected due to human-wildlife conflict in the area?
5. What role do communities play in forest management in the study area?

6. How do the present community forest management practices contribute in livelihood of local communities?

The hypotheses framed for the study are as follows:

1. Patterns of both availability and the extraction of forest resources in the study area change along the elevational gradient.
2. Human–wildlife conflicts negatively impact livelihood generation of affected communities.
3. Community forest management practices play a role in augmenting livelihood of local communities in the area.
4. Better managed forests in an area are the result of community participation in forest management.

1.6 Organization of the Thesis

The thesis is organised into seven chapters:

Chapter 1 provides the background of people-forest interaction in context of the Alaknanda basin in Indian Western Himalaya, putting emphasize on the biomass extraction and phyto-resource availability along the elevational gradient, the monetary value of damage caused to local communities and their livelihood by wildlife and community participation in forest conservation. It reviews the studies conducted globally by workers and highlights the significance of the present work. The chapter concludes with objectives and hypothesis of the study.

Chapter 2 describes the study area *viz.,* Alaknanda river Basin in Western Himalaya and gives details on geographical location, flora and fauna, human habitations and history of management and various conflict issues in the intensive study area in the Kedarnath Wildlife Sanctuary Landscape.

Chapter 3 (first research objective) deals with the phyto-resource use patterns and determinants of resource use along elevational gradient in the study area. Extraction of forest resources viz. fuelwood, fodder, leaf litter by local communities might vary with a number of factors and can be detrimental for forest conservation, particularly within a Protected Area landscape and for poverty alleviation programs in the rural Himalaya. The chapter gives details of methods followed and results obtained on the socio-economic status, resource use patterns along elevational gradient and the contribution of the forest phyto-resources towards the livelihoods of local communities in the study area.

Chapter 4 (second research objective) presents the methods followed and the estimates of phyto-resource availability in the forests and agro-forestry systems along elevational gradient in the region. It gives the results of phyto-sociological analysis in forests including tree community composition, trees stand density, total basal area and total above-ground biomass and of most preferred fuelwood and fodder tree species within forests and agro-forestry systems. The results help to understand the status of resource availability within natural and human systems in the Protected Area Landscape which forms the intensive study area.

Chapter 5 (third research objective) assesses the extent of human-wildlife interaction affecting the livelihood in the study area. It gives results for economic implications of human-wildlife interactions in terms of attacks on human, livestock and crop raiding by large-bodied mammals in the study area. It also describes the acceptability of local communities to government compensation schemes. The baseline information on Human Wildlife Conflict or Negative Interaction is essential for conservation planning, managing conflict scenario and engaging local communities in co-management.

Chapter 6 (research objective four) details the community forest management practices and local institutions involved and measures the direct and indirect impacts of these practices and collective actions of villagers on livelihood of local communities. I also studied the role of community forest management practices on the forest condition (degradation and regeneration status).

Chapter 7 synthesizes the results of the thesis and concludes the thesis, with regards to the forest-people interface within the Protected Area Landscape of Kedarnath Wildlife Sanctuary. Chapter also includes recommendations for reducing phyto-biomass dependence of local communities from forests and to mitigate negative interaction between local communities and wildlife and wildlife managers.





Chapter 2

Chapter 2

Study Area

2.1 Alaknanda River Basin

The Alaknanda River, one of the two head-streamsof the Ganga River, originates from Satopanth and Bhagirath Kharak glaciers in the Chamoli district of the state of Uttarakhand. With an area of approximately 11,000 km², the basin is a highly diversified ecological region with vastly variable climatic conditions and wide elevational variations from 642 m to 7817 m. The river is fed by a number of glaciers, rivers and *nallahs* across its length. Catchment of the river and its tributaries in headwater region is largely barren and is covered largely with snow and glacial moraines. Important tributaries of the river include the Saraswati, Rishi Ganga, Ghrit Ganga, Dhauli Ganga, Khiron Ganga, Birahi Ganga, Pinder, Nandakini and Mandakini. Towards the lower channel; below 3000 m elevation, slopes are covered with great diversity of forests whichgive rise to many *nallahs* and *gad,* feeding Alaknanda and its tributaries along the lower stretches. Like rest of the Himalaya, a mix of hard and soft lithology and tectonic setup makes the Alaknanda River Basin prone to slope failure and landslides (Joshi and Goel, 1988; Negi and Joshi, 2014). A single June 2013 extreme weather event caused new landslides at 3472 locations covering 30.4 km^2 across Uttarakhand state and a loss of around 46 ha of forest and 125 ha of grassland, a major part of which lied in the Alaknanda river basin (Martha et al., 2014).

The river basin lies between 29°58' to 31°04' N latitude and 78°34' to 80°17' E longitude and drains an area of approximately 11,000 km^2 (Devi and Goswami, 2014). The Alaknanda river basin falls in five districts of Uttarakhand; which include Tehri, Pauri, Chamoli, Bageshwer and Rudraprayag. The river originates at the eastern slopes of Chaukhamba peak in Chamoli district and meets Bhagirathi River at Devprayag to form the Ganga. Srinagar, one of the major towns of Uttarakhand, is located along the banks of the Alaknanda upstream from its confluence with the Bhagirathi. The river runs for 141.5km and drains a huge and highly dendritic catchment.

The Alaknanda basin comprises of three faults viz. Trans Himadri Fault, Main Central Thrust and North Almora Thrust. The basin is characterized by varied rock groups, which include tethyan (white sericite quartzite, green to dark phyllite and pelitic schist), central (streaky gneiss with intercalated schist and fine-grained garnetiferous mica schist), crystalline (mica gneiss, quartzite and quartz-mica gneiss garnet amphibolites), Garhwal (dolostone, quartzite and bluish limestone) and Dudhatoli group (phyllites and quartzite) (Negi and Joshi, 2014).

The precipitation in the basin is both in the form of snow and rain. The amount of average rainfall generally varies between 85cm to 200cm with Peepalkoti, Phata and Ukhimath receiving maximum rainfall and Srinagar and Devprayag receiving least.

The basin has three Protected Areas *viz.*, the Nanda Devi National Park and the Valley of Flowers National Park; which are UNESCO world heritage sites and are core zones of Nanda Devi Biosphere Reserve, and the Kedarnath Wildlife Sanctuary. The important mammals are snow leopard (*Uncia uncia*), musk deer (*Moschus* sp.), bharal

(*Pseudois nayaur*), Himalayan tahr (*Hemitragus jemlahicus*), Serow (*Capricornis sumatraensis*), Asiatic black bear (*Ursus thibetanus*) and Himalayan brown bear (*Ursus arctos*) (Bhattacharya et al., 2012; Khachar, 1978; Sathyakumar, 1993, 2004)

There are a number of studies from Alaknanda basin on various aspects including plant species diversity (Kala and Gaur, 1982; Rai et al., 2010; Rawat et al., 2001), fauna and its habitat (Bhattacharya et al., 2009; Green, 1985; Kittur et al., 2010; Sathyakumar et al., 2009; Uniyal, 2004), phyto-resource inventory (Dangwal et al., 2011; Singh, 2008; Singh et al., 2009), human use of resources and anthropogenic pressure (Kala et al., 2002; Kittur et al., 2010; Misra et al., 2009; Sati, 2006, 2008; Silori, 2001; Singh et al., 2010; Thakur et al., 2011), people-protected area conflicts and local's perception (Bosak, 2008; Maikhuri et al., 2001) and human wildlife conflicts (Rao et al., 2002). Studies have evidenced habitat destruction and successional changes in the area because of ongoing unsustainable harvesting and logging practices (Manral et al., 2017; Misra et al., 2009; Thakur et al., 2011). The basin faces several challenges in terms of wildlife offences, encroachment, irresponsible activities of tourists, infrastructure development, pressure from unsustainable harvesting of resources and lack of livelihood opportunities in the area with a continuous change in regeneration patterns in forest stands (Misra et al., 2009; Thakur et al., 2011). There is a wide gap of studies, which stress on managing forests, taking in account the economy and requirements of local communities and enhancing practices to reduce pressure on forests.

2.2 Intensive Study Area

Intensive study was conducted in Madhmaheshwer and Kalimath valleys, which fall in Mandakini sub-watershed in the western part of Alaknanda basin. The sub-watershed covers a significant area of the Alaknanda watershed after the Pinder sub-basin. It is spread over an area of 1638 km^2 and has 441 revenue villages. The higher reaches of the sub-watershed form part of Kedarnath Wildlife Sanctuary (KWS) landscape. Both the valleys form a part of the Kedarnath Wildlife Sanctuary Landscape (Fig. 2.1).

2.3 Kedarnath Wildlife Sanctuary Landscape

2.3.1 Location

The Kedarnath Wildlife Sanctuary (hereafter KWS or PA) is situated in the catchments of Mandakini and Alaknanda Rivers, and forms a large sub-catchment of River Ganga. It is located between 78°54'E and 79°27'E Longitudes and 30°25'N and 30°45' N Latitudes, spread in Rudraprayag and Chamoli districts. The total area of the sanctuary is 975 km^2, of which 722 km^2 lies in Rudraprayag district and remaining in Chamoli district. It is among the largest Protected Areas in the western Himalaya and in the state of Uttarakhand. KWS comprises of two forest ranges *viz.*, Gopeshwar range (14 beats and 3 sections) and Ukhimath range (33 beats and 6 sections) (Singh and Gangte, 2009).

2.3.2 Physical Features

KWS has a wide elevation range from 1200 m to 7068 m, one of the Chaukhamba's peaks being the highest point. Maximum area of KWS is under the elevation zone of 3000-4000 m elevation zone followed by 2001-3000 m zone (Fig. 2.2). Topography is characterized by undulating slopes that are gentler on the North and North-western aspects and steep (> 60°) on South and South-Western faces (Rai, 2012).

2.3.2.1 Geology and Terrain

The sanctuary lies in the central crystalline geological formation in Garhwal Himalaya. The area falling in the parts of Malla Nagpur, Ragsi, Ukhimath and Malla Kaliphat reserves is made up primarily of metamorphic rocks grouped under Central crystalline that consist of gneiss of varying character, chloride schist, kyanite schist, garnet mica schist, and granite (Singh and Gangte, 2009). At the higher elevations, micro-topography is more diverse and reflected in the plant community composition.The elevations above 4500m in sanctuary are characterized by permanent glaciers and snow. Most of the valleys are oriented in a North-South direction so that the area is fully exposed to the summer monsoon (Rai, 2012). Soils in the mountains have a close relationship with the geomorphology and vegetation patterns that play a major role in the pedogenic processes. The soil in KWS is sandy loam in texture, with a high proportion of sand and silt, and generally acidic with pH value between 4 to 5 (Singh and Gangte, 2009).

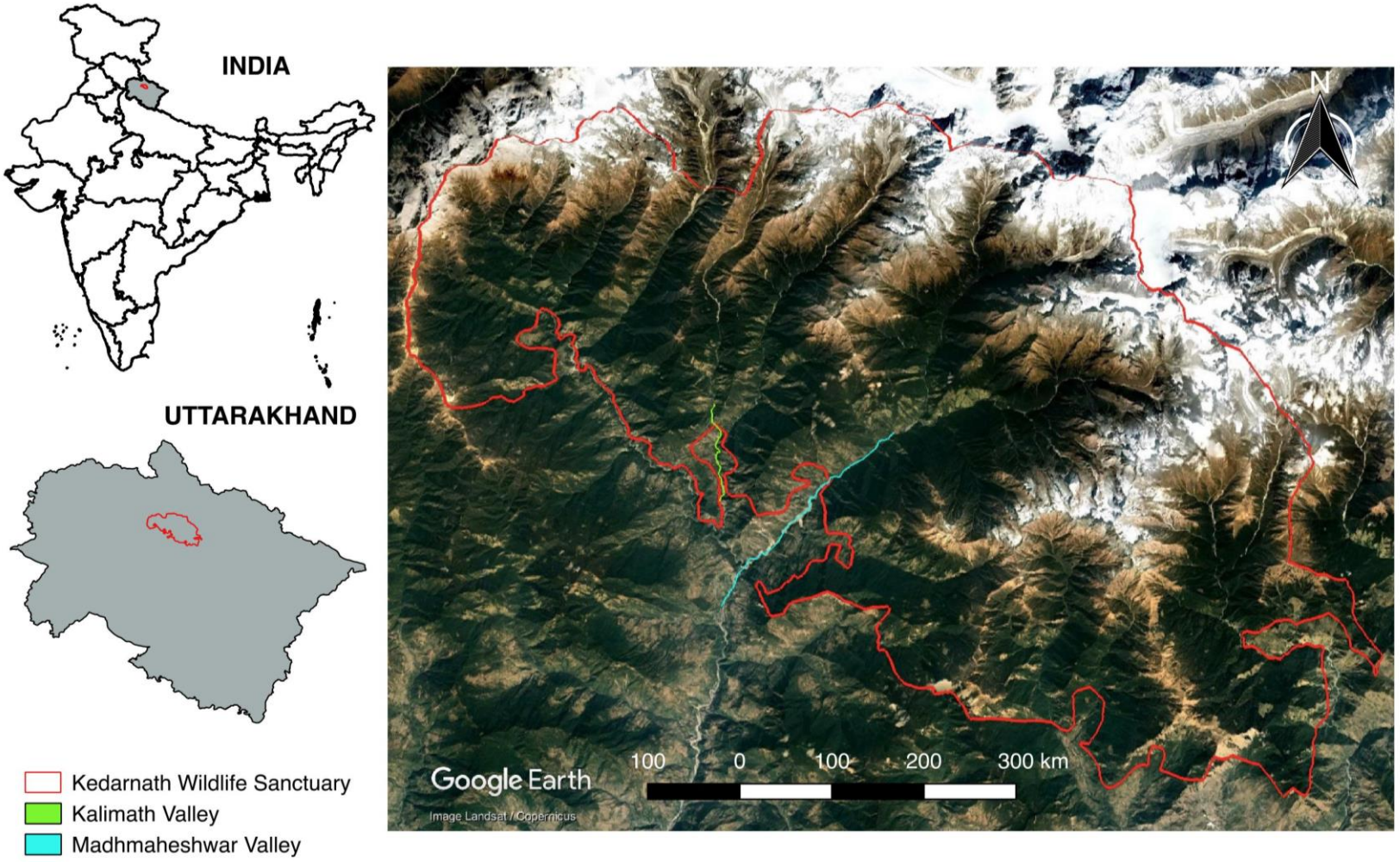


Fig. 2.1. Location map of Kedarnath Wildlife Sanctuary and Madhmaheshwar and Kalimath Valleys

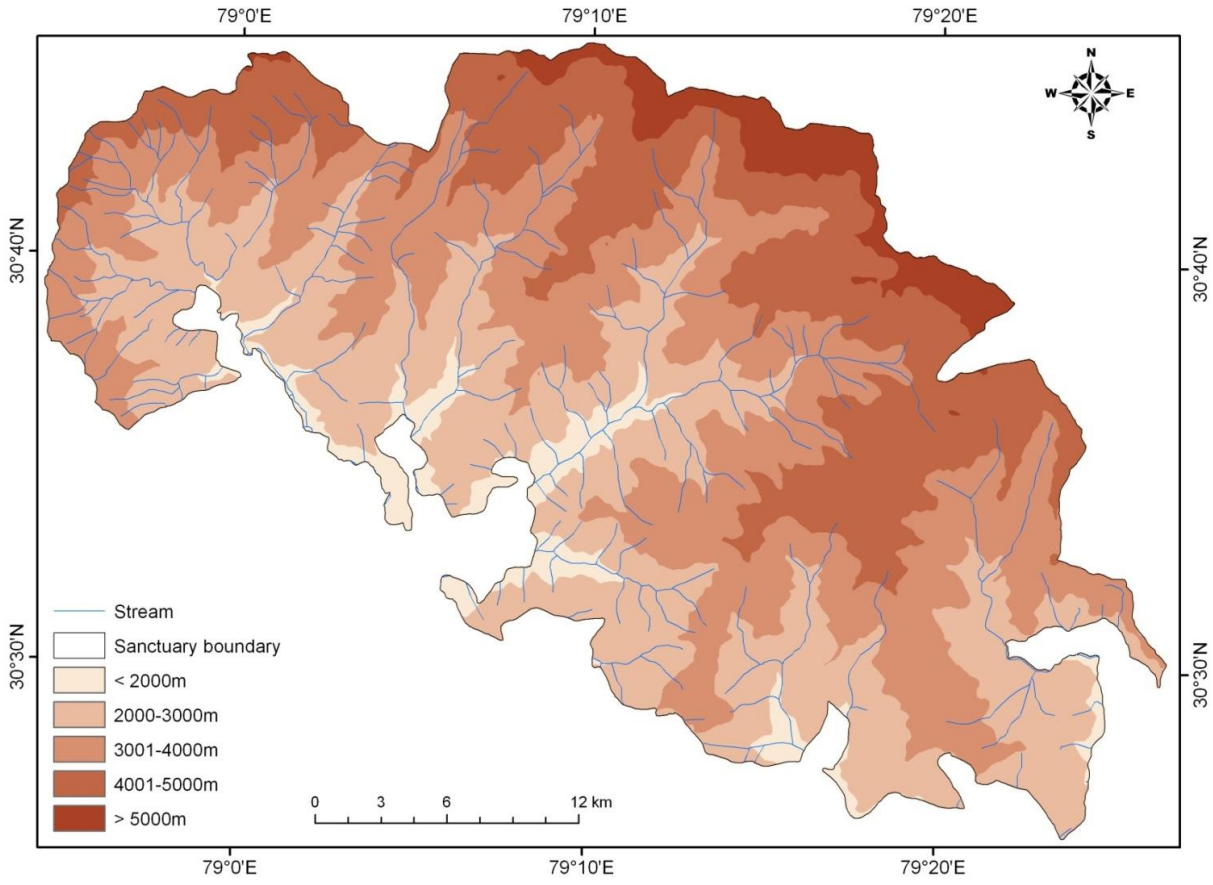


Fig. 2.2. Elevational gradient within the Kedarnath Wildlife Sanctuary

Many regions have sandy and micaceous soil varying in depth with the degree of slope and are rich, deep and excellent for tree growth on favorable aspects (Agrawala, 1973). The terrain of the entire sanctuary is undulating and very steep except in the low lying valleys where there are comparatively gentler slopes.

2.3.3 Climate

The annual climate of the Sanctuary can be divided into four prominent seasons *viz*., summer (May–June), rainy (July–mid-September), autumn (mid-September–October) and long winter (November–April). The Sanctuary is influenced by the South-West monsoon arriving in the June that continues until the end of the September. The sanctuary receives heavy rainfall due to North-South orientation of most of the valleys and the sudden inner Himalayan elevational rise. The mean annual precipitation, which is mostly from South-West monsoon, is 3093 mm. The humidity is high during the monsoon season, on average exceeding 70%. The driest part of the year is the pre-monsoon period when humidity drops down to 35%. In many parts of the area, the annual precipitation reaches up to 3000 mm. Winter sets in November and high reaches of the Sanctuary (> 2000 m) receive light to heavy snowfall from November to March with frequent hailstorms. The landscape has witnessed a number of extreme rain events and cloud-bursts; among these the Kedarnath tragedy of June 2013 is prominent when a large stretch of central and western Himalaya faced unprecedented rainfall and rainfall-induced flash-floods-associated disasters (Sati and Gahalaut, 2013).

The area has a typical temperate to sub-arctic climate with prevalence of cold temperature.Temperature is an important factor in determining vegetation types. In general, the temperature of the area varied greatly along the elevation gradient. At lower elevation along 1500 m, mean minimum and maximum temperature were 8ºC and 30ºC, at 2600 m it ranged from 2.6ºC to 23ºC and at 3300 m it is -15ºC to 25ºC. The mean

minimum and maximum temperatures vary inversely with elevation where January is expected the coldest and June the warmest month of the year.

2.3.4 Biological diversity and significance

The KWS falls under the Himalayan Bio-geographical Zone-2 and West Himalayan Biotic Province- B with alpine, temperate, temperate broadleaf, subtropical forest as biomes (Rodgers and Panwar, 1988).The wide elevation gradient supports a rich diversity of the vegetation type from temperate to subalpine and alpine vegetation. The temperate forest of the region (1500–2900m) is mainly dominated by the oak species. At the warm temperate zone (1500–2200m) *Quercus leucotrichophora* forms dominant vegetation, where landslide areas and river banks are colonized by *Alnus nepalensis*. Cool temperate zone (2200–2700 m) is represented by *Quercus floribunda* forest, where other dominant species are *Acer caesium, Daphniphyllum himalayense, Aesculus indica*, and few species of Lauraceae. Sub-alpine zone (2700–3300m) has preponderance of brown oak (*Quercus semecarpifolia)* on the warmer aspects and *Betula utilis* and *Abies* spp. on the cool northern aspects. The vegetation of alpine region (above treeline) consists of dwarf shrubs *i.e. Rhododendron campanulatum, R. anthopogon, Salix elegans*, *Lonicera myrtillus*; cushionoid herb, grasses and sedges. Permanent ice and snow line has been demarcated as 5000m. The sanctuary is recognised as 'Habitat/Species Management Area' by the IUCN and is reputed to be among the world's richest bio-reserves.

2.3.4.1 Vegetation types and floral diversity

The diverse climate, geology and topography of the region result in a varied floral assemblage in the sanctuary. It is estimated that about 44.4–48.8% of the area is forested, 7.7% is alpine meadows and scrub, 42.1% is rocky or under permanent snow and 1.5% is degraded which was formerly forested (Prabhakar et al., 2001).Champion and Seth (1968)described the vegetation types of the area into four major groups *viz*., Subtropical Pine forest (9), Himalayan moist temperate forest (12), Subalpine Forest (14) and Alpine Scrub (15) and further into19 broad vegetation types. Rai et al. (2017) regrouped the forests of the area (Table 2.1) and recorded 886 dicotyledons and 253 monocotyledons from the area. As many as 17 plant species listed in the IUCN Red List of Threatened species were recorded from the sanctuary (Rai et al., 2017) including *Aconitum heterophyllum, A. violaceum, Angelica glauca, Cypripedium elegans, C. himalaicum, C. cordigerum, Malaxis muscifera, Nardostachys jatamansi* and *Taxus wallichiana* are some of them.

2.3.4.2 Faunal diversity

Thirty two mammals are known to occur in the Sanctuary however, 28 species have been confirmed (Green, 1985; Sathyakumar, 1994). Sanctuary is home to Himalayan musk deer (*Moschus* sp.), an Endangered species under IUCN Red list of threatened species. The common carnivores recorded from KWS include common leopard (*Panthera pardus*), red fox (*Vulpes vulpes*), Himalayan weasel (*Mustela sibirica*) and Himalayan yellow throated martyn (*Martes falvigula*). Among the primates, the Nepal

grey langur (*Semnophithecus schistaceus*) and Rhesus macaques (*Macaca mulatta*) are recorded from KWS. The Himalayan mouse hare or Pika (*Ochotona roylei*) is also recorded in the alpine regions above 2700 m especially in the boulder habitats, feeding on various grass and herb species. Other than musk deer, six ungulate species are also reported from the sanctuary, which include Barking deer (*Muntiacus muntjak*), Himalayan tahr (*Hemitragus jemhalicus*), Himalayan goral (*Naemorhedus goral*), Sambar (*Rusa unicolor*), Serow (*Naemorhedus sumatraensis*) and Wild pig (*Sus scrofa*).

With a wide elevational gradient and rich habitat-diversity, the KWS offers a potential for rich avian diversity. However, no comprehensive list is available and few studies are conducted in parts of Sanctuary. According to a partial checklist, the Sanctuary has 244 species of birds with three globally threatened species (http://avibase.bsceoc.org). Prominent among these are partridges including Snow partridge (*Lerwa lerwa*), Hill partridge (*Arborophila torqueola*), Chukar (*Alectoris chukar*) and Himalayan snow cock (*Tetraogallus himalayensis*) and pheasant species including Himalayan monal (*Lophophorus impejanus*), Kalij (*Lophura leucomelana*) and

Table 2.1. Major vegetation types recorded from the Kedarnath Wildlife Sanctuary (Rai et al., 2017)

S. No.	Broad Classes	Floristic sub-types	Characteristic / Dominant Species	Elevation range (m asl)
1	Subtropical Needleleaved Forest	Chir Pine forest	*Pinus roxburghii* *Myrica esculenta*	1100–1800
2	Montane Boadleaved Evergreen Forests	Banj oak	*Quercus leucotrichophora* *Lyonia ovalifolia* *Myrica esculenta* *Sinarundinaria falcata*	1100–2200
		Oak-*Rhododendron*	*Q. leucotrichophora-* *R. arboreum*	1400-2200
		Lauraceous Mixed Forest	*Neolitsea pallens* *Machilus* spp. *Q. leucotrichophora* *Daphniphyllum himalayense*	1500–2200
		Moru oak	*Q. floribunda* *Symplocos chinensis*	2000–2600
		Kharsu oak	*Q. semecarpifolia* *R. arboreum* *Thamnocalamus falconeri*	2600–3300
3	Montane Broadleaved Deciduous Forests	Alder Forest	*Alnus nepalensis*	1500–2500
		Aesculus-Acer	*Acer villosum* *A. caesium* *Betula alnoides* *Juglans regia* *Aesculus indica* *Carpinus viminea*	1800–3000
4	Montane Needleleaved Forests	Silver Fir	*Abies pindrow*	2400–3300

		Spruce forest	*Picea smithiana*	2500–3000
5	Montane Grasslands	Grasslands on steeper slopes	*Themeda anathera* *Chrysopogon gryllus* *Cymbopogon distans* *Andropogon munroi*	Up to 3300
6	Subalpine Forests	Oak – Fir mixed forest	*Q. semecarpifolia* *Abies pindrow* *Taxus wallichiana*	3000–3500
		Birch – *Rhododendron*	*Betula utilis* *R. campanulatum*	3300–3600
		Himalayan Fir forest	*Abies spectabilis*	
7	Subalpine Bamboo Brakes	Tham ringal	*Thamnocalamus falconeri*	2700–3700
8	Subalpine Scrub	*Krummholtz*	*R. campanulatum, Sorbus foliolosa,* *R. barbatum*	2700-3800
9	Alpine Moist Scrub	*Salix – Lonicera*	*Salix denticulata* *S. lindleyana* *Lonicera myrtillus*	3300–3800
		Rhododendron scrub	*Rhododendron anthopogon* *R. lepidotum* *Cassiope fastigiata* *Cotoneaster microphyllus*	3300–4000
10	Alpine Moist Meadows	Mixed herbaceous formations	*Potentilla atrosanguinea* *Ranunculus* spp. *Geranium wallichianum*	3400–4500
		Danthonia meadows	*Danthonia cachemyriana*	3400–4000
		Kobresia meadows	*Kobresia nepalensis*	4000–4500

Koklas (*Pucrasia macrolopa*). Other recorded fauna include 147 species of butterfly (Singh, 2009) and 64 species of spiders (Quasin and Uniyal, 2010).

2.3.5 Management History

In 1815, the British took control of the forest of the region after they defeated the *Gorkhas*. The Sanctuary forests formed part of Alaknanda catchment *i.e.*, the British Garhwal and during the first two decades of their possession, they classified these forests into class-I and class-II forests. The commercially unimportant forests were included in class-I forest under the control of revenue authorities, while primarily coniferous, commercially important forests were kept in class II under the control of the Forest Department after reserving them. KWS was created in 1972 under the rule 4 of General Hunting Rules UP for a period of 10 years. With the enactment of the Indian Wildlife (Protection) Act 1972, the Sanctuary came under preview and under dual control of the Wildlife Wing (ensuring protection of wildlife) and territorial staff (looking after silviculture and other forestry activities). The Sanctuary is currently managed and protected by Kedarnath Wildlife Forest Division, transferred by the letter of additional Chief Conservator of Forests Wildlife (UP) Lucknow -3705/2-11 dated 5-5-97. Before 1997, KWS was under the DFO Nanda Devi National Park, Chamoli, Uttarakhand.

In 1953; after the National Forest Policy (1952),a 10-year ban on green felling was imposed in the hill region at or above 1000 m elevation that resulted in an end to green felling in KWS also. Various timber extraction practices including fuelwood and

bamboo harvest were done as mentioned in the working plan of the Kedarnath Forest Division, however, the amendment in the Indian Wildlife (Protection) Act, 1972 in 1991 brought all commercial activities from the Sanctuary to a halt. The bonafide residents of Garhwal have rights of livestock grazing, lopping and grass cutting from the Sanctuary area. However written permission of the Deputy Commissioner is needed for felling or lopping of certain species including Deodar, Surai, Toon, Mulberry, Angu, Chir, Jamnoi, Utis, Kaphal, Dalchini, Sain and Akhrot, which is prohibited otherwise (Singh and Gangte, 2009). The landscape has around 172 villages; inhabitants of which depend largely on the Sanctuary forests for their fuelwood and fodder requirements. In the current management plan of Sanctuary, 128 villages situated within 5 km from the sanctuary have been grouped into three categories based on their firewood dependency on the sanctuary area as follows:

1. Villages totally dependent on sanctuary area for firewood.
2. Villages partially dependent on sanctuary for firewood i.e., they also visit forests outside the sanctuary for firewood.
3. Villages not dependent on sanctuary for firewood.

Van Panchayat also exist in the Kedarnath Wildlife Sanctuary Landscape *viz.*, Gaurikund (3032.90 ha), Makku (617.30ha), Ushada (602.9 ha) and Kalimath(800 ha) which are under the control of a village's *Panchayat* and revenue authority.

2.3.6 Park-People Interface: People, their economy and conservation concerns

There are 12 villages inside the sanctuary and 160 villages within 5km of the boundary of the sanctuary. The villages are located from sub-tropical to temperate

region (≤ 2400m). The main community in the area is Garhwali. All the villages have permanent settlements; however, some of the inhabitants from temperate villages seasonally migrate to temporary summer settlements (at higher elevations in forests gaps and secondary meadows and alpine meadows) with their livestock because of better fodder availability. Like most parts of the Western Himalaya, the local communities in the KWS landscape are largely agro-pastoralist with small terraced agricultural land and largely depend on forest resources for day-to-day sustenance such as for collection of fuelwood, fodder and NTFP, forest floor biomass to be used as bedding material in cowsheds and as farm manure, edible fruits, fiber and medicinal plants (Singh et al., 2012; Malik et al., 2014). The poor families of villages collect grass from forest slopes or dried wood to be sold within the village.

Surplus agricultural harvest of crops such as potato and other vegetables and mustard are sold within the village while citrus fruits (*Malta*), kidney beans and amaranth are sold to contractors from the lower plains. Livestock reared by locals include cow, oxen, goat, sheep, mules and horses. Cows are reared for dairy products for household consumption or sometimes for supplementing a family's income. Oxen are mainly used for agricultural work. Goats and sheep are reared primarily for meat and as source of quick cash; however, sheep are also kept for wool. The traditional weaving by locals is decreasing, as less and less youth are willing to learn the practice. Mules and horses are kept by a few families only for income from transportation of goods within the village and during the tourist season. People have also started rearing hybrid cows and buffaloes for better production of milk. Other livelihood opportunities

include silviculture and other forest activities conducted by the forest department, religious and adventure tourism, armed forces, teaching and other government and private sectors.

The KWS landscape has a number of Hindu shrines, prominent among which are five Kedars (*Shiva* temples) *viz., Kedarnath, Madhmaheshwar, Tungnath, Rudranath* and *Kalpeshwer*. The Kedarnath temple; dating back to the 8th century, is part of the *Char Dham* circuit in Uttarakhand Himalaya, attracting thousands of pilgrims. Other temples include Mandani, Kalimath and Anusuya Devi. These temples; particularly Kedarnath support local economy greatly, as men and young boys from villages of landscape work as guides, porters or run shops, *dhabas* and lodges in and around these temples. Nature and wildlife tourism is also gradually gaining momentum among tourist in the area. Famous treks include *Deoriya–Tungnath-Chopta, Madhmaheshwer, Nandikund* and *Mandani*, to name a few.

Studies have indicated impact of disturbances on wildlife and its habitat inside the Sanctuary. In recent times, the landscape has seen increased population growth, encroachment and development activities on the fringes of KWS and unsustainable harvesting of resources from within the Sanctuary and consequent, forest degradation and change in regeneration patterns of native flora and wildlife offences (Baghar et al., 2014; Misra et al., 2009; Thakur, 2011). Kittur and Sathyakumar (2010) and Bhattacharya et al., (2012) found a minimal habitat overlap between wild mountain ungulates and livestock in the alpine regions of KWS. However, presence of wild herbivores in these locations during winters indicates that the minimal habitat overlap

could be due to spatial displacement or exclusion of the wild animals from certain habitats due to anthropogenic disturbance. Studies have also indicated continuous extraction pressure on Sanctuary forests by local communities and predicted dispersal of anthropogenic disturbance deeper into relatively undisturbed forests (Malik et al., 2014; Singh et al., 2010).

Like the rest of the Himalaya; in the KWS too, subalpine forests terminate into a sharp and abrupt treeline separating two extensive ecosystems of Himalaya *viz.,* subalpine forest and alpine meadows. Along with anthropogenic pressure, the area is highly prone to projected climate change in Himalaya and consequent changes in vegetation structure and composition. In recent decades, changes have been observed in precipitation and temperature, which have its implication on plant phenology (Kulkarni et al., 2013; Rashid et al., 2015; Zomer et al., 2016). Adhikari et al. (2012) studied the plant phonological responses to inter-annual climate variation and found a significant variation in major processes such as leaf bud break, leaf fall and flowering in timberline species with respect to variable environmental variables such as snowfall, temperature and snow melting patterns. They also studied the response of small range mammals to inter-annual climate variation and found it varied significantly with variable abiotic and biotic factors such as temperature and availability of food plants.





Plate 2.1: Religious and Natural tourism sites within the Kedarnath Wildlife Sanctuary Landscape. A: Kedarnath*;* **B:** *Madhmaheshwer;* **C:** *Tungnath;* **D:** *Kalishilla;* **E:** *Deoriya Taal;* **F:** A village temple in Ransi

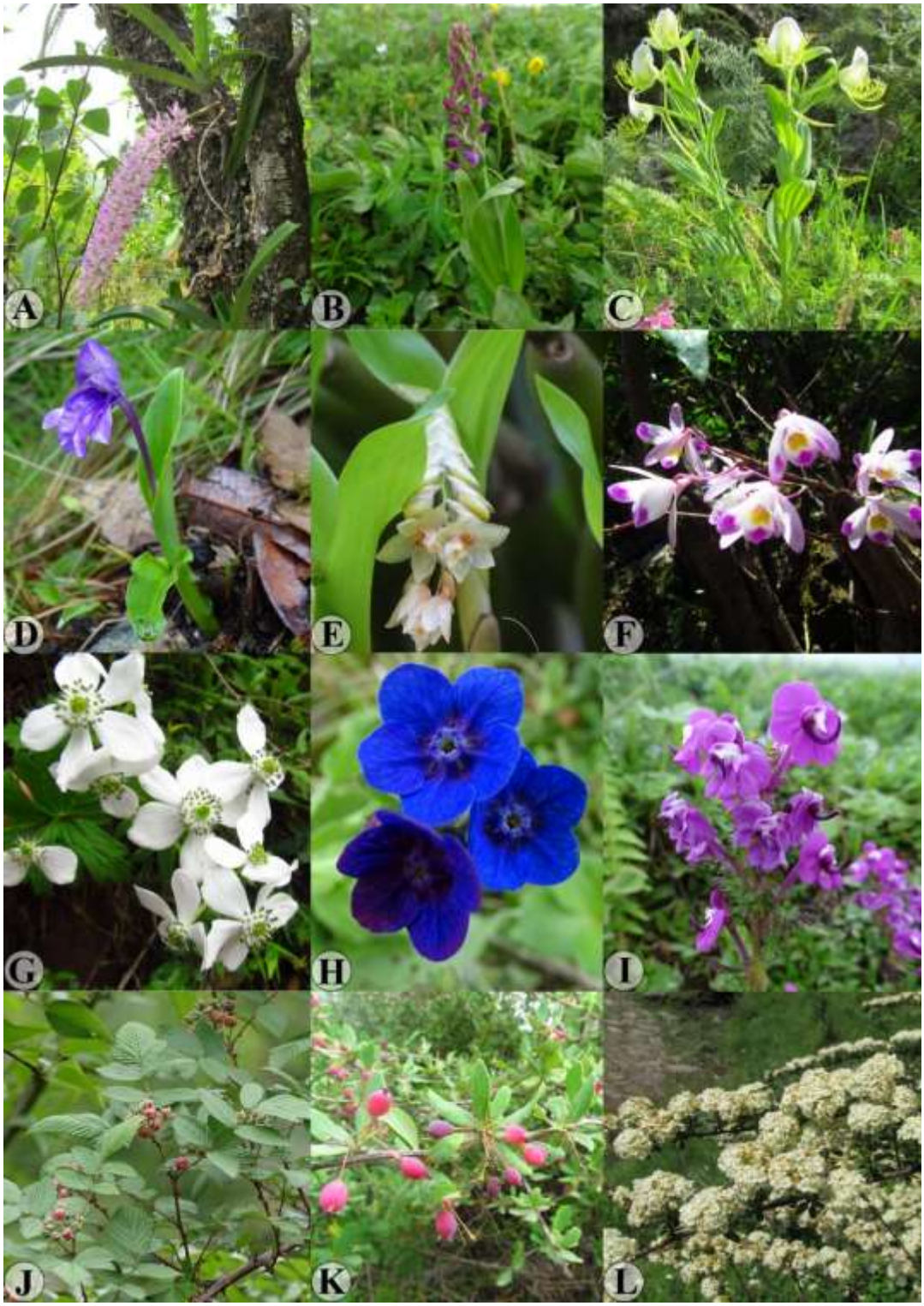


Plate 2.2: Glimpses of floral diversity of the region. A: *Rhynchostylis retusa;* **B:** *Gymnadenia orchidis;* **C:** *Habenaria intermedia;* **D:** *Roscoea alpina;* **E:** *Pholidata articulata;* **F:** *Dendrobium amoenum;* **G:** *Anemone raui;* **H:** *Cynoglossum zeylanicum*; **I:** *Pedicularis punctata*; **J:** *Rubus niveus*; **K:** *Berberis lycium;* **L:** *Spiraea canescens.*



Plate 2.3: Glimpses of faunal diversity. A: *Vanessa indica;* **B:** *Acraea issoria;* **C:** *Heliophorus sena;* **D:** *Alectoris chukar;* **E:** *Columba leuconota;* **F:** *Garrulax albogularis;* **G:** *Urocissa erythroryncha;* **H:** *Gyps himalayensis*; **I:** *Lophophorus impejanus*; **J:** *Ochotona roylei*; **K:** *Martes flavigula;* **L:** *Ursus thibetanus*.

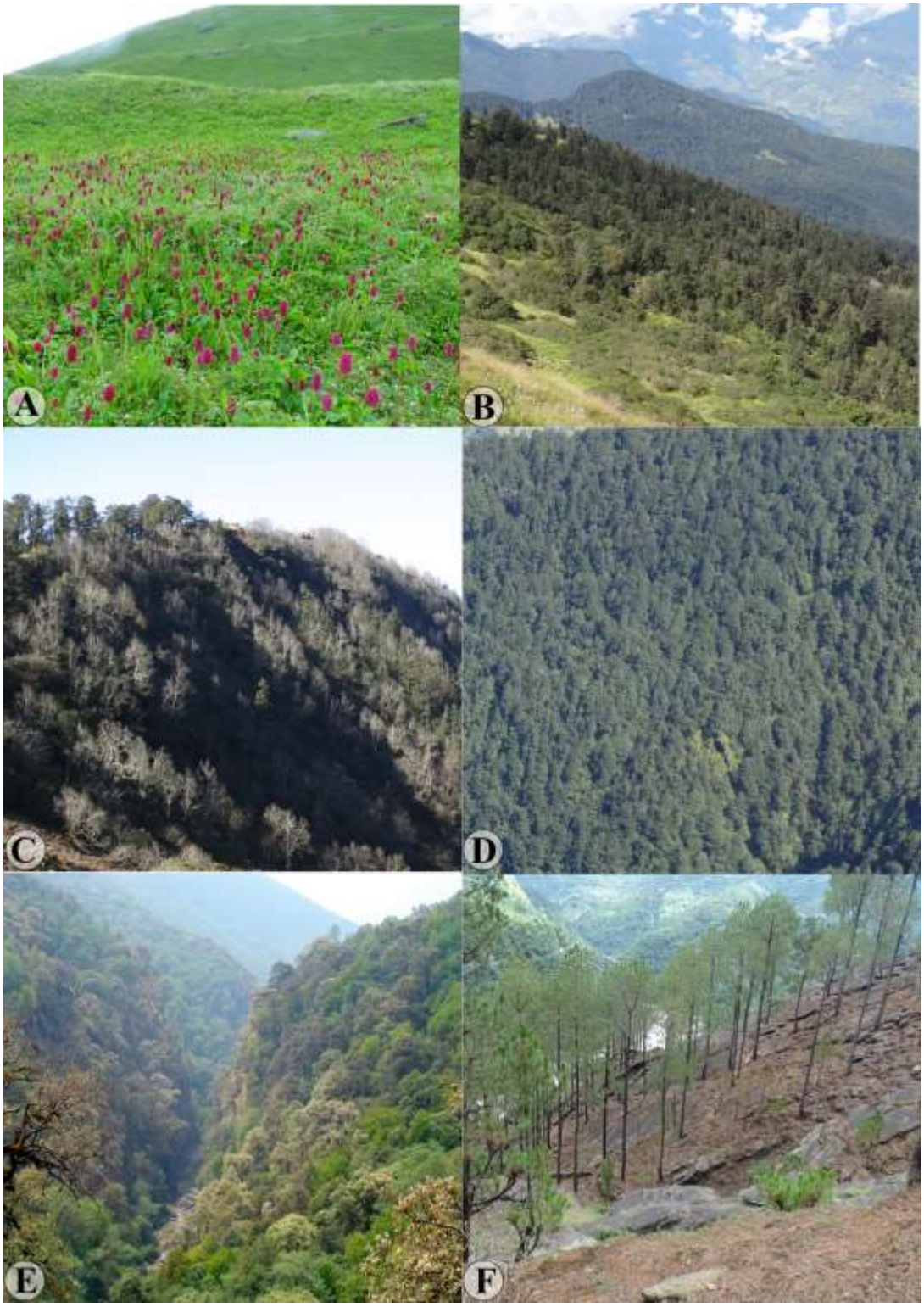


Plate 2.4: Vegetation types in the landscape. A: Alpine meadow; **B:** Subalpine fir forest and treeline; **C:** Subalpine birch forest; **D:** Kharsu oak forest*;* **E:** Banj oak-mixed forest*;* **F:** Chir Pine forest.

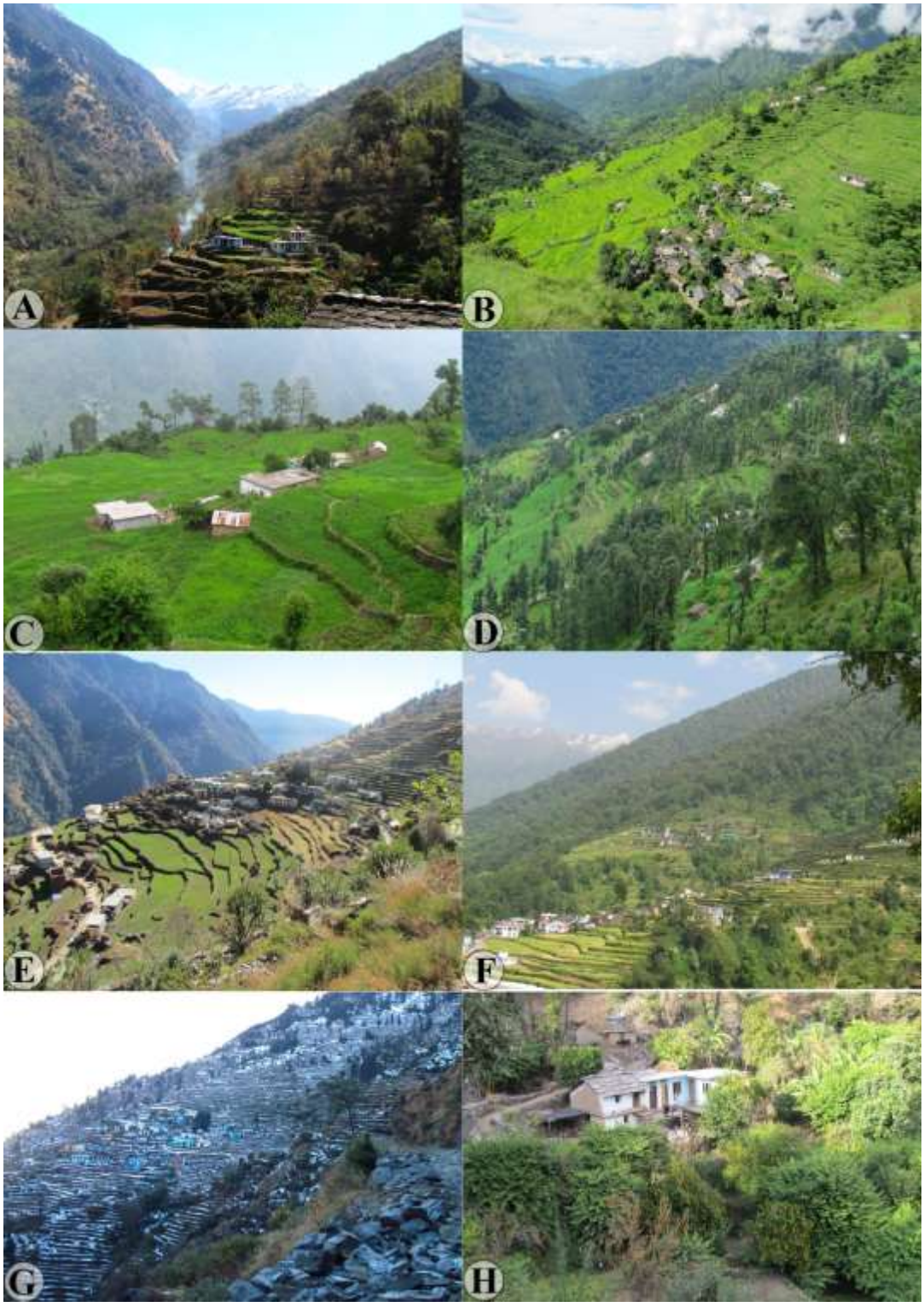


Plate 2.5: Representative villages from study area (A-G); H: Multi-purpose tree species in Agro-forestry system within a study village



Chapter 3

Chapter 3

Socio-Ecological System:

Socio-Economic Status and Resource Use Pattern

3.1 Introduction

Forests significantly contribute towards the livelihoods and well-being of millions of people across the globe, with many communities depending on a number of forest products and services for their day-to-day sustenance and income (Adhikari et al., 2004; Babulo et al., 2009; Belcher et al., 2015; Jagger et al., 2014; Mamo et al., 2007; Pokorny et al., 2012; Zenteno et al., 2013). Forests act as 'the hidden harvest' or 'livelihood asset' which lays the foundation of human survival and provide a safety net for the marginalized sections of society in a forested landscape (Angelsen and Wunder, 2003; Barrow and Mogaka., 2007; Sherbinin et al., 2007). A number of studies in developing countries have shown that for market-remote rural economy, subsistence resource use and nonmonetary income is more important than cash income (Cavendish, 2000; Fisher, 2004). In the Indian Himalayan Region, forest constitute an important natural capital stock providing a number of tangible ecosystem services such as fuelwood, fodder, timber, wild fruits, medicinal plants and intangible services such as hydrologic regulations, climatic control, soil formation, carbon sequestration, recreation etc. (Dobriyal, 2015; Saxena et al., 2005; Singh and Singh, 1986; Singh and Singh, 1992). The remoteness and isolation due to low connectivity combined with lack of access to sources of cash income and alternatives for natural resources have made forests the main source of sustenance

for local communities, mainly for energy demands and to sustain the agro-pastoralist economy (Bhatt and Sachan, 2004).

Forest resource extraction can be extremely heterogeneous, even at local levels. A number of factors such as socioeconomic and demographic conditions, cultural values and belief systems and market influence lead to variation in an individual's, household's or a community's dependence on natural resources (Anglesen et al., 2014; Baral and Heinen, 2007; Jumbe and Angelsen, 2007; Coulibaly-Lingani, 2009; Maskey et al., 2006). One of the most important factors that influence forest dependence is a family's income or economic well-being (Adedayo et al., 2010; Cavendish, 1999; Pyhälä et al., 2006; Quang and Anh, 2006). A number of environmental factors such as climate, household's geographic location within the landscape and distance of household from resource base also influence resource use patterns (Adhikari et al., 2004; Coomes et al., 2004; Mamo et al., 2009). In the mountainous systems such as Himalaya, high spatial and climatic variability results in spatial-temporal variability in floral assemblages and availability of plant biomass to dependent communities (Rao et al., 2003). Elevation is an important component of this spatial variation and the relationship between elevation and plant diversity is well studied in Himalaya (Anthwal et al., 2008; Bhattarai and Vetaas, 2006; Ren et al., 2006; Vetaas and Grytnes, 2002; Wang et al., 2003). This high variability in plant resources might give an advantage to households having better access to resources, based on their geographical location.

Management regime of forests also influences the forest dependence and income of households from natural systems as reported by Jagger (2014) in a study done across

the tropics. Creation of Protected Areas has become a key strategy to address the immense forest and biodiversity loss across the globe as the Protected Areas now constitute world's dominant land use type (UNEP-WCMC, 2014; Watson et al., 2014) and are recognized as the cornerstones for conservation of natural systems and biodiversity (Mulongoy and Chape, 2004). The exclusionist policies involved in PA creation have resulted in either displacement of people from the landscape or denied and limited access to resources (Brockington and Igoe, 2006). The adverse effect of such exclusionist policies has been felt particularly hard by many communities in India, given the high biodiversity and large population size. In India, a large landscape within Protected Area network is either inhabited by various local and indigenous communities or supports subsistence resource use by neighboring communities (Kothari et al., 1995). Plant resource extraction is not permitted in the national parks, is partially allowed in sanctuaries and permitted in reserved and other categories of forests (Shahabuddin and Prasad, 2004). Thus, local communities and their use of resources is a prevalent feature of many protected area landscapes in the country.

The study area falls in Alaknanda river basin and constitutes the part of Kedarnath Wildlife Sanctuary Landscape in Mandakini sub-watershed. With 441 revenue villages falling in Mandakini sub-watershed and 172 in Sanctuary landscape, forests of the region form the foundation of local rural economy. The region is rapidly changing due to increasing human population and development activities and has seen unanticipated environmental events in the recent past. This has exposed the local communities to risks and vulnerabilities and in such a scenario, the forests and natural

resources of the region might improve their capacity for resilience. A household or community's extraction choices may drive either environmental degradation or enhancement, thus having strong implications for forest conservation of a region (Cavendish, 2002). Thus, it becomes imperative to understand how forests are related to rural sustenance and livelihood in the study area for developing sustainable pro-poor incentives and designing conservation and development policies. Keeping this in mind, I quantified the extraction of forest resources by the local people from the Sanctuary, community forests and agro-forestry systems and uncovered the key factors that influence the use of major phyto-resources in different villages. As the region has wide elevational gradient, I hypothesized that patterns of forest resource extraction in the study area change along the elevational gradient.

3.2 Methodology

3.2.1 Reconnaissance survey and secondary data collection

At first, I visited the study area for a rapid survey to obtain information about the area *viz*., major forest types, location of villages with respect to distance from forests and roads, and elevation. As the intensive study area falls within the Kedarnath Wildlife Sanctuary (KWS) landscape, location of villages with respect to the Sanctuary was also recorded. Discussions regarding general community characteristics, principal services available, primary livelihoods, primary crops and traded agricultural products, forest-resources collected and collective actions of community relating to forest conservation or other environmental issues were held with the villagers. Secondary data on

demography and socio-economic indicators, number of beneficiaries of various government schemes related to employment opportunities and cases of human-wildlife conflict in the area was procured from government departments such as Block development office, Forest department and Horticulture department.

3.2.2. Site selection

A total of 38 villages grouped into 23 *Gram sabha* (revenue villages) were identified as falling in the intensive study area (both Madhmaheshwer and Kalimath valleys). The data, collected from reconnaissance survey and from various departments and agencies, was subjected to Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA), to identify homogeneous groups of villages based on selected characteristics using an algorithm that starts with each case in a separate cluster using SPSS 16.0.A total of 33 variables were used to run PCA out of which 23 were chosen for HCA based on their contribution to the variance in the data (Appendix 3.1). For HCA, I used the 'Nearest neighbors' method while intervals were measured using 'Squared Euclidian Distance'. HCA resulted in four clusters of villages (Fig. 3.1, 3.2) and representative villages within each of the identified clusters were selected in proportion to the size of each cluster.

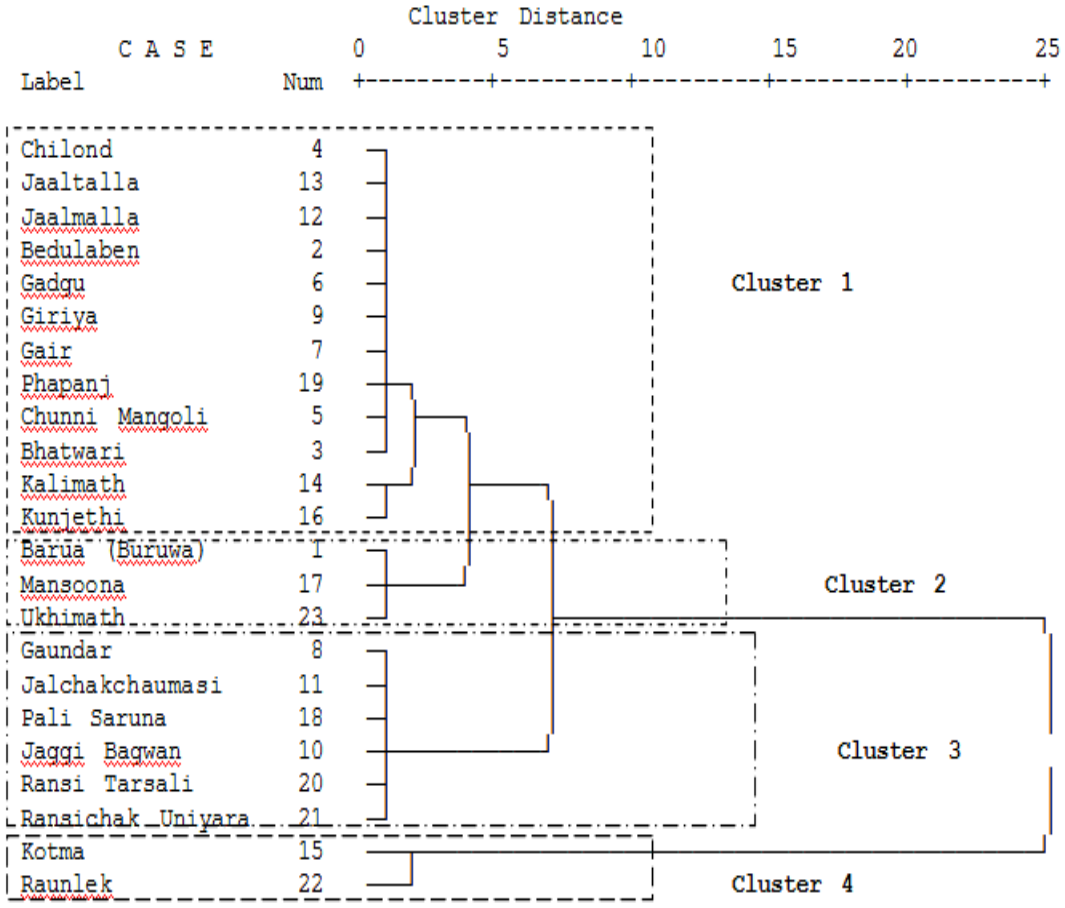


Fig. 3.1. Clusters of villages (n=23) resulted from Hierarchical Cluster Analysis based on demographic and infrastructural variables (Bedulaben = Bedula and Kheti nadla, Bhatwari = Bhatwari and Sansari, Jalchakchaumansi = Chaumansi, Ransi Tarsali = Ransi, Kotma = Kotma, Khonu and Kaviltha)

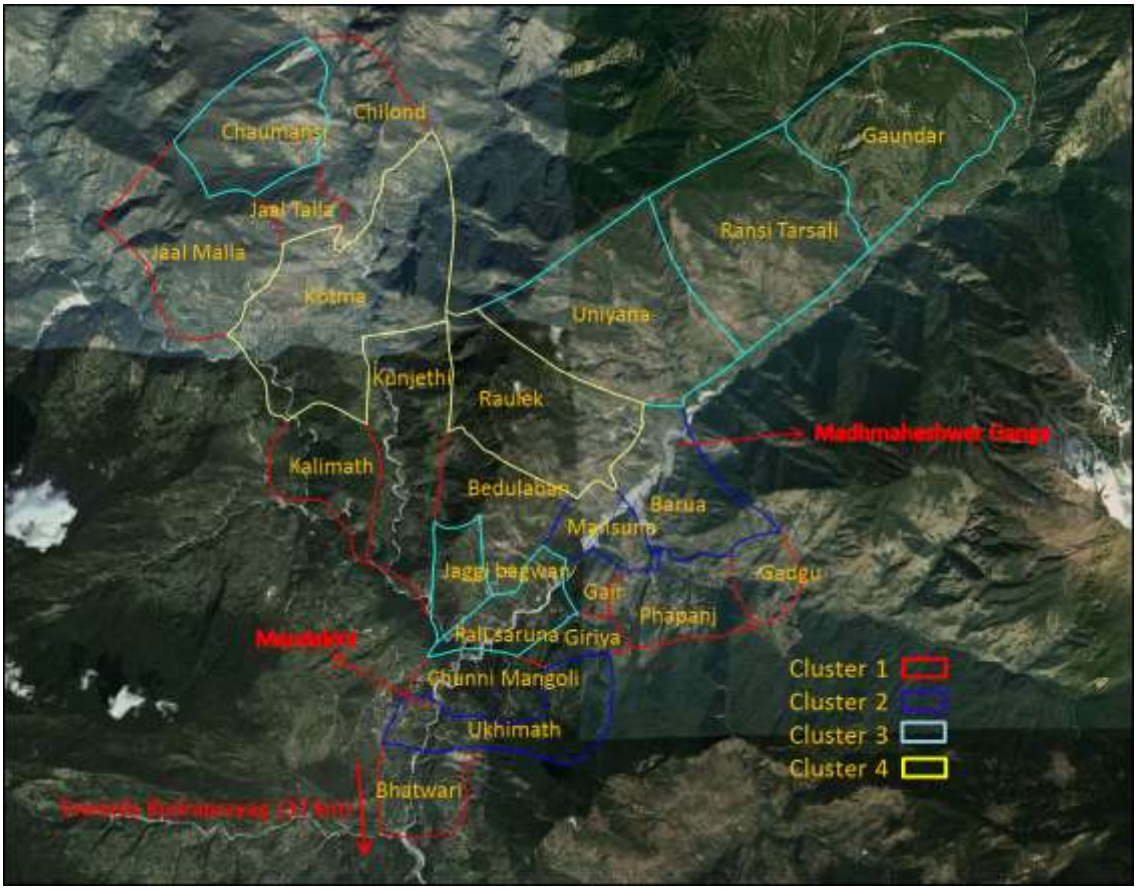


Fig. 3.2. Map of intensive study area showing the village clusters resulted from HCA

3.2.3. Preparation of survey instrument and pilot survey

A semi-structured survey instrument (household questionnaire) was designed for primary data collection (Appendix 3.2). It was divided into four sets of questions: 1) Social, demographic and economic aspects (household size, education, basic amenities, non-farm livelihood strategies, income and assets), 2) Farm based livelihood and resource use (agriculture, animal husbandry, phyto-resources extracted, requirement, areas visited, perception), 3) Human wildlife negative interactions (any attack on humans or livestock, crop raiding, compensation schemes and attitude of people

towards wildlife and forest department), and 4) Participation in forest management activities (local institutions involved, types of activities, benefits to household and community). A combination of qualitative and quantitative questions was used to address the study objectives. The survey instrument was pilot tested in four villages covering 20 households. Based on this, the survey instrument was refined to remove repetitive and redundant questions and few questions were modified.

3.2.4. Primary data collection

After performing Hierarchical Cluster Analysis, 13 revenue villages were identified in proportion to the size of each cluster for intensive sampling. Kotma village in cluster 4 consisted of Kotma, Kaviltha and Khonu villages and primary data were separately collected and analyzed for each. Khonu had become a separate revenue village by the time data collection was started. Study villages selected after HCA were re-divided into three elevational categories *viz.*, high-elevation villages (HEV, villagers frequently access forest above 2000 m asl), mid-elevation villages (MEV, villagers frequently access forest from 1500 to 2000 m asl) and low-elevation villages (LEV, villagers frequently access forest from 1000 to 1500 m asl). Village and household level surveys and focal group discussions with semi-structured questionnaires having open-ended and close-ended questions were conducted (Badola et al., 2012; Bernard, 1988; Burgess, 1982). A stratified random process was adopted while selecting households in a study village based on the location of household in different settlements within a village.

Respondents were selected from different sex, age group, educational and economical classes. Questionnaires were used to collect information of patterns amongst large number of respondents (Harris and Brown, 2010). Household representatives were mainly household heads or members involved in forest resource collection related activities. We investigated livelihood system in study villages and focused on strategies of income diversification. A total of 418 households (20-25% of each study village) were surveyed in the study area from November 2013 to October 2014. To estimate the phyto-biomass used to support weak stem crops in agricultural fields (tree branches/ stems and hill bamboos), number of these were counted and weighed in a field. Five replicates of these were taken and woody biomass used (kilogram) was calculated. Name of plant species was also noted down.

3.2.5. Entry point survey

Entry point method was used to identify preferred tree species used as fodder and fuelwood and to validate the data on biomass extraction obtained from questionnaire (Dhaundiyal, 1997). In all the study villages, traditional entry points to forests were identified and most used points were selected. Monitoring was done in the morning and late afternoon when most people go for resource collection. People and livestock entering into the forest were counted and head loads were weighed using a spring balance. The species extracted were noted down. A total of 22 entry points were monitored.

3.2.6. Data analysis

Qualitative data obtained through questionnaire survey was coded for the categorical data where needed. Preliminary descriptive analysis (mean and standard deviation) was calculated for various socio-economic variables and biomass consumption patterns. Sustenance income from forest resources (fuelwood and fodder use from Sanctuary forests) was estimated by multiplying a household's self-reported physical quantities of the resources and the prevailing local market prices (fodder at INR 300 per head-load and fuelwood at INR 150 per head-load).

Box plots were used to visualize the difference in average annual fuelwood, fodder and leaf litter consumption along elevational gradient. Kruskal Wallis Test and pair-wise post-hoc comparisons were performed between different elevation categories of villages for amount of fodder (total and from various sources), fuelwood and leaf litter collected (kg per year per household) using the Statistical Package for Social Sciences (SPSS) PC version 21.0. One-way ANOVA was performed to test whether nearness to Sanctuary played any role in phyto-resource use patterns by households. For the ANOVA, villages were grouped into three categories *viz.*, villages located within the Sanctuary, villages located at the Sanctuary boundary and distant villages.

Generalized linear modeling was used to determine which socio-economic and environmental variables best explained use of phyto-resources and alternatives (LPG as energy source) using the package MuMIN (Barton, 2015) in R3.2.4. To check multi-collinearity among independent variables, Pearson correlation coefficient was calculated and no significant correlation was found among any of the independent

variables. The independent variables were z-standardized for the analysis and model-selection was carried out using the Akaike information criterion and the models with lowest AICc score were selected (Burnham and Anderson, 2004; Mazzarolle, 2006). Information Theoretic approach was used along with model-averaging to calculate parameter estimates when competing models had AICc difference of less than 2 (Dutta, 2012; Grueber et al., 2011).

3.3. Results

3.3.1. General profile of study villages

High elevation villages included Ransi, Chilond, Chaumansi and JaalMalla, mid-elevation villages included Gadgu, Gaundar, Raulek, Buruwa, Khonu, Kotma, Kaviltha and Kalimath and low elevation villages were Bedula (including Khetinadla), Bhatwari (including Sansari) and Mansoona (including Kunjalpur). Of these, five villages *viz.*, Ransi, Chilond, Chaumansi, Gadgu and Gaundar are located inside the Kedarnath Wildlife Sanctuary; all LEV are located at a distance of more than 2 km from KWS while the rest are located along the sanctuary boundary. Table 3.1 gives a general profile of studied villages. The elevational range for settlements (sampled households) for each elevation categories varied from 1600 m to 2269 m for HEV, 1446 m to 1907 m for MEV and 1050 m to 1551 m for LEV. All the villages were located at road head (motorable) except Chilond (~ 2 km from road), Gadgu (~3.5 km from road) and Gaundar (~ 6 km from road).

The numbers of households in each village varied from 39 (Khonu) to 234 (Raulek) and the average (mean±sd) was 95.73±47.28 households per village. Village population varied from 237 (Khonu) to 1207 (Raulek) and the average population per village (mean±sd) was 566.93±283.27. The literacy rate varied from 61.06% (Gadgu) to 85.13% (Kotma) and average per village (mean±sd) was 71.57±61.83. The average total female population per village (mean±sd) was a little higher (292.2±148.28) than mean male population per village (279.27±133.63).

Seasonal migration to high elevation alpine meadows (including to secondary meadows or kharak) with livestock was recorded in only five villages, which were situated inside the sanctuary. However, a very small fraction of families performed this temporary summer migration (Table 3.1), which was highest in Gaundar where families also have *dhabas* and lodges along the Madhmaheshwer trek.

3.3.2. Informant's details

Results are presented (Table 3.2) for household survey done in fifteen villages (n= 418). Sampling was performed from November 2013 to October 2014. Out of total respondents interviewed during the study, 39.56±8.86% were men and 60.34±8.99 % were women. The ratio of women: men respondents was similar in all three village groups. Majority of the respondents (49.66±11.09 %) were 30–50 years old with similar ratios for age groups in all three village groups except high elevation villages, where higher percentage of individuals in the age group below 30 years were interviewed.

Table 3.1. General profile of study villages

Elevation category (Sampled households)	Village name	Elevation (m)	Distance from motor road (km)	Household number (Sampled households)	Total population	Male population	Female population	Literacy rate (%)	Seasonal migrant households
HEV (90)	Ransi	1600–2269	0	154 (35)	964	455	509	66.29	3
	Chaumansi	2060–2130	0	57 (15)	284	135	149	73.24	8
	Chilond	1800–1910	2	60 (16)	353	185	168	69.12	6
	JaalMalla	1934–2071	0	84 (24)	543	267	276	62.62	0
MEV (221)	Gadgu	1636–1850	3.5	117 (33)	601	275	326	61.06	12
	Gaundar	1655–1907	6	45 (12)	294	145	149	68.03	20
	Buruwa	1542–1657	0	71 (26)	386	168	218	73.83	0
	Khonu	1480–1720	0	39 (14)	237	128	142	79.75	0
	Kotma	1462–1597	0	126 (29)	565	293	272	85.13	0
	Kaviltha	1459–1475	0	62 (13)	341	182	159	72.43	0
	Kalimath	1300–1400	0	95 (28)	510	275	270	73.92	0
	Raulek	1446–1738	0	234 (66)	1207	577	630	71.25	0
LEV (107)	Mansoona	1250–1400	0	200 (52)	936	442	494	64.85	0
	Bedula	1191–1551	0	109 (27)	568	277	291	70.25	0
	Bhatwari	1050–1280	0	157 (28)	715	385	330	81.82	0
Overall (mean±sd)				95.7±47.3	566.9±283.3	279.3±133.6	292.2±148.3	71.6±6.8	

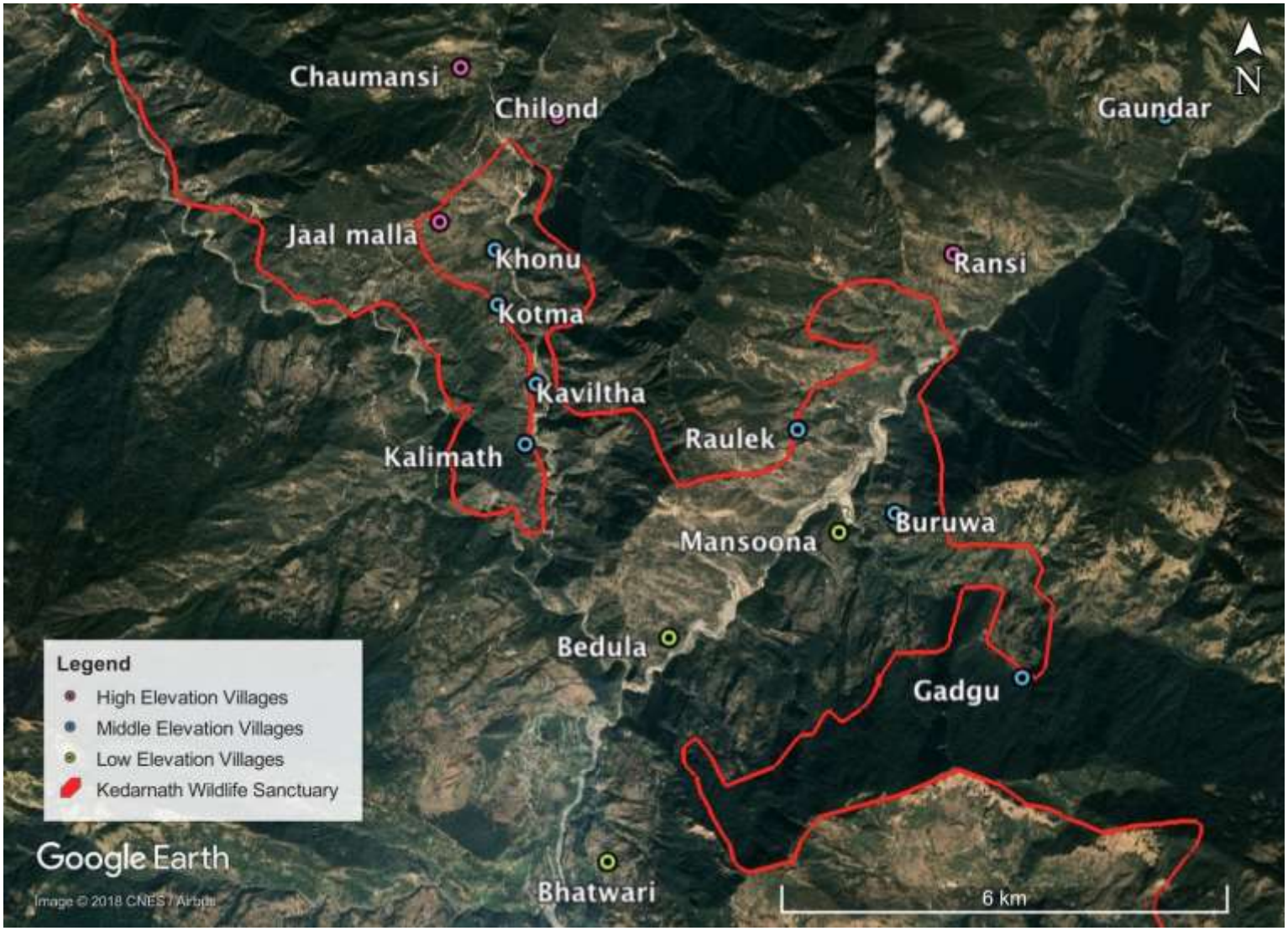


Fig. 3.3. Location of study villages, grouped along elevation, with respect to Kedarnath Wildlife Sanctuary boundary

Table 3.2. Characteristics of the respondents surveyed (n = 418; mean±st.dev.)

Parameters (%)		HEV (Mean±sd)	MEV (Mean±sd)	LEV (Mean±sd)	Total (Mean±sd)
Household head	Yes	33.13±11.87	41.31±8.31	37.61±18.83	38.39±9.11
	No	66.88±11.87	58.49±8.46	62.39±18.83	61.51±9.18
Gender	Male	37.98±9.29	41.97±10.68	35.24±8.24	39.56±8.86
	Female	62.02±9.29	57.83±10.88	64.76±8.24	60.34±8.99
Age (years)	<30	41.85±30.80	20.37±7.06	18.17±10.86	25.66±9.89
	30-50	38.84±6.47	51.10±6.34	60.23±12.83	49.66±11.09
	>50	34.32±10.64	28.52±6.87	33.94±28.34	31.15±12.49
Education	Illiterate	29.73±17.99	27.94±14.07	27.00±10.91	28.23±10.91
	Primary school	41.13±18.68	40.53±21.41	35.47±11.69	39.68±16.03
	Secondary school	26.76±16.03	20.81±10.96	25.86±2.75	23.40±11.08
	University	6.55±7.28	9.18±6.87	11.67±7.24	8.98±6.47
Employment status	Yes	33.15±6.18	47.63±15.01	36.43±6.95	41.53±12.80
	No	66.85±6.18	52.37±15.01	63.57±6.95	58.47±12.80

3.3.3. Socio-economic and demographic conditions of the households

3.3.3.1. Household characteristics

Table 3.3 gives information on the characteristics of sampled households and access to basic amenities along the elevational gradient. HEV had highest percentage of joint families and highest number of family members (or largest household size) per households.

Table 3.3. Characteristics of the households surveyed (n = 418; % of households)

House characteristics		HEV	MEV	LEV
Family size (mean±st.dev)		6.82±3.05	5.92±2.32	6.19±2.14
Family Structure (%)	Joint	75.28	58.56	62.39
	Nuclear	24.72	41.44	37.61
House Type (%)	Cemented	57.30	74.77	88.99
	Traditional	17.98	13.96	4.59
	Semi-cemented	24.72	11.26	6.42
Roof (%)	Cemented	76.40	79.73	93.58
	Tin/Asbestos	3.37	2.25	0.92
	Slate	17.98	17.12	5.50
	Thatch	1.12	0.90	
Sanitary facilities (%)	Yes	87.64	77.48	90.83
	No	12.36	22.52	9.17
Source of water (%)	Tap	66.29	52.70	60.55
	Community tap	31.46	42.79	30.28
	Natural spring	2.25	4.50	9.17
Amenities (%)	TV	77.53	62.61	72.48
	Two wheeler	3.37	1.80	7.34
	Four wheeler	-	1.35	-
	Fridge		0.90	
Electricity (%)	Yes	100	94.59	100
	No	-	5.41	-
Number of rooms (mean±st.dev)		4.13±1.91	4.04±2.34	4.26±1.80
Agricultural land holding (ha; mean±st.dev)		0.12± 0.15	0.13±0.19	0.17±0.19
LPG usage per month (kg; mean±st.dev)		3.32±1.45	6.15±3.75	7.41±4.79

LEV had highest percentage of households with cemented houses followed by MEV. Similarly, LEV had highest percentage of cemented roofed houses and least of other alternatives. Both HEV and MEV had similar percentage of houses with Tin or Asbestos sheets as roof or slate roof and also had one and two houses with part of the house having thatched roof. LEV had highest percentage of houses with sanitary facilities while MEV had least. HEV had highest percentage of households with water tap at home among all elevation categories while MEV had

highest percentage of households dependent on community taps. Number of rooms per household was almost similar for all three elevation category villages with LEV having slightly higher number of rooms per household followed by HEV and MEV. All the sampled households had access to electricity except the Gaundar village where the whole village does not have access to electricity. LEV had highest percentage of households with Liquefied petroleum gas (LPG) connection (75 %) and highest LPG consumption per month per household (7.41±4.79 kg) followed by MEV (55%, 6.15±3.75 kg) and HEV (40%, 3.32±1.45 kg).

3.3.3.2 Land holdings, crops cultivated and harvest

One household each in high elevation and mid elevation villages and two in low elevation villages did not have agricultural lands. The average landholding size in the region varied from 0.17±0.19 ha per household in LEV to 0.13±0.19 ha per household in MEV and 0.12±0.15 ha per household in HEV. The yield of grains including wheat, paddy, barnyard millet and finger millet lasted for less than six months (4.53±1.68 months per household in HEV, 4.69±2.45 months per household in MEV and 4.46±2.18 months per household in LEV). However, yield of pulses lasted for over six months to a year depending on landholding size and family size. Vegetables (bottle gourd- *Lagenaria siceraria,* cucumber- *Cucumis sativus,* snake gourd- *Trichosanthes cucumerina,* spinach- *Spinacia oleracea,* pumpkin- *Cucurbita maxima,* potato- *Solanum tuberosum*) were grown primarily during monsoon and early winter. Most sampled households (~80% across all elevation categories) do not buy vegetables from the market during the harvest period of these.

Composition of crops was similar across all the villages. However, yield and preferred crops varied with elevation. Crops with good yield in high elevation villages included Amaranth (87.93±71.06 kg/ household/ season), finger millet (103.93±70.57 kg/ household/ season) and barnyard millet (96.32±63.88 kg/ household/ season); crops with moderate yields included wheat (85.32±67.47 kg/ household/ season), mustard (31.80±31.28 kg/ household/ season), barley (67.08±56.05 kg/ household/ season), lentils (26.85±15.10 kg/ household/ season) and kidney beans (20.51±12.89 kg/ household/ season); and crop with poor yield included paddy (79.25±32.42 kg/ household/ season). Grains like wheat and paddy were grown on larger proportion of landholdings compared to traditional millets (mostly on > 60 % of land holding per households). Villagers also grew potato (49.85±23 kg/ household/ season).

Crops in MEV included Amaranth (49.57±19.53 kg/ household/ season), finger millet (91.10±61.24 kg/ household/ season), barnyard millet (44.8±27.05 kg/ household/ season), paddy (126.74±87.56 kg/ household/ season), wheat (89.38±52.86 kg/ household/ season), mustard (25.28±23.05 kg/ household/ season), barley (22.39±11.27 kg/ household/ season), lentils (27.28±23.88 kg/ household/ season), kidney beans (14.82±8.33 kg/ household/ season) and potatoes (24.87±9.23 kg/ household/ season). Crops in LEV included paddy (144.27±99.17 kg/ household/ season), wheat (101.75±79.90 kg/ household/ season), finger millet (62.64±27.41 kg/ household/ season), mustard (20.59±19.90 kg/ household/ season), lentils (28.78±31.36 kg/ household/ season), kidney beans (11.43±8.52 kg/ household/ season) and potato (17.06±9.57 kg/ household/ season). Sampled households in MEV and LEV also grew spices such as chilly and turmeric having a

combined production of 6.1±1.85 kg/ household in MEV and 14.29±9.32 kg/ household in LEV.

3.3.3.3. Livestock holdings

Livestock reared by local communities included cow, buffalo, ox, mule, sheep and goat. These were reared for various needs and purposes like dairy (cow and buffalo), meat production (sheep and goat), carrying loads and tourists (mule and horses), and ploughing land (oxen). In HEV, 98.88% sampled households had livestock. Of these, 88.64 % had cows (2.22±1.40 per household), 68.18% had oxen (1.95±0.29 per household), 63.64% had buffaloes (1.34±0.48 per household), 30.68% had sheep or goats or both (26.59±30.75 per household) and 10.23 % had mules or horses (2±0.5 per household). In MEV, 92.79% sampled households had livestock. Of these, 80.58 % had cows (1.98±1.35 per household), 51.46% had oxen (1.93±0.56 per household), 44.66% had buffaloes (1.26±0.49 per household), 16.99% had sheep or goats or both (18.89±15.85 per household) and 6.31 % had mules or horses (2.08±2.08 per household). In LEV, 97.25% sampled households had livestock. Of these, 78.30 % had cows (1.77±0.85 per household), 58.49 % had oxen (1.77±0.46 per household), 55.66% had buffaloes (1.19±0.39 per household), only one household had sheep (25) and 4.72 % had mules or horses (2.40±0.89 per household).

Independent Kruskal Wallis Test and pairwise post-hoc comparisons revealed that livestock numbers per household were higher in HEV than MEV (p value < 0.001) and LEV (p value < 0.001). There was no statistically significant difference between MEV and LEV (p value = 1.000). Similarly, Sanctuary villages

had higher livestock numbers per household than fringe villages (p value = 0.007) and distant villages (p value = 0.037). There was no statistically significant variation between Fringe villages and distant villages (p value = 1.000).

3.3.3.4. Household income and livelihood strategies

There was no significant difference in income along the elevational gradient (Mean± S.D.: LEV= INR 207844.3±198616.3, HEV = INR 193923.8±197543.9, MEV = INR 171703.0±168308.5, p-value = 0.368). Like most rural communities, majority of sampled households in the study area were engaged in more than one livelihood strategies. The number of income diversification strategies per household varied statistically significantly along the elevational gradient (HEV = 3.04± 1.17, MEV = 2.30±1.04 and LEV = 1.74±0.76; p value < 0.001 for all three elevation pairs). All income sources were grouped into eight broad groups (Table 3.4). HEV had highest percentage of sampled households engaged in earning incomes from all three primary income generating activities including agriculture, animal husbandry and from forests followed by MEV and LEV. Income from agriculture included selling of *Amaranthus* seeds (only high and mid elevation villages), various lentils including Kidney beans, fruits such as *Malta* and vegetables. Income from animal husbandry included selling of dairy products (milk and ghee), wool or woolen products from sheep and selling of sheep and goats for meat or other purposes. Income from forests included selling of fodder and baskets weaved from hill bamboos. There was not much difference in the proportional contribution of these activities to total annual income per household along elevation, except in case of animal husbandry where it contributed the least in HEV.

Other livelihood sources included businesses such as running a shop (grocery or vegetable shop, tea shop, mobile repair shop, photographer, photocopier, etc.) or hotel, rearing load carrying animals or contractual businesses (with PWD) etc. All three elevation categories had a similar percentage of sampled households engaged in various businesses. This category contributed around 50% (in HEV) to 60% (in LEV) towards annual income. Some people held public-sector or government jobs in the armed forces, postal services, health sector, public works department and academia. This sector also included the village head and members of *Panchayat Raj* institutions. This sector contributed most to household income in all three village groups. Private sector included people who work in factories and hospitality industry, teachers in private schools and villagers working in various NGOs in the region and included highest percentage of people who have migrated to urban or semi-urban centers. HEV had the highest percentage of households engaged in private sector followed by MEV and LEV.

Table 3.4. Percentage of sampled households engaged in a livelihood activities group (%) and proportion of each group in the household's (HH) total annual income (% per household per annum)

Elevation category		Agri-culture	Animal husbandry	Business	Govt. sector	Pvt. sector	Daily wages	Welfare pensions	Forest
HEV	HH % engaged	56.18	53.93	34.83	31.46	21.35	55.06	38.20	14.61
	Proportion/ HH (%)	8.71± 15.87	15.79± 22.69	50.45± 31.92	75.06± 21.05	60.74± 27.94	42.76± 32.53	18.86± 20.88	11.58± 7.17
MEV	HH % engaged	31.18	29.03	32.80	31.18	15.05	52.69	26.88	9.68
	Proportion/ HH (%)	6.28± 7.41	22.42± 17.50	56.02± 32.37	74.06± 26.17	63.62± 27.54	56.21± 33.71	29.82± 36.07	17.76± 19.57
LEV	HH % engaged	6.54	3.74	33.64	45.79	12.15	41.12	28.04	2.80
	Proportion/ HH (%)	8.56± 6.22	28.95± 26.22	59.22± 31.78	81.29± 23.36	55.74± 32.14	65.14± 36.84	25.28± 34.45	12.85±5 .63

*(the total of income proportion is more than 100 % for each elevation category as average for each category was calculated only for the households engaged in that activity, households with zero values were excluded)

Daily wage jobs included working as a construction worker or porter in markets. It also included people working in tourism industry as a porter with a local guide. This was the sector with least job security and regular income fluctuations. Least percentage of households in LEV were engaged in this activity. Welfare pensions were the government aids for marginalized sections of society and included senior citizen pension, widow pension and handicap pension. It was an amount of 9600 INR per year and is not directly an income generating activity. Higher percentage of sampled households received government aid in HEV than the other two village groups.

3.3.4. Forest resource dependency

The primary phyto-resources that people extracted from forests included fuel wood and leaf and grass fodder. Leaf fodder included leaves of trees like *Quercus* spp., *Lyonia* sp. etc. from forests and of multi-purpose tree species from agro-

forestry system. Villagers also took their livestock for grazing in the forest and grassy slopes. Other phyto-resources extracted from the forests include leaf litter, tree branches and hill bamboo to be used as '*awan*' (to support kidney bean or other weak stem crops) and for weaving baskets, edible plants and mushrooms, and dry grass for thatch roofs. A very small percentage of sampled households (< 5 %) also reported collection of medicinal plants from the forests, but only for personal use. The local communities do not extract all the resources throughout the year. Fig. 3.4 gives a seasonal calendar of phyto-resource extraction practices. Fuelwood is collected throughout the year, except during the rainy season (July - September). However, women sometimes collect fuelwood during the rainy season also if there is no precipitation for over a week. Hill bamboo is collected during summers (May-June) for *awan* or for basket weaving and in September for use as fodder.

Fodder: In villages, fodder demand was met from sanctuary forests, community forests and agro-forestry systems. Few households bought grass fodder from other households or from *Panchayat* of other villages (leasing out a small area in forest by paying a lump sum amount). Agro-forestry systems (AFS) included multi-purpose tree species along field boundaries and on fields not suitable for cultivation, grass along the field boundaries and byproducts after harvesting crops.

There was seasonal variation in fodder fed to the livestock that varied according to the availability within human-scape and in forests (Table 3.5). Tree fodder from AFS was mainly extracted during winter or when people were busy in agricultural activities. Agricultural byproducts primarily included paddy, barnyard and finger millets in August and September (or dried and kept for winters) and wheat and Barley from Mid-may to July.

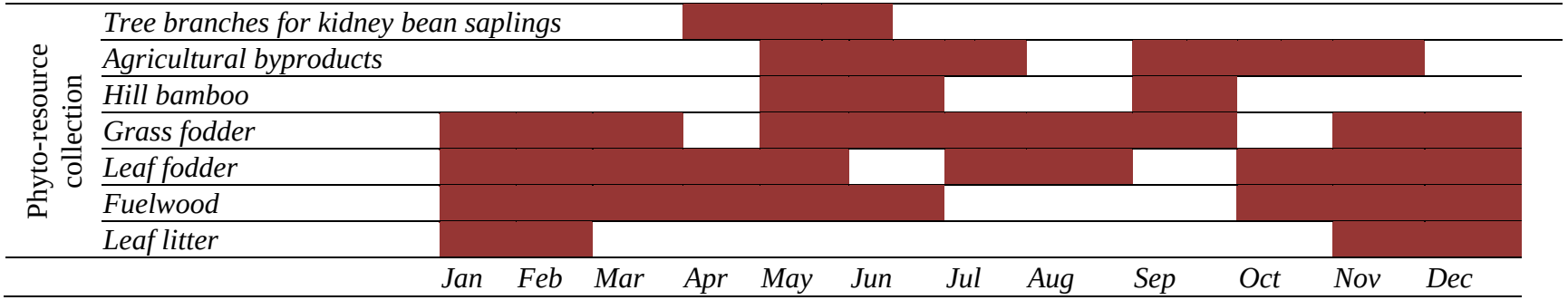


Fig. 3.4. Seasonal calendar (month-wise) of phyto-resource collection in the area

Table 3.5. Monthly fodder use from various sources in the Study area

January	Community forests, multipurpose tree species in agro-forestry systems, *Q. leucotrichophora* (or *Q. glauca* at lower elevations) from forests
February	Same as above
March	*Q. floribunda* from forests, rest same as above
April	*Q. floribunda* from forests, new leaves of *Q. leucotrichophora* from forests, grass from field boundaries
May	New leaves of *Q. leucotrichophora*, grass from field boundaries, agricultural byproducts from wheat and barley
June	Agricultural byproducts from wheat and barley and grass from community forests or grass slopes, forests and agricultural fields
July	Same as above
August	Green grass from fields and forests, *Lyonia ovalifolia* and other leaf fodder from forests, *Q. semecarpifolia* (only at higher elevations)
September	Green grass from fields and forests, *Lyonia ovalifolia* and other leaf fodder from forests
October	Agricultural byproducts from paddy and barnyard millet, *Q. leucotrichophora* (or *Q. glauca* at lower elevations) from forests
November	Any leaf fodder from forests including *Q. leucotrichophora*, fodder from community forests, multipurpose tree species in AFS
December	Same as above

(This is a general pattern and is not strictly followed, but greatly varies based on the availability of resources)

Table 3.6. Fodder consumption by sampled households along elevational gradient in the study area (mean±sd)

Fodder consumption	HEV		MEV		LEV		Total	
	Head-loads/ year	Annual fodder (kg/hh)	Head-loads/ year	Annual fodder (kg/ hh)	Head-loads/ year	Annual Fodder (kg/ hh)	Head-loads/ year	Annual fodder (kg/ hh)
Total fodder consumption	416.3± 120.9	14571.3± 4234.6	301.8± 116.5	10563.5± 4076.0	264.9± 111.1	9274.3± 3890.6	320.6± 128.7	11221.5± 4506.3
Fodder from Sanctuary forest	343.7± 118.1	12031.7± 4135	222.6± 101.8	7792.6± 3564.5	135.10± 67.60	4728.4± 2366.1	230.9± 123.6	8080.9± 4335.2
Fodder from community forest	24.6± 23.6	862.8± 827.9	28.6± 29.0	1002.3± 1016.7	8.80± 10.49	308.1± 367.1	21.8± 24.7	763.1± 865.2
Fodder from AFS	48.7± 54.2	1706.4± 1896.2	70.7± 70.9	2456.3± 2483.0	107.70± 90.51	3769.5± 3167.8	70.2± 70.9	3891.8± 8442.2
Fodder bought	10.1± 8.1	354.6± 283.4	24.9± 67.5	871.7± 2361.8	32.21± 43.89	1127.5± 1536.2	26.1± 51.2	912.8± 1791.1
Grazing (No. of months)	8.38±2.21		7.71±2.24		4.59±1.76		7.66±2.42	

Not all households extracted fodder from all the sources. In HEV, 98.88 % of the sampled households were involved in fodder collection. Of these, 99.02% extracted fodder from Sanctuary forest, 100 % each from community forests and AFS and 22.55 % bought fodder from other households within village or from neighboring villages. 82.35 % of these households took their livestock to forest (both PA and community forests) for grazing. In MEV, 92.79 % of the sampled households were involved in fodder use. Of these, 97.54 % extracted fodder from Sanctuary forests, 62.56 % from community forests, 98.52 % from AFS and 26.11 % bought fodder from others or from *Panchayat* of neighboring villages. 63.55 % of these households took their livestock to forest (both PA and community forests) for grazing. In LEV, 97.25 % of the sampled households were involved in fodder use. Of these, 95.33 % extracted fodder from Sanctuary forest or reserve forests, 85.01 % from community forests, 100 % from AFS

and 65.42 % bought fodder from others or from *Panchayat* of neighboring villages. Only 20.56 % of these households took their livestock to forest (both PA and community forests) for grazing.

There was a significant difference in the total fodder consumption and fodder consumption from each kind of forest and agro-forestry system along the elevation (Fig. 3.4 and Table 3.6 and 3.7). The total fodder consumed per year per household (and the total number of fodder headloads per year per household) was highest for HEV followed by MEV and LEV (Table 3.6). The amount of fodder extracted per year per household (and the average annual headloads number) from Sanctuary forests was also highest for HEV followed by MEV and LEV. In case of community forests, MEV had highest values for both amount and number of headloads extracted followed by HEV and LEV. LEV had highest values for fodder consumed annually per household from AFS and fodder bought followed by values for MEV and HEV. Families from HEV took their cattle for grazing to forests for higher numbers of months (8.38±2.21 per household) followed by MEV and LEV.

Fig. 3.6 shows the proportion of various fodder sources in total fodder consumed by households along elevational gradient. The proportion of fodder extracted from forest (Sanctuary forest) was highest in HEV followed by MEV and LEV. In LEV, proportion of fodder from Sanctuary and reserved forests and from AFS was comparable.

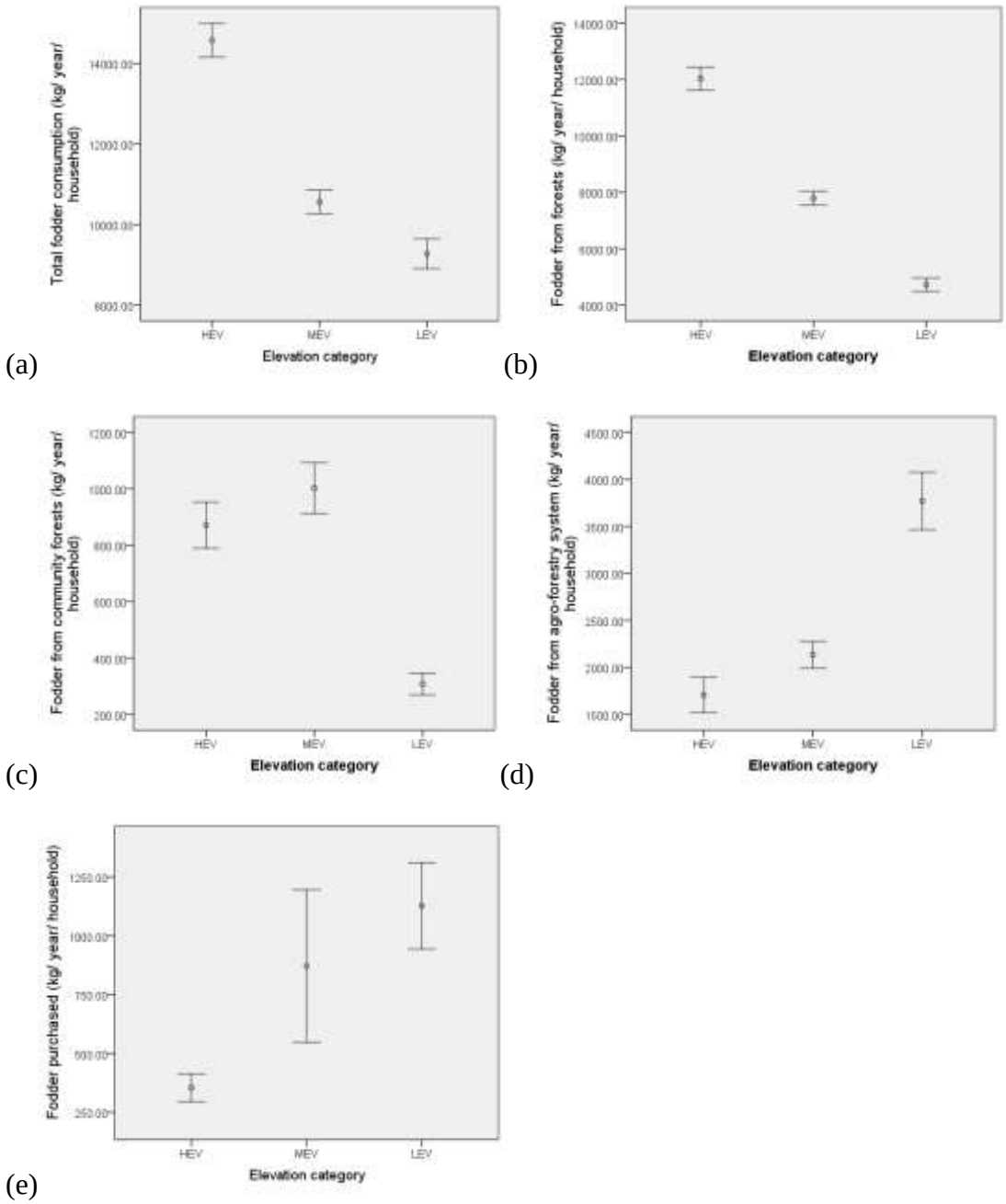


Fig. 3.5: Error bar diagram (Mean±SE) for amount of fodder (kg per year per household) along elevational gradient: a - total fodder; b - fodder from Sanctuary forests; c - fodder from community forests and d - fodder from agro-forestry system and e - fodder purchased

Table 3.7: P-values for pair-wise post hoc comparison between different elevation categories of villages for amount of fodder, fuelwood and litter (kg year^{-1} household^{-1}; Independent sample Kruskal Wallis Test and pairwise post hoc test; significance level is 0.05)

Parameters	HEV-MEV	MEV-LEV	HEV-LEV
Total fodder consumption	**<0.001**	**0.016**	**<0.001**
Fodder from Sanctuary forest	**<0.001**	**<0.001**	**<0.001**
Fodder from community forest	0.120	**<0.001**	**<0.001**
Fodder from agro-forestry system	0.160	**<0.001**	**<0.001**
Fodder bought	0.088	0.344	**0.002**
Grazing (number of months)	0.099	**<0.001**	**<0.001**
Total fuelwood consumption	**<0.001**	**0.017**	**<0.001**
Total litter consumption	**0.006**	1.000	**<0.001**

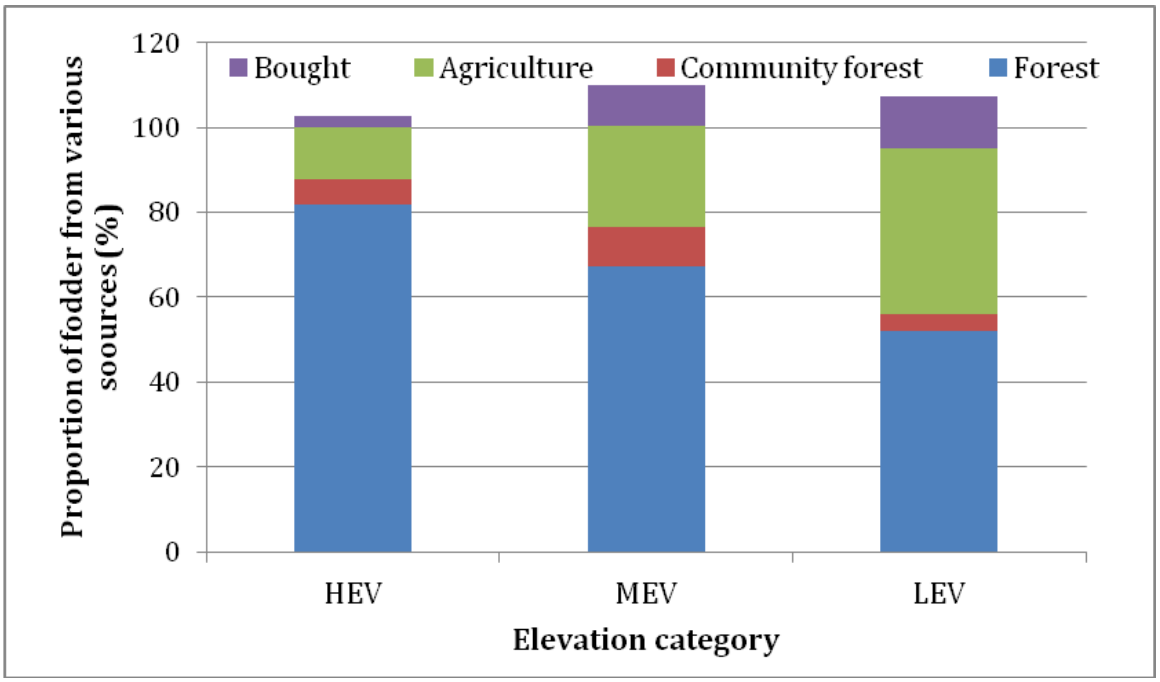
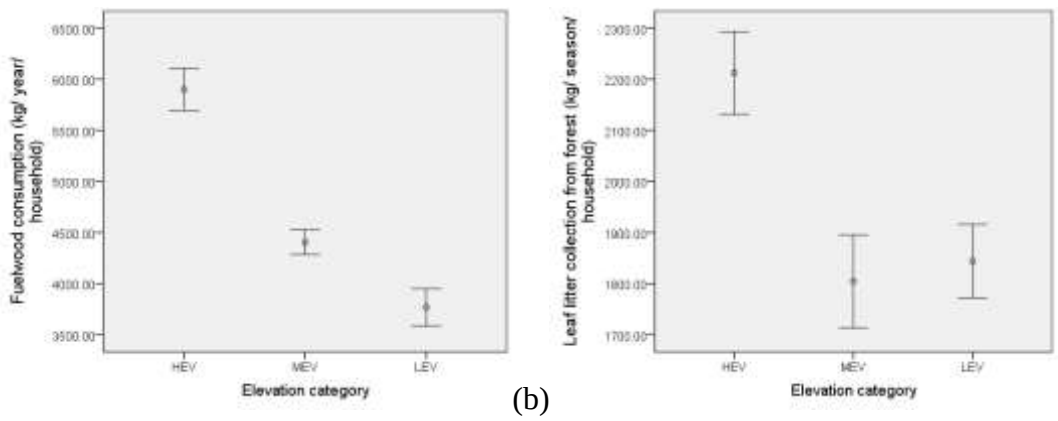


Fig. 3.6. Proportion of various fodder sources in total fodder consumed by sampled households (total n = 418; the total is more than 100 % for each elevation category as average for each category was calculated for the households with consumption in that category only, those with zero values were excluded)

Table 3.8. Phyto-biomass extracted from forests by sampled households (*hh = household)

Resource category*		HEV	MEV	LEV	Total
Fuelwood	Kg day^{-1} hh^{-1}	16.2±5.3	11.9±4.9	10.2±5.1	12.5±5.3
	Kg $year^{-1}$ hh^{-1}	5899.5±1926.1	4323.4±1839.1	3733.4±1871.1	4568.4±1962.5
	No. of head-loads $year^{-1}$ hh^{-1}	198.2±62.9	142.4±62.3	124.45±62.37	151.4±66.1
Litter	No. of head-loads $year^{-1}$ hh^{-1}	60.2±20.2	58.3±26.7	52.85±19.92	57.4±23.7
	Kg $year^{-1}$ hh^{-1}	2212.3±753.1	2175±1132.8	1844.20±697.2	2099.5±964.4
Hill bamboo	Kg $year^{-1}$ hh^{-1}	188.5±345.9	302.3±419.7	267.3±524.9	240.9±417.7
Thatch	Kg $year^{-1}$ hh^{-1}	233.3±76.4	210	-	-
Vegetables	Kg $year^{-1}$ hh^{-1}	9.3±6.4	8.9±4.7	9.5±5.1	9.5±5.6

Fuelwood: Fuelwood was the most common and primary source of energy, used for cooking and heating, in all the village clusters. 97.14 % of the sampled households extracted fuelwood or used it as a source of energy, at least during winters (94.49% in LEV, 96.85% in MEV, 100% in HEV. In HEV, 100 % sampled households, 96.85% in MEV and 94.49 % in LEV consumed fuelwood. High elevation villages had highest average fuelwood consumption per household per day followed by MEV and LEV. Similarly, average fuelwood consumption per year per household and number of headloads (or number of days of fuelwood collection) per year per households were also highest for HEV followed by MEV and LEV. Fuelwood consumption varied significantly along the elevational gradient (Fig. 3.7a). It was significantly higher for HEV than MEV (p value <0.001) and LEV (p value < 0.001) and for MEV than LEV (p value = 0.017) (Table 3.7).



(a) (b)

Fig. 3.7: Error bar diagram (Mean±SE) for a - fuelwood consumption along the elevation gradient (kg/ year/ household) and b - leaf litter collection from forest along the elevation gradient (kg/ season/ household)

Leaf litter: A mixture of leaf-litter and livestock excreta is used as manure in crop fields in the region. Litter collection starts in the month of November and lasts till February or March. Most sampled households collected leaf litter from forests (97.75% in HEV, 84.68% in MEV, 86.24% in LEV). Average litter collection from forest floor in the region was 2099.53±964.41 kg per year per household and average numbers of head loads was 57.36±23.76 per year (season) per household. It was significantly higher for HEV than MEV and LEV (both p values < 0.001) and was high for MEV than LEV (p value = 0.017) (Table 3.6, Fig. 3.7b).

Other forest products: Other forests products extracted regularly from forests included hill bamboo for making baskets, for *aawan* and sometimes for fodder. 60.66 % of sampled households in HEV, 13.96 % in MEV and 23.85 % in LEV collected hill bamboo from forests. Along with hill bamboos (*Thamnocalamus spathiflorus* and

Arundinaria falcata), tree branches were also cut for use as support for kidney bean crop or other weak stem crops such as climber vegetables in fields. These are collected in May and June. A field with an area of 60 m^2, exclusively of kidney beans requires about 150±30 kg woody biomass for this purpose. If only tree branches were used than the weight of wood was 213.69±262.88 kg for similar area of field while if hill bamboo was used, then the biomass was 6.86±11.54 kg. Trees used were *Pyrus* spp., *Pinus roxburghii*, *Lyonia ovalifolia, Juglans regia, Rhododendron arboreum* and *Debregeasia* spp. Tree branches used for this purpose are later burned in winter, but hill bamboo is re-used for up to three crop seasons. Thatch was collected by three households in Chilond (233.33±76.38 kg per year per household) and two in Gaundar (210 kg per year per household). Both of these villages are inside the Sanctuary and these families had cowsheds with thatch roof. *Lyora*, a fern and mushrooms were collected for seasonal consumption and had comparable values for all elevation categories (Table 3.8).

3.3.5. Determinants of resource use

Total annual fodder consumption: Results from generalized linear modeling showed that the model which best explained total annual fodder consumption by a household included seven variables (Table 3.9a and 3.9b).

Table 3.9. Predictors of total annual fodder consumption (kg) per household in the study area:

3.9 a. AICc scores and weight showing best fit model

Model structure	df	AICc	delta	weight
Livestock numbers+ Elevation+ Landholding size+ Number of grazing months+ Household size+ Number of sheep and goats+ Distance of household from road	9	8023.9	0	0.741
Livestock numbers+ Elevation+ Landholding size+ Number of grazing months+ Number of sheep and goats+ Distance of household from road	8	8026.1	2.17	0.25
Livestock numbers+ Elevation+ Landholding size+ Annual household income+ Number of grazing months+ Household size	8	8034.7	10.78	0.003
Livestock numbers+ Elevation+ Landholding size+ Annual household income + Number of grazing months	7	8036.1	12.15	0.002
Livestock numbers+ Elevation+ Landholding size+ Number of grazing months+ Number of sheep and goats	7	8036.4	12.49	0.001
Livestock numbers+ Elevation+ Landholding size+ Annual household income+ Number of grazing months+ Household size+ Number of sheep and goats	9	8036.7	12.74	0.001
Livestock numbers+ Elevation+ Landholding size	5	8036.8	12.85	0.001
Livestock numbers+ Elevation+ Landholding size+ Annual household income	6	8038.5	14.58	0.001

3.9 b. Parameter estimates of the top model (mean±1SE unstandardized regression coefficients, t value and p–values of predictors)

Parameters	β_{Unstd}	SE	t value	p-value
Intercept	10663.49	172.24	61.909	< 2e-16 ***
Livestock numbers	2397.83	194.39	12.335	< 2e-16 ***
Elevation	1579	214.04	7.377	9.06e-13 ***
Landholding size	852.6	176.06	4.843	1.82e-06 ***
Number of grazing months	643.75	225.04	2.861	0.004445 **
Household size	371.86	181.41	2.05	0.041020 *
Number of sheep and goats	18.94	184.64	0.103	0.918348
Distance of household from road	-707.19	198.54	-3.562	0.000411 ***

Signif. codes: ***= 0.001, **= 0.01, *= 0.05, . = 0.1, nothing = 1

The variables that positively predicted a household's fodder consumption strongly and precisely were livestock numbers of the household (β_{Unstd} = 2397.83_{mean}±

194.39_{SE}, p value < 0.001), elevation ($\beta_{Unstd} = 1579_{mean} \pm 214.04_{SE}$, p value < 0.001), landholding size ($\beta_{Unstd} = 852.6_{mean} \pm 176.06_{SE}$, p value < 0.001), number of grazing months ($\beta_{Unstd} = 643.75_{mean} \pm 225.04_{SE}$, p value = 0.004) and household size or number of family members ($\beta_{Unstd} = 371.86_{mean} \pm 181.41_{SE}$, p value = 0.041). Number of sheep and goats ($\beta_{Unstd} = 18.94_{mean} \pm 184.64_{SE}$, p value < 0.918) positively predicted the total fodder consumption however it was not precise. Distance of household from road negatively but strongly and precisely predicted fodder consumption ($\beta_{Unstd} = 707.19_{mean} \pm 198.54_{SE}$, p value < 0.001).

Total annual fodder consumption from Sanctuary forest: Results from GLM showed that the model which best explained total annual fodder consumption from forest (Sanctuary forests or reserve forests) by a household included six variables (Table 3.10 a).

Table 3.10. Predictors of annual fodder consumption (kg) from Sanctuary or reserved forest per household:

3.10 a. AICc scores and weight showing best fit model

Models	df	logLik	AICc	delta
Livestock numbers+ Elevation+ Landholding size+ Number of grazing months+ Household size+ Number of sheep and goats	8	-3969.42	7955.2	0
Livestock numbers+ Elevation+ Landholding size+ Household size	6	-3976.54	7965.3	10.1
Livestock numbers+ Elevation+ Landholding size	5	-3978.07	7966.3	11.09

The variables that positively predicted a household's fodder consumption from Sanctuary or reserve forests strongly and precisely were livestock numbers of the household ($\beta_{Unstd} = 1878.1_{mean} \pm 178.3_{SE}$, p value < 0.001), elevation ($\beta_{Unstd} = 1823.6_{mean} \pm$

190.6_{SE}, p value < 0.001) and number of grazing months ($\beta_{Unstd} = 762.8_{mean} \pm 202.2_{SE}$, p value <0.001). Household size ($\beta_{Unstd} = 289_{mean} \pm 167.3_{SE}$, p value = 0.084) predicted the consumption positively but not precisely. and. Landholding size ($\beta_{Unstd} = 660.1_{mean} \pm 162.3_{SE}$, p value < 0.001) predicted consumption strongly and precisely but negatively while number of sheep and goats ($\beta_{Unstd} = 110.7_{mean} \pm 168.8_{SE}$, p value = 0.512) negatively predicted fodder consumption from Sanctuary forests but not precisely.

3.10 b. Parameter estimates of the top model (mean±1SE unstandardized regression coefficients, t value and p–values of predictors)

Parameters	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	7461.7	158.9	46.972	< 2e-16 ***
Livestock numbers	1878.1	178.3	10.535	< 2e-16 ***
Elevation	1823.6	190.6	9.57	< 2e-16 ***
Landholding size	-660.1	162.3	-4.068	5.68e-05 ***
Number of grazing months	762.8	202.2	3.773	0.000185 ***
Household size	289	167.3	1.728	0.084780 .
Number of sheep and goats	-110.7	168.8	-0.656	0.512413

Signif. codes: ***= 0.001, **= 0.01, *= 0.05, . = 0.1, nothing = 1

Annual fuelwood consumption by a household: GLM for total annual fuelwood consumption by a household showed two best fit models with delta values less than 2, thus I took average estimates of both the models (3.11 a). The variables that positively predicted a household's fuelwood consumption strongly and precisely were household size ($\beta_{Unstd} = 937.37_{mean} \pm 70.5_{Adj.SE}$, p value < 0.001), elevation ($\beta_{Unstd} = 390.75_{mean} \pm 85.1_{Adj.SE}$, p value < 0.001), number of grazing months ($\beta_{Unstd} = 301.92_{mean} \pm 81.87_{Adj.SE}$, p value <0.001), distance of household from road ($\beta_{Unstd} = 204.83_{mean} \pm 76.19_{Adj.SE}$, p value = 0.007) and livestock numbers of the household ($\beta_{Unstd} = 1397.84_{mean} \pm 72.61_{Adj.SE}$, p value = 0.006). Monthly LPG consumption of household predicted household's

annual fuelwood consumption negatively and strongly and precisely (βUnstd = $754.91_{mean} \pm 74.78_{Adj.SE}$, p value < 0.001).

Table 3.11. Predictors of annual fuelwood consumption per household in the study area:

3.11 a. AICc scores and weight showing best fit model

Models	df	AICc	delta	weight
Household size+ Monthly household LPG consumption+ Elevation+ Number of grazing months	7	7241.9	0	0 0.647
Household size+ Monthly household LPG consumption+ Elevation+ Distance of household from road+ Livestock numbers	7	7243.5	1.6	2 0.288
Household size+ Monthly household LPG consumption+ Elevation+ Livestock numbers+ Number of rooms	6	7248.6	6.6	6 0.023
Household size+ Monthly household LPG consumption+ Elevation+ Livestock numbers	6	7248.8	6.8	6 0.021
Household size+ Monthly household LPG consumption+ Elevation+ Distance of household from road	5	7249	7	6 0.019
Household size+ Monthly household LPG consumption+ Elevation	4	7253.5	11.5	6 0.002
Household size+ Monthly household LPG consumption	3	7299.3	57.3	5 0.000

3.11 b. Parameter estimates after model averaging (mean±1SE unstandardized regression coefficients, t value and p–values of predictors)

(Intercept)	Estimate	Std. Error	Adjusted Std. Error	t value	Pr(>|t|)
(Intercept)	4477.83	67.86	68.06	65.788	< 2e-16 ***
Household size	937.37	70.3	70.5	13.297	< 2e-16 ***
Monthly LPG consumption	-754.91	74.56	74.78	10.095	< 2e-16 ***
Elevation	390.75	84.86	85.1	4.592	4.39e-06 ***
Number of grazing months	301.92	81.63	81.87	3.688	0.000226 ***
Distance of household from road	204.83	75.96	76.19	2.689	0.007176 **
Livestock numbers	197.84	72.39	72.61	2.725	0.006434 **

Signif. codes: ***= 0.001, **= 0.01, *= 0.05, . = 0.1, nothing = 1

Monthly LPG consumption: Results from GLM showed that the model which best explained monthly LPG consumption from Sanctuary forest by a household included five variables (Table 3.12 a). The variables that positively predicted a household's monthly LPG consumption strongly and precisely were annual household income $\beta_{Unstd} = 0.7517_{mean} \pm 0.180_{SE}$, p value < 0.001) and household size ($\beta_{Unstd} = 0.9804_{mean} \pm 0.209_{SE}$, p value < 0.001). Elevation of household ($\beta_{Unstd} = 0.6237_{mean} \pm 0.203_{SE}$, p value = 0.002), distance of household from road ($\beta_{Unstd} = 0.3492_{mean} \pm 0.1915_{SE}$, p value = 0.069) and annual fuelwood consumption of household ($\beta_{Unstd} = 2.1706_{mean} \pm 0.227_{SE}$, p value <0.001) predicted LPG consumption strongly and precisely but negatively.

Table 3.12. Predictors of monthly LPG consumption per household in the study area

3.12 a. AICc scores and weight showing best fit model

Models	df	logLik	AICc	delta
Annual household income+ Elevation+ Distance of household from road+ Household size+ Annual household fuelwood consumption	7	-1112.4	2239.1	0
Annual household income+ Elevation+ Distance of household from road	5	-1154.44	2319	79.95
Annual household income+ Elevation+ Distance of household from road+ Household size	6	-1154.38	2321	81.88

3.12 b. Parameter estimates of the top model (mean±1SE unstandardized regression coefficients, t value and p–values of predictors)

Parameters	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.461	0.1706	20.283	< 2e-16 ***
Annual household income	0.7517	0.1802	4.172	3.69e-05 ***
Elevation	-0.6237	0.2038	-3.06	0.00235 **
Distance of household from road	-0.3492	0.1915	-1.823	0.06902 .
Household size	0.9804	0.2099	4.67	4.08e-06 ***
Annual fuelwood consumption of household	-2.1706	0.2267	-9.573	< 2e-16 ***

Signif. codes: ***= 0.001, **= 0.01, *= 0.05, . = 0.1, nothing = 1

3.3.6. Phyto-resource use pattern and nearness of village to Sanctuary

There was a significant difference between village groups in annual fodder consumption ($F(2,415) = 16.541$, $p < 0.001$). A Tukey post-hoc test revealed that the fodder consumption was statistically significantly higher for villages located inside the Sanctuary ($12882.23_{mean} \pm 4576.15_{sd}$) than fringe villages ($10206_{mean} \pm 5547.74_{sd}$, $p < 0.001$) and distant villages ($9240.65_{mean} \pm 3882.92_{sd}$, $p < 0.001$). There was no statistically significant difference between fringe villages and distant villages in total fodder consumption ($p = 0.229$).

Results for total annual fodder consumption by households (kg) from forests (Sanctuary or Reserve forests) in different village groups indicated that there was a statistically significant difference between village groups ($F(2,415) = 52.012$, $p < 0.001$). A Tukey post hoc test revealed that the fodder consumption from Sanctuary was statistically significantly higher for villages located inside the Sanctuary ($10382.27_{mean} \pm 3858.68_{sd}$, $p < 0.001$) and fringe villages ($7441.24_{mean} \pm 5094.37_{sd}$, $p < 0.001$) compared to the distant villages ($4497.66_{mean} \pm 2533.51_{sd}$). It was statistically significantly higher for Sanctuary villages than the fringe villages ($p < 0.001$).

Results for one-way ANOVA for total annual fuelwood consumption by households (kg) in different village groups indicated that there was a statistically significant difference between village groups ($F(2,415) = 38.099$, $p < 0.001$). A Tukey post hoc test revealed that the fuelwood consumption was statistically significantly higher for villages located inside the Sanctuary ($5770.32_{mean} \pm 1831.35_{sd}$, $p < 0.001$) and fringe villages ($4203.93_{mean} \pm 1887.0_{sd}$, $p = 0.044$) compared to the distant villages

($3663.64_{mean}\pm1921.73_{sd}$). It was statistically significantly higher for Sanctuary villages than the fringe villages ($p < 0.001$).

Results for litter collection by households (kg/ season) in different village groups indicated that there was a statistically significant difference between village groups ($F(2,415) = 18.762$, $p < 0.001$). A Tukey post hoc test revealed that the litter collection was statistically significantly higher for villages located inside the Sanctuary ($2437.45_{mean}\pm1141.85_{sd}$) than fringe villages ($1771.27_{mean}\pm1127.98_{sd}$, $p < 0.001$) and distant villages ($1620.14_{mean}\pm890.45_{sd}$, $p < 0.001$). There was no statistically significant difference between fringe villages and distant villages on total litter collection ($p = 0.470$).

3.4 Discussion

Study results indicated that forest phyto-biomass, mainly fuelwood, leaf and grass fodder and leaf litter, were important products for subsistence use for rural households in both Madhmaheshwer and Kalimath valleys. This is consistent with other studies across similar socio-ecological systems in the Himalaya (Awasthi et al., 2003; Chandola, 2012; Chettri and Sharma, 2006; Dobriyal, 2015; Khuman, et al. 2011; Lam et al., 2017; Pandey, et al. 2013; Senganimalunje et al., 2016; Sharma et al., 2009; Singh et al., 2010; Wangchuk et al., 2014). These resources primarily formed the non-cash component of forest income and their use varied significantly along the elevational gradient. Other determinants of resource-use pattern were family size, distance from sanctuary, distance from road and size of land and livestock holdings.

Rural households in the region showed varied livelihood strategies with majority of sampled households using diverse livelihood portfolios to improve their standard of living. The simultaneous engagement of households in a number of livelihood strategies in studied villages is a characteristic of poor, rural communities across developing nations (Ellis, 1998, 2000). Despite having a low contribution to the household's annual income, primary activities including agriculture, animal husbandry and sale of fodder still constitute a crucial component of livelihood in the region. These were most important for families with no sustainable flow of income; specifically, in households with members lacking skills for better paying jobs, lack of opportunity or absence of any able-bodied male member. These primary activities particularly improved the livelihood security of female dominated households. A highly diverse livelihood portfolio strengthens a household's ability to withstand economic shocks, as was observed in the study area.

The reported average annual income in the current study is higher compared to the previous studies for Western Himalaya, a surprising result considering the poor economy of the region. I included the income of men who were not living in the village but whose families were staying in the village in household's income. This could be one reason for higher income recorded in this study. The most important income categories for cash income were government sector, private sector and business or self-employed (small-scale business activities mainly). Private sector contributed more to household annual income than self-employment. However, majority of the members employed in this sector worked in urban centers of the country. Only part of their total income (30-

50%) was spent on family related issues, mostly when the member visited the village. Almost 90% of the households had a bank account (the number has surged in recent times under central Government's *Jan Dhan Yojna*). However, most of the account holders did not know how to operate the account and therefore, it was difficult for them to receive remittance from migrated members of the family. Similar situation was observed for households with members employed in the government sector. However, this sector gave job and economic security and members were better able to contribute to family's expenditure and savings.

All three primary livelihood activities including forest resource collection, agriculture and animal husbandry formed crucial component of subsistence income. Annual fuelwood consumption contributed an average of INR 22702.59±9909.59 to a household's sustenance income. It varied from INR 29403.23±9869.55 for HEV to INR 21761.15±8957.93 in MEV and INR 19029.61±9070.63 in LEV. The cash value for fodder extracted from forest per household was INR 69264.84±37158.89 and varied from INR 102117.65±36715.47 for HEV to INR 66793.94±30552.79 in MEV and INR 40529.41±20281.17 in LEV. Very few sampled households (14.61% in HEV, 9.68 % in MEV and 2.80 % in LEV) traded forest resources for cash income, which was primarily fodder sold by poor households and hill bamboo baskets sold by weavers. The average cash income varied from INR 6210.53 ($\pm 3412.87_{sd}$) in MEV to INR 6000 in LEV and INR 4730.77 ($\pm$ 1562.79$_{sd}$) in HEV. The results indicate that the consumptive value of forest was much higher than the productive value of the resources. Davidar et al. (2008) reported similar results from Kalakad-Mundanthurai Tiger Reserve landscape in

southern Western Ghats, India. There are numerous studies across Himalaya that quantify resource use of local communities from forests and estimate contribution of resource trade to household income. However, work on estimating subsistence use income from forest is largely lacking from the Indian Himalayan Region.

Similar to forest, agriculture also had higher consumptive value than productive value. The yield of grains mostly supported a household for less than six months and rest was bought from shops, either at subsidized rate from ration distribution shops or at market price. Animal husbandry was also a crucial source of subsistence as well as cash income in the region that supplemented other two primary activities. Rearing sheep, in particular, acted as savings or capital item that can be sold as an added income. The cash income from selling products from both agricultural and animal husbandry varied from INR 14866.01±15903.59 in HEV (71.91 % of sampled households engaged in these) to INR 16125.31±13119.65 in MEV (43.01% engaged) and 12275±11116.37 INR in LEV (only 7.48 % engaged). High elevation villages had higher production of both Amaranths and Kidney beans, two most traded crops of the area. Villages at mid and low elevations had higher income from dairy because they were able to sell milk regularly to co-operatives or NGOs due to proximity to roads and markets.

Fuelwood formed the primary source of energy for the local communities and showed spatial variation along the elevational gradient. Sources for fuelwood were sanctuary forests, community land and trees in agro-forestry systems. Around 30% of fuelwood consumed by households situated close to the river (primarily LEV and few settlements in MEV) came from logs collected from the river after rains. This required

labor and few households (<5%) paid wages to others to cut and collect this wood. Fuelwood collection increased just before winter (November to mid–December) as villagers collect fuelwood in large quantities for storage before the forests get covered with snow and become inaccessible.

Total fodder consumption and fodder from Sanctuary or Reserve forests was positively correlated with elevation and negatively correlated with distance from Sanctuary forests. This indicated that proximity to a free resource and year-round accessibility to un-prohibited use of biomass contributes to resource consumption. Community forests are closed for some part of the year (late summer to late autumn) and are opened for a few days during early winter and then for grazing for the rest of the open period. In some villages, community forests were closed year round and were opened only for 3-6 days in winters. This limited the amount of fodder extracted from these forests. LEV had highest fodder consumption from agro-forestry systems. This could be due to larger landholding sizes and higher fodder tree biomass in low elevation villages (refer Chapter 4). The LEV were situated at a distance of 2 km or more from protected areas and because villages which shared their boundaries with protected areas had first access (right) to the resource base, inhabitants of LEV had to walk to greater distances to avoid inter-village conflicts. Malik et al. (2014) in a study in the western valleys of KWS found similar trends in resource collection with high elevation villages having higher fodder consumption. In a similar study in Govind Wildlife Sanctuary, Negi and Maikhuri (2017) also found an increase in fodder extraction from forest with elevation.

Fodder extraction from forests was also predicted by family size that might indicate that more members in the family meant greater requirement and more human resource for collecting resources. Bigger landholdings were correlated with higher fodder extraction from agro-forestry systems. Families with more livestock tend to depend more on grazing access to forests; similarly, families with larger livestock holdings tend to have higher fodder consumption. Another predictor for total fodder consumption was distance of household from road. Households closer to roads were either in LEV or MEV (villages with bigger landholdings) and had access to fodder sources to purchase; a combination of such factors might have played a role in a positive prediction of fodder consumption by household's distance from road.

High elevation villages showed highest fuelwood consumption per household per year. These villages had larger families and were endowed with year-round accessibility to free and un-prohibited use of forest resources due to their location within the Sanctuary or along the boundary. Other than cooking, fuelwood is also used for space heating in the study area. High elevation villages experience snow fall in the winter; sometimes experiencing continuous precipitation for more than 24 hours. This might also have contributed to higher fuelwood consumption in these villages. On snowy days, villagers put small burning pieces of wood in a container in the animal sheds (personal observation) which may explain the positive prediction of fuelwood consumption by livestock numbers. Results on fuelwood consumption along the elevational gradient are consistent with other studies in Western Himalaya (Awasthi et al., 2003; Malik et al., 2014; Negi and Maikhuri, 2016). Mostly, villagers brought

fuelwood from forests when they took their cattle for grazing. This could be the reason for significantly positive correlation between fodder consumption and number of grazing months. Many settlements within these villages were at greater distance from roads, and thus had poor access to alternative sources of energy including LPG which might have resulted in a positive prediction of fuelwood consumption by distance to roads.

The alternatives to fuelwood used in the region include kerosene oil, LPG and electricity-based induction cook tops. The supply of Kerosene oil to the region was affected during the study period (after June 2013 disaster) and it was not being supplied regularly. Therefore, LPG was the most common alternative fuel. Induction cook tops were mentioned by less around 20 households and were bought by the members working in the armed forces. The amount of LPG consumed per month per household varied significantly with elevation with low elevation villages having higher consumption. Year round access to fuelwood in high elevation villages could be one of the reasons for least LPG consumption in these villages. Overall, LPG consumption varied positively with household income and family size. This shows that better economic condition of households might have increased purchasing capability of families, and led to commercial energy (LPG) becoming a more preferred energy source. Similar relationship between income and LPG consumption was found by Sharma et al. (2009) in Chamoli and Uttarkashi districts. Larger family size meant more earning members, which could have contributed towards higher LPG consumption in larger households. HEV were situated at greater distances from the LPG suppliers.

Some of the settlements in these villages were situated 1 to 3 km from roads, thus requiring more labor for carrying LPG cylinders. People have to travel higher distances from villages situated farther from these suppliers and have to incur travel costs. This also made it a less preferred choice of fuel. Government has provided easy or free LPG connections to many affected families in this region as part of aid efforts after the June 2013 floods. However, in many of the households that we sampled, these cylinders lied unused.

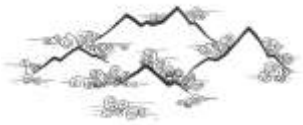




Plate 3.1: Resource extraction from forest. A: A temporary summer settlement within Sanctuary*;* **B-F:** Fodder, Fuelwood and leaf litter from forests; **G:** Basket from hill bamboo*;* **H:** *Lyora*, an edible fern collected from forests



Plate 3.2: Social survey in the study area. A-D: Household level survey **E-G:** Informal and formal community discussion **H:** Entry-exit point monitoring in Sanctuary village



Chapter 4

Chapter 4

Phyto-resource Availability along the Elevational Gradient

4.1 Introduction

Globally, forest biomass acts as a source as well as sink of carbon and plays a crucial role in global carbon and other bio-geochemical cycles (Eriksson and Berg, 2007; Houghton, 2005). In forests, tree biomass is a significant contributor to the total carbon pool and nutrient stocks (Dixon et al., 1994). Given that forests are the largest terrestrial carbon sinks and that increase in atmospheric carbon dioxide and its potential role in climate change are among the major global concerns in today's time, forests play a decisive role in global carbon balance. Forests also act as natural capital stock for a large population across the globe dependent on these for their day-to-day sustenance and well-being, while millions of other people are employed in forest-based industries (Angelsen et al., 2014; Newton et al., 2016). However, forests are rapidly shrinking globally due to large scale consumptive actions of humans, encroachment into forests and deforestation (FAO, 2015). Anthropogenic pressures and consequent changes in forests composition, structure and function have adversely affected the carrying capacity of these systems (Ehrlich et al., 1989). This large scale forest loss and degradation throughout the world is greatly impacting the biomass accumulation in these ecosystems.

Tree biomass within a forest ecosystem is influenced by various natural factors which include forest types, stand age, site conditions, species composition, size class of trees, edaphic factors, rainfall pattern, and elevation (Cao et al., 2012; Gairola et al, 2011; Peichl and Arain, 2006; Terakunpisut et al., 2007; Zhao et al., 2014). Elevational gradients are associated with several climatic variables including precipitation, wind velocity, seasonality and edaphic factors such as nutrient deposition and availability (Aiba et al., 2004; Körner, 2007; Lovett and Kinsman, 1990; Silver et al., 1999). Thus, elevation can play a significant role in vegetation structure and biomass pattern in mountain forests (Alves et al., 2010; Bruijnzeel, 2002; Namgail et al., 2012).

The Himalayan forests are among earth's most multifaceted and diverse ecosystems with Indian Himalayan Region supporting about 18,440 species of plants, of which 25.3% are endemic to the region (Samant et al., 1998; Singh and Hajra, 1996). This richness is not distributed uniformly and a number of factors including elevation influence the plant community structure and function across the region (Anthwal et al., 2008; Bhattarai and Vetaas, 2006; Ren et al., 2006; Vetaas and Grytnes, 2002; Wang et al., 2003). In addition, forest dependent communities form a prevalent feature of the natural systems. Thus, the Himalayan forests are ideal systems to examine the intersection of elevational gradients in biomass and forest resource use by people. Moreover, understanding the availability of major phyto-resources in and around human settlements is an integral part of forest management in the region.

My study objective was to assess the availability of major phyto-resources in and around the villages and surrounding forests along an elevational gradient from

~1100 m to 2700 m in the Alaknanda river basin. The study was conducted in the Mandakini river basin in Ukhimath block within the larger Kedarnath Wildlife Sanctuary Landscape. The diversity and status (availability in terms of biomass per ha) of tree species most used for green fodder and fuelwood were studied in forests and agro-forestry systems of villages in the landscape. Based on previous studies in similar mountain forests, I hypothesized that the 'patterns of availability of forest resources in the study area change along the elevational gradient'. The results of this study on estimates of tree biomass from human-use landscapes at the micro-watershed level can serve as a useful benchmark in the Himalayan region at other sites with similar agro-climatic and socio-economic conditions.

4.2 Methodology

Sampling was done in two kinds of systems *viz.*, natural forests which included Sanctuary forests and reserve forests under forest department and community forests under village *panchayat*, and agro-forestry systems (AFS) in the villages (Fig. 4.1). A list of most used tree species of fuelwood and fodder was prepared based on household surveys and forest entry point monitoring (Chapter 3); and biomass availability of these in the forests was recorded. During the sampling all tree species having some utility values to local community such as fuelwood, fodder, agricultural implements, timber, household articles and *aawan* or support for kidney bean plants were noted down.

Aboveground biomass in forest: Villages were categorized based on elevation of forests accessed by villagers for extracting resources and forest accessed (Chapter 3). Forests around ten villages (*Gram sabha*) were sampled; four villages at mid-elevation and three each at high- and low- elevations. For the assessment of status and composition of major plant resource species in the forests, stratified random transect sampling was done in various forest types along the elevational and human use gradients (Fig. 4.2). Major resource use trails were identified and followed for laying transects; length varying from 600 m to 2400 m based on lopping signs encountered in forests. Circular plots of 10 m radius (314 m^2 area) for tree species, with concentrated plot of 5 m radius (78.5 m^2 area) within the larger plot for regenerating individuals, were laid at every 200 m (Mueller-Dombois and Ellenberg, 1974). In each of the stipulated plots, name of the species, number, circumference at breast height (CBH, 1.37 m) and canopy cover were measured for trees and species name and number of individuals were recorded for the regenerating individuals. Plants with >30 cm cbh and >3 m straight bole were considered as trees and woody species having cbh <30 cm, height <3 m were considered as saplings. Anthropogenic pressure was also recorded in terms of lopping intensity, cut stumps, cattle dung and presence of human and livestock in 10 m plot that was used to rank the plot for disturbance (explained in more details below in data analysis section). Sampling was done from June 2014 to November 2015, primarily after the monsoon.

Biomass in agro-forestry system: To assess the phyto-biomass of fodder species in agro-forestry systems (AFS), 20 belt transects were laid within all 15 villages along the village trail and agricultural fields. Transect was laid from the highest point within the village to the lowest point (Fig. 4.3). Tree species were noted up to 15 m on both the sides of transect. As no regression equations are available for most of the fodder species in AFS, the available fodder was noted through ocular estimation. The quantity of fodder on the sampled tree was gauged by visually estimating the number of *pulla*, *bhari* and *bhara*, which are local terms for head-loads weighing around 4 kg, 25 kg and 35 kg, respectively (explained in more details below in data analysis section). Sampling was done just before the winter in the months of October and November in 2014 and 2015.

Data analysis: Mean and standard deviation were calculated for variables studied for forest characteristics such as canopy cover, distance of sampled plots from settlement, disturbance rank of plots and regeneration status along elevation. To study the regeneration status, regenerating species richness and seedling and sapling densities were calculated. To calculate the disturbance rank, average lopping intensity of trees (≤30%=1, 30–60%=2, >60%=3), lopping proportion (number of lopped trees in the plot/ total trees in the plot which was a sum of both lopped and unlopped trees), grazing intensity (no grazing=0, old grazing signs or mildly grazed=1, heavily grazed with fresh grazing signs and animal dung=2) and regeneration proportion (Number of regenerating species in the plot/ Number of adult tree species in the plot) were calculated. For

assigning disturbance score to a plot, first three disturbance parameters were added and regeneration status was subtracted from the value. Disturbance was ranked as high for scores of ≥3, moderate for 1–3, and low for <1.

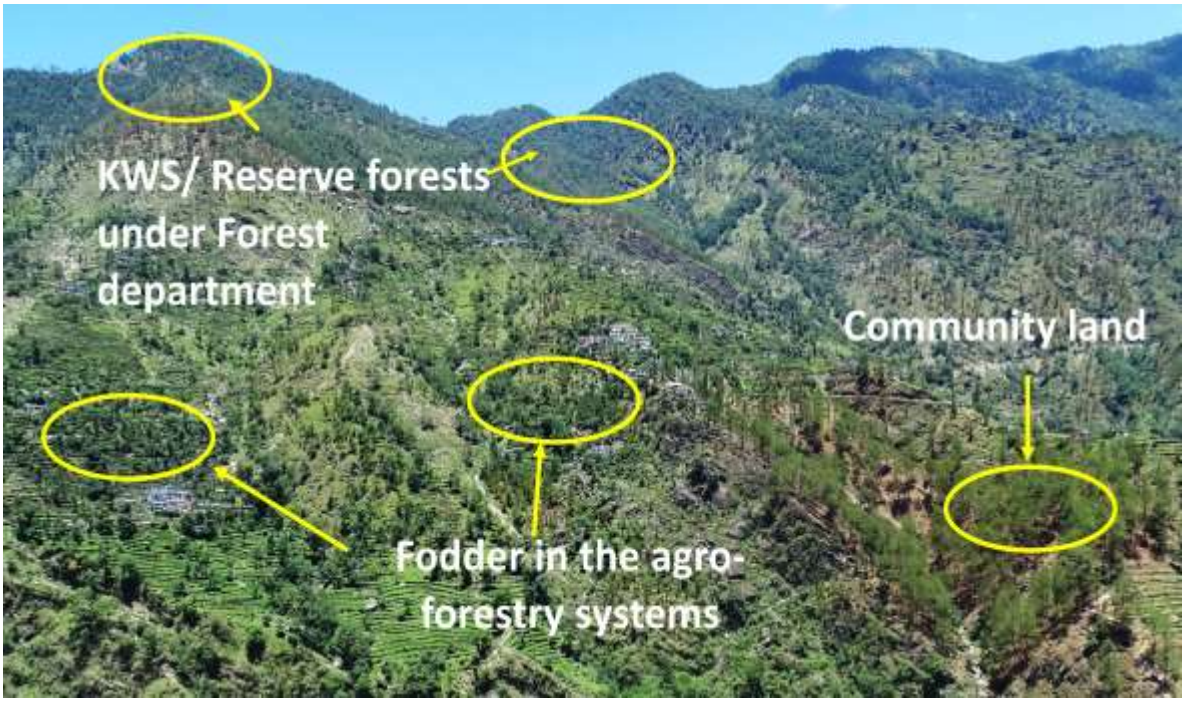


Fig. 4.1. Types of systems where sampling was done for resource availability

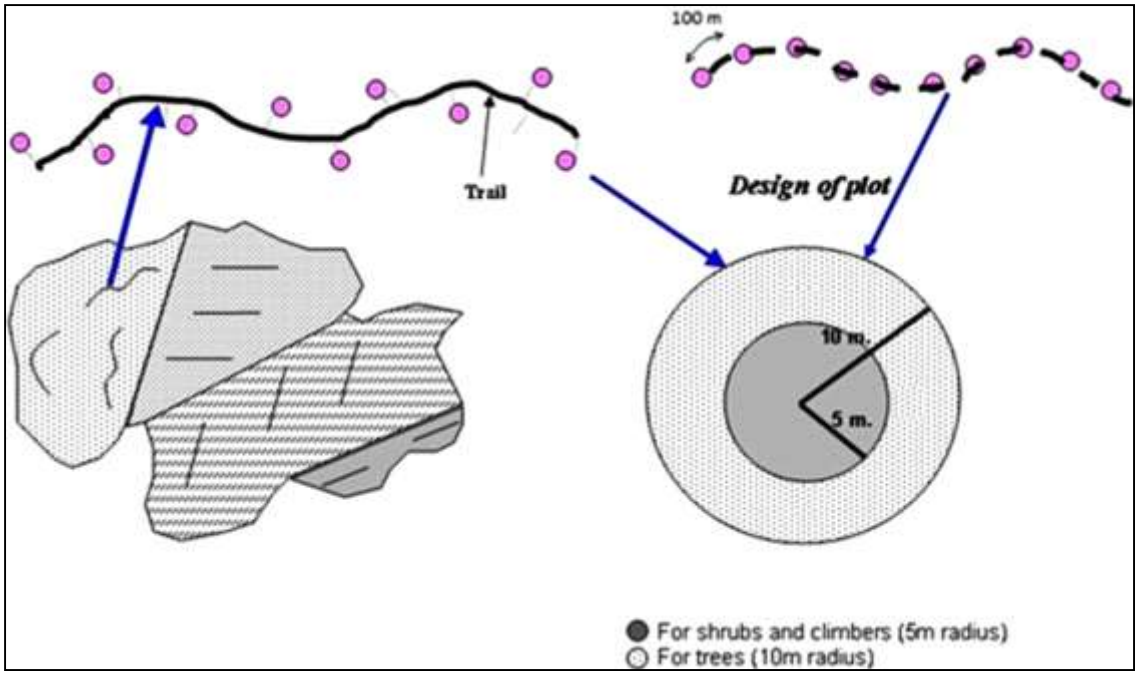


Fig. 4.2. Sampling strategy in forests to estimate resource availability

To study the tree community structure, species richness, stand tree density (no. ha^{-1}), basal area (m^2ha^{-1}), importance value index (sum of relative frequency, relative density, and relative basal area), Shannon Weiner Diversity Index, evenness and effective number of species were calculated for forests in each elevation category. The population structure of tree species was characterized based on the relationship of density to girth (Dhar et al., 1997). Individuals were grouped into seedlings (<10 cm), saplings (10–30 cm), and 4 classes of trees (30–60 cm, 60–90 cm, 90–120 cm, and >120 cm).

In forests, the available above ground tree biomass (ton/ ha) was calculated for major fuelwood and fodder tree species such as *Quercus* spp., *Pinus roxburghii*,

Rhododendron arboreum and other associates through existing regression equations (Chaturvedi and Singh, 1987; Rana et al., 1989; Singh and Singh, 1992) as

$$\ln Y = a + b \ln X,$$

where Y is the dry weight of the component, X the DBH (cm), a the Y intercept and b the slope or regression coefficient.

In agro-forestry system species richness of multi-purpose trees and fodder trees, total tree and fodder tree densities (no. ha^{-1}), fodder sapling density (no. ha^{-1}) and leaf fodder biomass were calculated. As mentioned earlier, fodder biomass was visually estimated in AFS. A correction factor was calculated for the visually estimated data of biomass in AFS. For this, fodder was estimated on a tree/ branch which was then cut and weighed. Both the values were noted and ten such replications were made in each head-load category for different species. Linear regression equation was plotted as given in Fig. 4.4.

The actual biomass was calculated from following equation,

$$\text{Actual biomass} = \frac{(\text{Estimated biomass} + 0.6871)}{1.0619}$$

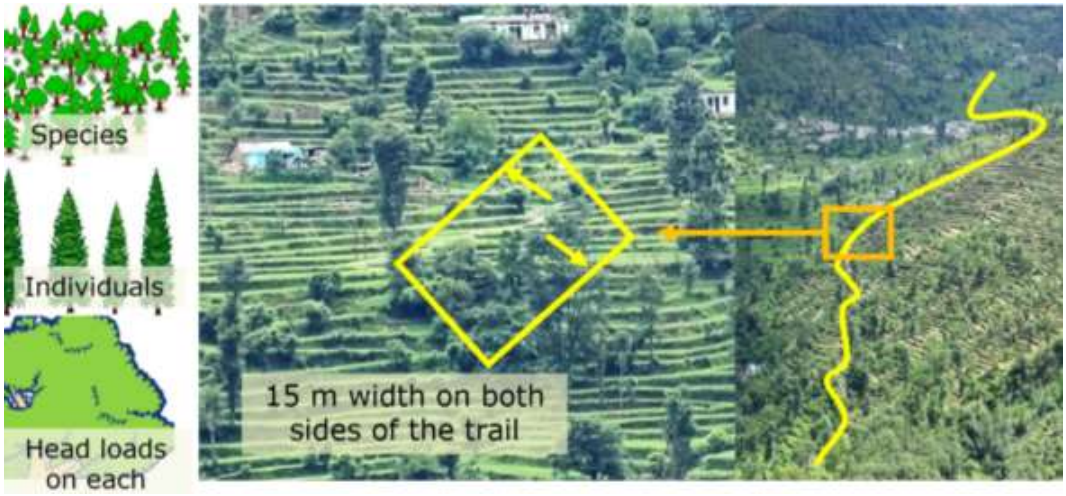


Fig. 4.3. Sampling strategy in Agro-forestry systems of villages to estimate tree fodder availability

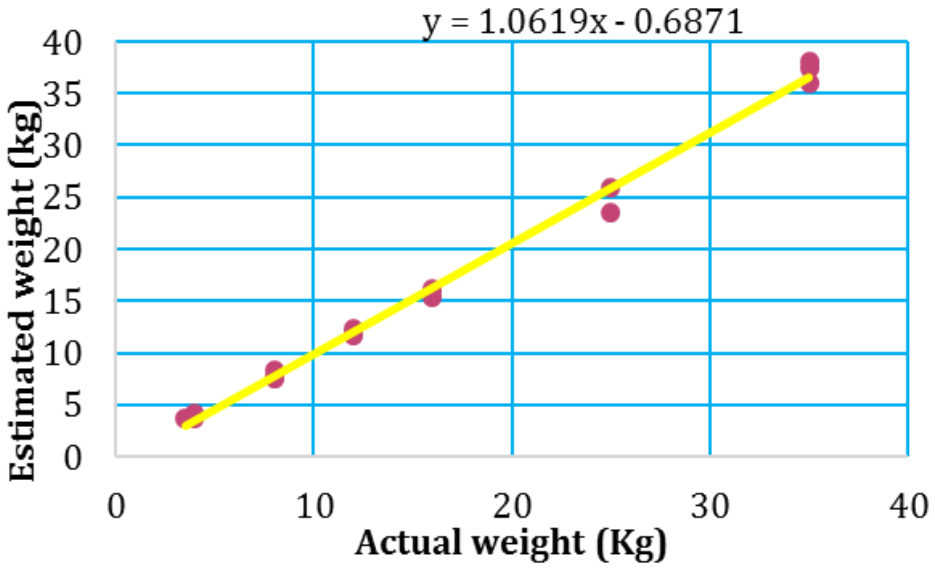


Fig. 4.4. Relationship between estimated and actual biomass on fodder tree species in agro-forestry systems

Kruskal Wallis test (with pairwise post-hoc comparisons) was performed to see whether various forest characteristics and biomass availability (total and species wise) in forests and agro-forestry systems varied significantly between the different elevations

categories using SPSS ver. 21.0. Mann-Whitney U test was performed for species present in only two elevation categories. Both these non-parametric tests are 'rank' tests and were used because these are less sensitive to outliers in data sets. These tests are suitable to the data sets where extreme values are present which might affect the results in parametric tests. As Kruskal-Wallis test does not tell which specific groups of independent variable are significantly different from each other, post hoc tests were performed. In the version of SPSS that I used, Dunn Post Hoc test is automatically performed for any variables for which the Kruskal-Wallis test is significant.

Table 4.1. Total number of transects in different elevation classes

Elevation category	**Line transects in the forests**		**Belt transects in AFS (30 m width)**		
	No. of transects*	No. of plots	Total # of transects	Transect's length (m)	Total area (ha)
HEV	8 (7)	61	6	300–1200	19
MEV	8 (6)	37	9	400–1800	26.9
LEV	4	26	5	250–1000	9
Total	20	124	20		54.9

*values in parenthesis are number of transects inside sanctuary

4.3 Results

The maximum distance travelled by villagers for resource extraction was highest in High Elevation Forests (HEF) followed by Mid Elevation Forests (MEF) and Low Elevation Forests (LEF) as suggested from the average plot distance. The plots in HEF had the highest disturbance rank, followed by MEF and LEF had the lowest disturbance rank. Although tree felling is prohibited in the forest with occasional permission given by the *Gram* Panchayat/ forest department, cut stumps were encountered in the forest

and their abundance decreased from HEF to LEF. HEF also had a higher proportion of lopped trees compared to total number of trees within a plot. However, none of these variables varied significantly with elevation (Table 4.2).

Table 4.2. Characteristics of forests across various elevational categories (Forest visited by High Elevation Village: HEF; Forest visited by Mid Elevation Village: MEF and Forest visited by Low Elevation Village: LEF).

Variables	HEF	MEF	LEF
Mean distance of plot from settlement (m; mean±sd)	659.84±454.04	609.46±358.98	513.46±328.19
Maximum distance travelled (m; mean±sd)	2000	1500	1300
Mean canopy cover (%; mean±sd)	29.02±20.41	35.76±19.36	37.88±19.09
Disturbance rank (mean±sd)	3.35±1.70	2.67±1.58	1.67±2.02
Percentage of plots inside the Sanctuary	80.33	72.97	0
Percentage of plots in the Community forest	19.67	27.03	100
Stump abundance per plot (mean±sd)	0.51±1.61	0.22±0.71	0.08±0.39
Proportion of lopped trees in a plot (mean±sd)	0.56±0.34	0.46±0.34	0.43±0.77
Proportion of fodder species (mean±sd)	0.39±0.28	0.41±0.26	0.42±0.31
Proportion of fuelwood species (mean±sd)	0.52±0.31	0.48±0.27	0.43±0.32
Tree species richness	24	27	23
Shannon Weiner Diversity Index (trees)	1.94	2.26	2.45
Evenness	0.61	0.68	0.77
Effective number of species	6.95	9.6	11.55
Stand tree density (no. ha^{-1})	402.58	430.72	453.90
Basal area (m^2ha^{-1})	21.49	29.10	16.89
Regenerating tree species richness	25	34	30
Seedling density (no. ha^{-1})	1034.87	2466.34	3622.38
Sapling density (no. ha^{-1})	116.84	374.94	602.10
Regenerating species number per plot (mean±sd)	2.23±1.74	4.62±3.31	5.65±3.01
Abundance of regenerating individuals per plot (mean±sd)	9.22±10.43	21.19±19.55	29.23±22.71
Total above ground tree biomass in forest	164.18	203.64	164.16

(ton ha^{-1})			
Total above ground biomass of fuelwood tree species in forest ($tonha^{-1}$)	156.49	195.51	137.76
Total leaf biomass of select fodder tree species in forest ($tonha^{-1}$)	2.32	2.87	3.67
Number of tree species in Agro-forestry system	44	59	44
Number of fodder species in Agro-forestry system	15	19	16
Total tree density in Agro-forestry system (no. ha^{-1})	166.62	264.52	313.07
Total fodder tree density in Agro-forestry system (no. ha^{-1})	100.44	172	175.73
Fodder sapling density in Agro-forestry system (no. ha^{-1})	49.85	140.17	122.2
Leaf fodder biomass in Agro-forestry system ($tonha^{-1}$)	1.5	2.14	2.62

4.3.1 Species composition and tree community characteristics in forests

Thirty-nine species of trees (adult individuals; 15 fodder and 17 fuelwood species) were recorded from the forests of the study area (Appendix 4.1). The tree species richness was highest in MEF followed by HEF and LEF (Table 4. 2). Ten highly most used fodder species were recorded from study area, of which eight were recorded from HEF followed by seven in MEF and five in LEF. Species richness for both fodder and fuelwood was least in LEF (Table 4.2; Appendix 4.1). LEF had the highest Shannon-Weiner diversity index, evenness and effective number of species followed by MEF and HEF. Similarly, LEF had highest tree density followed by MEF and HEF. The total basal area ($m^2\ ha^{-1}$) for trees was highest for MEF (29.10) followed by HEF (21.49) and LEF (16.89) (Table 4. 3).

The IVI results indicated that *Rhododendron arboreum* was the dominant species in both HEF and MEF while *Quercus leucotrichophora* was the dominant species in LEF (Appendix 4.1). Other dominant species included *Q. leucotrichophora* and *Lyonia ovalifolia* in HEF and MEF and *R. arboreum* and *Pinus roxburghii* in LEF. *Q. leucotrichophora*, among the most used fodder species in forests, had highest total basal area in MEF.

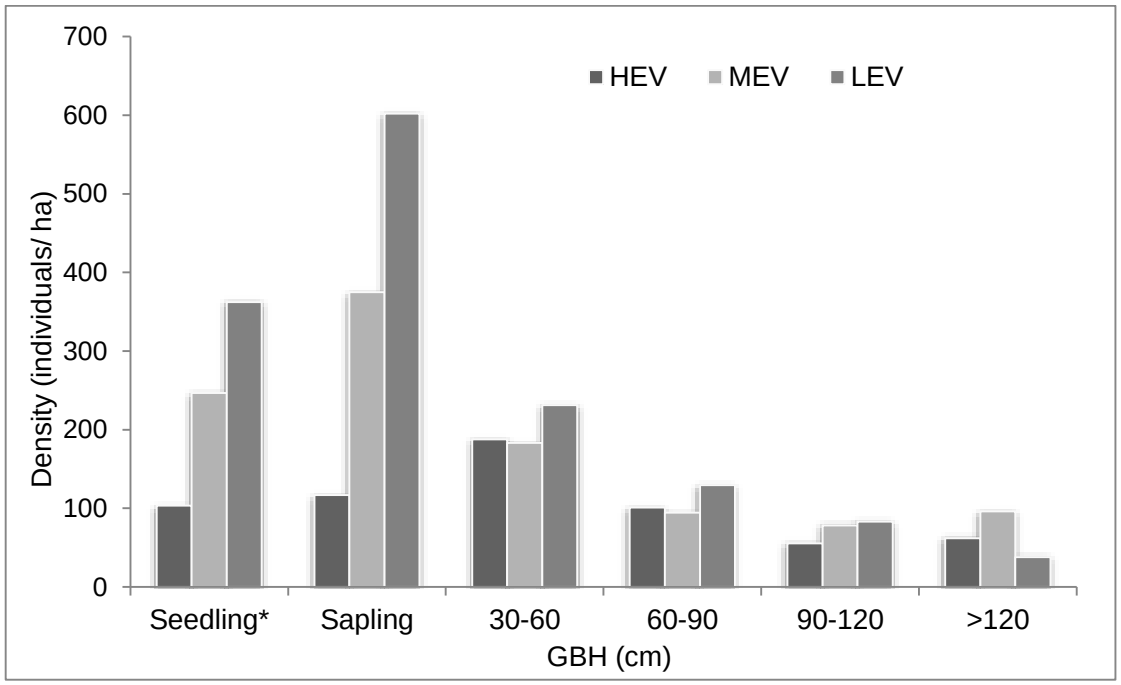


Fig. 4.5. Population structure of forest across elevational gradient (*actual seedling values are in the multiples of 10; n=124)

Regeneration status and population structure of trees

42 species were regenerating in the study area (Table 4. 2, Appendix 4.2) with highest species richness recorded from MEF (34) followed by LEF (30) and HEF (25). Both seedling and sapling densities decreased from low to high elevation forests (Table

4.2). Similar trends were recorded for regenerating species per plot and abundance of regenerating individuals per plots. In HEF, *Q. leucotrichophora* had highest seedling density while *A. nepalensis* had highest sapling density. In MEF, *Pyrus pashia* had highest seedling density while *Q. leucotrichophora* had highest sapling density. In LEF, *Engelhardtia spicata,* a subordinate species in Chir pine forests, had highest seedling density while *Syzygium cumini* had highest sapling density. Number of regenerating species per plot varied significantly from HEF to MEF (p value=0.001) and HEF to LEF (p value<0.001). Similarly, proportion of regenerating species to total species found in a plot also varied from HEF to MEF (p value=0.004) and HEF to LEF (p value <0.001).

The density - diameter curve of forest assumed an overall declining trend in all elevation classes with trees in highest girth classes having least densities among all (Fig. 4.5). LEF had highest densities in all the age classes except for trees >120 cm girth. MEF had highest density in the older age class and higher density of regenerating individuals and higher girth class individuals than the HEF. HEF had more individuals in the intermediate class than both the established saplings and higher size classes.

4.3.2 Biomass availability in Forests along elevational gradient

Total above ground tree biomass (203.64 ton/ ha) and total above ground biomass of fuelwood tree species (195.51 ton/ha) was highest in the mid elevation forest followed by high and low elevation forests (Table 4. 2). The most used species for wood extraction such as *Rhododendron arboreum* and *Q. leucotrichophora* had highest

biomass in MEF followed by HEF and least in LEF. MEF had highest biomass for almost all the preferred species while LEF had least (Fig. 4.6). But biomass of species like *Engelhardtia spicata* and *Q. glauca* in LEF compensated for this.

The total biomass per hectare for fuelwood trees did not vary significantly in forests along the elevational gradient. However, it varied significantly for certain species. The total biomass for *R. arboreum* varied significantly along elevation from MEF to LEF (p value=0.008). For *Alnus nepalensis*, it varied significantly from HEF to MEF (p value=0.023) and HEF to LEF (p value=0.008). It also varied significantly from MEF to LEF for *P. roxburghii* (p value=0.017) and from LEF to HEF for *E. spicata* (p value<0.001), while it was significantly higher from LEF to MEF for *Q. glauca* (p value=0.001) and *E. spicata* (p value<0.001).

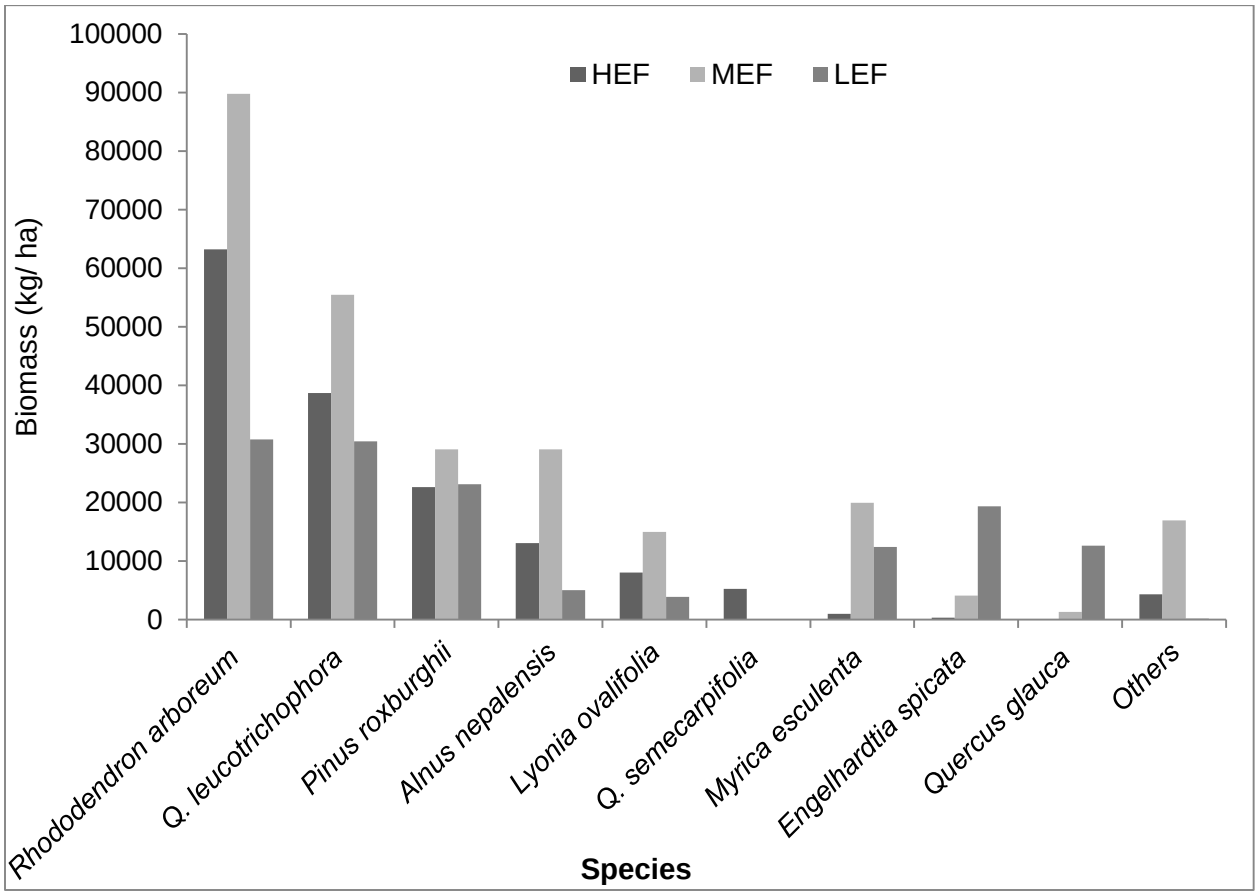


Fig. 4.6. Available above ground biomass of major forest tree species most used as fuelwood across elevational gradient. (Others include *Albizia lebbeck, Quercus floribunda, Carpinus viminea, Cornus macrophylla, Ilex dipyrena, Litsea monopetala, Symplocos paniculata, Betula alnoides*)

LEF had highest leaf biomass of select fodder tree species in forest (3.67 ton/ha) followed by MEF and HEF. MEF had highest biomass of *Q. leucotrichophora;* most used fodder species in forest, along with *L. ovalifolia, A. lebbeck* and *C. viminea*. *Q. glauca* and *E. spicata* had higher biomass in LEF which compensated for lesser biomass of other fodder species. The total leaf biomass per hectare did not vary significantly along elevation; however, it was significantly higher for LEF from HEF for *Q. glauca*

(p value<0.001) and for *E. spicata* (p value<0.001) and for MEF than LEF for *Alnus nepalensis* (p value=0.018) and for LEF than MEF for *Q. glauca* (p value=0.002) and *E. spicata* (p value<0.001). It also varied significantly from HEF to LEF for other fodder species (Fig. 4. 7).

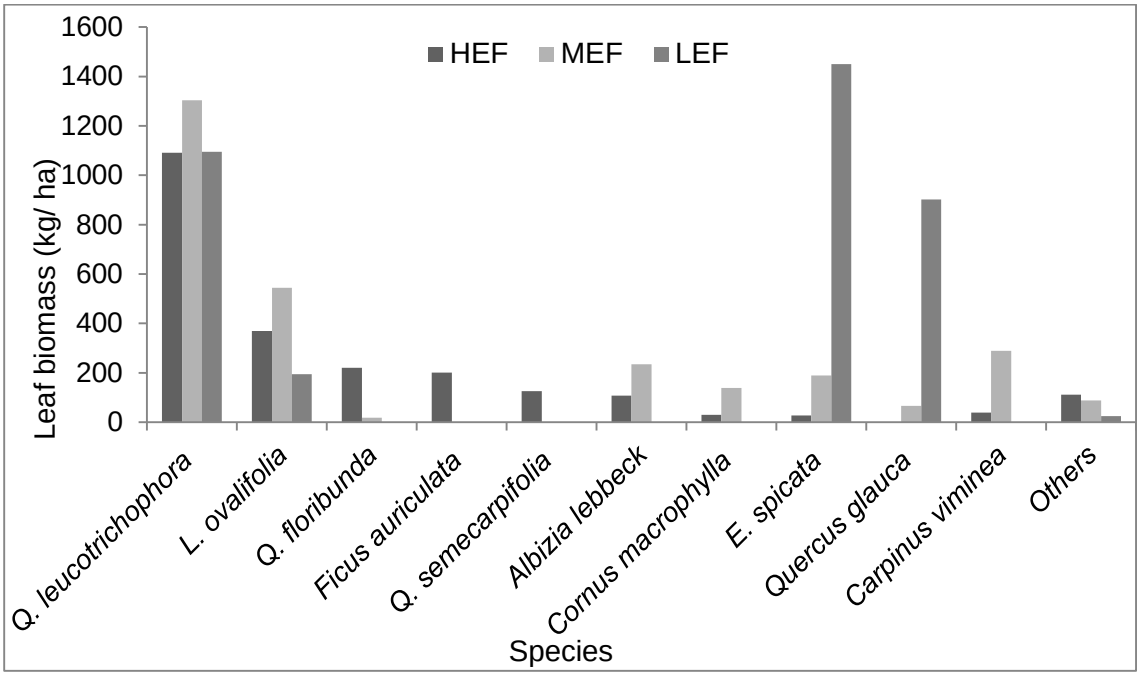


Fig. 4.7. Available leaf biomass of forest tree species used as fodder across elevational gradient. (Others include *Betula alnoides, Bauhinia variegata, Ficus neriifolia, Ficus subincisa, Ilex dipyrena, Symplocos paniculata, Celtis australis*)

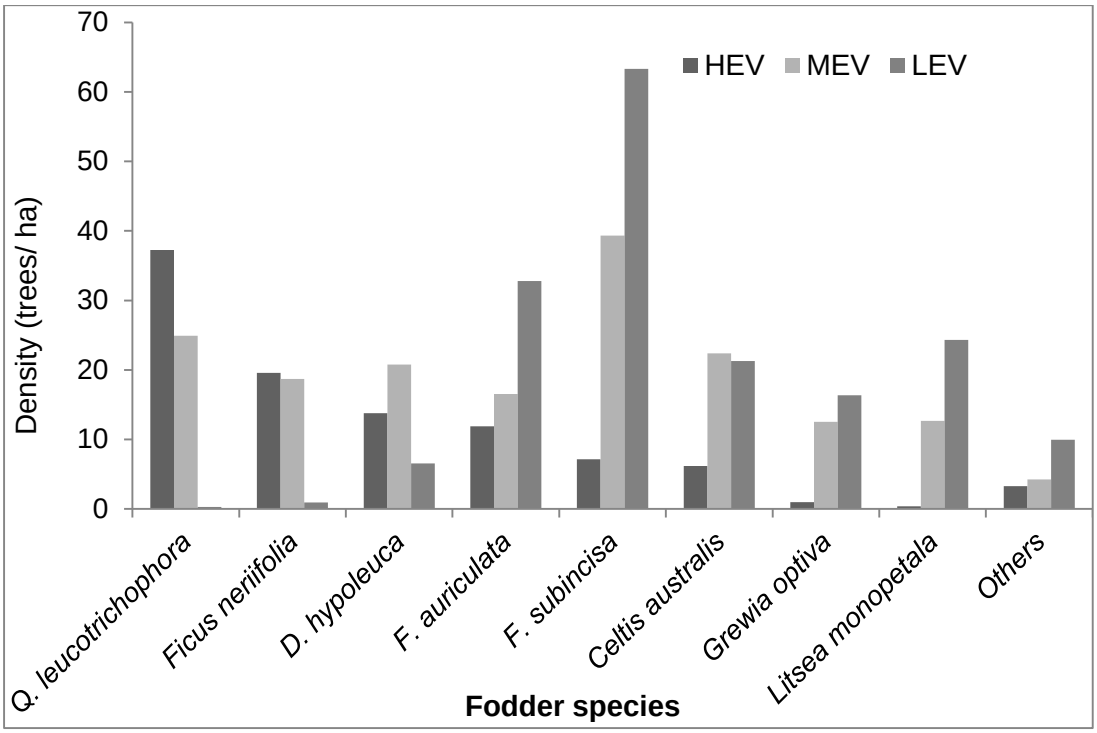


Fig. 4.8. Density of most used fodder tree species in Agro-forestry system across elevational gradient. (Others include *Bauhinia variegata, Cornus macrophylla, Carpinus viminea, Engelhardtia spicata, Ficus palmata, Ficus semicordata, Ficus virens, Grewia* sp., *Lyonia ovalifolia, Morus alba, Ougeinia oojeinensis, Q. floribunda, Quercus glauca, Symplocos chinensis*)

4.3.3 Tree species composition and biomass availability in Agro-forestry System along elevational gradient

65 species of both planted and naturally occurring trees were recorded in the agro-forestry systems (AFS) of studied villages (Table 4.2, Appendix 4.3). Of these, highest numbers of species were recorded from MEV (59) while both HEV and LEV had equal number of species (44). LEV had highest tree density (Ind. ha^{-1}) in AFS (313.07) followed by MEV (264.52) and HEV (166.62). Twenty two fodder tree species were recorded in agro-forestry system of which 15 were recorded from HEV, 19 were recorded from MEV and 16 were recorded from LEV. LEV had highest fodder tree

density (175.73/ HA), followed by MEV (172/ ha) and least in HEV (100.44). MEV had highest sapling (fodder species) density (140.17/ ha) followed by LEV (122.2/ ha) and HEV (49.85/ ha).

Quercus leucotrichophora (37.26/ ha) had highest tree density in HEV while *Ficus neriifolia* (16.75/ ha) and *F. subincisa* (14.81/ ha) had highest sapling densities. *F. subincisa* had both highest tree and sapling densities in MEV (39.31/ ha and 44/ ha) and LEV (63.33/ ha and 58/ ha). Tree species other than fodder species in the AFS included fruit trees particularly *Citrus* spp. and *Prunus* spp. (Appendix 4.3). Availability of leaf fodder biomass in AFS varied along elevation with LEV having highest biomass (2.62 ton/ ha) followed by MEV (2.14 ton/ ha) and HEV (1.5 ton/ ha) (Table 4.2). LEV had higher density and biomass of almost all the cultivated species (Fig. 4.8 and 9) while naturally occurring species *viz.*, *Q. leucotrichophora* and *Debregeasia* spp. had higher densities and biomass in HEV and MEV respectively. *F. neriifolia* was the only planted species with higher biomass in HEV and MEV than LEV.

The results from Kruskal-Wallis test and pair-wise comparisons indicated that total tree fodder biomass did not vary significantly along elevation; however, it varied significantly for certain species. It varied significantly from HEV to LEV for *Ficus neriifolia* (p value=0.01), *F. subincisa* (p value=0.034), *Litsea monopetala* (p value=0.005), *G. optiva* (p value=0.027), *Lyonia ovalifolia* (p value=0.009) and *Q. leucotrichophora* (p value=0.03). It also varied significantly from MEV to LEV for *Q. leucotrichophora* (p value=0.007).

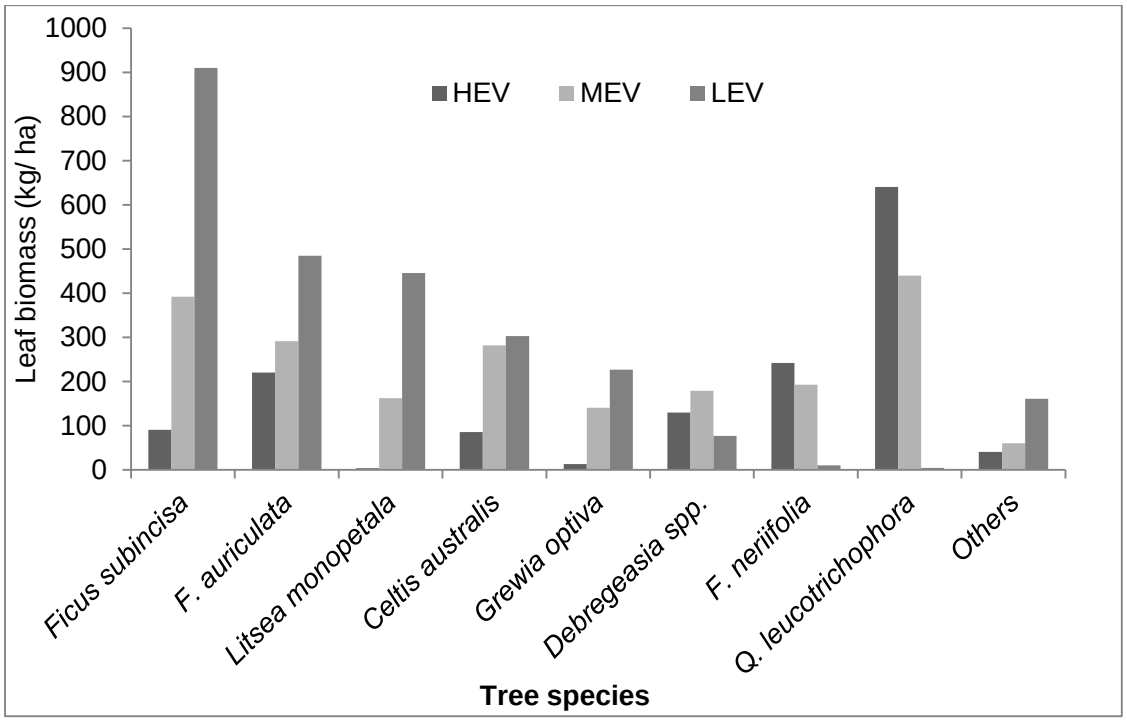


Fig. 4.9. Available leaf biomass of most used fodder tree species in Agro-forestry system across the elevational gradient. (Others include *Bauhinia variegata, Cornus macrophylla, Carpinus viminea, Engelhardtia spicata, Ficus palmata, Ficus semicordata, Ficus virens, Grewia* sp., *Lyonia ovalifolia, Morus alba, Ougeinia oojeinensis Quercus floribunda, Q. glauca, Symplocos chinensis*)

4.4 Discussion

4.4.1 Disturbance and forest community characteristics along elevational gradient

In the study area, greater disturbance was observed in high elevation forests as indicated by higher numbers of stumps per plot and proportion of lopped trees resulting in highest disturbance rank. The disturbance did not vary significantly along the elevational gradient as sampling strategy was to focus around the areas frequented by villagers for resource collection. As both the high and mid elevation villages were located either within the Sanctuary or along the boundary, villagers visited Sanctuary forests frequently for resource collection. Though the forest is protected under Wildlife

(Protection) Act 1972, the bonafide residents of the area have certain rights of grazing, lopping and grass cutting (Singh and Gangte, 2009). The open accessibility to the phyto-biomass in the Sanctuary might have resulted in higher dependence of HEV on Sanctuary forest. At the lower elevations, villages were located at a distance of more than 2 km from KWS and were surrounded by community-owned forests. Due to strict *Panchayat* rules, these forests provided limited spatial-temporal access to phyto-resources resulting in less disturbance. In community forests, the primary objective of community-enforced regulations is management of resources, which effectively leads to forest conservation in many regions (Berkes, 2009). Similar observations were made by Baland et al. (2010) and Måren et al. (2014), who concluded that forests managed by local communities were less lopped and degraded relatively to state protected/ managed forests.

Tree stand densities, basal cover and mean canopy cover recorded in current study were much below than previously recorded for Himalayan forests, particularly from protected landscapes in similar elevational range (Dhar et al., 1997; Hussain et al., 2008; Prasad et al., 2015; Singh and Singh, 1992; Singh et al., 2016). This could be due to continuous resource extraction and loss of old growth forests due to landslides, as the area has seen many landslide events in the recent past. There was not much difference in the species richness and diversity in the forests across elevation; however, higher species richness of mid-elevation forests could be either due to the hump relationship between species richness and elevation or a sampling biasness, as reported by Grytnes and Vetaas (2002). The tree species diversity was comparable with forest stands in

similar elevational range as reported by Singh and Singh (1992). Though low elevation forest had least species richness, it showed high species diversity and had higher number of effective species. These forests had higher tree stand density but lower basal cover which indicates predominance of trees of lower girth classes. The LEF was primarily riverine forests, prone to landslides, which could be the reason for younger tree stands.

The continuous biotic pressure in the form of logging, lopping, grazing and litter removal is known to bring changes in species composition and structure of mountain forests (Bagchi et al., 2012; Bebi et al,. 2016; Dzwonko and Gawronski, 2002; Gimmi et al., 2008; Savage, 1991; Sharma et al., 2009; Singh et al., 2014). Within the elevational range in the study area, Oak forests (*Quercus* spp.) form the climax communities (Singh and Singh, 1992; Singh et al., 2016). However, various disturbances such as extreme events like landslides, selective extraction of certain species and forest management practices might have resulted in establishment of Chir pine forest or Chir Pine-Banj oak mixed forests. Frequent landslides in the region have also resulted in prevalence of early succession or pioneer species such as *Alnus nepalensis, Carpinus viminea* and *Betula alnoides* in some areas. Continuous biotic pressure on climax species such as *Quercus* spp. in the form of selective biomass extraction of trees and heavy browsing by livestock at seedling and sapling stages might have resulted in the dominance of less preferred species. In high and mid elevation forests, two unpalatable and less preferred associate natives of Banj oak forests *viz.*, *Rhododendron arboreum* and *Lyonia ovalifolia* had higher dominance than Banj oak.

In the study area, the forest showed an abundance of trees in smaller girth classes, indicating a young population. This may indicate the dominance of light-demanding species in certain forest stands such as Chir pine and its associates, as a plateau in the growth curve is observed at the intermediate classes for these species (Manral et al., 2017; Singh and Singh, 1992). The density of saplings was higher than that of trees in the 30–60 cm girth class, indicating their failure to convert to trees. Both seedling and sapling densities were highest in low elevation forests, indicating good regeneration. As mentioned earlier, low elevation forests were better protected; there was no or low grazing signs in these forests which could be the reason for better regeneration. However, these forests had lower density of trees in higher girth class compared to other two elevation categories. A large part of LEF included riverine forests that have incurred loss due to cloud burst caused landslides and floods in recent past. This might have brought major structural changes in forests, leading to a preponderance of younger individuals. Another reason could be that these forests were under higher anthropogenic disturbance in the past and are better protected currently which might have resulted in improved forest status over a period of time.

Q. leucotrichophora, a climax species in the studied elevational range, was under great anthropogenic pressure and had low density of regenerating individuals. The seedlings and saplings of the species showed signs of browsing and lopping (personal observation). Lopping, along with leaf litter collection, enhance disturbance by causing loss of acorn producing branches from the canopy and desiccation of the fallen acorns and seedlings by exposure to the sun with the removal of litter bed. Singh

et al. (2014) found that this incessant small-scale disturbance adversely impacts the functioning of banj oak forests in the region, with significantly higher biomass stocks, soil carbon, and carbon sequestration rates observed in the least human-influenced forests. However, Singh et al. (2016) found that regeneration patterns were adequate across the banj oak zone in Uttarakhand, though their results also indicated large-scale fragmentation of these forests. Previous studies have shown that despite lower regeneration rates, oak forests tend to survive disturbances reasonably well (Singh et al., 1985; Thadani and Ashton, 1995). Canopy openings and protection of seedlings from grazing could maintain the banj oak population in the area. Seedling establishment is sustained by favorable climatic conditions and protection from disturbances. *Alnus nepalensis*, a pioneer colonizer in Himalaya, had higher density of saplings and young tree individuals in high and mid elevation forests, indicating a large disturbance in the past. While it has no or very few seedlings in these forests, it had good seedling density in low elevation forests indicating a recent disturbance event there.

4.4.2 Biomass availability in forests along elevational gradient

The above ground biomass (AGB) recorded in the forests of the Kedarnath Wildlife Sanctuary Landscape (164.16 t/ ha to 203.64 t/ha) was within the intermediate biomass category (150-300 t/ha) as given by Tiwari and Singh (1987) for the Uttarakhand Himalaya. The values are lower than previously recorded from mixed broadleaved forests or mixed oak-pine forests at similar elevations in Garhwal and Kumaun Himalaya (Gairola et al., 2011; Negi et al., 1983; Rawat and Singh, 1988;

Singh and Singh, 1992). However, these values were comparable to or higher than the values recorded by Sharma et al. (2010) and Tiwari and Singh (1987) in similar forest types. Singh and Singh (1992) broadly divided the Himalayan forests into two categories based on biomass values *viz.*, early successional communities like chir pine (200 t/ha) and late successional communities of climax species such as sal and oaks (400 t/ha). They noted that biomass values for undisturbed mixed oak forests in the region range from 556-782 t/ha, however, most of the forest stands have undergone human-caused changes in structure and function in the region. Thus, AGB values recorded in present study are comparable to early successional communities despite having climax tree community dominated by Oaks. Continuous lopping of green branches of various oaks might have caused low biomass in the forests in this area.

A number of studies have shown phyto-biomass variation along elevation as various environmental and community characteristics change (Kitayama and Aiba, 2002; Moser et al., 2007; Namgail et al., 2012; Rana et al., 1989; Singh and Singh, 1992; Singh et al., 1994; Waide et al., 1998). I found a hump-shaped relationship for the studied short elevational gradient in the study area as highest biomass (per unit area) was recorded in mid-elevation forests. However, there was no significant difference in total AGB and available fuel wood AGB along the elevational gradient. Forest use by locals and selective lopping of certain species might have also resulted in heterogeneity in AGB along this short elevational gradient. As mentioned earlier, mid-elevation forests had higher density of trees in higher girth class which could be the reason for highest biomass. LEF with trees in lower girth classes had least wood biomass which

could be due to loss of older forest stands to floods and landslides in the past, as these forests had higher occurrence of serial stage species compared to other two categories (Appendix 4.1). Available foliage biomass of most used tree fodder species was estimated, which decreased with the elevation. LEF despite having least number of fodder species had highest foliage biomass which might be due to better protected forests at lower elevation.

The results highlight disproportionate contribution of only a few species to the standing AGB in the region. Though the availability of fuel wood and fodder estimated as total AGB and foliage biomass did not vary along elevation, it varied significantly for few most used species between elevation categories. Many of the abundant species in studied forests had higher total basal area in MEF such as *Q. leucotrichophora, L. ovalifolia, R. arboreum* and *C. viminea*, despite having lower or comparable density to HEF or LEF which support higher AGB values in MEF. The elevational range of species might have also affected biomass values as species like *Engelhardtia spicata* and *Q. glauca* had higher biomass in LEF. Similarly, *Q. floribanda* and *Q. semecarpifolia* which primarily occurred beyond 2000 m had higher biomass in HEF.



Fig. 4.10. Location of study villages with respect to Sanctuary boundary and other villages

Though the available tree biomass (AGB tons ha^{-1}) did not vary significantly along the elevational gradient, spatial-temporal access to forests for resource collection changed along elevation as the village distance from Sanctuary forests varied (Fig. 4.10). Villages situated within the Sanctuary or along the boundary had access to greater extent of forests for resource collection as they had sanctuary forests on two or three sides. However, low elevation villages were situated at a distance of 2 or more kilometers from Sanctuary forests, surrounded by other villages and rivers. This gave a spatial disadvantage to LEV, as forests were less accessible for resource collection. The high and mid elevation villages also had temporal advantage for resource collection in

terms of year-round access to forests nearby. The villagers took their livestock for grazing and collected resources (fodder, leaf litter and dried fallen branches for fuel) from protected area as and when needed, along with their community forests, which were open, from November (early winter) to May (before monsoon) barring a few days in the beginning. All the LEV had only community forests in close vicinity; on which they have access either only for a few days early in winter for fodder collection (2-4 head loads per household mostly) or opened for fodder collection and/ or livestock grazing during winter months. In some cases, there were small riverine patches open for grazing but not for fuelwood or litter collection. Thus, villages at higher elevation had more opportunities to extract resources from forests compared to lower elevations.

4.4.3. Tree species richness and biomass availability in agro-forestry system along elevational gradient

A number of multi-purpose tree species were recorded in the agro-forestry system (AFS) of the landscape. These species varied based on their utility values such as fodder, fruits, fuelwood and timber, and mode of occurrence (*viz.*, naturally occurring or planted). Unlike the AFS of *tarai* and Ganga floodplains with predominance of timber trees, the AFS in the Himalayan Mountains are dominated by fodder species (Bhatt et al., 2010; Goswami et al., 2014; Kanime et al., 2013; Nautiyal et al., 2008). The AFS of the study area also showed preference of villagers towards fodder trees, which included *Ficus* spp., *Bauhinia variegata, Grewia* spp., *Litsea monopetala* and *Quercus* spp.

Similar to forests, AFS of mid elevation villages also had highest species richness while low elevation villages had higher tree density. The MEV had species from both high and low elevations, thus overlapping species elevational ranges might be responsible for higher species richness reported here. LEV with higher density of multi-purpose trees in AFS also had higher density of fodder species and higher fodder biomass values per hectare. Poor access to forest resources, greater distance from Sanctuary forests and strict regulations in community forests might have prompted villagers to enhance availability of resources within the AFS at LEV. On the other hand, HEV had least densities of multi-purpose trees, fodder trees and saplings in the AFS along with least available fodder biomass.

The preference for, and abundance of the species (as indicated by density and leaf biomass) varied with elevation. *Ficus* spp. are considered highly valuable fodder in the region with various species occurring at different elevations. Seven *Ficus* species were recorded from the region, all but *F. religiosa* have high fodder values. Similar to forests, only a handful of tree species dominated the AFS. *F. auriculata, F. subincisa, L. monopetala, Grewia optiva* and *Celtis australis* dominated the AFS of LEV while *Q. leucotrichophora, F. neriifolia* and *Debregeasia* spp. dominated that of HEV and MEV. Along with preference of people, dominance was also influenced by suitability of species to the area as MEV and LEV provided greater favorability to higher number of species. Interviews with local people revealed that HEV at or above 2000 m had fewer options and availability of saplings to be planted in the AFS.

Bhatt et al. (2010) in a study from Garhwal Himalaya noted that multi-purpose tree species are grown in marginal and un-irrigated lands and their presence closer to crop fields was considered unwanted. However, in the study area these trees were planted or allowed to grow along the boundary of agricultural fields. Other than field boundaries, the trees were grown in fields not suited for cultivation due to landslides, being situated far from home or with depleting production. In villages like Kotma where many families have migrated out, their fields are looked after by their relatives who mostly plant multi-purpose tree species on these lands. These trees were personal assets of a household and were harvested during the lean fodder availability, especially in winter months. The AFS of LEV and most of the settlements of MEV had predominance of cultivated species, while the HEV had predominance of *Q. leucotrichophora*, a slow growing climax species of region's forests. The species was encountered most commonly in forest-agriculture ecotones in settlements located closer to *Q. leucotrichophora* dominated forests. Majority of the trees were individuals that are left along the field boundaries after encroachment of civil forests and are owned by families on whose land the trees stand.

Other than fodder species, fruit trees also formed an important component of AFS. Agro-horticulture was not practiced at commercial scale in the region and fruits were mostly consumed by the families. The most encountered species included *Citrus* spp. such as malta, lemon, sweet lime, etc., *Prunus* spp. such as peach, apricot and plum and *Juglans regia*. As few non-governmental organizations (NGOs) are working in the region, particularly after the June 2013 flooding disaster, local communities have

started selling fruit harvest contributing to surplus agriculture income. These NGOs also provide saplings of various fruit and fodder species to local communities to be planted in the AFS. Every monsoon, forest department carries out plantation drives in villages situated within the Sanctuary or along the boundary. In such drives, saplings of species like *Cedrus deodara, Fraxinus micrantha, Prunus cerasoides* and *Q. leucotrichophora* are planted on marginal lands in the villages.





Chapter 5

Chapter 5

Human Wildlife Interaction:

Impacts on Livelihoods of Local Communities

'*We sow the seeds, we nurture the plants but all is taken by the wild animals. Bears take our corn and fruits, boars eat our millet and paddy and dig our potatoes, porcupines consume our lentils and vegetables. We are left with nothing.'*

-An elderly woman from study area (translated in English)

5.1 Introduction

Human - Wildlife Conflict (HWC) or Human Wildlife Negative interactions (HWNI) is defined as the 'interaction between humans and wildlife where negative consequences, whether perceived or real, exists for one or both the parties; when action of one has an adverse effect on the other party' (Conover, 2001; Decker, 2002). It has been in existence for as long as wild animals and humans have co-existed and shared the same resources (Barnes, 1996). Such conflicts have negative impacts on conservation of wildlife populations or of their environment; and social, economic and cultural well-being of humans (WWF, 2005). The species involved may vary from grain eating sparrows or rodents to man-eating tigers; affecting from marginal agro-pastoralists of developing countries to elite section of developed world. The negative consequences for local communities include attacks on humans (Jadhav and Barua, 2012; Löe and Röskaf, 2004; Packer et al., 2005), depredation of livestock or game (Banerjee et al., 2013; Thirgood et al., 2005), destruction of stored harvest or crop-

raiding (Karanth et al., 2012; Perez and Pacheco, 2006; Pimentel et al., 2005) and spread of zoonotic diseases to humans or stock (Daszak et al., 2000; Hegglin et al., 2015; Singh and Gajadhar, 2014). At times people have to make lifestyle choices and bear opportunity costs due to presence of wildlife or eviction from or prohibition of resource extraction due to creation of protected areas (Barua et al., 2013; Woodroffe et al., 2005a, b). Consequences are no better for wild species which bear the brunt in the form of retaliatory killing and lethal control (Bergstrom et al., 2014; Liu et al., 2011; Mateo-Tomás et al., 2012; Northrup et al., 2012)

The intensity of the problem is increasing because of a number of factors such as increase in human populations and consequent anthropogenic encroachment into wildlife habitats resulting in transformation of wildlife habitats into urban and sub-urban areas and agrarian ecosystems and fragmentation of wildlife habitat causing constriction of wildlife populations into marginal habitat patches (Estes et al., 2012; Hegel et al., 2009; Nyhus and Tilson, 2004; Siex and Struhsaker, 1999; Yadav et al., 2012). Recovery of populations of many large mammals due to efficient wildlife management and large network of protected areas worldwide has also lead to increased conflicts (Fall and Jackson, 2002; Saberwal et al., 1994; Vijayan and Patil, 2002; Woodroffe et al., 2005b). Stochastic events such as fire and climatic change also augment conflict situations *e.g.* more cases of livestock depredation by wild predators during seasonal rains in Kenya (Butler, 2000; Nyhus and Tilson, 2004; Patterson et al., 2004).

India is a mega-diverse country owing to its wide climatic and topographic gradient. With more than 100 National Parks and more than 500 Wildlife Sanctuaries, the country has an extensive network of protected areas and wildlife reserves. With a fast developing economy and large rural population, the protected area landscapes of country are not untouched of human presence. High rate of human population growth put the wilderness areas under threat due to increasing interference, deforestation, fragmentation of natural habitats and expansion of agricultural lands in the forested landscapes. As the wild habitats become conservation islands surrounded by human-dominated landscapes, the negative interaction between human and wildlife species, particularly large mammal increases. A close interface between large mammals such as tigers, elephants, lions and others with humans and their land use has caused serious conflicts countrywide over space and resources (Banerjee et al., 2013; Karanth et al., 2013; Madhusudan and Mishra, 2003; Mishra, 1997; Mishra et al., 2003; Sukumar, 1994). The attacks on human and livestock, and incidences of crop raiding have significant consequences for people's food security and livelihood and psychosocial wellbeing (Barua et al., 2013).

Human Wildlife Conflict is well studied in India, however, there are sporadic studies on certain species (Table 5.1) but no realistic estimates are available for any species across its range (Manral et al., 2016). The research on HWNI has primarily been focused around natural science with a resultant well-understood ecology of some conflicts (Woodroffe et al., 2005a). However, it involves people, and it is very essential to understand attitudes, beliefs and values of stakeholders to mitigate conflicts (Ogra,

2008; Redpath et al., 2004). In rural areas where livestock holdings and agriculture are an important part of household's livelihoods and incomes, competition between local communities and wild animals for the use of natural resources is intense thus escalating conflict (Mishra et al., 2003). The relative impact of damage on household's income varies greatly according to the economic dependence on agriculture and livestock and for households with subsistence economies even small losses can be significant (Oli, 1994; Rao et al., 2002; Sukumar, 1993). Costs escalate if investments are made in fencing or mitigating measures or if the conflict is severe, families abandon cultivation of otherwise profitable land (Naughton-Treves et al., 1998). HWNI is a growing problem for forest dwelling communities of Uttarakhand. The state has seen changes in agricultural pattern (Misra et al., 2009; Negi, 2007; Semwal et al., 2004; Sen et al., 2002), increase in population pressure (Nandy and Rao, 2001b) and accompanied land use changes (Negi, 2007; Sen et al., 2002) disrupting the natural balance and increasing competition between human and wildlife for space and resources.

The study area falls in the Kedarnath Wildlife Sanctuary (KWS) Landscape, with five study villages located inside the Sanctuary. Three of the study villages are at or more than a distance of 2 km from Sanctuary boundary, while rests are located along the Sanctuary boundary. As concluded in previous chapters, the inhabitants of these villages depend substantially on forest resources of the Sanctuary. Studies have pointed out habitat destruction and successional changes within the KWS because of ongoing unsustainable harvesting and logging practices (Manral et al., 2016; Misra et al., 2009; Thakur et al., 2011).

Table 5.1. Monetary value of loss incurred by local communities due to Human Wildlife Conflict

Species	Location	Extent of loss/ monetary loss	Reference
Blackbuck	Gujarat	48,600 kg of Sorghum crop in two villages of value ~ US$ 558	Jhala, 1993
Snow leopard	Kibber Wildlife Sanctuary, Himachal Pradesh	18% of household's livestock holdings with economic loss that equaled to 25% of annual income/ household	Mishra, 1997
Wild ungulates, tiger and leopard	Sariska Tiger Reserve, Rajasthan	6 - 27% of total crop yield per ha, valued at US$ 48 to 67/ household/ year	Sekhar, 1998
Snow leopard and wolf	Hemis National Park, Jammu & Kashmir	492 cattle in 14 months valued at US$ 23,500	Jackson and Wangchuk, 2001
Ungulates, common leopard and Asiatic Black Bear	Nanda Devi Biosphere Reserve, Uttarakhand	40% of sown area with crop loss of US$ 50 while livestock loss of US$ 5/ household/ year	Rao et al., 2002
Elephants, tiger and leopard	Bhadra Tiger Reserve, Karnataka	11% of the annual production from agriculture and animal husbandry in the area lost, valued at US$ 5404	Madhusudan, 2003
Tibetan wolf, snow leopard and lynx	Proposed Gya-Miru Wildlife Sanctuary, Jammu & Kashmir	2.9% of household' livestock holdings, valued at US$ 190/household/year	Namgail et al., 2007
Wild ungulates	Kanha National Park, Madhya Pradesh	US$155 from crop loss/ household/ year	Karanth et al., 2013
Wild ungulates	Ranthambore National Park, Rajasthan	US$ 264 from crop loss/ household/ year	Karanth et al., 2013
Wild ungulates	Nagarahole National Park, Karnataka	US$ 546 from crop loss/ household/ year	Karanth et al., 2013
Wild dog	Arunachal Pradesh	20.3% of the total monetary value of livestock valued at US$ 134,493 for two years in 48 sampled villages	Lyngdoh et al., 2014

Bhattacharya et al. (2012) made observations that there was very little spatial overlap between wild mountain ungulates and livestock in the alpine areas of KWS.

However, in winters wild ungulates were observed to graze in areas occupied by livestock in summer and early autumn, thus, indicative of impact of anthropogenic pressure on habitat use by wild ungulates. With the increased human population and augmented anthropogenic pressure on natural resource, the KWS landscape faces several challenges including Human Wildlife Negative Interactions. Thus, it becomes imperative to study the dynamics of Human wildlife interaction in the landscape where agro-pastoralist communities are a prevalent feature. This study examined the current situation of negative interaction between human and wildlife in the landscape. The objective of the present chapter was to assess the extent of negative interaction affecting the livelihoods of the villagers. It was hypothesized that human–wildlife conflicts negatively impact livelihood generation in the study area (by causing substantial losses to sustenance income from primary livelihood activities). The monetary value of loss associated with attacks on humans, cattle and crop raiding by wild animals was calculated and the attitude of respondents to compensation schemes was studied.

5.2 Methodology

Study village selection: Secondary data regarding incidences of HWNI and compensation to the affected households was collected from records of Uttarakhand Forest Department and reconnaissance survey was done in the study villages to understand the nature and the pattern of HWNI. This data was used in Hierarchical Cluster Analysis (explained in chapter 3) to select representative study villages from each cluster. Selected villages were re-categorized into three groups based on nearness

to Kedarnath Wildlife Sanctuary *viz.*, villages inside the Sanctuary (SV; Chaumansi, Chilond, Ransi, Gaundar and Gadgu; sampled households = 111), fringe villages (FV; Raulek, Buruwa, Kalimath, Kotma, Kaviltha, Khonu, JaalMalla, sampled households = 200) and distant villages located >2 km from Sanctuary boundary (DV; Mansoona, Bhatwari including Sansari and Bedula, sampled households = 107).

Primary data collection*:* The primary data was collected in two stages. In first stage, interview based semi-structured questionnaire survey were conducted in randomly selected households in selected villages (Ogra and Badola, 2008). Though, HWNIs have both monetary and psychological implications (Ogra, 2008), the objective of the study was limited to evaluate the extent of loss to livelihood and income of local communities. The types of negative interaction or conflict between humans and wildlife were categorized into three categories *viz.,* attacks on humans, livestock depredation and crop raiding. For the first, questions were asked about any attack on members of household (in last two years), wild animal involved, place of attack and activity in which the person was involved during attack, types of injuries, loss of working days of injured (in case of adult) or of member taking care of the injured, money spent on treatment and travel to access the medical facilities. For the second, questions were asked about attacked livestock (in last five years), wild species involved, place, season and time of incidence and presence of any human during the incident. For crop raiding, questions were asked about the problem animal, crops raided, percent loss of crop harvest, location of fields most raided and money spent on preventive measure. People

were also asked questions on their awareness of wildlife and their habitat, acceptability towards compensation schemes and attitude towards forest department. As most of the information was based on recall data, it was cross-checked by group discussions. Unrealistic estimations were avoided to maintain the accuracy of recall information (Bernard et al., 1988).

At the second stage, crop damage was validated in the fields through laying line transects along the agricultural field in six villages (three PA villages, two fringe and one distant village) before the harvesting period of *rabi* crops *viz.,* wheat (*Triticum aestivum*), mustard (*Brassica compestris*), barley (*Hordeum vulgare*) etc. Signs of crop damage were noted down along with crop name, any signs of problem animal, number/proportion of crop fields, total crop (area) affected, proportion of harvest lost and distance from houses, trail and forest. Incidences of livestock depredation or attack on humans during field work durations were also noted down along with problem animal.

Data analysis: To assess the monetary loss, price of livestock and damaged crop was noted down from local market. As, respondents gave information on loss of percentage of harvest of various crops, the loss incurred was calculated by estimating the amount of crop lost from total harvest and price of lost harvest was calculated. Monetary loss due to livestock depredation was estimated using value of the livestock species in the local market. To see economic loss due to attack on humans, the money spent on treatment and travel to avail medical facilities was noted down.

5.3 Results

5.3.1 Attacks on humans

There were only three incidences of attack on humans by wildlife in last two years. One attack occurred in Chaumansi (PA village) while other two occurred in Raulek and Buruwa (both fringe villages). None of the attacks resulted in death of the person. In Chaumansi, a leopard attacked a six years old child playing outside his house, with other children, during late evening hours. The child received claw marks on body and it took him three months to recover fully. The family spent around INR 10,000 on his treatment and the parents had not complained to forest department. In Buruwa, a 50 years old man was attacked by a leopard in forest while he watched his sheep in the evening. The site of attack was closer to village-forest edge. The man received injuries in the form of teeth and claw marks on arms and back, however, was able to resume his work in less than a week. The last attack was by an Asiatic black bear on a man during early morning hours. The bear had entered into his cowshed and unaware of this, when the man went to took out his livestock from the shed, he was attacked by the animal. He had received severe wounds and had spent around INR 40,000. He lodged a written complaint with the range officer at Guptakashi. In all three cases, there was no compensation made till the survey was conducted.

5.3.2 Livestock depredation

Common Leopard (*Panthera pardus*) and Asiatic Black bear (*Ursus thibetanus*) were reported to be involved in the livestock depredation in the study villages. All cases

of cattle lifting were attributed to leopard except two incidents where black bear was held responsible. Table 5.2 gives details of attacks on livestock by wild animals in the study villages across three village categories as reported by villagers in last five years. Out of 418 households surveyed, 196 (46.89%) reported livestock depredation by wild animals. Highest percentage of households attack on cattle was in Sanctuary villages (61.47%) followed by fringe village (41.67%) and distant villages (41.12%). The average monetary loss of these households was INR 14,500±24,472 per household in PA villages, INR 15,566±29,674 per household in fringe villages and INR 7,814±8,581 per household in distant villages. The highest loss incurred was INR 174,000 by a household in fringe villages which lost around 30 sheep in 2 separate incidence (different years) of leopard attack in the alpines during migration. SV reported 100 incidents of livestock depredation which resulted in death of 201 animals, FV reported 108 incidents resulting in death of 248 animals and DV reported 63 incidents leading to death of 76 animals. The attacks were reported in alpine meadows (primarily seasonal migration of sheep and goats with village *Palsi* or shepherd during summer and monsoon *viz.,* late April to late July), forest edge (livestock grazing near village boundaries, uncultivated fields closer to forests, animals returning back from forests after grazing etc.), cowshed within village, fields closer to or surrounded by settlements and forests. Most attacks in all the village groups were in forests.

In DV, attacks were comparable in forests and cowshed. Most attacks occurred during evening hours across all three village groups. DV had higher percentage of attacks occurred during night compared to other two village groups. In DV, highest

percentage of attacks were recorded during unsupervised grazing while in SV, highest percentage of attacks were under male supervision. Attacks on sheep and goats occurred mostly in alpine or forests where males are the ones watching the animals, which could be the reason.

Table 5.2. Livestock depredation across village groups and economic loss (in last five years)

		Sanctuary villages (n = 109)	**Fringe villages (n = 204)**	**Distant villages (n = 107)**
% of hh reporting killing (No.of hh)		61.47 (67)	41.67 (85)	41.18 (43)
Average monetary loss hh^{-1} (INR)		14,500±24,472	15,566 ± 29,674	7,814±8581
Range of loss (INR)		1,000-134,000	1,000 –174,000	1,000 –36,500
Number of animals killed (number of incidents)	Total	201 (100)	248 (108)	76 (63)
	Buffalo	12 (3)	-	5 (5)
	Cow	50 (42)	70 (50)	37 (27)
	Oxen	22 (22)	39 (25)	24 (23)
	Calf	15 (12)	8 (7)	4 (4)
	Mule	1 (1)	2 (2)	-
	Goat and Sheep	101 (20)	129 (24)	6 (4)
Location of Attack (%)	Alpine meadows	9.90	4.85	0.00
	Forest edge	8.91	7.77	16.98
	Cowshed	9.90	17.48	24.53
	Fields	3.96	3.88	11.32
	Forest	67.33	54.37	30.19
	Don't remember	-	11.65	16.98
Season (%)	Autumn	7.55	7.77	3.77
	Monsoon	27.36	28.16	9.43
	Spring	5.66	2.91	3.77
	Summer	29.25	14.56	30.19
	Winter	25.47	36.89	22.64
	Don't remember	4.72	9.71	30.19
Time of day (%)	Morning	9.90	5.83	3.77
	Afternoon	17.82	21.36	16.98
	Evening	31.68	32.04	33.96
	Night	5.94	19.42	22.64
	Don't remember	34.65	21.36	22.64
Human supervision (%)	Children	7.92	5.83	13.46
	Adult female	25.74	29.13	16.98
	Adult male	38.61	29.13	18.87
	None	27.72	35.92	49.06

5.3.3 Field validation of livestock depredation

On-field validation of livestock depredation was done by noting down incidents of livestock depredation by wild animals in three Sanctuary villages (Ransi, Chaumansi and Gaundar), three fringe villages (JaalMalla, Khonu and Kotma) and two distant villages (Mansoona and Bedula) from October 2014 to June 2015. No incident of livestock killing by wildlife was noted in Gaundar and both the distant villages. In SV, 40 animals were killed in 24 incidents and 14 animals were killed in eight incidents in FV (Table 5.3). All the attacks were by leopard except one each in SV and FV where black bear was the problem species. The monetary loss per household (only for households which incurred the loss) was INR 10,696±7,061 in SV and INR 5,187.5±2,724.7 in FV. In SV, higher percentage of attacks occurred in forest while in FV, attacks were more in cowsheds.

5.3.4 Crop raiding by wild animals

Crop damage was reported by almost 99% of the sampled households and only 6 (1.43%) households did not face a crop raiding by wild animals in last one year. In SV, 95% sampled households held wild pig (*Sus scrofa*) responsible for raiding crops, 65% held primates (Rhesus macaque, *Macaca mulatta* and Nepal Grey Langur, *Semnopithecus schistaceus*) responsible, 34% named Asiatic black bear, 24.29% named Indian crested porcupine (*Hystrix indica*) and only 4% mentioned birds including sparrows and red and green finches. In FV, 69.35% sampled households named wild pig involved in raiding crops, 68.55% named Rhesus macaque and Langur, 38.71% named

black bear, 12.90% named porcupine and only 7.26% mentioned birds. One household mentioned damage from some (unidentified) mountain ungulate species. In DV, 85.71% sampled households held primates responsible for raiding crops, 67.35% named wild pig responsible, 38.77% named black bear, 11.22% named porcupine and only 4.08% mentioned birds. The percentages do not add up to 100 as few of the respondents were unsure about the answer.

Table 5.3. Livestock depredation across village groups and economic loss (on-field validation; October 2014 to June 2015)

		Sanctuary villages	**Fringe villages**
Average monetary loss per household (INR)		10,696±7,061	5,187±2,724
Range of loss per household (INR)		3,000 – 28,000	2,500–9,000
Number of livestock and pet killed (number of incidents)	Total	40 (24)	14 (8)
	Cow	8 (5)	13 (7)
	Oxen	1 (1)	1 (1)
	Dog	3 (3)	-
	Goat and Sheep	31 (17)	-
Location of attack	Forest edge	17.24	12.5
	Cowshed	6.90	75.0
	Fields	13.79	12.5
	Forest	62.07	-
Season	Autumn	11.11	-
	Spring	3.70	-
	Summer	18.52	37.5
	Winter	66.67	62.5
Time of day	Morning	14.81	25.0
	Afternoon	22.22	12.5
	Evening	48.15	-
	Night	14.81	62.5

In Sanctuary villages, 48.54% respondent claimed that wild pig raided all the fields uniformly irrespective of the location of fields, however, 29.13% claimed that they raided fields closer to forest margin or valley bottoms; 31.25% claimed that black bear raided all locations uniformly while 43.75% claimed raids were closer to forests; in

case of primates the proportion was 57% and 36% respectively, while in case of porcupine, these were 34.62% and 61.54%, respectively (Fig. 5.1). In fringe villages, these percentages were 18.60% and 76.74% for wild pigs; 13% and 69% for black bear, 53.49% and 38.37% in case of primates and 25% and 75% in case of porcupine, respectively. In distant villages, these percentages were 27.27% and 66.67% for wild pigs; 15.79% and 84.21% for black bear, 85.55% and 13.04% in case of primates and 36.36% and 54.54% in case of porcupine, respectively. In SV, 5.8% of the respondents said primates raided crops closer to center of village while in FV, 7% of the respondents claimed so.

Wild pig was held responsible for loss of 30±14% of harvest in SV, 28±13% in FV and 18±9% in DV (Fig. 5.2). The crops raided included paddy (*Oriza sativa*), finger millet (*Eleusine coracana*), wheat and barnyard millet (*Echinochloa esculenta*). Black bear was held responsible for loss of 28±19% of harvest in SV, 19±7% in FV and 14±7% in DV. The crops included paddy and finger millet, primarily and vegetables and corn, reported by few households (17.21%). Primates were held responsible for loss of 20±8% of harvest in SV, 26±12% in FV and 23±7% in DV. The crops raided by primates included all the grains and lentils, except barnyard millet and amaranths (*Amaranthus* spp.). Porcupine was held responsible for loss of 12±8% of harvest in SV, 15±6% in FV and 9±5% in DV. The crops raided included lentils and vegetables including potato (*Solanum tuberosum*). Birds were held responsible for loss of 10±4.08% of harvest in SV, 16±7% in FV and 8±3% in DV. The crops damaged by birds included all the grains and mustard.

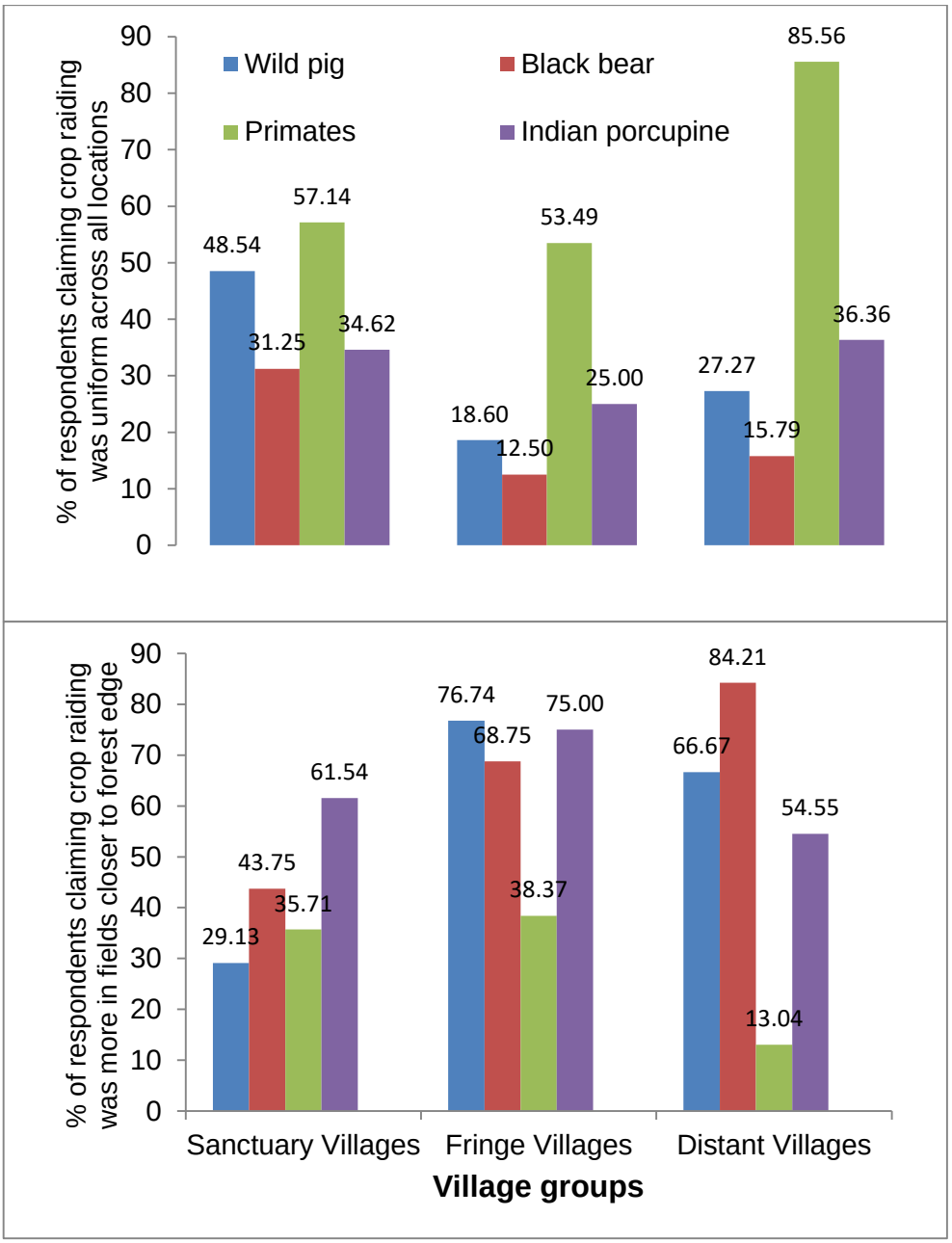


Fig. 5.1. Variation in the location of crop raiding by wild animals across three village groups, as claimed by respondents (n = 412)

5.3.5 Monetary loss due to crop raiding by wild animals

In SV, sampled households reported a harvest loss of 24.08±15.97 Kg household^{-1} wheat (INR 240.80±159.7), 14.09±9.59 kg household^{-1} of rice (INR 633.89±431.34), 25.78±17.64 kg household^{-11} of finger millet (INR 257.76±176.42), 15.02±14.01 kg household^{-1} of barley (INR 150.20± 140.13), 6.36±6.26 kg household^{-1} of mustard (INR 190.80±187.68), 5.37±3.02 kg household^{-1} of lentils (INR 483.31±271.86), 4.10±2.58 kg household^{-1}of kidney beans (INR 410.23±257.91) and 9.97±4.60 kg household^{-1}of potato (INR 149.55±68.99).

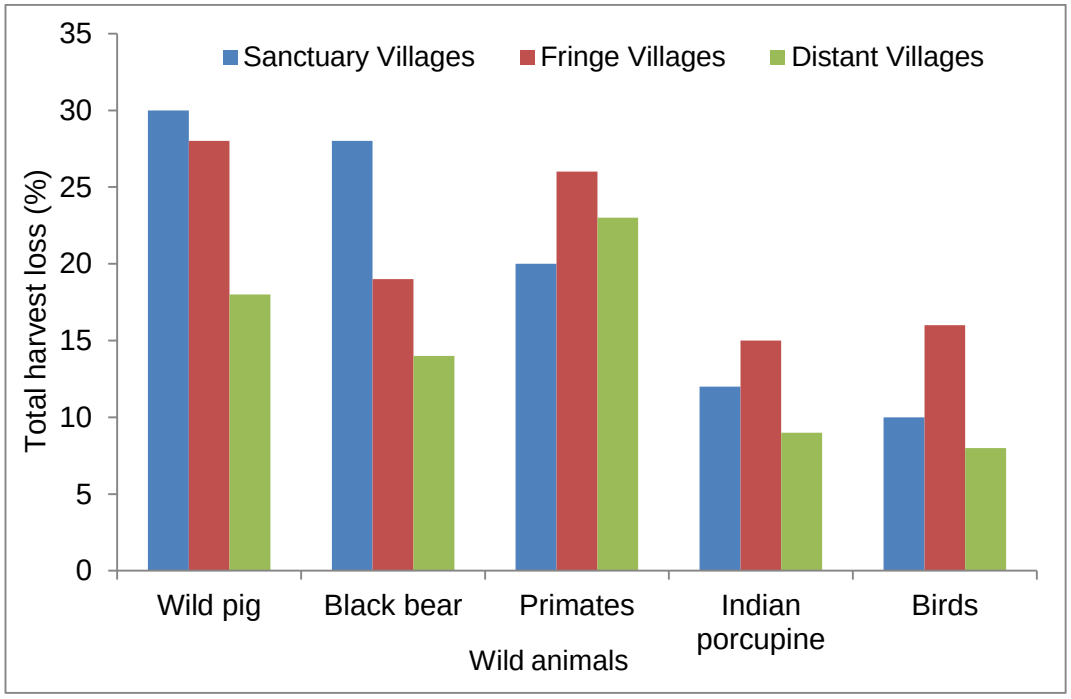


Fig. 5.2. Percentage of total harvest lost by wild animals across three village groups (as claimed by respondents)

In FV, respondents reported a harvest loss of 19.66±11.63 kg household^{-1} wheat (INR 196.44±116.29), 17.88±19.26 kg household^{-1} of rice (INR 804.73±686.90),

20.06±13.47 kg household^{-1} of finger millet (INR 200.55±134.73), 4.93±2.48 kg household^{-1} of barley (INR 49.26±24.79), 5.60±4.61 kg household^{-1} of mustard (INR 168±138), 5.46±4.78 kg household^{-1} of lentils (INR 491.04±429.84), 2.96±1.67 kg household^{-1} of kidney beans (INR 296.40±166.60) and 4.97±1.85 kg household^{-1} of potato (INR 74.61±27.69). In DV, sampled households reported a harvest loss of 16.28±12.70 kg household^{-1} of wheat (INR 162.80±127.04), 10.08±5.87 kg household^{-1} of rice (INR 453.74±264.02), 10.02±4.39 kg household^{-1} of finger millet (INR 100.22±43.86), 2.47±2.39 kg household^{-1} of mustard (INR 74.12±71.64), 3.45±3.76 kg household^{-1} of lentils (INR 310.82±338.69) and 1.37±1.02 kg household^{-1} of kidney beans (INR 137.16±102.24).

5.3.6 Validation of crop raiding

Five transects were laid in Sanctuary villages (two in Ransi, two in Chaumansi and one in Gadgu), three were laid in fringe villages (two in Kotma and one in JaalMalla) and two were laid in distant village (both in Bhatwari) and information was noted down at every location where any sign of crop loss from wild animals were observed. One transect in Chaumansi (600 m in length) that started from house clusters towards forest edge had no signs of crop raiding. About 5% damage by birds (seeds eaten from ears of wheat and barley) was observed in two fields. Similarly, no damage by wild animals was observed during transect walking in JaalMalla (500 m) that started from village center (road head) to the ridge where village ends (Pairak). However, there

were no forests nearby to this transect and the other side of mountain ridge had steep slopes. Leopard scats were noted along the trail.

In SV, 22 crop fields per 1 km of line transect showed signs of crop damage by wild animals. Out of these, in 90% damage was done by wild pig, while other crop fields were damaged by birds and primates. Of the total 3567.78 m^2 area raided, 3445.56 m^2 was by wild pig, 44.44 m^2 by birds and 77.78 m^2 had damage signs of primates. In one of the fields, we encountered troop of Rhesus macaque feeding on wheat stalks. The total percentage of plants damaged was 15.65±13.97%; crop damaged in the fields raided by Wild pig was 13.68±13.97%, by birds was 32.59±9.25% and by primates was 8.89±6.29%. The crops which were damaged by the wild animals included wheat (3474.22 m^2 area with 14.90±13.53% damage to harvest), lentils (52.22 m^2 area with 10±7.86% damage to harvest), mustard (28.89 m^2 area with 34.07±11.18% damage to harvest) and barley (159.11 m^2 area with 16.11±17.34% damage to harvest). Damage signs due to black bear were not encountered in fields but in backyard kitchen gardens at two locations which included complete damage of corn and pumpkins in the impacted fields.

In FV, 21 fields per 1 km of line transect showed signs of crop damage by wild animals. All these were wheat fields and were raided by primates with some signs of grains eaten from wheat ears by birds. Total area raided was 492.5 m^2. The total percentage of harvest lost was 38.89±21.95%. At two of the locations, troop was encountered feeding on the crops. In DV, 19 fields per 1 km of line transect showed signs of crop damage by wild animals. All these were wheat fields and were raided by

primates and the total area raided was 61,500 m^2. The total percentage of standing crop damaged was 15±13.23%. At one of the locations, a langur troop of 20 individuals was encountered in wheat fields.

5.3.7 Compensation scheme and use by local communities

Villagers apply for compensation only when there is an attack on humans or livestock. Only two respondents mentioned that they had verbally informed forest department about crop loss but no written application for compensation was made. Among the three attacks on humans, only one respondent (black bear attack in Raulek) had applied for compensation. Out of 271 incidents of livestock depredation, only 43 had applied for compensation. Of these, 76.74% had submitted a written application, 13.95% had informed the forest department staff over telephone and 9.30% had informed verbally to the official present in the village. Eighteen of those who had filed a written complain found the application procedure complicated, one was satisfied while rest (20) did not reply to this question. Of 43, only 25.58% had received compensation while rests were still waiting for the same. About 80% of these households received compensation equivalent to actual monetary loss while for rests it was less than actual loss. The time taken to receive compensation was from six months to more than a year.

5.4 Discussion

Results indicate that the average economic loss per household due to human wildlife negative interaction is very small compared to average annual income (INR

186751.29±184133.14 household^{-1}) in the area. However, the loss is detrimental for households dependent largely on primary livelihood activities, particularly female-headed households. The relative impact of damage caused to household's income varies greatly according to the economic dependence on agriculture and livestock and for households with subsistence economies even small losses can be significant (Oli, 1994; Rao et al., 2002; Sukumar, 1993). A household's livelihood can comprise of a mix of on-farm and off-farm activities which together form the procurement strategies for food and cash for the family (Frankenberger and McCaston, 1998). Both agriculture and animal husbandry are important component of subsistence income for the local communities of the study area (Chapter 3 results) and loss of a single cattle or >20% of total harvest becomes detrimental for the economically marginalized households.

Higher percentage of households in villages situated with KWS reported incidents of livestock depredation compared to other two village groups. These villages also reported higher percentage of incidents in forests and alpine areas. In SV, higher percentage of sampled households took their livestock for grazing in forests (SV= 96.33%, FV = 52.94%, DV = 20.56%) and a small proportion of sampled households also migrate temporarily to sub-alpine areas closer to alpine meadows during summer and early monsoon. These could be the reason for higher livestock depredation in these villages. Similar results were also found by Dobriyal (2015) in Nanda Devi Biosphere Reserve landscape, where author reported more incidences of livestock predation in forest than in the agriculture fields and human settlement. Most incidents happened in

the evening, particularly late evening when livestock return from forests or are left to graze in the fields or common land within village.

The incidents of human wildlife negative interactions are rampant across India. Livestock depredation by wild dog in Arunachal Pradesh resulted in loss of around 20.3% of the total monetary value of livestock in sampled villages (Lyngdoh et al., 2014). In Bhadra Tiger Reserve, a loss of 11% of crop harvest and 12% of livestock was attributed to elephants and large cats, respectively by Madhusudan (2003). In Nanda Devi Biosphere Reserve, more than 40% sown area was damaged with an average monetary loss of INR 2,590 per household, annually. Locals in the reserve also suffered from livestock depredation with an average loss of INR 272 per household annually. The projected total values of livestock and crop losses for buffer zone villages were estimated at INR 1,024,520 and INR 538,620, respectively (Rao et al., 2002). Karanth et al. (2013) reported an annual loss of INR 9,817, 16,722 and 34,584, from crop loss per household in Kanha, Ranthambore and Nagarahole National Parks, respectively.

In the study area as the loss and frequency of incidents increased, people showed more intolerance towards wildlife. Monetary losses were greater if one single incident resulted in loss of more than one cattle or sheep and goat or death of pack animal. Loss of a pack animal or a milking animal (high milk yielding cow or buffalo) also meant direct loss of cash income for the household. Among the crop raiders, people showed greater intolerance towards wild pig and primates. Wild pigs are blamed not only for eating the crop but also digging the field and mauling the plants. This renders the agricultural byproducts unsuitable for cattle feed also (informal discussions with

respondents). When asked about the changes in the conflict patterns, 80% respondents said the frequency of such incidents has increased in last 10 years while 15% said it has not changed. High percentage of households (72.65%) said primate population has increased followed by wild pig (57.26%). When asked about the reasons for increased incidents, respondents (both household surveys and informal discussion) gave a variety of reasons. These included increase in human population and consequent expansion of human settlements into natural habitats, reduced and degraded forests due to both anthropogenic and natural (landslides and floods) causes, increased population of wild animals due to prohibited killing and decreased efforts by humans in putting night vigil or other preventive measures. One interesting reason given by respondents for increased Rhesus macaque population was relocation of the troops from urban areas of state to rural areas in mountains by the state government. However, none of the respondents answered in affirmative when asked if they saw government officials releasing the animals.

Conflict and associated monetary loss lessen the public support towards wildlife and wildlife managers and reduces the cultural tolerance of local communities towards wild animals (Madhusudan, 2003; Ogra and Badola, 2008). Similar observations were made in the study area as respondents complained about increased population and occurrence of wild animals closer to human habitation and reduced access to forest resources, lack of access to motor-able road or electricity (only in Chilond and Gaundar, both inside the sanctuary) due to declaration of Protected area. Despite this, majority of people understood and recognized the anthropogenic role in the increased negative

interaction between humans and wild life. In such scenario, compensatory measures and awareness drives by management authority can act as stepping stones for building positive attitude of local community towards wildlife conservation. In the absence of tangible economic gains, local communities are often unable to support conservation-friendly production and consumption practices, thus, programs are required to offset their economic loss (Mishra et al., 2003). Tools for mitigating financial loss of locals involve direct cash compensation and indirect compensation through insurance schemes, integrated conservation development programs and alternative source of income such as ecotourism or wildlife tourism (Sillero-Zubiri et al., 2006).

Though, compensation could be only a partial strategy to reduce hostility of local communities but timely payment and supportive staff would improve relationships between management authorities and communities and can reduce retaliatory activities of locals. Studies have indicated that insufficient compensation provided to locals and often time-consuming procedures are considered responsible for augmenting anti-government and wildlife sentiments (Madhusudan, 2003; Gubbi, 2012). Similarly, majority of the respondents complained that payments were often insufficient, delayed and involved time-consuming procedures. There was a general lack of awareness among respondents as only a small fraction (five respondents) knew that compensation is not received for a kill in the forests.

With increasing human population, the pressure on natural systems has also increased in the Himalaya, leading to increased magnitude of conflict. This will further amplify the negative repercussions for biodiversity conservation and human well-being,

thus posing a challenge for policy-makers (Young et al., 2010). For many state governments, wildlife conservation is considered a non-priority sector with delayed or meager flow of funds. Lack of resources with the authorities to compensate loss of local communities is one major challenge (Jackson and Wangchuk, 2001). It becomes imperative to find alternatives for income generation for the local communities without making major lifestyle changes and putting pressure on natural resources. For the communities living in a protected area landscape, finding sustainable economic linkages between inhabitants and protected area can help in achieving conservation goals. To reduce crop raiding by wild animals, cultivation of crops unpalatable or repelling to wild herbivore as a buffer to food crops has been suggested as an option to reduce the crop raiding by wild ungulates. However, often there are constraints in marketing of such produce (Maikhuri et al., 2001) thus farmers tend to not prefer such crops. Thus, civil organizations and government departments should work towards creation of market and training of locals in marketing of such produce.

Negative interactions between humans and wild animals for resources have always characterized the co-existence of both landscapes where both share the resources (Barnes, 1996; Ellis et al., 2010). However, as the human population has increased, putting enormous demands on natural systems and shrinking natural wildlife habitats, the competition between both has reached to unparallel levels (Bulte and Rondeau, 2005; Woodroffe et al., 2005b). In Protected Area landscapes, it becomes Human (local communities)-Human (management authorities) conflict as it becomes a question of their animals (wild animals) and our animals (livestock). At the end, it is imperative to

mobilize and educate the community about the wildlife values and significance of an intact natural habitat. Local youth could be trained to monitor wildlife signs in and around villages and report sightings to local officials so that timely actions could be taken to prevent conflict (Dhanwatey et al., 2013). A participatory strategy where affected community is involved while drafting and initiating a project leads to a sense of project ownership by local stakeholders and results in community empowerment, self-reliance, and willingness to co-exist with problem species (Jackson and Wangchuk, 2004). It is important to bring down Human Wildlife Conflict and programs are required to offset economic loss of locals to achieve an integrated conservation and development goal.





Plate 5.1: Incidents of Human Wildlife Negative Interactions: Attacks on humans and livestock. A: Leopard scat within a study village on village trail; **B:** A villager attacked by black bear; **C-D:** Livestock killed by leopard in agricultural fields in a study village

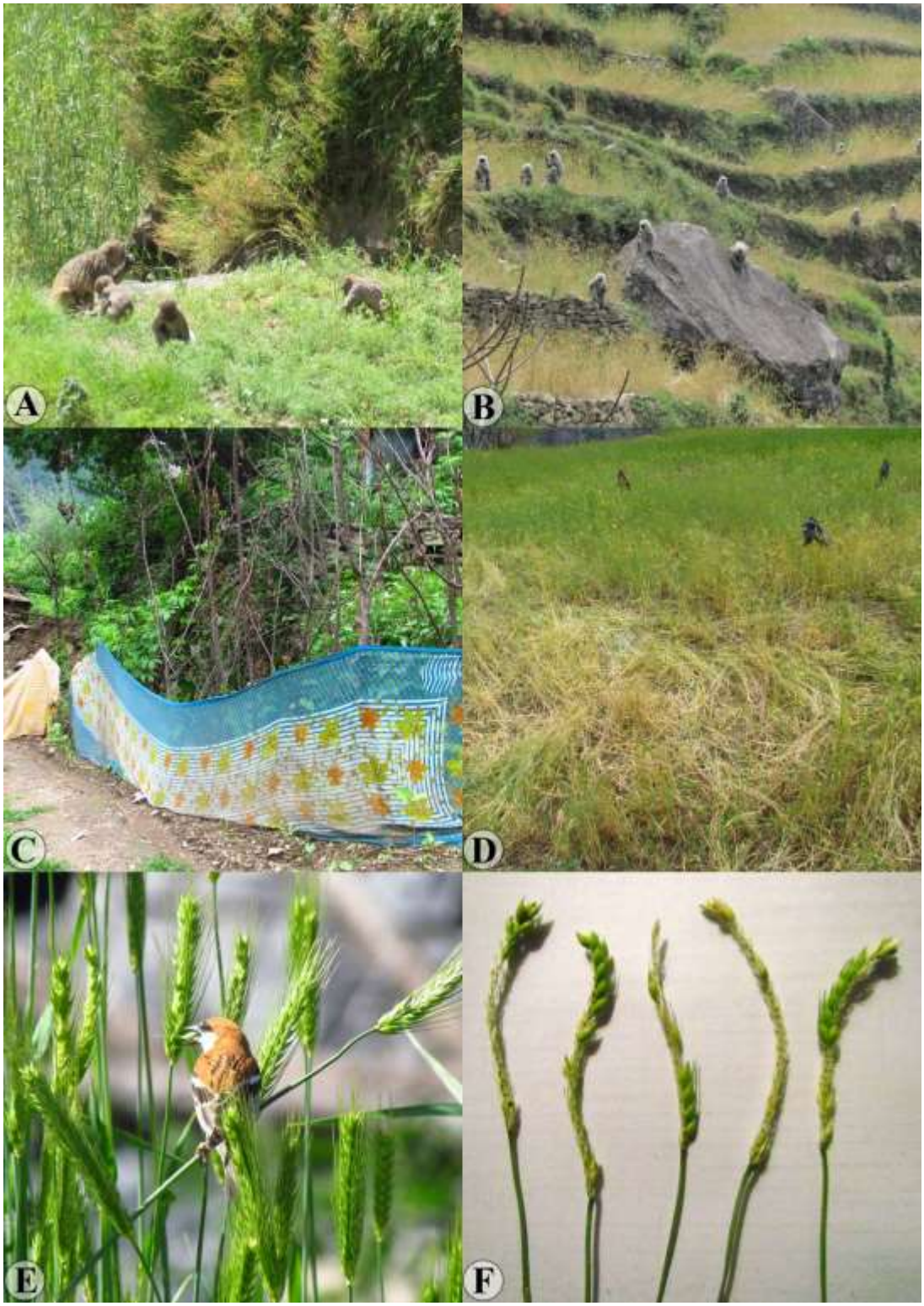


Plate 5.2: Incidents of Human Wildlife Negative Interactions: Crop raiding. A & B: Rhesus macaques and Grey langur devouring crops **C:** Clothes used as a visual and olfactory (human smell) barrier against Porcupine; **D:** Crop raiding by wild pig; **E & F:** Crop damage by Russet sparrow



Chapter 6

Chapter 6

Community Participation in Forest Management

Oh girl, oh sister, do not cut Banj
How will you get cool breeze from Akhrot trees only
From where will you get water, so do not cut Banj
Treat them tenderly as your own children.

…a folk song from Uttarakhand (translated to English)

6.1 Introduction

For long, centrally administered, top-down regulatory approach has dominated the global forest governance scene; however it's been transforming to more decentralized or participatory governance in recent times (Kumar et al., 2015). The benefit of decentralization or involving communities in forest conservation and management has long been questioned (Wright et al., 2016), however, a vast literature is available that supports the decentralized control for successful forest management (Agrawal and Ostrom, 2001; Berkes et al., 2000; Coleman, 2009). Despite the long held proposition that natural resources should be protected from the destructive actions of forest dependent people, communities have shown that they can work together for long-term management and conservation of these resource bases (Pretty, 2003). It has been argued that participation of local communities and their consequent access to benefits can lead to sustainable forest management involving both forest conservation and poverty alleviation (Agrawal and Gibson, 1999; Andersson et al., 2004; Ostrom, 1990; Somanathan et al., 2009).

A number of researchers have found that community forestry and the decentralized forest management has successfully improved both forest conditions and sustainable forest product and benefit flows to local communities in Himalaya (Adhikari et al., 2004; Adhikari et al., 2007; Agrawal and Chhatre, 2006; Dev et al., 2003; Yadav et al. 2003). Due to their nature as common pool resources, the management and use of these forests involve costly exclusion and rivalry among user groups (Ostrom et al., 1999). Thus, it has been argued that community-based rights and community forestry could be most viable options to avoid the depletion of resource base due to a temptation of user groups to free ride (Adhikari et al., 2004).

The traditional and decentralized form of local governance of natural resources including forests has existed in India for long in the form of Gram Panchayat or village councils (Tiwari and Joshi, 2015). There have been a number of government schemes and programmes to contribute in forest conservation and management by involving local communities. Joint Forest Management had been one such effort on community forestry in India that was established on the structural relationship between the state agency (local Forest Department) and the local community (local governance organizations) (Ballabh, 2002). Another example of community based approach of forest conservation could be Van Panchayat (VP) of Uttarakhand. These were created during British *Raj* at the beginning of the 20th century, as a response to local community's movement and fight against state control of forest resources (Agrawal, 1999; Guha, 2010; Jayal, 2001; Tiwari and Joshi, 2015). Forest Panchayat rule was enacted in 1931 that gave the control of civil lands to VPs or village councils. These

councils decide on how to use the forest and give permission for collection of resources such as fuelwood, fodder and timber from the forests, thus playing a crucial role in sustaining these resources.

In remote, rural areas of Uttarakhand, the local communities have had an intimate relationship with natural resources, particularly forests. Traditional farming, animal husbandry and resource extraction are sub-systems of the integrated traditional resource management system (Rao et al., 2003). Villages which do not have a registered VP, still have local institutions with a system of specific rules and regulations for governing resource extraction and conserving natural resources and to resolve disputes at the village level (Agrawal and Yadama, 1997; Pandya et al., 1992; Poffenberger et al., 1996). Various activities under such institutions and VPs include management of grazing grounds and fuelwood and fodder reserves, rotational lopping and cleanliness and weed eradication drives in community forests (Kandari and Gusain, 2001).

In the study area, there are both state-controlled (Kedarnath Wildlife Sanctuary) and community-managed forests. Local communities extracted plant-resources from both these system which varied with a number of factors including forest management regimes. I studied the role of local communities in forest management in the study area and measured the contribution of this in augmenting their livelihood. As the rural economy in Himalaya is intimately associated with the forests, I hypothesized that people have been managing forest resources in their surroundings which in turn resulted in protection of forests and augmented livelihood of local communities.

6.2 Methodology

Initially, two open-ended community discussions were held as part of reconnaissance survey to get familiarize with important community characteristics and to identify various natural resource (forest) management practices, and government bodies and local institutions involved in such activities (Bernard, 1988; Grootaert and Bastelaer, 2002). The step helped in establishing boundaries for the "community" within which research took place and information was used throughout the exercise for planning further.

Purposive sampling was done with village leaders and representatives of local institutions involved in forest management following the group discussions. Emphasis was given on identifying the role of village and forest councils, as these have highest representation of village households (Lise, 2000). A total of 40 such interviews were conducted. Additionally, six focus-group discussions were held when we happened to reach at the time of group (of local institution's) meetings.

Household questionnaire surveys were conducted to gather information on involvement of household members in forest management activities and various other collective actions. Sampling was done in 15 villages selected after Hierarchical Cluster Analysis (Chapter 3). Semi-structured questionnaire with both open and close ended questions were used for surveying 418 households in the study area. Respondents were asked questions on participation of household's members in natural resource management activities and representation in local institutions, attitude towards participatory activities, benefits from such practices to the community and household,

and satisfaction with the current representatives of local governing bodies (Ameha et al., 2014; Lise et al., 2000).

To see the difference in livelihood and other benefits to sampled households from community and institutional level activities, study villages were re-grouped into three categories based on resource use from community forests *viz.,* villages with no community forests (NCV; Gadgu and Gaundar), villages with community forests open for almost six months, beginning from *Updhi* days for fodder collection (early winter to late summer) for fodder collection and grazing (OCV or open community forest village; Ransi, Raulek, Buruwa, Kotma, Chaumansi, Chilond), and lastly, villages with community forests opened only during *Updhi* days (CCV or closed community forest villages; JaalMalla, Kalimath, Khonu, Kaviltha, Mansoona, Bhatwari and Bedula). Numbers of head loads of fodder from community forests in each category (later two categories only) were noted down during household surveys and their monetary value (@ INR 300 per household) was calculated. Both Chaumansi and Chilond do not have any community forests, but resource use is regulated in some grassy slopes within Sanctuary in village surroundings.

Forests around ten villages were sampled for the assessment of disturbance signs and regeneration status. Forests were categorized based on management regime (Sanctuary forests, open community forests or OCF and closed community forests or CCF). Major resource use trails were identified and followed for laying transect. Anthropogenic pressure was noted in terms of lopping intensity, cut stumps, cattle dung and presence of human and livestock (Chapter 4). Sampling was done from June 2014 –

November 2015. Mean and standard deviation were calculated for variables studied for forest characteristics such as canopy cover, distance of sampled plots from settlement, disturbance rank of plots and regeneration status along elevation and to study the regeneration status, regenerating species richness and seedling and sapling densities were calculated and each plot within different management regimes were given a disturbance rank (Chapter 4; Manral et al., 2017).

Data analysis: Qualitative data obtained through questionnaire survey was coded for the categorical data where needed. Exploratory data analysis (EDA) was performed using MS excel for headload numbers and monetary benefits. To see whether community forest management practices play a role in augmenting livelihood of local communities in the area, Mann Whitney U test was performed. It was tested whether number of headloads of fodder varied between village categories (between OCV and CCV). Independent sample Kruskal Wallis test and Pair wise post-hoc comparisons were performed to see if community participation in forest management played any role in disturbance and regeneration proportion in forests of area. Qualitative methods, particularly participant's observations, were crucial in analyzing the data and inferring the results (Badola et al., 2018; Creswell, 2013).

6.3 Results

6.3.1. Local institutions: Organization, management and responsibilities

There were primarily two self-governing local institutions that played a role in forest management *viz., Gram Panchayat* or Village *Panchayat* (GP) and *Mahila Mangal Dal* or Women Welfare Groups (MMD). Former is the primary body of the local self-governance at the village level while later are groups of village women registered with the state government to avail various welfare schemes. GP are different than the *Gram Sabha* which are the basic democratic institutions in the region and at the base of *Panchayati Raj* system under 73rd and 74th Constitutional Amendment Acts (1993). GP are older institutions and have no legal status until they are registered as a *Van Panchayat* (Jayal, 2001). MMD are registered for five years, and needs to be re-registered for the next term. Both the institutions are pillars of local support systems and play a crucial role in regional environmental governance and mobilizing villagers for collective actions for ameliorations of surroundings and for overall well-being of community and households.

The GP is a committee of six members primarily, which includes *Sarpanch* or head, a minister, a cashier, two helpers and one watchman for community forests. All the households of the village are GP members and the president takes decision with the consent of executive members. MMD include one president chosen from village women and rests are the members. Only one woman per household can be a member of MMD, however any or all women can participate in various MMD activities. The elections for

the core team of both are done informally, mostly members raising hands in support of a candidate. The final decisions on members are made after consultation and consensus through a transparent process.

GP look after the community forest and civil land with fodder plants in villages. Such land is closed for most part of the year and members of GP decide the days for resource collection. Forests are opened early winters when each household from village can collect one headload per day for few days. The process is called *Updhi*. Most of these lands are characterized by dominance of grass species such as *Chrysopogon* sp., *Themeda* sp., *Apluda* sp., and *Pennisetum* sp. The open community forests are also opened for grazing during winter and summer months. In many of the villages, the forests regulated for resource use by GP included some part of sanctuary or reserved forests (Ransi, Chaumansi, Chilond, Gadgu, Jaal Malla and Bedula).

In the study area, sampled MMD were either registered with Block development office or were in the process of renewal. The primary job of MMD was to organize women for activities such as cleaning of resource use trails in forest and forest streams, chasing away rhesus macaques and grey langurs that damage crops and convincing women to not extract resources from *panchayat* land during prohibited period and not to cut green branches. In few villages including Ransi, Raulek, Chilond and Kalimath, MMD members protested against local production of alcohol and complained to police against violators. As a result, these villages saw a decline in alcohol production within village. However, these protests prompted men in Chilond to oppose MMD and its meetings, resulting in still un-registered MMD.

Annexure 6.1 provides details of various activities carried out by GP and MMD of sampled villages and also gives information on conflicts within few of these. A small number of respondents (<5%) were unsatisfied with the groupism in selection of GP members. This resulted in conflicts within the management and during decision making process.

Only Kalimath and Bhatwari (Bhatwari and Sansari) villages had registered '*Van Panchayat*' (VP) under Kumaon Panchayat Forest Rules, 1931. Raulek, Buruwa, Jaal Malla, Gadgu, Mansoona, Bedula, Chilond and Khonu had '*Bala Van panchayat'* and villagers were trying to register these (except in Gadgu). Kalimath VP was established in 1954 with an area of 8 sq. km. There are two forest patches under the VP, one of which was a Banj oak-Chir pine mixed patch. Rotational lopping was practiced in this patch and lopping was banned for five years for villagers. However, almost 60 % of this was lost in the floods and landslides during June 2013 event in Kedarnath valley or Mandakini watershed. Grass fodder collection and occasional grazing was allowed during winter months in the other forest stand. *Sarpanch* mentioned that the budget allocated for the upkeep of forest is very limited. They had been asking for money for past few years for check dams but to no avail and as a result large part of forest which had *Banj* oak got washed away. Occasional plantation was done, saplings for which were received from forest department. A wall was built around the plantation to restrict cattle entering into it.

Bhatwari VP also lost some forest to floods and landslide in 2011 after a cloud burst event in the region. The Van Panchayat is seeing a decline in regulation

arrangements as it has become a part of Ukhimath *Nagar Panchayat.* People who had lost their land after landslide have encroached upon some part of civil land. The traditional resource management system has become weaker with time.

6.3.2 Livelihood Impacts

In order to understand the role of community institutions in livelihood of locals, benefits were broadly divided into direct impacts and indirect impacts.

6.3.2.1. Direct impacts

The indicators of direct impacts were the quantity, sustainability and equity in forest product flows.

Quantity of resource: The average number of fodder head loads per households in villages with open community forests (OCV) was 31.85 ± 27.67 (worth INR 9556.68 ± 8286.24) while it was 7.04 ± 8.12 head loads per households (worth INR 2111.80 ± 2436.24) in villages with closed community forests. The villages with community forests opened for longer duration got higher quantity of fodder from community regulated forests. Mann Whitney U test showed that there was a statistically significant difference in the head load numbers per household between the two village categories with difference in role of community institutions in managing forest resources (p value < 0.001). Villagers with open community forests (only Ransi, Raulek, Buruwa and Kotma) also took their cattle for grazing into these forests for 3-4 months. Among closed community forests, grazing was done in the fringes of community forests in

Bhatwari. The results indicate that villagers with OCF received more resources from community forests than the villages with CCF where rules and regulations were stricter.

Sustainability and equity in access to resources: A strong local governance system ensured equal access to phyto-resources to all the village households. 80% of respondents in closed community forest categories saw equal and fair resource extraction as chief benefit of strict regulations. Similarly in villages with strong GP even when it had open community forests, 60 % respondents said so. Both the formal and informal institutional arrangements, of *Panchayat* and MMD ensured that the villagers followed the regulations. The GP committees are empowered to punish violators by levying a fine or by putting pressure as a community on the violators to change their ways. Often, resource collectors are women, thus, MMD played a crucial role as an aid by convincing the members to abide to the resource use regulations. The member households in both GP and MMD are fined if they do not attend the meetings or do not come for collective actions such as cleanliness drives. Fines in such cases vary from INR 25 to 51. However, a higher fine (INR 100–500) is charged if rules regarding natural resource management are violated such as lopping in prohibited area, not obeying watchman's directions while collecting resources or grazing livestock in forests closed for any resource use. Some GP such as Buruwa gave a part of community land on lease for grass collection to families from neighboring villages such as Mansoona. All the GP maintained an account either in a bank or the cashier keeps the money. The

revenue earned from leasing out forest or resources and the money generated from fines and fees are kept in GP account.

In one incidence in Khonu village, four families took their cattle into closed forests. This was brought into notice of GP and INR 500 was levied on the violators. The head of *Gram Sabha* reduced the money to INR 250. However, violators denied paying this too. Then the violators were called in an MMD meeting and were shamed publically for their actions against community. One of the violators (man) had come drunk and abused his wife who had brought money to pay fine. Village women strongly opposed his actions. Eventually, all the violators paid the money and it was not repeated again. In another incident in village Ransi, women started grass collection from a banned patch on an *Updhi* day. They did not listen to GP watchman who complained to other committee members. Eventually, all the women present (almost whole of village) had to pay a fine of INR 100. These incidents proved that both GP and MMD were crucial for governance in the region and for ensuring equitable and sustainable supply of resources to all members by building a strong social fence against violators.

6.3.2.2 Indirect impacts

GP play a role in local-level development planning as an aid to *Gram Sabha* in decision-making process and to create a social support structure for various issues where collective actions of community members are needed. MMD provided a platform for the village women for community participation and social integration. Both the institutions were medium to strengthen ‘social capital’ within the community and the

most important way of imposing regulations were by social fencing. Though, almost all GP kept a watchman (mostly paid INR 3000 for six months from GP's funds), but many times whole community came against the violators. Rotational guarding of forests from inhabitants of neighboring villages and of agricultural fields from primates was done by villagers. In villages where people came regularly for chasing away macaques, respondents mentioned that the loss due to primates particularly macaques has reduced over a period of time (Chauamansi, Mansoona, Buruwa etc.). However, this cohesion within the community has diminished over a period of time. In the large villages such as Ransi, inhabitants of smaller settlements or *Tok* within village come together and create their own MMD or a smaller *Panchayat*. This has started showing signs of an intra-community conflict as few respondents complained about other *Tok's* actions of encroachment of civil land or unregulated lopping in forests.

Both the institutions also acted as medium for development of human capital as external agencies (both government bodies and NGOs) approach them and attend meetings to inform the villagers about various development schemes or training programs. However, with advent of Self Help Groups where smaller groups of villagers are created for livelihood improvement, this role of both GP and MMD has declined to certain extent. The collective actions of people of maintaining and cleaning village and forests trails and water sources maintain and enhance the physical assets or capital for the community and user households. The region was badly affected after the June 2013 deluge and resulted in landslides and floods in the watersheds of Mandakini and its tributaries. Villagers came forward to restore roads, bridges and houses of those who

were affected in many of the studied villages. Many times people work on creating physical assets for the community such as water tanks and check-dams along the village forests and field boundaries closer to river. Though, workers are paid under MNREGA now, however, people take out their time despite being paid a meager amount for the work. Respondents also felt that cleanliness drives result in a hygienic and healthy environment and benefit the whole community.

6.3.3 Management regime and status of forests

Results show higher disturbance in both Open community and Sanctuary forests as indicated from disturbance rank, proportion of lopped trees to trees present in the plot and number of stumps (Table 6.1). Closed community forests had lower disturbance signs and higher proportion of regenerating species. There was a significant difference in the disturbance rank of plots, proportion of regenerating species, canopy cover (%) and proportion of lopped trees between open community and closed community forests (p values = 0.002, 0.002, <0.001 and 0.044, respectively). Similarly there was significant difference in all these parameters, except canopy cover between closed community and Sanctuary forests (p values = <0.001, 0.004 and 0.036, respectively). Only canopy cover varied significantly between open community and Sanctuary forests (p value = 0.027).

Table 6.1. Forest characteristics (disturbance & regeneration) under different management regimes

Forest management Regime	Disturbance rank of plot	Proportion of regenerating species	Canopy cover (%)	Proportion of lopped trees	Number of Stumps
Open community forests	3.07± 1.70	0.80±0.70	21.85±14.62	0.56±0.33	0.22±1.15
Closed community forests	0.98±1.68	1.51±0.58	45.59±17.13	0.29±0.31	0.12±0.49
Sanctuary forests	3.09±1.71	0.91±0.68	33.91±20.47	0.53±0.35	0.41±1.34

Table 6.2. P-values for pair-wise post hoc comparison between forests under different management regimes (Independent sample Kruskal Wallis Test and pairwise post hoc test; significance level is 0.05)

Variables	OCF - CCF	OCF - SF	CCF - SF
Disturbance rank of plot	**0.002**	1.000	**<0.001**
Proportion of regenerating species	**0.002**	1.000	**0.004**
Canopy cover (%)	**<0.001**	**0.027**	0.067
Proportion of lopped trees	**0.044**	1.000	**0.036**
Number of stumps	0.231 (No Pairwise post hoc comparison)		

6.4 Discussion

Study results showed that both Gram Panchayat (GP) and Mahila Mangal Dal (MMD) were central to community forest management in the area that was supported by collective actions of member households. GP formulated rules and regulations for putting a spatial-temporal barrier in resource use from community-managed forests. None of the GP forests were open throughout the year for resource (fodder) collection and no cutting of trees and branches and shrubs was allowed. Spatial barrier was achieved by alternately opening smaller forest stands or sections of a larger forest stand for fodder collection and livestock grazing. The rules were strictly followed by levying

a fine on violators and trespassers. A forest guard was kept to look after the resource use when forests were opened. He was paid a salary of INR 500-600 per month (mostly for six months) and two kg each of wheat and rice every month. The guard's job was to monitor various entry points into the forest, observe any trespassing in prohibited forests and make sure that one head load of fodder per family is taken on *Updhi* days. GP members who had migrated out from village but still paid the *saalana* (yearly fee) would often authorize their relatives to collect their share of fodder. Though fuelwood collection or tree cutting was not permitted, however, GP committee would make exceptions if any household had special requirements, *e.g.* during wedding or other family functions. In such cases, even if the forest was close at that time, family would be allowed to cut the tree (often dead trees) by paying a price (less than the actual cost of wood). In such cases, other villagers would often come to help the family in cutting the tree and carrying wood. Other than regulating resource use, both GP and MMD organized drives within forests to clear resource use trails of bushes and for weed eradication from community land.

A number of researchers have studied local governance institutions in Himalaya including the *Van/ Gram Panchayat* in Indian Himalayan Region and the community forest councils and forest user groups in Nepal (Agrawal and Chhate, 2006; Agarwal, 2009; Dev et al., 2003; Jina et al., 2013; Rawat and Rawat, 2010; Tiwari and Joshi, 2014; Tompsett, 2014). In Western Himalaya, Uttarakhand has a long history of traditional and decentralized local rural governance in the form of Gram/ Van Panchayat or village councils (Agrawal, 1999; Jayal, 2001; Nagahama et al., 2016).

These councils are the grass-root level institutions for environment governance as these lay the foundation of participatory management of forests, mainly civil forests but also sometimes forests under forest department, as was noted in the study area. The results show that the community forests in the fringes of Kedarnath Wildlife Sanctuary were crucial to meet fodder demands of local communities; however, these met a small proportion of total demand. Community-owned forests showed a spatial-temporal variation in resource access and extraction across various GP. A comparison of impacts of GP and MMD activities and various regulations on local's livelihoods indicated that the monetary gains were higher in villages with open community forests. Member households in such villages received higher number of fodder head-loads from forests under GP due to higher number of *Updhi* days and accessibility of community forests for grazing during winter months. A similar study in Nepal also found that community forestry (with strict rules) had limited success in improving livelihood, particularly for poorest household who had to pay a greater price in the form of lost access due to strict forest protection (Thoms, 2008). However, I did not find any class (wealth-based power) based disparity in access to resources. In the study area, strong local governance and strict regulations by strong GP (particularly in closed community forests villages) ensured a sustainable and equitable flow of benefits. There was no or very less encroachment of civil lands in such villages and higher percentage of respondents was satisfied with the GP.

In India, 21.34 % of geographic area is under forest cover; however, a little less than 5 % of total geographic area of country is protected under various categories (WII

ENVIS, http://www.wiienvis.nic.in/Database/_Protected_Area_854.aspx). Forests and other natural habitats outside the Protected Area network of country are critical to the long term biodiversity conservation goals of country and the community forests form an important component of these goals. In the study area, greater disturbance was observed in Sanctuary and open community forests as indicated by higher disturbance ranks of plots in these forests. Villages which were located within the Sanctuary or closer to Sanctuary extracted higher amount of resources from Sanctuary forests (Chapter 3 and 4). The primary objective of GP-enforced regulations in community-managed forest was management of resources, which effectively lead to forest conservation. Baland et al. (2010) and Måren et al. (2014) also found similar results in comparisons made between state-controlled and community-managed forests; as they concluded that forests managed by local communities were relatively less lopped and degraded than state protected/ managed forests. The rotational lopping of green fodder and branches and prohibited grass collection and grazing during monsoon ensured regeneration and recovery of vegetation within community-managed forests and grassy slopes. The results are consistent with results of studies conducted on community managed forests from other parts of Himalaya with positive implications for forest conservation and resource use by local communities (Agrawal and Chhatre, 2006; Agrawal and Ostrom, 2001; Brandt et al., 2017; Somanathan et al., 2009; Thoms, 2008; Tiwari and Joshi, 2015)

In the study area, though, Sanctuary forests were more degraded but there was no encroachment of Sanctuary land by neighboring communities due to secure land

tenure under forest department. On the contrary to this, encroachment of forest land was a more common phenomenon in civil lands or community-managed forests. In most cases, this encroachment was born out of necessity as the region has seen many landslide events in recent past. In villages like Ransi, households which lived closer to river and lost their landholdings have moved towards ridge forests on civil lands. Similarly in Bhatwari GP too, few respondents mentioned civil land encroachment by families affected due to landslides. However in three incidents, encroachment of fringe Oak forests by households to ensure uninterrupted fodder supply was noted.

GP and MMD prioritized collective actions of member households for community benefits that contributed to livelihoods of local communities not only by enhancing natural capital but also through enhancing other capitals too. Foremost among these was 'social capital'; the local governance institutions acting as medium for enhancing social cohesion among members. The collective actions of people under these institutions are a sign and product of strong social capital. However, it can be argued that these actions and formulation of these institutions could be achieved as a result of pre-existing social capital and goodwill within the hill communities of region (Jayal, 2001). In either case, both GP and MMD are crucial for creation and maintenance of 'social capital' and for community-decision making.

The second crucial capital contributed by local institutions was 'physical capital' or community infrastructure. Other than forest management, GP and MMD mobilized members for *shramdan* (voluntary labor) for a number of tasks that included cleanliness drives within village, restoring village roads, forest walls and check dams, cleaning

forest streams and water-tanks and funding the temple and religious activities and observances. GP's members are also invited in meetings organized by *Gram Sabha* to discuss about the use of budget money provided for infrastructure development. MMD on other hand provided a platform to village women for local-level development planning, for discussing local priorities, and raising voice to demand necessary and appropriate services from government line agencies. Sometimes, some little amount of GP funds are mobilized for infrastructure development like restoration work in village school or of village road. However, this is mostly done as a last resort when line agencies fail to provide these. Both GP and MMD also have a stock of utensils, small musical instruments, chairs, mats and tents which can be hired by members (at cheaper rates than a caterer) during some family functions. In Kotma village, respondents also mentioned about loaning money from GP during family emergency.

Resources like fodder and fuelwood, and utensils and other necessary items during family functions and loans from GP and/ or MMD contributed in boosting financial capital of member households. Both the institutions, particularly MMD also contributed in enhancing human capital. Many times government line agencies and Non-government organizations come to public meetings where villagers are informed about various development and welfare schemes. Though, such meetings by government agencies were organized with *Gram Sabha*, however, GP and MMD committee members played a crucial role in success of various welfare works. They raise issues related to community welfare and in case of government schemes like

housing for poor and welfare pensions and villagers discuss who needs these most and often voted for the rightful candidates.

In recent times, a new form of local institutions *viz.*, Self Help Groups (SHG)* are emerging in the region that have become a mean for human capital development (Manral et al., In Press). Both government agencies and NGOs act as Self Help Promoting Agencies (SHPA) and worked towards micro-financing and livelihood improvement of members. GP and MMD meetings set the stage for the initial meetings and interactions with SHPA representatives. The effects of SHGs are multiplicative as members learn organizing and income generating skills and learn about micro-financing. Self Help Groups are slowly becoming financially sound instruments for women empowerment in the region. These groups resulted in a growing sense of self-worth in their members as they gained economic security and a role in decision making at household and village level.

The studied communities also had some differences leading to both intra and inter-community conflicts. The foremost reason for intra-community conflict was unequal participation from member households. In almost all study villages, there were families who skipped GP meetings or activities which required voluntary labor. These were more well-off families with members having well-earning jobs and mostly preferred to pay fines then to participate in collective actions. Migration of families to the urban centers is also affecting the traditional social structure in few villages. One *Sarpanch* complained that these people have lost touch with the village traditions and

are absent from all community actions but would call him once in a while to ask about any government benefit schemes that they can claim for.

In many villages, villagers also took turns in chasing away macaques or sometimes putting up night vigil against wild boars. However, this has reduced to a great extent as pointed out by many respondents. I also observed how people just walked by as Rhesus macaques devoured crops from someone else's agricultural fields. Respondents also pointed out that how government's employment generation schemes such as MNREGA might be impacting the social structure within the village. Works which were previously done as voluntary labor by villagers are many times conducted under MNREGA now. Villagers, thus, might be losing interest in voluntary activities once they start getting money or see others being paid for similar work under government schemes. This indicates that the local institutions and social cohesion could get disintegrated or weaken with time if local institutions are not recognized and supported. However, despite the weakening social institutions, the community spirit remains, as was observed during recent natural disasters in the region. In the absence of immediate relief, the villagers of the region came together for *shramdan* for repairing roads, forest protection walls and check dams in many of the villages of the region. In the Kalimath valleys, inhabitants even provided food and clothing to survivors from Kedarnath valley that had come via Kham alpine meadow.

The anti-liquor agitations by MMD members of few villages (*e.g.,* Kalimath) were successful in the beginning and inspired MMD of other villages. However, these resulted in intra-community conflicts as families involved in production of liquor

opposed the move and also men of the community became against the women's meetings. In one village, women respondents complained how men are afraid that MMD representatives become strong and thus they oppose group's meetings. The village head also did not show any interest in guiding women with registration of group and men do not allow women to work properly as part of MMD. Under such circumstances, women groups are less effective and with time, their value within the community might deteriorate.

Inter-community conflicts primarily occur if women from neighboring villages enter into GP forests. In such situations, sickles and baskets of trespassers are confiscated, if caught and a notice is sent to respective GP regarding them. Trespassers then have to pay a fine to the GP from whom they were stealing.

The principle behind the functioning and success of local governance institutions in the study area is betterment and survival of whole community and fairness and sustainability in the natural resource use. Recent intra-community conflict might threaten the survival of these institutions. It might be difficult to keep alive or revive local institutions or activities under these as was noted by Jayal (2001) in other parts of state. In case of Sanctuary forest, the changed tenure of forests might have weakened the sense of belongingness among the villagers in the landscape as this forest is seen as a state property; with no ownership of community, conservation of Sanctuary forests is often not considered responsibility by the villagers.





Chapter 7

Chapter 7

Conclusion and Recommendations

7.1 Patterns in Phyto-Resource Use and Availability

Study indicates that the resource use pattern varied in the area along elevational gradient, with a household's consumption of forest resources also predicted by factors such as family size, nearness to Sanctuary (Kedarnath Wildlife Sanctuary; hereafter KWS) forests and motor-able road, landholding size and livestock numbers. Though the cash income from primary livelihood activities based on agro-pastoralism and forest resources was very small compared to secondary and tertiary activities, however, their subsistence values were crucial for wellbeing of local communities. As suggested by Babulo et al. (2009) in north Ethiopia, forests are pro-poor, reducing the inequality among the rural households. Similarly, the forest resources in the study area provided a safety net or insurance for households that were not able to earn enough from other activities. Sampled villages at high elevation were relatively better endowed with natural resources due to nearness to Sanctuary forests, thus enabling them to harvest more forest products. Settlements, closer to these resource reserves reported higher forest income than the villages farther from the Sanctuary forests or without such access. Even in the presence of other existing income opportunities, dependence did not differ much among the households in the area. This might be due to habitual dependency of local communities on subsistence income from forests. Hegde and

Enters (2000) in a study in Mudumalai Wildlife Sanctuary found that in the absence of any restriction on forest use, economically better off families used the resources more heavily. However, the availability of alternatives to these resources might have also influenced the resource use in the area. Though LPG is fast becoming an alternative to fuel wood, it is still out of reach for many households due to distance from cylinder suppliers, uncertainty in the availability of cylinders with suppliers, greater walking distance for remote settlements and economic condition of household.

Results for availability of phyto-resources in the study area indicated an elevation derived pattern of biomass availability; however it was in terms of spatial-temporal access to forests for resource collection and not in terms of above ground biomass per unit area. High and mid elevation villages that are situated within the Sanctuary or along the boundary had access to larger extent of year round open forests for resource collection. Low elevation villages were located at a distance of 2 or more kilometers from Sanctuary forests. These villages had community forests in close proximity which were closed for resource collection for most part of the year. This limited access to forest resources has prompted LEVs to enhance availability of resources within the agro-forestry system. These villages had higher density and biomass of multi-purpose trees in AFS as compared to other elevation categories.

The above ground biomass recorded in the forests was comparable to degraded or early successional communities of these elevational zones (Gairola et al., 2011; Sharma et al., 2010; Singh and Singh, 1992). Similar to biomass, values for other forest characteristics such as tree stand densities, total basal cover and mean canopy cover

were relatively low than previously recorded for Himalayan forests of comparable elevational range (Hussain et al., 2008; Prasad et al., 2015; Singh et al., 2016). Studies have shown that the incessant small-scale anthropogenic disturbance adversely impacts the functioning of native mountain forests across the globe (Bebi et al., 2017; Dzwonko and Gawronski, 2002; Gimmi et al., 2008; Thadani and Ashton, 1995; Thakur et al., 2011). The low density of trees in higher girth classes and relatively low recruitment of seedlings, as indicated by population structure of forests, point to disturbance caused successional trend in the forests. However, abundant saplings of native tree species indicate the resilient dynamism of Himalayan forests (Manral et al., 2017).

7.2 Human-Wildlife Negative Interactions

The negative outcome of Human-Wildlife interaction in the form of attacks on Humans and livestock and crop raiding by wildlife put an additional burden on rural households of the region, particularly by compromising with the subsistence output from agro-pastoralism activities. Studies across India have found that conflict and associated loss lessen the public support and tolerance towards wildlife and wildlife managers; it not only undermines well-being of humans but also threatens the conservation of wildlife, particularly of large-bodied mammals (Lyngdoh et al., 2014; Maclennan et al., 2009; Madhusudan, 2003; Mishra et al., 2003). In the study area, respondents complained about reduced access to forest resources and lack of access to motor-able road or electricity (only in Chilond and Gaundar, both inside the sanctuary) due to status of Sanctuary forests and increased population of and occurrence of wild

animals closer to human habitation resulting in negative interactions. Many respondents showed resentment against wild pig and rhesus macaque and held them responsible for the reduced harvest and misery. Such attitude could be detrimental for the biodiversity of Sanctuary as incidents of poaching have been reported from the region (personal observation).

Researchers have noted that effective management of human-wildlife negative interactions requires collaboration between local communities and wildlife managers with suitable training and capacity building of rural wildlife managers (Osborn and Parker, 2003; Treves et al., 2006). In the study area, there was a lack of awareness among the villagers as many respondents blamed the protected status of Sanctuary forests and prohibition of killing wildlife for frequent conflict events and population increase in problem animals. A communication gap between the villagers and the forest department was noted as villagers blamed the complicated procedure, delayed and measly compensation, bribery and non-cooperative forest department staff as the reasons for not applying for compensation. During one livestock depredation incident, three cattle owned by a family were killed by leopard while they were grazing in the agricultural fields during evening hours. The incident came to light next morning when people became suspicious of an unusually high number of Himalayan griffons soaring over that spot. The family had not received compensation even after three and half years of the incident. Such delays in compensation might increase the dissatisfaction of local communities towards management authorities and intolerance towards wildlife.

Some respondents (<5%) argued that the changing lifestyle of local communities could also be leading to increased incidents of conflict within the villages. An elderly woman's statement can rightly explain sentiments of these respondents as '*youth today have become lazy and do not watch over the crops at night and prefer to enjoy the warmth of their houses watching daily soaps on televisions* (translated in English). Respondents (~ 50 %) also noted that the increasing demand and extraction of natural resources have degraded the forest but some argued that there is no check on the wildlife population too. They also complained of lack of alternatives for fodder, fuelwood and for income generation which make them more dependent on forest resources. This indicates that local communities understand that HWNI is a result of a mix of situations and no single factor can be blamed for the increase. As noted by Treves et al. (2006) that often conflicts and resentment build up over years, it becomes imperative to find ways to mitigate or prevent the loss to local agro-pastoralist community due to HWNI in the region before the problem reaches to irrevocable levels. Though compensation has been considered the best way to offset the monetary loss to local communities, however, various researchers challenge the practicality of the approach in long run (Chandola, 2012; Nyhus et al., 2005). Thus, alternatives for livelihood diversification such as developing sustainable tourism strategies and providing alternatives for fodder within the human-scape should be promoted.

7.3 Institutional Support and Forest Resource Management

The study results indicate that the local institutions with the support of community have been playing significant role in forest conservation and in management of natural resources in the area. The results are consistent with previous studies done on the role of community participation in forest management across the Himalaya (Agrawal and Gibson, 1999; Andersson et al., 2004; Somanathan et al., 2009; Tiwari and Joshi, 2015). These institutions mobilize and motivate villagers towards the well-being of community through collective actions and building and maintaining social cohesion. The role of community in forest management provides sustainable and equitable flow of natural resources (primarily fodder) from community-managed forests. These activities are also crucial for forest conservation in the area as community- managed forests (particularly closed community forests) are less degraded and have better regeneration status of native tress than the Sanctuary forests in the region. The capability of local institutions to restrict the access of community to forests and consequent temporal closure of forests resulted in visible improvement in forests conditions (informal discussions with community representatives and household surveys). It also ensured that outsiders (neighboring villagers) had to abide by these rules to avoid any inter-community conflicts.

Plantation drives within the civil land or agro-forestry systems both by government agencies and civil society organizations were found to be a crucial component of participatory approach towards forest management in the region. Improving biomass availability within the human landscape has long been popularized

as a mean for both forest conservation and to reduce women's drudgery for resource collection over long distances. However, certain issues regarding the success of plantations and selection of species were observed in the area. Forest department (KWS management authorities) often organized plantation drives with villagers in Sanctuary and fringe villages. But many interviewed *Sarpanch* complained that after plantation staff never come back to look after the plantation. They demanded a watchman for upkeep of such plantation but also understood the limited resources with FD. In some of the villages the Self Help Promoting Agencies gave saplings of fodder species such as *Bauhinia* sp., *Grewia* sp., and Napier grass to the member households to improve the fodder availability within the agro-forestry systems within the villages. However, many times species are not planted with consultation with villagers, particularly women who are primary resource-collectors in these communities. Species such as *Prunus cerasoides* which were popular for plantation, either had very less utility values (some medicinal and religious values) or people were unaware of it. In another incident, one NGO was distributing *Leucaena leucocephala* saplings for fast growing fodder and (fuel) wood. The species is considered among the top 100 of the World's Worst Invasive Alien Species' (http://www.iucngisd.org/gisd/species.php?sc=23) and both the locals and NGO staff were unaware of the threats it might pose to local ecosystems in future.

7.4 Recommendations

7.4.1 Reducing resource dependency from forests

The current scenario of extraction of plant resources revolves majorly around Sanctuary forests while availability to alternative resources is limiting either due to poor services and infrastructure or due to lack of efforts of local communities in improving availability of resources within Agro-forestry systems. Thus, it is imperative to formulate long-term sustainable natural resource management strategies and promote renewable-energy technologies to reduce reliance of local communities on forests biomass.

The biomass production within human systems should be increased through scientific or organizational innovation, such as by planting fast-growing native grasses on common land and multi-purpose native tree species particularly fodder species on civil lands and along field boundaries. Often, villages have abandoned fields (due to declining production, crop raiding or landslides) or degraded forest slopes near village boundaries (due to landslides, debris flow) where fodder species can be planted. Villagers with better irrigation facilities should be encouraged to establish nurseries in their fields. During the study, I found that it is difficult to get desired fodder species (native *Ficus* spp., *Grewia* spp., *Celtis australis* etc.) for plantation. Most of the plantation drives in the region focused on greening of land or improving the timber produce. However, villagers kept extracting resources from forests. When I tried to find fodder tree species for the plantation drives, it was difficult to get fodder saplings from

nurseries across the state (primarily Forest Department nurseries). I ended up delaying the plantation drive by almost a year (Colour plate 7.1). I then encouraged families with seedlings in their agro-forestry systems to protect them and 750 seedlings (*Ficus* spp., *Bauhinia variegata*, *Celtis australis*, *Quercus leucotrichophora*, Hill bamboos etc.) were planted with few households on their lands and students in village schools. Improving biomass production within the human systems will not only lessen the burden from Sanctuary and community forests but will also reduce the workload of hill women as they will not have to travel huge distances with heavy head/ back loads.

Another alternative could be promotion of renewable alternatives to fuelwood. LPG is being promoted as an alternative cooking source; however, its usage was being affected due to various reasons as discussed earlier. Emphasis should be given on promoting products such as photovoltaic lights, solar cookers and water heaters, and improved cooking stoves. Often, research on such alternatives is marred by lack of funds. Thus, it is imperative to fund the transformation of laboratory discoveries into subsidized, durable and portable commercial products and to fund the effective monitoring of their usage. Emphasis should also be put on continuous up-gradation to make these more efficient and economically accessible to larger population and on providing tax breaks for local entrepreneurs interested to work in the area of renewable energy sources.

7.4.2 Possible strategies to mitigate Human Wildlife Negative Interactions and economic loss

Management authorities should be provided with sufficient funds to compensate loss incurred by local communities due to wildlife and conservation related conflicts. However compensation is only a partial strategy to reduce hostility of local communities but timely payment and supportive staff may improve relationships between management authorities and communities and can reduce retaliatory activities of locals. It was found that most wildlife attacks on livestock were of leopard on sheep and goats grazing in riverine forests during winters or during summer migration to alpine meadows. Ways for improved herding practices, particularly limiting free ranging livestock in wilderness or closer to forests should be encouraged. There are traditional grazing rules for summer migration routes of local shepherds in the timberline zones and alpine meadows that should be strictly followed by the graziers. Many of these routes are historic and fall in highly fragile ecosystems of the Sanctuary, thus it is imperative that grazing and non-grazing areas are demarcated with community leaders to avoid expansion of these activities in untouched wildlife habitats in future. Villagers often lose their livestock to diseases (community discussions and purposive sampling), thus, health camps for livestock for vaccination and to raise awareness among healthy diets for the animals should be organized from time to time.

Sometimes (during field validation), wild pig signs were found closer to waste disposal sites near village boundaries. Few respondents also complained that increased waste dumps including sites to store cattle dung near settlements and fields are often

raided by wild pigs that then raid nearby fields. Thus, emphasis should be put on proper waste disposal mechanisms and storage of manure. Respondents mentioned that wild animals often did not raid crops like turmeric, ginger, cardamom or chili peppers. A buffer of such unpalatable or repelling crops as a buffer to food crops could be used and their success monitored to deter crop raiding by wildlife. However, local community should be provided with a market for these crops. At the end, it is imperative to mobilize and educate the community about the values of wildlife and of an intact natural habitat. Awareness drives for local communities on relevant rules and regulations regarding natural resource use, compensation schemes and other welfare programmes and workshops for ground staff on participatory approach and goodwill and relation building with local communities can be organized. It is important to bring down Human Wildlife Negative Interactions before problem escalates irreversibly and programmes are needed to offset economic loss of locals, to achieve an integrated conservation and development goal.

7.4.3 Livelihood improvement interventions

The region has many promising areas to invest in, for improving livelihood opportunities for local communities and for augmenting their income and livelihood security. One of the activities could be promoting value-added products (such as jam, squash or pickles from local products and organic-certified agricultural products) and developing a niche market for these products. Thousands of tourists visiting pilgrimage sites and natural attractions of the landscapes every year can be a potential market for

local value-added products. Capacity of youth, particularly women, needs to be built in various scientific and technical expertise and other skills related to marketing and micro-financing including both savings and credits. Both government and non-government agencies involved in rural development can cash in on the social capital of the existing local institutions and community to create community level cooperative societies and enterprises.

Despite a large proportion of village families of the landscape being associated with various tourism related livelihood activities, a majority of tourism benefit is siphoned-off either by outsiders or community elites (personal observation). Barring a few sites, tourism industry needs to be organized; and clear regulations regarding influx of tourists to pristine areas and infrastructure development needs to be put in place. Equitable distribution of tourism benefits within local community can be ensured by providing technical and financial aid to economically marginalized sections of community. Eco-development in and around major tourism sites can be developed which will not only ensure sustainable livelihood for villagers but will also guarantee that tourism won't be detrimental for the conservation goals.

Specialized payment schemes can be initiated based on Payments for Ecosystem Services (PES) and REDD+ (Reducing Emissions from Deforestation and Forest Degradation) programmes within the community-managed forests; Close-community forests in particular can provide excellent opportunity for integrating PES and REDD+ within the forest management. A benefit sharing mechanism under either PES or

REDD+ could be formulated by relevant authorities to provide appropriate monetary benefits to the local communities.

7.4.4 Building partnership between management authorities and local communities

In a social-ecological system where local communities form prevalent feature of protected area landscapes, a participatory approach of forest conservation and natural resource management will be an ideal governance system for natural areas. There is a need for creating horizontal and vertical linkages between the three types of institutions *viz.,* local level self-governing or/ and government registered bodies, civil society or non-government organizations and government line agencies and management authorities. These associations and linkages can provide a multi-stakeholder platform and ensure participation of local communities, particularly marginalized sections of society, in both decision-making and success of sustainable resource management. Various civil society organizations and research institutions can provide critical knowledge and information for capacity building of local institutions, technological interventions and sustainable livelihood alternatives while government bodies could give the necessary financial resources under various welfare programmes. Furthermore, intra-community conflicts arising due to external interventions should be identified, assessed and settled for higher success rate of such interventions. A participatory strategy and involvement of local communities while drafting and/or initiating a project, not only for environmental governance but also for conflict mitigation (regarding HWNI) will give a sense of ownership and belongingness to local communities and

might enhance their willingness to conserve Sanctuary forests and co-exist with wildlife.

7.4.5 Future research frameworks

It is well documented that mountainous forests across the Himalaya and their high plant richness are the foundation of human well-being. Most of the research conducted on the social-ecological systems of Himalaya (cited across the thesis) sets the benchmark and improves understanding about the linkages between the local rural economy and natural systems and about the usage of various forests products by local communities under varying socio-economic, cultural and ecological settings. It is imperative now that the wider context of extraction patterns which includes understanding the carrying capacity of Himalayan forests to support local economy (through provisioning services) without affecting their ability to provide regulating and supporting services is studied through in-depth, empirical research. The sustainability of resource use and various development activities in the fragile Himalayan Mountains should be assessed at the larger scale to apprise the policy planners and for appropriating development and forest conservation policies. It is imperative to understand that the issues pertaining to poverty alleviation and biodiversity conservation are inter-connected in the region. Not only the increasing human population and resultant resource demand but also the burgeoning large scale development activities in the region including hydropower projects and wide-scale infrastructure development for tourist industry, and projected climate change could be

detrimental for both ecological health of the region and livelihood security of local communities. Future research frameworks and policy planning in the area should consider both the spatial scale and high heterogeneity within the social-ecological systems of the Himalayan landscape for achieving sustainable development in the region.

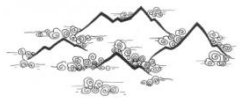




Plate 7.1: Plantation drives in Ransi village by research team with school students and village women (A & B)

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Appendix 3.1

Variables used to run Principal Component Analysis and Hierarchical Cluster Analysis (marked with *) to identify homogeneous groups of villages

1	Area of the village	18	Distance from nearest town
2	Number of households*	19	Total income*
3	Total population*	20	Total expenditure*
4	Population female*	21	Total forested area
5	Population Scheduled class*	22	Total irrigated area*
6	Total literate*	23	Un-irrigated area
7	Total female literate*	24	Cultivable waste
8	Total work population*	25	Area not available for cultivation
9	Total main workers*	26	Primary and middle schools*
10	Total main workers as cultivators*	27	Secondary and senior secondary school*
11	Total main workers in household industries*	28	Medical facility*
12	Total other main workers*	29	Households registered under MNREGA*
13	Total marginal workers*	30	Households which got 100 days employment
14	Total marginal workers as cultivators*	31	Number of major agricultural produce*
15	Total marginal workers in household industries*	32	Self-help groups operational in village
16	Total other marginal workers	33	Reported cases of HWC
17	Total non-working population*		

Appendix 3.2

Questionnaire for socio-economic survey

1. **Identification of sample household (CODE): BLGPVINO.**

BL= Block name, **GP=** Gram Panchayat, **VI=** Village name, **NO**= Number

2. **Respondent profile: HY/NM/FAge**

HY/N= head yes/ no

M/F= male/ female

3. Roster of the Members and Non-members in your family?

Members	Age*	Qualification**	Marital Status***
Male			
Female			
Non-members			
Male			
Female			

*Age: (if respondent is unable to give accurate age, make class range, <14, 14-21/18, 18-40, 40-60, >60)

** 1. Illiterate 2. Primary 3. Secondary 4. Degree 5. PG and above

*** 1. Married 2. Unmarried 3. Widowed/Divorced

4. House and economy details of house hold (observed by interviewer)

Characteristics	1	2	3	4	5	6
Type of house	Individual house	Open roof and patio	Room within a larger house	Other (specify)		
House Roof	Thatched	Tiles	Concrete	Concrete and tiled	Concrete and asbestos	Other (specify)
Walls	Mud	Concrete	Leaves and Poles	Stones	Bricks	Others
Number of rooms used by family						
Toilet	Yes	No				
Sanitary	Sewage	Septic	None	Others		

service	system	tank		(specify)		
Primary source of water	Piped water system	Public well (naulah)	Open tap or faucet	River or stream	Other (specify)	
Waste disposal	Garbage service	Forests	In the surroundings	Compost Pits	Burn/ Bury	River/ stream
Lighting	Electricity	Solar	Kerosene, gas, candles, wood	Watermill	Other (specify)	
Amenities	Electricity	TV	VCD player	Radio	Phone	Cable TV
Vehicles	Cycle	Bike	Car	Other		
Homestead	Yes	No				
Use of forest* products in construction	Nil	Very low	Low	Neither High Nor Low	High	Very High

(*fill this after, asking questions about forest resource collection)

5. Livelihood strategy and members involved

Primary occupation:

Agriculture

Forest produce

Employed (Govt./ pvt.)

Seasonal employment

Livestock

Business/ Trading

Any combination of above (explain):

5.1 Resource Use (Non-cultivated phyto-resources)*

a. List of resource

Fuel-wood	Fodder	Leaf-litter	Timber	Thatch grass
MAPs	Fruit	Vegetable	Grazing	Spices
Employment	Flower	Others		

*Who does the collection: (write in front of resources) Adult male or female, male or female child

b. Quantification of resource collection (except fuelwood and fodder)

Species	**Plant part**	**Season/ month**	**From where (distance trv. & time taken)**	**How much**		**Any related cost***	**Income generated****
				hh-consumption	**Sell**		

*transportation cost of bringing resources or selling produces

**ask indirect questions *e.g.* market prince etc.

c. Quantification of fodder and fuelwood collection

Fodder species and requirement/kg/day*					**Quantity sold**	**Income generated/ sell price**
Species or source (if possible)	Summer	Rain	Winter	Spring		

Fuelwood species and requirement/kg/day*					**Quan. sold**	**Income generated/sell. price**
Species (if possible)	Summer	Rain	Winter	Spring		

Preferred species:

_____

- Perception towards resource conservation:

_____

_____

_____

_____

5.3 Agriculture (farming)

- Size of land holding:
- Members involved:
- Number of crops per year:

Season/ months	Crop name	Total yield	Consumption	Cost incurred (rs.)			Dependency on forest
				seeds	chemical	other	

- **Agriculture economy (for crops sold in market)**

Crop name	Quantity sold (kg)		Income generated (Rs)	Where/ to whom**	Others
	On an average	In last season			

*calculate income from crops using market price also

**Barter system

5.4 Animal husbandry

Particulars of livestock:

Livestock	Breed	Graze in forest (where)	Cost incurred/ day/ season		Output (yield)/ day	Income generated
			Fodder	Other supplements		

*estimate income from market price

5.5 Other income generating assets held by the family (taxi, bee-keeping, horses, hotels etc.) and relevant information (member involved, cost, income etc.):

5.6 Govt./ pvt. employment and relevant information (member involved, income etc.):

6 Human-Wildlife Conflict

List problematic animals and rank	
Intensity of crop-raiding and animal involved	
Name of crop and proportion of harvest affected in raiding	
Value of crop lost in rupees	
Does this affect hh ability to sell surplus produce	
Intensity of livestock predation	
Number and name of livestock lost to predation, time and place of attack and other information	
Monetary loss due to predation	
Compensation paid by Forest department: amount, time taken	
Any attack on family members	
Is compensation enough for monetary loss	

Others:

_____

_____

_____

7. Participation in forest management activities

What are the issues that needs/ needed to be solved?	
What are the activities?	
Is any member of your family part of such activities?	
If yes then, to what extent and since when?	
What were the reasons for this?	
Do you think such activities have done any good for the community?	
Have your hh benefitted from this?	
Have you gained any livelihood benefits from such activities? If yes then what?	Monetary: Non-monetary*:
Costs of such activities**	

***Subsistence resource use, secure resource rights, empowerment of marginalized groups (hh), strengthened capacity and learning, cultural and religious values etc.**

****restricting resource use, time spent on such activities**

Others:

_____

_____

_____

Appendix 4.1

Tree species density (no.ha$^{-1)}$, total basal area (m^{2}ha^{-1}) and Important value index in forest across elevational gradient (High Elevation Village: HEV; Mid Elevation Village: MEV and Low Elevation Village: LEV).

F: Fodder, FW: Fuelwood, M: Miscellaneous uses including agricultural implements, branches to support climber crops in agricultural field, T: Timber, F*: Most preferred fodder; **Local name

Species name	**Utility values**	**HEV**			**MEV**			**LEV**		
		Density/ha	**TBA**	**IVI**	**Density/ha**	**TBA**	**IVI**	**Density/ha**	**TBA**	**IVI**
Albizia lebbeck	F, FW	2.61	0.17	1.99	5.16	0.50	4.20			
Alnus nepalensis	FW, M	30.25	1.98	26.15	30.95	5.35	35.77	11.01	0.37	7.30
Bauhinia variegata	F*	1.56	0.01	1.00				1.22	0.01	1.23
Betula alnoides	F, FW, T	0.52	0.01	0.72	0.86	0.18	1.44			
Carpinus viminea	F, FW	1.56	0.05	1.17	9.46	0.56	6.67			
Celtis australis	F*				0.86	0.01	0.87			
Cinnamomum tamala	M				0.86	0.01	0.86			
Cornus macrophylla	F, FW	0.52	0.08	1.07	3.44	0.26	2.98			
Phyllanthus emblica L.	M							1.22	0.03	1.34
Engelhardtia spicata	F*, FW	1.04	0.04	0.99	2.58	0.65	4.75	66.07	1.75	34.63
Erythrina suberosa	-							1.22	0.07	1.56
Ficus roxburghii	F*	2.09	0.04	2.35	0.86	0.01	0.87			
Prunus sp. *(GadAaru**)*	-				0.86	0.46	2.40			
Ilex dipyrena	F*, FW, M	3.13	0.07	2.24						
Juglans regia	-	0.52	0.02	0.78						
Lannea coromandelica	-							1.22	0.07	1.57

Lindera pulcherrima	-	1.04	0.02	0.89				2.45	0.07	1.85
Litsea umbrosa	FW, M	3.13	0.11	2.38	14.62	0.64	8.77	8.56	0.27	5.27
Lyonia ovalifolia	F*, FW	61.53	3.20	46.84	101.45	3.64	51.98	37.93	1.18	26.09
Mallotus philippensis	-							4.89	0.20	3.13
Melia azedarach	-							1.22	0.00	1.18
Myrica esculenta	FW, M	2.61	0.10	3.33	34.39	1.49	19.48	22.02	1.33	20.76
Neolitsea cuipala	-	0.52	0.01	0.71	0.86	0.06	1.03			
Pinus roxburghii	FW, T	66.75	2.33	35.74	26.65	3.12	22.02	56.28	2.90	36.49
Prunus cerasoides	M				0.86	0.02	0.89	23.25	0.89	16.61
Pyrus pashia	M				6.02	0.10	6.21			
Quercus floribunda	F*, FW	6.26	0.57	8.11	0.86	0.01	0.86			
Q. glauca	F*, FW				0.86	0.25	2.32	34.26	1.33	22.51
Q. leucotrichophora	F*, FW	66.75	4.53	60.46	67.06	5.47	49.65	80.75	3.03	50.79
Q. semecarpifolia	F*, FW	6.78	0.54	5.84						
Rhododendron arboreum	FW, M	137.15	7.34	88.22	97.15	5.55	56.27	70.96	2.11	39.61
Rhus wallichii	-	1.04	0.02	0.89	2.58	0.06	2.71	1.22	0.01	1.26
Sapium insigne	-				0.86	0.09	1.15	6.12	0.13	3.93
Symplocos chinensis	F, FW	2.61	0.07	3.75	11.18	0.20	7.73			
Symplocos ferruginea					2.58	0.16	3.04	15.91	0.44	10.57
Symplocos theifolia	-	0.52	0.03	0.80	6.02	0.15	3.81	1.22	0.02	1.27
Syzygium cumini	M							7.34	0.46	7.04
Toona ciliata	T	2.09	0.18	3.57				2.45	0.44	4.02
Toona serrata	T				0.86	0.12	1.27			
		402.58	21.49	300.00	430.72	29.10	300.00	453.90	16.89	

Appendix 4.2

Density of regenerating individuals (seedling and saplings; no.ha^{-1}) across different disturbance regimes

Species	HEF		MEF		LEF	
	Seedling	Sapling	Seedling	Sapling	Seedling	Sapling
Albizia lebbeck			17.20	3.44	4.90	0.00
Alnus nepalensis	25.04	25.04	0.00	6.88	63.64	9.79
Bauhinia variegata			17.20	0.00	4.90	0.00
Betula alnoides	2.09	0.00				
Carpinus viminea	14.61	4.17	92.87	0		
Cedrus deodara	2.09	0.00	13.76	0.00	509.09	0.00
Celtis australis			30.96	0.00	9.79	0.00
Cinnamomum tamala			44.72	0.00	9.79	4.90
Engelhardtia spicata	4.17	0.00	61.92	0.00	665.73	107.69
Ficus nemoralis	2.09	0.00	24.08	3.44	0.00	9.79
Ficus roxburghii	16.69	8.35	13.76	0.00	0.00	4.90
Ficus subincisa	10.43	8.35	6.88	27.52	73.43	9.79
Fraxinus micrantha			6.88	0.00	4.90	0.00
Glochidion velutinum	2.09	0.00			9.79	0.00
Ilex dipyrena	2.09	4.17				
Juglans regia			6.88	0.00		
Lindera pulcherema	25.04	0				
Litsea umbrosa	70.94	0	147.91	0		
Lyonia ovalifolia	121.01	4.17	134.15	17.20	215.38	4.90
Mallotus philippensis			3.44	0	34.27	4.90
Morus alba			3.44	0		
Myrica esculenta	2.09	0	72.24	34.40	24.48	0
Neolitsea cuipala			110.07	0	200.70	48.95
Pinus roxburghii	116.84	8.35	24.08	0	9.79	4.90
Prunus cerasoides	2.09	0			4.90	9.79
Pyrus pashia	54.25	0	354.30	17.20	411.19	44.06
Quercus serrata					14.69	0
Q. floribunda	58.42	10.43				
Q.glauca			55.04	0	48.95	19.58
Q.leucotrichophora	256.63	22.95	209.83	113.51	283.92	83.22

Q.semecarpifolia	0	14.61				
Rhododendron arboreum	194.04	6.26	147.91	6.88	323.08	0
Rhus wallichii	10.43	0	113.51	10.32	4.90	0
Sapium insigne			10.32	0	44.06	0
Symplocos chinensis	29.21	0	134.15	3.44	19.58	4.90
S. theifolia	8.35	0	103.19	96.31	19.58	4.90
S. ferruginea			292.38	0		
Syzygium cumini			48.16	13.76	543.36	146.85
Toona ciliata	4.17	0	48.16	20.64	63.64	73.43
Toona serrata			6.88	0		
Viburum coriacium			106.63	0		
Zanthoxylum armatum			3.44	0	0	4.90
Total	1034.87	116.84	2466.34	374.94	3622.38	602.10

Appendix 4.3

Tree species and sapling densities (no.ha$^{-1)}$ in Agro-forestry System of studied villages across elevational gradient (High Elevation Village: HEV; Mid Elevation Village: MEV and Low Elevation Village: LEV).

F: Fodder, N: Naturally growing, FR: Fruits, M: Miscellaneous uses including cheap timber or wood, religious value, household items such as baskets, food for silk worm, etc., T: Timber

Species name	Utility Value	HEV		MEV		LEV	
		Tree	Saplings	Tree	Saplings	Tree	Saplings
Aesculus indica	N, M	2.11	0				
Alnus nepalensis	N, M	1.79	0.93	0.93	3.53	0.13	1.80
Bauhinia variegata	F			0.24	0.22		
Betula alnoides	N			0.03	0.03	1.47	0.47
Camellia sinensis	M			0.06	0		
Carpinus viminea	N, F	0.25	0				
Cedrus deodara	T	0.06	0	0.66	0.04		
Celtis australis L.	F	6.17	0.60	22.39	19.28	21.27	15.40
Cinnamomum tamala	M			0	0.03		
Citrus aurantiifolia	FR	0.32	0	0.47	0	0.53	0
Citrus aurantium	FR	0.15	0	1.94	0.13	0.93	0
Citrus limon	FR	0.57	0	2.22	0	1.53	0.40
Citrus sinensis	FR			0.06	0		
Cornus macrophylla	N, F	0.05	0.05	0.04	0		
Cupressus torulosa	T	0.31	0	0.24	0		
Debregeasia hypoleuca	N, F	13.75	6.38	20.76	5.60	6.53	1.87
Engelhardtia spicata	N, F	0.14	0.14	0.90	0.84	2.67	1.20
Ficus auriculata	F	11.88	2.65	16.54	14.69	32.80	18.87
Ficus neriifolia	F	19.57	16.75	18.68	15.20	0.93	0.80
Ficus palmata	F			0.78	0.97	0.80	0.07
Ficus religiosa	M			0.03	0	0.47	0.13
Ficus semicordata	F			0.21	0	0.60	0.13
Ficus subincisa	F	7.16	14.81	39.31	44.00	63.33	58
Ficus virens	F			0	0.35	0.27	0.07
Fraxinus micrantha	T	0.76	0.05	0.08	0		
Grevillea robusta	M			0.13	0		
Grewia optiva	F	0.99	0	12.51	5.90	16.33	6.60
Grewia sp.	F					0.73	0
Hill bamboos	M	4.34	0	9.95	0	2.33	0.33
Juglans regia	FR	5.58	0.26	4.71	0.31	1.13	0
Litsea monopetala	F	0.37	0.99	12.66	15.79	24.33	15.80
Litsea umbrosa	N	3.95	0			0	0.13
Lyonia ovalifolia	N, F	2.05	0.54	0.85	1.24	0	0.53
Machilus duthie	N			0.06	0		

Citrus sp. (Malta)	FR	14.99	0.60	34.13	2.77	27.40	3.60
Malus domestica	FR	1.90	0.09	0.28	0.02	0.13	0
Mangifera indica	FR			0.22	0	1.67	0.13
Melia azedarach	-					0.27	0.13
Morus alba	F, M	0.23	0	0.93	0.52	4.67	2.87
Musa paradisiaca	FR	13.10	0	23.49	0.14	76.27	0
Myrica esculenta	N	0.09	0	0.51	0.14	0.40	0
Ougeinia oojeinensis	F					0.20	0
Phyllanthus emblica	FR	0	0.05	0.04	0		
Pinus roxburghii	N	0.51	0.14	0.83	1.85	0.80	0.27
Prunus armeniaca	FR	0.97	0.03	0.21	0	0.27	0
Prunus cerasoides	N, M	1.51	0.31	1.44	0.39	1.80	0.13
Prunus domestica	FR	0.37	0	0.46	0	0.13	0
Prunus persica	FR	7.60	0.38	6.15	0.50	3.33	0.47
Psidium guajava	FR			0.21	0.03	7.53	0.33
Punica granatum	FR	0.28	0	0.25	0	0.20	0
Pyrus pashia	N	0.49	0.99	0.22	0.80	3.27	3.13
Pyrus sp.	FR			0.04	0		
Quercus floribunda	N, F	0.49	0.50	0.04	0		
Q. serrata	M	0.59	0.09	0.15	0.08		
Q.glauca	F			0.12	0		
Q. leucotrichophora	N, F	37.26	6.25	24.92	15.06	0.27	0
Rhododendron arboreum	N	1.11	0.28	0.05	0.48		
Sapindus emarginatus	M			0.39	0.20	0.33	0
Sapium insigne	N			0.04	0.62	1.87	3.60
Symplocos chinensis	N, F	0.09	0.19	0.11	0.51		
Symplocos cochinchinensis	N			0.29	0.18		
Syzygium cumini	N	0.06	0	0	0.07	1.20	2.73
Toona ciliata	T	1.91	1.28	0.31	1.18	1.87	2.80
Toona serrata	N	0.17	0.68	0.32	0.15		
Zanthoxylum armatum	N	0.57	0.15	0.91	0.23	0.07	0.07
Total		166.6204	56.14815	264.5169	154.057	313.0667	142.8667

Appendix 6.1

Collective actions under *Gram Panchayat* and *Mahila Mangal Dal*

Village name	Local institution	Activities	Conflict scenario and/ or reasons
Chaumansi	*Gram panchayat*	*Shramdaan** for building forest wall, clearing forest trail, guarding agricultural fields from primates, work distribution under MNREGA	-
	Mahila Mangal Dal	Cleanliness drives in village, clearing forest trails and weed eradication from community land, issuing mats and chairs for family functions	Head's husband was killed during June 2013 disaster, no meeting since then.
Chilond	*Gram panchayat*	*Shramdaan* for restoring village roads during Monsoon, clearing forest trail	Most restoration works such as of village roads and water tanks done under MNREGA now, GP losing ground.
	Mahila Mangal Dal	No meeting since June 2013 disaster	Men opposed MMD meetings as women protested against local alcohol production
Jaal Malla	*Gram panchayat*	Guarding community forests, clearing forest trails and cleaning streams, guarding against primates	-
	Mahila Mangal Dal	Cleanliness drives in village, clearing forest trails and weed eradication from community forests, plantation drives under Forest Department	-
Ransi	*Gram panchayat*	*Shramdaan* for restoration work within village such as forest wall, decisions on religious ceremonies in village temple, solving conflict between families	-
	Mahila Mangal Dal	Cleanliness drives in village, clearing forest trails, protest against alcohol, plantation drives under Forest Department	Meetings became irregular as protests against alcohol resulted in conflict and women from different settlements created separate groups
Kalimath	*Van Panchayat*	Rotational lopping in community forests, community came together to restore village road after June 2013 disaster	*Van Panchayat* losing relevance, particularly after June 2013 disaster, members not satisfied with *Panchayat* committee, work mostly carried out under MNREGA now
	Mahila Mangal Dal	Protest against local alcohol production within village	Irregular meetings earlier, no meetings after June 2013 disaster
Gaundar	*Gram panchayat*	Cleanliness drives within village and clearing forest trails	Not very active, rarely discusses environment related issues
	Mahila Mangal Dal	Proposed, will start soon	-
Khonu	*Gram panchayat*	Guarding agricultural fields from primates, loaning	-

		money to villagers, restoring village roads and small bridges	
	Mahila Mangal Dal	Cleanliness drives in village, clearing forest trails, plantation of fodder species on community land	-
Kotma	*Gram panchayat*	Cleanliness drives in village, clearing forest trails and fencing forests, regulating MNREGA work, plantation in community forest	*Panchayat* has lost context in recent times due to out-migration of many families and loss of community forests due to floods
	Mahila Mangal Dal	Cleanliness drives in village, clearing forest trails, forest protection, appointing watchwomen, plantation with NGOs	-
Buruwa	*Gram panchayat*	*Shramdaan* for restoration of village roads and forests trails	-
	Mahila Mangal Dal	Cleanliness drives in village, clearing and restoring forest trails, plantation under Forest Department	-
Kaviltha	*Gram panchayat*	Restoration of village roads only during emergency such as after rains, and clearing forest streams and drainages within village	Community forest has reduced a lot due to encroachment and floods
	Mahila Mangal Dal	Cleanliness drives in village and clearing forest trails	No meeting for over a year
Raulek	*Gram panchayat*	Building forest wall and mending water sources	-
	Mahila Mangal Dal	Cleanliness drives in village, clearing forest trails and weed removal, plantations with NGO, protests against alcohol production within village	Men interrupted meetings and opposed various activities such as protests against alcohol
Bedula	*Gram panchayat*	Work distribution under MNREGA	-
	Mahila Mangal Dal	Cleanliness drives in village and clearing forest trails, plantation, protecting forest resources from violators	-
Bhatwari	*Van panchayat*	Restoration works needed for village	Many households have encroached upon the community land after recent landslides; part of Nagar Panchayat now
	Mahila Mangal Dal	Cleanliness drives in village, issuing mats and chairs for family functions	There is no cooperation among members, meetings are infrequent
Mansoona	*Gram panchayat*	Clearing forest trail, Guarding fields from primates, weed removal from community land	-
	Mahila Mangal Dal	Cleanliness drives in village, issuing mats and chairs for family functions	-

**Shramdan* = Voluntary labor

Publications

Research article

1. Manral, U., Badola, R., & Hussain, S. A. (2017). Forest composition and structure under various disturbance regimes in the Alaknanda River Basin, Western Himalaya. Mountain Research and Development, 37(3), 310-322.
2. Manral, U., Sengupta, S., Hussain, S. A., Rana, S., & Badola, R. (2016). Human Wildlife Conflict in India: A Review of Economic Implication of Loss and Preventive Measures. The Indian Forester, 142(10), 928-940.
3. Manral, U. (Under review). Kedarnath Wildlife Sanctuary: Nature-Culture linkages in a sacred landscape in Indian Himalayan Region. Capacity Building Workshop on Nature-Culture Linkages in Heritage Conservation in Asia and the Pacific (CBWNCL) – 2017. Journal of World Heritage Studies.

Popular Article

1. Manral, U. August 2016. Banj, Beasts and People - Life in the fringes of the Kedarnath Wildlife Sanctuary, Western Himalaya. *Sanctuary Asia,* 36(8).

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Forest Composition and Structure Under Various Disturbance Regimes in the Alaknanda River Basin, Western Himalaya

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Forest Composition and Structure Under Various Disturbance Regimes in the Alaknanda River Basin, Western Himalaya

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This study explored the resilience of mountain forests in a protected area in Alaknanda River basin, Western Himalaya, to various disturbance scenarios. The resource dependency of village communities in the Kedarnath Wildlife Sanctuary Landscape was studied through a questionnaire survey in 10 villages situated along an elevational gradient. Vegetation sampling was done in government-owned sanctuary forests and community-owned forests, both visited by villagers. Forest community composition, regeneration status, and tree population structure were studied to understand the impact of disturbance on forests and their resistance to anthropogenic alterations. Results indicated a reduction in both fuelwood and fodder consumption with decreasing elevation, with villages at higher elevations and located inside the sanctuary depending more on forest resources. Forests showed evidence of disturbance in the form of lower basal cover, mean canopy cover, regeneration, and disturbance-influenced distribution of shrubs. However, despite the signs of secondary succession, Quercus leucotrichophora *forest has retained the original tree species composition. Vegetation recovery on 3 landslide sites at varying successional stages was also studied. The old successional site had higher species richness than early successional sites. The only tree species with adult individuals recorded in early successional sites was* Alnus nepalensis*, an early successional nitrogen-fixing species. The community composition of the old successional site, at Bandwara, included young individuals of* Q. leucotrichophora*, the climax species of forests in that elevational range. The current forest structure of both disturbed forest and vegetation recovery on the old succession site indicate the resilient dynamism of native Himalayan forests. Considering the role of mountain forests in achieving sustainable development, it is imperative to study the dynamics of changes in forest community and structure in response to increasing human pressure and climate change impacts.*

Keywords: *Anthropogenic disturbance; elevation; Kedarnath Wildlife Sanctuary; resource dependency; regeneration; resilience; vegetation recovery; Sustainable Development Goals; Agenda 2030.*

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Introduction

Mountain forests around the world constitute an important natural capital stock, providing a plethora of ecosystem services to local and downstream communities and a source of livelihood for a large human population (MEA 2005; TEEB 2010). They play a multifaceted role in achieving the Sustainable Development Goals, particularly in developing economies like India, where they form the foundation of the local economy for a large part of the population. For mountain communities, forest resources are crucial to poverty alleviation, economic growth, and food security. In a region like the Himalaya, where very few livelihood options are available, mountain forests form an essential life-support system for local people (Khan et al 2014; Bhandari et al 2016). The region is prone to hydro-geomorphic disasters including landslides and floods, causing forest degradation and fragmentation, which are exacerbated by anthropogenic disturbances such as resource extraction (Ali et al 2005; Pandit et al 2007; Petley 2010; Ruiz-Villanueva et al 2017).

Both natural and anthropogenic disturbances are integral drivers of forest dynamics that alter species composition and diversity, which in turn determine ecosystem productivity and the flow of ecosystem services (Tilman et al 1997; Bagchi and Ritchie 2010; Bagchi et al 2012). Fragmented and degraded forests with altered forest structure, composition, and ecosystem processes are more vulnerable to climate change (Noss 2001), thus putting pressure on resource managers to focus on maintaining ecological resilience against various stressors. In the current scenario of uncertainty, altered

disturbance regimes, and their implications for forest health and the flow of ecosystem services to humans, the role of Himalayan forests in achieving Sustainable Development Goals in the region might come under threat. It is important to understand the multiple successional sequences following disturbances in order to better understand forests' resilience to these events.

This study was conducted in the Alaknanda River basin in the western Himalaya to explore (1) the dependency of villagers on forest resources at different elevations, (2) the species composition and community characteristics of forests under different disturbance regimes, and (3) vegetation recovery and successional sequences at landslide sites of different ages (from 10 to more than 50 years). The Alaknanda Basin is characterized by rich biological and cultural diversity. It is representative of the Himalayan mountain system in terms of natural geological instability, intricately linked ecological and social systems, lack of economic opportunities leading to heavy dependence on natural resources, and anthropogenic disturbances in forests. Any unwanted structural and compositional changes to the region's forests will impact both biodiversity conservation and local livelihood security and thus the attainment of the Sustainable Development Goals in the region.

Study area

The Alaknanda River, a major tributary of the Ganga River, originates from the Satopanth and Bhagirath Kharak glaciers in the Rudraprayag district of the state of Uttarakhand, India. The river basin lies at 29°58′ to 31°04′N latitude and 78°34′ to 80°17′E longitude and drains an area of approximately 11,000 km^2. Like the rest of the Himalaya, because of a mix of hard and soft lithology and tectonic setup, the Alaknanda River basin is prone to slope failure and landslides (Joshi and Goel 1988; Negi and Joshi 2014). A single June 2013 event caused new landslides at 3472 locations covering 30.4 km^2 and a loss of around 46 ha of forest and 125 ha of grassland across Uttarakhand state, a large proportion of which occurred in the Alaknanda basin (Martha et al 2015).

An intensive study was carried out in Kalimath, Madhyamaheshwar, and Mandal Valleys in the Kedarnath Wildlife Sanctuary Landscape in the Alaknanda River basin (Figure 1). It included sampling within the sanctuary and proposed ecosensitive zone as per the guidelines of the Ministry of Environment, Forests, and Climate change of the Government of India. The sanctuary is part of the Himalayan biogeographic zone and the West Himalaya biotic province (Rodgers and Panwar 1988). A total of 173 villages are located in the protected area landscape, 12 of those inside the sanctuary. The inhabitants of these villages depend heavily on forests in the sanctuary for day-to-day sustenance; this has led to habitat degradation, worsened by frequent flash floods and landslides.

Resource use was studied in 10 villages in Kalimath and Madhyamaheshwar Valleys (Figure 1; Table 1), which differ in their proximity to Kedarnath Wildlife Sanctuary, forest management regimes, and elevation (Table 2). Vegetation disturbance and consequent changes in forest structure and composition were studied in forests visited by local communities for resource extraction. Vegetation recovery after extreme disturbance was studied in 3 landslide sites within the sanctuary landscape: 2 early successional sites, Jaggi-Bagwan (hereafter Jaggi) and Jugansu (about 15 years old), and 1 older successional site, Bandwara in Mandal Valley (>50 years old). The first landslide incident on Jaggi slope occurred some 70 years ago on a smaller scale and stabilized with time. However, with every extreme rainfall event the landslide area increased, particularly longitudinally. Thus, only more recent, stabilized landslide areas were accessible for sampling, as older parts moved towards the river and were mostly buried in new debris.

Methods

Field sampling

The data on local communities' dependency on forest resources and the socioecological variables affecting a household's dependency were collected in 3 stages. The first stage involved collection of secondary information from government agencies on demographic and socioeconomic indicators, and a reconnaissance survey to obtain information about village elevation, dependency on forest resources, and proximity to sanctuary forest, as well as major forest types. A total of 38 villages grouped into 23 *gram sabha* were identified in the study area. (A *gram sabha* is the village assembly of all the adults that forms the foundation for the Indian electoral system in rural areas.)

In the second stage, the collected data were subjected to principal component analysis and hierarchical cluster analysis (Badola et al 2012), using SPSS 16.0, to identify homogeneous groups of villages. A total of 33 variables were used to run principal component analysis, out of which 23 variables that caused the highest variance in the dataset were chosen for hierarchical cluster analysis. Representative villages (n = 10) were selected from each of 4 clusters that resulted from the cluster analysis and divided into 3 groups, based on the elevation of the forest that villagers accessed. Villages were categorized as high elevation if villagers frequently accessed forest at >2000 m above sea level (masl), medium elevation for forest at 1500–2000 masl, and low elevation for forest at 1000–1500 masl.

In the third stage, 260 households (20% of the total households) were interviewed from selected villages. A stratified random sampling was done wherein households were selected based on socioeconomic and ecological variables such as type of house, geographical location

FIGURE 1 Location of study villages and landslide (succession) sites in Kedarnath Wildlife Sanctuary Landscape. (Map by Upma Manral)

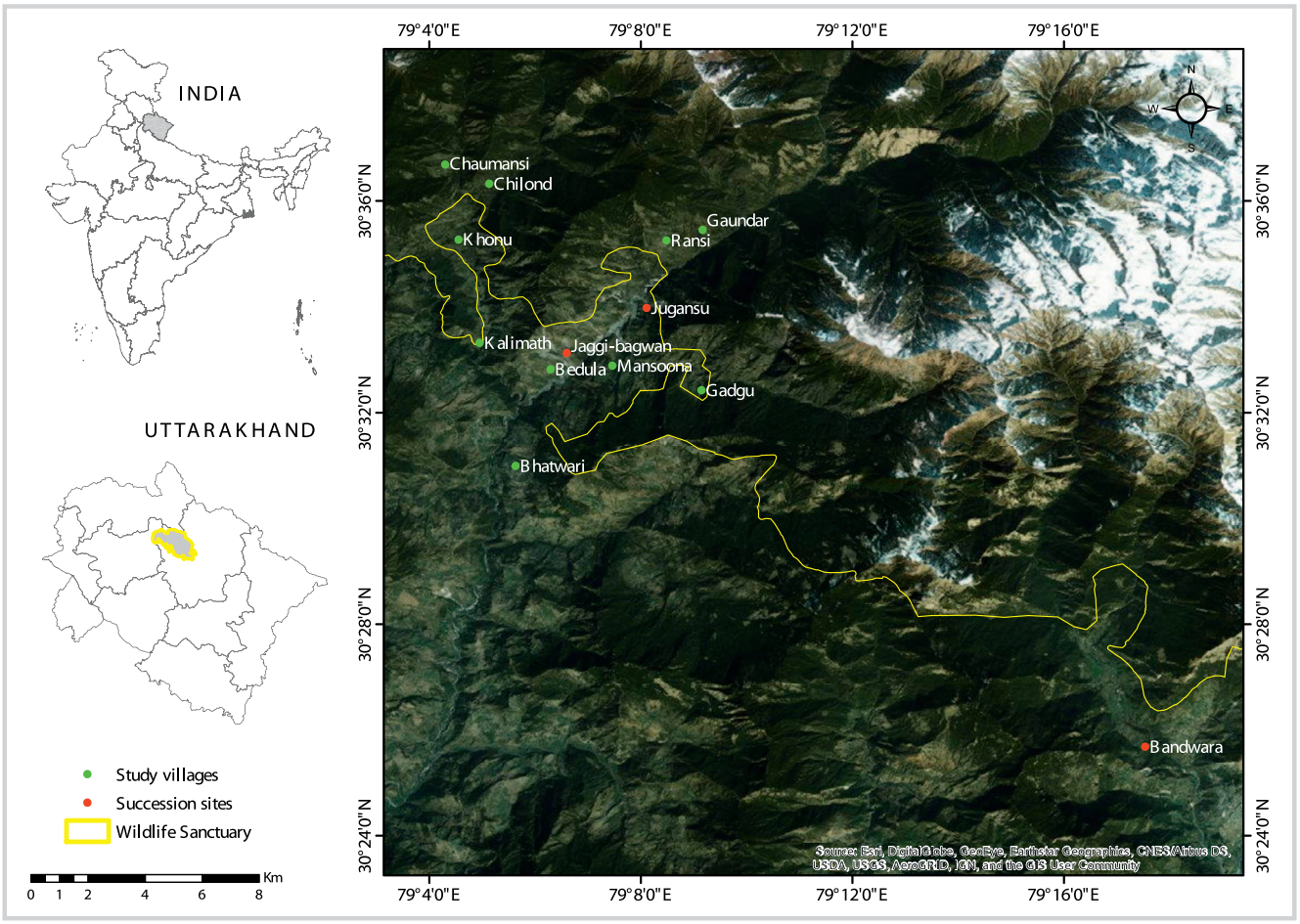


TABLE 1 Average annual resource dependency and household income across elevation gradient in the study area.

Villages (village elevation, m)	Average annual household consumption (kg)		Average annual household income (US$)	Key occupations
	Fuelwood	Fodder		
High elevation **Chaumansi (2060–2130)** **Chilond (1800–1910)** **Ransi (1600–2269)**	6166	10,420	3413 ± 3292.7	Agriculture and animal husbandry Business (shops, lodge, restaurants along treks)
Medium elevation **Gadgu (1636–1850)** **Gaundar (1665–1907)** **Khonu (1480–1720)**	5235	9946	2506 ± 2271	Agriculture and animal husbandry Day labor
Low elevation **Kalimath (1300–1400)** **Mansoona (1250–1400)** **Bedula (1191–1551)** **Bhatwari (1050–1280)**	3629	7746	4189 ± 4055	Day labor Business Armed forces

TABLE 2 Sampling intensity in the forests surrounding the study villages across elevation and disturbance gradient.

Villages (forest elevation)	Village (forest elevation, m)	Relation to Kedarnath Wildlife Sanctuary	Plot distribution across disturbance classes (%)		
			High	Moderate	Low
High	Chaumansi (2158–2334)	Inside	33.33	50.00	16.67
	Chilond (1658–2360)		50.00	25.00	25.00
	Ransi[a)] (1493–2695)		72.10	18.60	9.30
Medium	Gadgu (1495–2090)		71.43	21.43	7.14
	Gaundar (1604–1861)		37.50	25.00	37.50
	Khonu[a)] (1787–1910)	At the boundary	0.00	80.00	20.00
Low	Kalimath[a)] (1207–1736)		30.00	60.00	10.00
	Mansoona[b)] (1321–1564)	>2 km away	27.30	45.40	27.30
	Bedula[b)] (1139–1483)		16.67	66.66	16.67
	Bhatwari[b)] (1192–1267)		0.00	66.67	33.33

[a)] Sampling was done in both sanctuary and community-owned forests.
[b)] Sampling was done only in community-owned forests; in the rest sampling was done in sanctuary forests.

within the village, and location with respect to roads, forest, and sanctuary. The survey was conducted from March to October 2014. The interviewer used a semistructured questionnaire with both open- and closed-ended questions to derive both qualitative and quantitative information (Badola et al 2012). Questions were asked about the household's use of forest products, preferred resource species, distance traveled for resource collection, land and livestock holdings, occupations, and income (Sapkota and Odén 2008; Hussain and Badola 2010). The data were transcribed, and each unit was assigned a tentative code (Creswell 2013).

It is imperative to understand the resilience of forests both to anthropogenic alterations and to complete denudation, in order to inform adaptive strategies under the current scenario of large-scale forest degradation in the Himalayan mountain system. To this end, we sampled vegetation in the forests harvested by villagers as well as in landslide sites of varying ages and degrees of vegetation recovery. Stratified random transects were laid along major resource-use trails in forests visited by villagers, during 2014 and 2015. At the landslide sites, transects were laid on the stabilized debris where succession had started, during 2012–2014. Circular plots—of 10-m radius for trees and, within those, of 5-m radius for shrubs, seedlings, and saplings—were laid every 200 m along the transects (Mueller-Dombois and Ellenberg 1974). Trees were distinguished from shrubs, seedlings, and saplings based on girth at breast height (defined as 1.37 m): individuals with a girth of $\geq$30 cm were classified as trees. For trees we recorded the species, number of individuals, girth at breast height, and canopy cover; for all others, we recorded the number of individuals. Disturbance was noted in terms of lopping and grazing intensity, canopy cover, number of stumps, and amount of cattle dung. A total of 124 plots were examined in forests under disturbance and 20 at landslide sites.

Data analysis

Pearson's correlation coefficients were calculated to ascertain the relationship between plant resource extraction and the various environmental and socioeconomic parameters given in Table 3.

The sampled vegetation plots were scored for the following:

a. Average lopping intensity of trees ($\leq$30% = 1, 30–60% = 2, >60% = 3);
b. Lopping proportion (number of lopped trees in the plot/total number of trees in the plot);
c. Grazing intensity (no grazing = 0, old grazing signs or mildly grazed = 1, heavily grazed with fresh grazing signs and animal dung = 2);
d. Regeneration proportion (number of regenerating species in the plot/number of adult tree species in the plot; regenerating individuals were both seedlings and saplings of a species).

A disturbance score was assigned to each plot using the calculation a + b + c − d. Disturbance was ranked as high for scores of $\geq$3, moderate for 1–3, and low for <1.

Density, total basal area, and importance value index (sum of relative frequency, relative density, and relative basal area with a value between 0 and 300) for tree species and density for shrubs were calculated. The population structure of tree species was characterized based on the relation of density to girth (Dhar et al 1997). Individuals were grouped into seedlings (<10 cm), saplings (10–30

TABLE 3 Pearson's correlation coefficient between resource use parameters and environmental variables. Values are listed for which correlation is significant at or below the 0.05 level.

Variables	Maximum elevation	Per capita income	Sheep and goats	Fuelwood	Fodder extraction	Fodder from forest	Liquefied petroleum gas
Number of cattle per household	0.809						
Number of sheep and goats per household	0.841						
Annual fuelwood consumption per household	0.787						
Annual fodder consumption per household		−0.657					
Fodder extracted from forest per household	0.681	−0.637	0.654		0.822		
Fodder from agroforestry system per household	−0.732		−0.787			−0.897	
Fodder purchased per household	−0.789						
Liquefied petroleum gas consumption per month per household	−0.779	0.633		−0.804			
Presence in the sanctuary	−0.796		0.668			0.654	−0.779

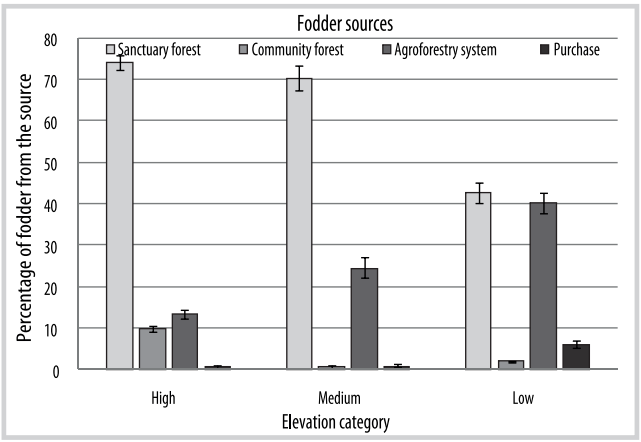
cm), and 4 classes of trees (30–60 cm, 60–90 cm, 90–120 cm, and >120 cm). To study regeneration status of trees within a plot, the number of regenerating species, density of seedlings and saplings, and pressure on these were calculated. A Dunn post hoc test was performed using SPSS 19.0 to see if distance of plot from human settlements, canopy cover, and regeneration status varied along the disturbance gradient.

Results

Forest resource use

Average fuelwood and fodder consumption per year per household were higher in high-elevation villages, followed by mid- and low-elevation villages. Fodder was extracted from the forest or from agroforestry systems or was purchased from other families or villages (Figure 2). In low-elevation villages, almost 50% of the fodder came from agroforestry systems, which included agricultural byproducts and tree species, including *Celtis australis*, *Litsea* sp. and *Ficus* spp., which are planted along a farm's boundary or on noncultivated land. Members of these households visited forests in the Kedarnath Wildlife Sanctuary to collect dry grass for fodder only from September to November (10 to 15 days a month), because of their larger distance from the sanctuary. Fuelwood consumption per household per year positively correlated with elevation, and fodder extraction from forest positively correlated with elevation and presence of the village in the sanctuary. Fodder extracted from agroforestry systems or purchased from other families negatively correlated with elevation and presence in the sanctuary (Table 3; Figure 2). Low-elevation villages had the highest annual income per household, followed by high- and mid-elevation villages. A higher percentage of households in low-elevation villages were employed in the army, had permanent employment (in the government or the private sector), or ran a business (eg a shop or a food outlet in a market area), followed by high-elevation villages. More households in mid-elevation villages depended on wages from day labor, which is usually uncertain and poorly paying (Figure 3).

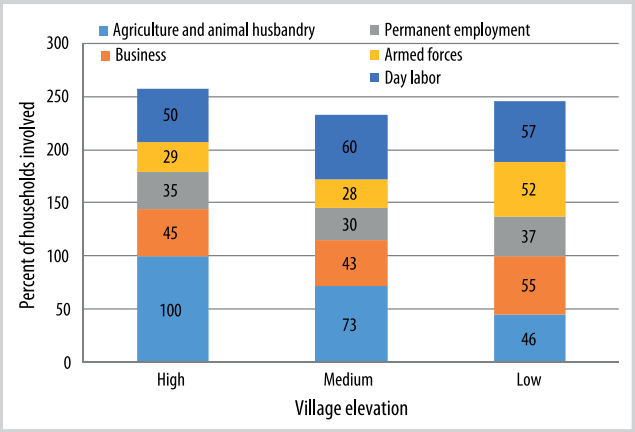
FIGURE 2 Percentage of fodder extracted from various sources across elevation categories. Error bars represent the standard error.



Forests under different disturbance and management regimes

Of the study plots, 52% fell in the high-disturbance, 32% in the moderate-disturbance, and 16% in the low-

FIGURE 3 Major occupational categories in the study area.



disturbance category. Average plot distance from a settlement and mean canopy cover increased significantly from high- to low-disturbance areas (Tables 4, 5). Both high- and moderate-disturbance plots also had tree stumps; the proportion of lopped trees also varied significantly across disturbance classes (Table 4).

There were 2 forest management regimes in the study area: government-owned sanctuary forest and community-owned forest (Table 6). Sanctuary forest made up the highest proportion in all disturbance classes; 58% of sampled forest was part of the sanctuary. Villages located inside the sanctuary had a higher proportion of high-disturbance plots, whereas villages with community forests had few high-disturbance plots, indicating less disturbance and better protection (Table 2). Regeneration proportion improved in both management regimes as disturbance decreased. There was not much difference in lopping intensity or proportion under the 2 management regimes, but both decreased as disturbance in general decreased. Somewhat paradoxically, grazing in sanctuary plots decreased from high- to moderate-disturbance plots but then increased in low-disturbance plots. The low-disturbance plots with grazing were in higher-elevation forest closer to temperate grassy slopes, where residents of high-elevation villages take their livestock for 6 months of summer and monsoon and pastoralists stay with sheep and goats on their way to alpine pastures.

Adult individuals of 38 species of trees (of which 3 species were preferred as fodder, 5 as fuelwood, and 12 were used for both fodder and fuelwood) and 36 species of shrubs were recorded. The tree species richness (total number of species) along with the number of preferred fodder and fuelwood species were highest in high-disturbance plots, followed by moderate- and low-disturbance plots (Table 4; *Supplemental material*, Table S1: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1). The stand density (number per ha) was highest for moderate-disturbance plots, followed by low- and high-disturbance plots. The total basal area (m^2 per ha) for trees was highest for low-disturbance plots, followed by moderate- and high-disturbance plots (Table 4). *Rhododendron arboreum* was the dominant species (as measured by importance value) in both high- and moderate-disturbance sites, whereas in low-disturbance sites, *Pinus roxburghii* was the dominant species (*Supplemental material*, Table S1: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1). The second dominant species in all the disturbance classes was *Quercus*

TABLE 4 Characteristics of forests across various disturbance classes.

Characteristic	Disturbance class		
	High	Moderate	Low
Mean distance of plot from settlement (m)[a]	521.87 ± 364.15	652.5 ± 356.07	832.5 ± 524.97
Mean canopy cover (%)[a]	27.03 ± 17.92	37.32 ± 18.59	42.75 ± 23.87
Stumps (number per plot)[a]	0.5 ± 1.57	0.16 ± 0.73	0
Tree species richness	29	25	21
Stand density (number per ha)	418.00	451.70	431.03
Basal area (m^2 per ha)	21.45	23.86	24.80
Shrub species richness	32	24	20
Shrub density (number per ha)	1122.65	1196.43	1756.46
Regenerating tree species richness	35	32	33
Seedling and sapling density (number per ha)	890.96	1450.99	951.27
Regenerating species per plot[a]	3.01 ± 2.83	4.375 ± 3.01	4.2 ± 2.86

[a] Values represent mean ± standard deviation.

TABLE 5 Differences in anthropogenic pressure and regeneration across disturbance classes (Dunn's post hoc test). Values are listed for which correlation is significant at or below the 0.05 level.[a)]

Variable	Disturbance classes compared		
	High and moderate	Moderate and low	High and low
Variables indicating anthropogenic pressure in the forests			
Distance of plot from settlement	0.208	0.924	**0.035**
Lopping and grazing pressure on seedlings and saplings	**0.001**	1.000	**0.001**
Canopy cover	**0.017**	1.000	**0.012**
Proportion of lopped trees	**0.001**	1.000	**0.001**
Variables indicating regeneration status of tree species in the forests			
Proportion of regenerating species	**0.014**	0.343	**0.000**
Number of regenerating species	**0.045**	1.000	0.218
Abundance of regenerating individuals	**0.013**	0.876	0.795

[a)] For values listed in cells in bold font, correlation is significant at or below 0.05 level.

leucotrichophora (banj oak), which is the most highly preferred species for both fodder and fuelwood. Its basal cover increased as disturbance decreased. Shrub species richness was highest for high-disturbance plots, followed by moderate- and low-disturbance plots. Total shrub density was highest for low-disturbance plots, where hill bamboo (ie *Arundinaria falcata* and *Thamnocalamus spathiflorus*) contributed more than 50% (*Supplemental material*, Table S2: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1).

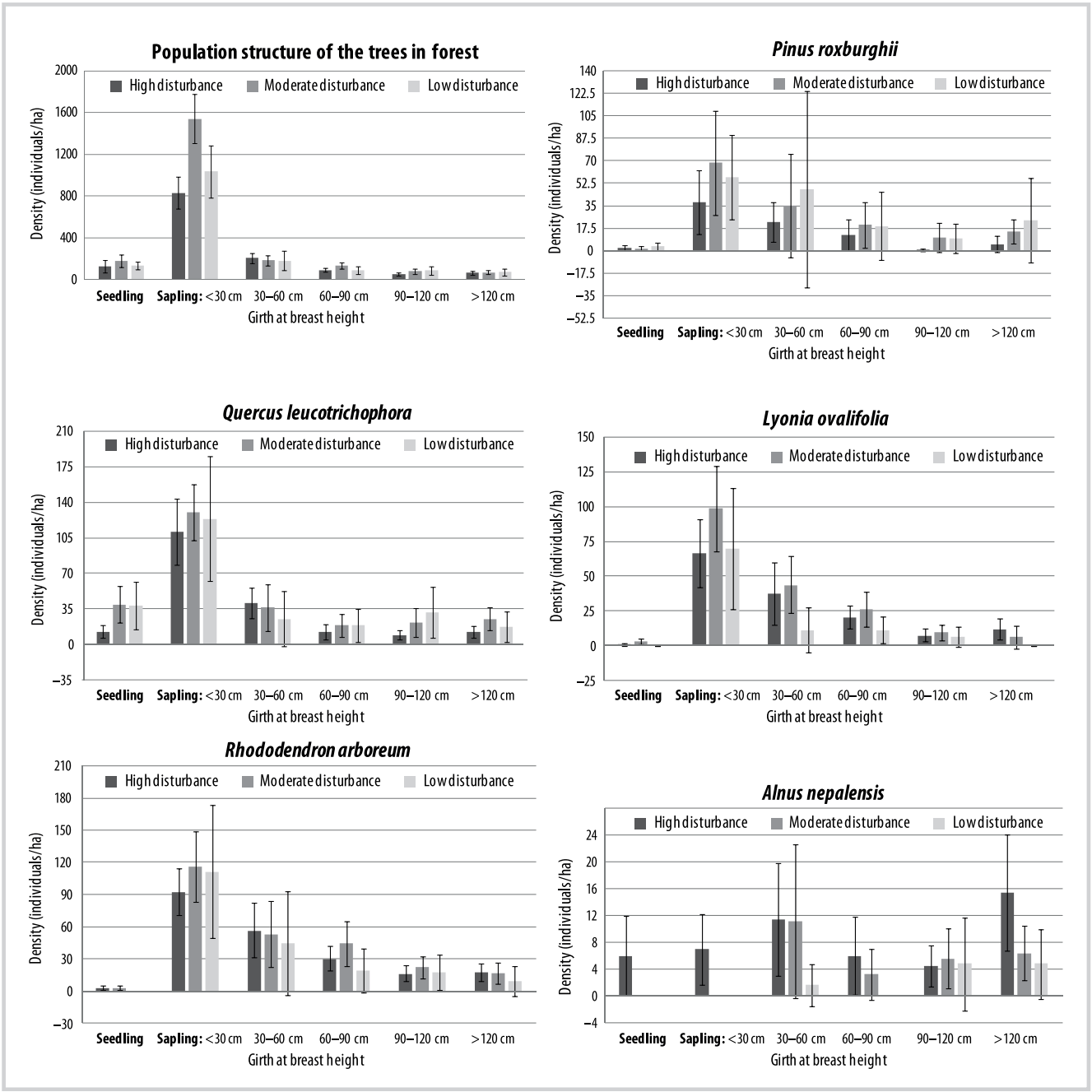
Forty-one tree species were regenerating in the study area (*Supplemental material*, Table S3: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1), with the highest species richness recorded in high-disturbance plots (Table 4). The highest density of seedlings and saplings and average number of species per plot were recorded in moderate-disturbance plots. Banj oak had the highest density in both high- and low-disturbance sites. *Engelhardtia spicata*, a subordinate species in chir *Pinus roxburghii*, had the highest density in moderate-disturbance sites. The number of regenerating species and their abundance varied significantly between high- and moderate-disturbance sites, and the proportion of regenerating species and anthropogenic pressure on regenerating species varied significantly between high- and moderate-disturbance plots and between high- and low-disturbance plots (Table 5). Density of trees in higher girth classes was low in all 3 disturbance classes (Figure 4). High-disturbance plots had higher tree density in a lower girth class (30–60 cm), whereas both moderate- and low-disturbance plots had higher density in larger girth classes than the high-disturbance plots. Almost all the dominant species showed a similar trend, except for *Alnus nepalensis*, which was found predominantly in high-disturbance sites,

TABLE 6 Values of anthropogenic pressure and disturbance ranking variables in 2 management regimes across disturbance gradient (values in parentheses are percentages of plots under each regime).

	High disturbance		Moderate disturbance		Low disturbance	
	Sanctuary forest (63%)	Community-owned forest (37%)	Sanctuary forest (53%)	Community-owned forest (47%)	Sanctuary forest (55%)	Community-owned forest (45%)
Regeneration proportion	0.73	0.71	0.99	1.23	1.50	1.50
Lopping intensity	2.65	2.50	1.81	1.74	0.45	0.44
Lopped proportion	0.64	0.71	0.43	0.41	0.20	0.05
Grazing score	1.73	1.46	0.71	1.00	1.18	0.44
Canopy cover (%)[a)]	31 ± 19	19 ± 14	38 ± 21	36 ± 16	45 ± 24	40 ± 25
Plot distance from settlement (m)[a)]	607 ± 388	379 ± 273	783 ± 369	508 ± 286	1127 ± 417	472 ± 414

[a)] Values represent mean ± standard deviation.

FIGURE 4 Population structure of the forest as a whole and of dominant tree species across disturbance regimes. Error bars represent the standard error.



where it had a bimodal distribution, with adult individuals in smallest and largest girth classes being more abundant.

Vegetation recovery in landslide sites

A total of 74 species of vascular plants were recorded at the landslide sites. Species richness increased with the age of the site; Bandwara had highest richness (60), followed by Jugansu (34) and Jaggi (31). Fifteen tree, 16 shrub, 30 herb, 6 grass, and 7 climber species were recorded. *A. nepalensis* was the only tree species with adult individuals present in Jugansu and Jaggi. The highest density of species was recorded at the Jugansu landslide site, followed by Jaggi and Bandwara (*Supplemental material*, Table S4: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1).

Of the species, 90% were perennial, showing established secondary succession in all sites. *Eupatorium*

adenophorum, *Reinwardtia indica, Bidens pilosa, Achyranthes aspera,* and *Girardinia diversifolia* had profusely colonized the sites. *Apluda mutica, Saccharum rufipilum,* and *Themeda arundinacea* were common grasses. The Bandwara site had 11 regenerating tree species, whereas Jugansu and Jaggi had 3 and 4 species, respectively (*Supplemental material*, Table S4: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1). Among shrubs, *Sarcococca saligna* had the highest density, followed by *Randia tetrasperma* in Bandwara. Bandwara also had higher herb species richness and was the only site where climbers and hill bamboo were recorded (*Supplemental material*, Tables S5, S6: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1). Twenty-six plant species were also encountered outside the sampling plots; of these, 17 were common to all sites and 9 were recorded only from Bandwara (*Supplemental material*, Table S6: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1).

Discussion

Forest resource use

High-elevation villages and those inside the sanctuary were more dependent on forest resources, whereas low-elevation villages depended more on alternative fuels such as liquefied petroleum gas, and on agroforestry systems for their fodder requirements. Other studies have also found that fuelwood consumption increases with increasing elevation in Himalaya, particularly during prolonged winters, when a large amount of wood is used for space heating (Awasthi et al 2003; Dhanai et al 2015). As community forests are closed for most of the year, a large part of fuelwood and fodder demand was met from sanctuary forests. Though the forest is protected under the Wildlife (Protection) Act 1972, bona fide residents of the area have the right to graze their livestock, lop, and cut grass (Anonymous 2010). The easy accessibility has resulted in higher dependence of high-elevation villages on sanctuary forest. This supports the argument that excessive state control and management of common-property resources contributes to higher degradation of these systems (Ostrom 1990: 279; Jodha 2001). In community-owned forests, on the other hand, the primary objective of community-enforced regulations is management of resources, which effectively leads to forest conservation in many regions (Berkes 2009). Sanctuary forests thus had a higher percentage of high-disturbance sites than community-owned forests owned by villages like Mansoona and Bhatwari, which had lower disturbance despite their proximity to settlements. Similar observations were made by Baland et al (2010) and Måren et al (2013), who concluded that forests managed by local communities were less lopped and degraded than state-protected and state-managed forests. Other than management regime, dominant species also affect biotic pressure, as broad-leaved forests provide higher utility to local people than *Pinus* forests.

Rural economies across Himalaya depend to a large extent on forests, particularly for energy, with many traditional societies utilizing forest resources depending on socioeconomic, demographic, and environmental conditions (Samant and Dhar 1997; Adhikari et al 2004; Maskey et al 2006; Baland et al 2007; Angelsen et al 2014). This not only has serious environmental effects in the form of forest degradation and air pollution, but also has adverse health implications for women, who walk across treacherous terrain to gather resources and cook on polluting stoves. Various government and nongovernment programs provide local communities with renewable energy alternatives at subsidized rates. However, these often fail because of lack of trained staff and public education and the high costs of sustaining the programs (Mirza et al 2003; Aggarwal and Chandel 2010).

Forests under different disturbance and management regimes

Though individual households and villages may extract only a small amount of biomass, the cumulative effect of chronic disturbance over a wide area has left little or no time for forest recovery. In the study area, high-disturbance sites had higher species richness of both trees and shrubs, which could be due to the larger area sampled or to the effect of disturbance, as disturbance increases diversity by mixing species of different successional stages (Kumar and Ram 2005). Tree stand and shrub densities, basal cover of trees, and mean canopy cover increased from high-disturbance to moderate- and low-disturbance forests and were well below those previously recorded for Himalayan oak forests (Singh and Singh 1992). This could be due to extraction of timber and continuous lopping resulting in reduced biomass accumulation. Continuous biotic pressure in the form of logging, lopping, grazing, and litter removal is known to change the species composition and structure of mountain forests globally (Savage 1991; Dzwonko and Gawronski 2002; Gimmi 2008; Bagchi et al 2012; Bebi et al 2017). In the study area, only 8 tree species had an importance value index of >10, which shows that less than one fourth of the recorded species were well represented in the area. Continuous biotic pressure on climax communities such as *Quercus* spp. has resulted in dominance of subordinate species (Singh and Singh 1992), as was noted in the study area for *R. arboreum,* which had a higher importance value in the forests.

In the study area, the forest showed an abundance of trees in smaller girth classes, indicating a young population. The seedling density was very low compared to saplings; this could be due to high competition for establishment in some stands with higher canopy cover, high grazing pressure, and the low frequency of successful and mast seed years in the recent past (Singh et al 2011).

The density of saplings was higher than that of trees in the 30–60-cm girth class, indicating their failure to convert to trees. The sapling density was higher in moderate-disturbance plots, indicating that moderate disturbance and low canopy cover might be benefiting regeneration (Thadani and Ashton 1995). Younger trees had higher density in high-disturbance sites, whereas older trees had higher density in moderate- and low-disturbance sites. Other studies have also found that continuous disturbance brings major structural changes in forests, leading to a preponderance of younger individuals (Savage 1991).

Q. leucotrichophora, a climax species in the region, was under great anthropogenic pressure and had lower density of both regenerating individuals and older trees in high-disturbance sites. The seedlings and saplings of the species showed signs of browsing and lopping. Lopping, along with leaf litter collection, create a double disturbance, as lopping reduces production of acorns and litter collection sweeps away the acorns and leads to desiccation of the remaining acorns and seedlings by exposure to the sun. Singh et al (2014) found that this incessant small-scale disturbance adversely impacts the functioning of banj oak forests in the central Himalaya, with significantly higher biomass stocks, soil carbon, and carbon sequestration rates observed in the least human-influenced forests. However, Singh et al (2016) found that regeneration patterns were adequate across the banj oak zone in Uttarakhand, though their results also indicated large-scale fragmentation of these forests. Previous studies have shown that despite lower regeneration rates, oak forests tend to survive disturbances reasonably intact (Singh et al 1985; Thadani and Ashton 1995). Canopy openings and protection of seedlings from grazing maintain the banj oak population in the area.

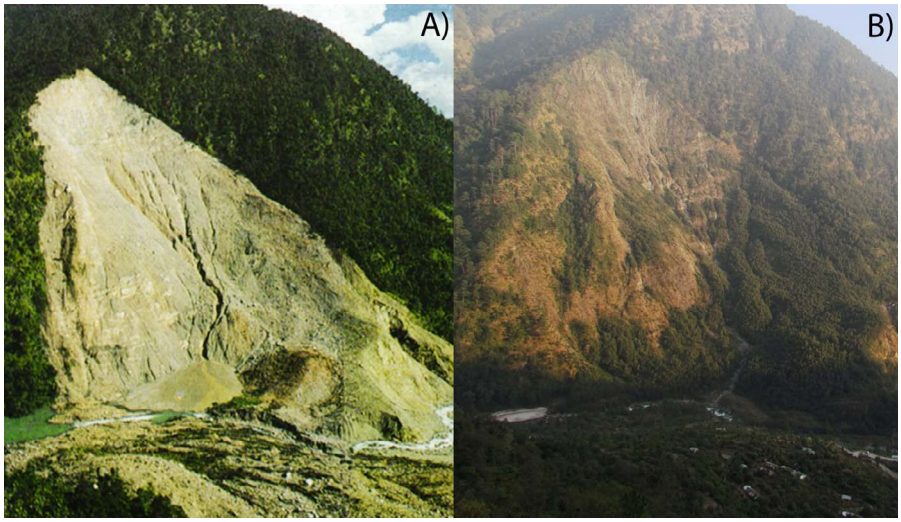
The low seedling density of most subordinate species might pose a threat to their populations in the future if current trends of regeneration prevail. Seedling establishment is sustained by favorable climatic conditions and protection from grazing and forest fires. However, current trends of disturbances, including human-induced forest fires in some of the forests in the region, would impact regeneration. *A. nepalensis* and *Carpinus viminea*, both pioneer species in Himalaya, had higher density in high-disturbance sites, indicating secondary succession due to both human-caused disturbance and landslides.

Though the tree communities tend to show good resistance to disturbance-caused changes, the same cannot be said about shrub communities. Microclimatic conditions on the forest floor caused by disturbance are suitable for certain species, whereas other species show sensitivity to disturbance by either a decrease in density or complete absence in disturbed sites (Prasad et al 2015). Disturbance-tolerant species that occur in open-canopy forests, such as *Berberis* spp., *Clematis buchananiana, Rosa moschata, Indigofera heterantha,* and *Himalrandia tetrasperma*, were found to have higher density in high-disturbance sites. Density of disturbance-sensitive species that prefer a closed canopy and good litter deposition, such as hill bamboos and *Daphne papyracea,* improved with receding disturbance and improved canopy cover. *Leptodermis lanceolata* prefers sites with steep slopes, usually devoid of disturbance, and its density improved with declining disturbance. A prominent weed species recorded in the area, *E. adenophorum*, was also associated with disturbance, as its average coverage decreased from 16.6% in high-disturbance plots to 5.75% in low-disturbance plots. Our results support previous studies carried out in the Himalaya that have shown that unregulated biomass extraction is widely associated with vegetation-related changes and declining forest cover and biodiversity (Dhar et al 1997; Pandit et al 2007; Tiwari 2008; Thakur et al 2011; Singh et al 2014, 2016; Prasad et al 2015; Bhatt and Bhatt 2016).

Vegetation recovery as a sign of resilience

Both Jugansu and Jaggi had a higher density of annuals, primarily *G. diversifolia,* an early colonizer. Other early colonizer herbs included *Rumex hastatus, Pouzolzia zeylanica*, *Urtica dioica, Cyathula tomentosa,* and *Boehmeria* spp.; these were also found in the old successional site. These species take advantage of canopy openings and colonize quickly around the borders of landslides, as reported by Joshi (1990). Figure 5 gives a comparison of the recently denuded Jugansu site and a recovered vegetation community, thus providing an idea of recovery on a landslide site. Jaggi had vegetation islands surrounded by debris, which might have slipped down with no significant damage to plant communities. Loss of soil and aboveground vegetation due to landslide slows vegetation recovery, whereas the presence of remnant forest patches promotes it (Chazdon 2003). Mass–seed-producing annuals start colonizing the site in first year, whereas early successional shrubs and trees that favor inorganic soils are recruited within 2–3 years of the disturbance (Singh and Singh 1992). Herb species richness tends to increase from 15 years to 45 years after a landslide and then stabilize (Reddy and Singh 1993), which was true for our study also. Shrubs like *Rubus* spp., *I. heterantha* (a nitrogen fixer), and *Debregeasia saeneb* had higher density in early successional sites, being early colonizers in bouldery sites and inorganic soils. *S. saligna,* which occurs in areas with rich humus, and *Berberis* sp., which prefers old disturbed sites and open canopy, were present only in the old successional site. That site had higher species richness of trees, mostly early colonizers including *Myrica esculenta,* with nitrogen-fixing root nodules, and *C. viminea,* which colonizes freshly formed soils in old landslides. The dominant tree species in all the sites was *A. nepalensis,* a fast-growing deciduous species that contributes to forest

FIGURE 5 Vegetation recovery on Jugansu landslide: (A) August 1998; (B) November 2012. (Photo [A] reproduced with permission from Rautela and Thakur 1999; photo [B] by Dr Gajendra Singh)



biomass and improves soil conditions with greater return of nutrients through litter fall and nitrogen fixation in secondary forests (Sharma et al 1998). Banj oak that starts appearing at 15 years in its preferred zone with young trees established in a 40-year-old site (Singh and Singh 1992), was recorded in the old successional site only. *R. arboreum,* having windblown seeds, also had established young trees in the sunny aspects of the old successional site. *Toona ciliata*, a species that colonizes old debris and boulder areas along riverbanks and disturbed sites, had started appearing in early successional sites. These results indicate that, with time and in the absence of further disturbances, landslide sites are restored to their original state with a similar characteristic taxonomic composition (Chaudhary 1989; Joshi 1990; Reddy and Singh 1993).

Conclusion

Forest resources contribute substantially to the livelihood security of remote and isolated rural communities across the Himalayan region; their use is influenced by factors such as elevation, income, and access to free resources. The study area underwent a 13% population growth during 2001–2011, which is remarkably high compared to population growth in the Rudraprayag district as a whole during the same period. This increasing human population and unregulated resource extraction, along with frequent landslides in river catchments, have degraded vast stretches of forest, resulting in secondary succession conditions and augmenting the growth of early succession species. The low density of trees in higher girth classes and relatively low recruitment of seedlings indicate disturbances have affected the successional trend of the native community; however, abundant saplings and regenerating forests at the sites of old landslides and other disturbances indicate the resilient dynamism of Himalayan forests. The natural process of vegetation recovery on degraded sites is well known; however, in the current scenario of unpredictable disturbances and changes, it becomes imperative to aid restoration with a better understanding of vegetation recovery and changing nutrient dynamics. Most of the afforestation activities to reclaim degraded and denuded lands focus only on planting trees; however, it is imperative to understand the sequence of appearance of various herbaceous flora and to identify indicator species for eco-restoration and monitoring. This will accelerate the recovery of native habitats by providing favorable understory conditions. However, care should be taken to avoid overcrowding of the understory, which might affect the growth of tree saplings.

Any degradation of ecosystem functions and services will increase both the environmental and socioeconomic vulnerability of mountain communities. Thus, it is imperative to formulate long-term energy strategies and promote renewable-energy technologies. This may include funding the transformation of laboratory discoveries into commercial products such as photovoltaic lights, solar cookers and water heaters, and improved cook stoves; effective monitoring along with continuous upgrading to make them more efficient and economically accessible to a larger population; and tax breaks for local entrepreneurs. Local communities across Himalaya have been provided with solar lamps; however, it is necessary to upgrade these products. Another alternative could be to increase biomass production within human systems through scientific or organizational innovation, such as by planting fast-growing native grasses on common land, which might also reduce lopping and grazing within forests. It was evident in the study area that households with better access to biomass from agroforestry made fewer trips to forests for biomass collection. Efforts by implementing agencies can not only

reduce pressure on conventional energy sources in sensitive and fragile mountain regions; they can also reduce indoor and outdoor atmospheric pollution and lessen the drudgery of rural people, particularly women, by providing cleaner kitchens and reducing the effort needed to access natural resources, thus enhancing their wellbeing.

The pursuit of the Sustainable Development Goals requires recognition of the role that mountain forests will play in achieving sustainable development. Understanding the current status of mountain forests and the dynamics of mountain socioecological systems can contribute to the establishment of policies and action programs to enhance the ecological sustainability of the water towers of the world.

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Supplemental material

TABLE S1 Tree species uses, density, total basal area (TBA), and importance value index (IVI) across different disturbance classes. F, fodder; F*, preferred fodder; FW, fuelwood; M, miscellaneous uses (including agricultural implements and support for climber crops); T, timber.
TABLE S2 Shrub species density (number/ha) across different disturbance classes.
TABLE S3 Density (number/ha) of seedlings and saplings across different disturbance classes.
TABLE S4 Tree species density, total basal area, and importance value index at 3 landslide sites.
TABLE S5 Shrub and herb species density (number/ha) at 3 landslide sites.
TABLE S6 Plant species that were recorded at landslide sites but were not observed during sampling.

All found at DOI: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00109.S1 (212KB PDF).

Supplemental material for

"Forest composition and structure under various disturbance regimes in the Alaknanda River Basin, Western Himalaya", by Upma Manral, Ruchi Badola, and Syed Ainul Hussain, published in *Mountain Research and Development* 37(3), 2017. (See http://www.bioone.org/toc/mred/37/3)

TABLE S1 Tree species and their utility value, density, total basal area (TBA) and importance value index (IVI) across different disturbance classes. F = fodder; F* = preferred fodder; FW = fuelwood; M =miscellaneous uses (including agricultural implements and support for climber crops); T = timber.

Species name	Utility value	High disturbance			Moderate disturbance			Low disturbance		
		Density (number/ha)	TBA (m^2/ha)	IVI	Density (number/ha)	TBA (m^2/ha)	IVI	Density (number/ha)	TBA (m^2/ha)	IVI
Albizia lebbeck (L.) Benth.	F, FW	3.98	0.22	2.81	-	-	-	4.77	0.85	6.34
Alnus nepalensis D.Don	FW, M	34.79	3.96	36.29	15.91	0.93	13.50	15.91	2.00	17.23
Bauhinia variegata L.	F*	1.99	0.01	1.37	-	-	-	-	-	-
Betula alnoides Buch. Hanm ex D.Don	F, FW, T	0.99	0.08	1.44	-	-	-	-	-	-
Carpinus viminea Wall. ex Lindl.	F, FW	6.96	0.37	5.44	-	-	-	-	-	-
Celtis australis L.	F*	-	-	-	0.80	0.01	0.89	-	-	-
Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm.	M	-	-	-	0.80	0.01	0.88	-	-	-
Cornus macrophylla Wall.	F, FW	1.49	0.13	1.78	-	-	-	3.18	0.31	3.82
Emblica officinalis Gaertn.	M	0.50	0.01	0.58	-	-	-	-	-	-
Engelhardtia spicata *Lechen ex Blume*	F*, FW	4.97	0.15	3.96	33.40	0.90	17.27	14.31	0.72	9.90
Erythrina suberosa Roxb.	-	-	-	-	0.80	0.04	1.03	-	-	-
Ficus roxburghii Steud.	F*	1.49	0.02	1.26	-	-	-	1.59	0.02	2.23
Gadaru (local name)	-	0.50	0.26	1.76	-	-	-	-	-	-
Ilex dipyrena Wall.	F*, FW, M	2.49	0.05	1.25	0.80	0.03	1.00	-	-	-
Lannea coromandelica (Houtt,) Merr.	-	-	-	-	0.80	0.04	1.03	-	-	-
Lindera pulcherrima (Nees) Hook. f.	-	-	-	-	1.59	0.03	1.14	-	-	-
Litsea umbrosa (Nees) Nees	FW, M	8.45	0.37	5.81	4.77	0.16	3.08	-	-	-
Lyonia ovalifolia (Wall.) Drude	F*, FW	75.55	3.50	50.51	77.14	2.84	44.53	28.63	1.01	21.64
Mallotus philippensis (Lam.) Mull. Arg.	-	1.49	0.03	0.92	-	-	-	6.36	0.26	4.34
Melia azedarach L.	-	-	-	-	0.80	0.00	0.85	-	-	-
Myrica esculenta Buch.-Ham. ex D.Don	FW, M	10.93	0.43	8.78	29.42	1.32	18.82	6.36	0.88	10.41

Species name	Utility value	High disturbance			Moderate disturbance			Low disturbance		
		Density (number/ha)	TBA (m^2/ha)	IVI	Density (number/ha)	TBA (m^2/ha)	IVI	Density (number/ha)	TBA (m^2/ha)	IVI
Neolitsea cuipala (Buch.-Ham. ex D.Don) Kosterm.	-	0.99	0.03	1.20	1.59	0.02	1.11	11.13	0.33	9.33
Pinus roxburghii Sarg.	FW, T	39.27	1.40	21.69	48.51	3.08	31.10	101.79	5.25	56.21
Pistacia integerrima J.L.Stewart	-	-	-	-	1.59	0.05	1.22	-	-	-
Prunus cerasoides Buch.-Ham. ex D.Don	M	0.50	0.01	0.58	-	-	-	-	-	-
Pyrus pashia Buch.-Ham.ex D.Don	M	7.95	0.18	7.72	11.93	0.42	8.47	4.77	0.23	5.62
Quercus floribunda Lindl. ex A.Camus	F*, FW	3.48	0.19	3.38	2.39	0.14	3.15	4.77	0.97	6.83
Quercus glauca Thunb.	F*, FW	0.50	0.05	0.76	12.72	0.64	9.55	20.68	0.56	12.57
Quercus leucotrichophora A.Camus ex Bahadur	F*, FW	69.58	3.71	52.13	68.39	4.86	52.41	74.75	5.15	52.92
Quercus semicarpifolia J.E.Sm.	F*, FW	-	-	-	3.98	0.36	3.75	12.72	0.91	8.51
Rhododendron arboreum Sm.	FW, M	121.28	5.90	72.64	122.47	7.22	74.94	90.66	4.09	50.67
Rhus wallichii Hook.f.	-	2.49	0.04	2.45	-	-	-	1.59	0.03	2.30
Sapium insigne Benth. & Hook.f.	-	-	-	-	0.80	0.09	1.21	6.36	0.15	3.90
Symplocos chinensis (Lour.) Druce	F, FW	4.97	0.11	5.01	5.57	0.09	3.64	3.18	0.06	4.59
Symplocos ferruginea Roxb.	-	3.98	0.03	2.76	-	-	-	-	-	-
Symplocos theifolia D.Don	-	3.48	0.08	2.47	-	-	-	3.18	0.09	4.69
Syzygium cumini (L.) Skeels	M	0.99	0.03	0.78	3.18	0.27	3.20	-	-	-
Toona ciliata M.Roem.	T	1.99	0.08	2.49	1.59	0.29	2.23	1.59	0.94	5.94

TABLE S2 Shrub species density (number per ha) across different disturbance classes.

Species	Disturbance		
	High	**Moderate**	**Low**
Arundinaria falcata Nees	132.25	318.20	362.75
Asparagus adscendens Roxb.	4.97	17.50	6.36
Berberis aristata DC.	30.83	1.59	-
Berberis chitria Edwards	12.93	-	-
Berberis lycium Royle	310.25	106.60	47.73
Buddleja paniculata Wall.	3.98	6.36	-
Cissampelos pareira L.	1.99	-	-
Clematis buchananiana DC.	32.81	9.55	6.36
Cotoneaster microphyllus Wall. ex Lindl.	3.98	3.18	-
Daphne papyracea Wall. ex G. Don	10.94	28.64	44.55
Debregeasia saeneb (Forssk.) Hepper & J.R.I.Wood	8.95	-	-
Desmodium sp.	4.97	12.73	9.55
Deutzia staminea R.Br. ex Wall.	1.99	-	-
Deutzia compacta Craib	-	-	3.18
Dioscorea bulbifera L.	-	-	3.18
Hedera nepalensis K.Koch	-	4.77	-
Indigofera heterantha Wall. ex Brandis	104.41	100.23	98.64
Ipomoea purpurea (L.) Roth	0.99	-	-
Jasminum humile L.	7.96	-	-
Leptodermis lanceolata Wall.	105.40	229.10	305.47
Myrisine semiserrata Wall.	32.81	22.27	-
Parthenocissus semicordata (Wall.) Planch.	3.98	-	-
Pyracantha crenulata (Roxb. ex D.Don) M.Roem.	2.98	4.77	-
Himalrandia tetrasperma (Wall. ex Roxb.) T.Yamaz.	70.60	54.09	117.73
Rhamnus virgatus Roxb.	1.99	-	-
Rosa moschata Benth.	29.83	7.96	12.73
Rubia cordifolia Thunb.	11.93	11.14	12.73
Rubus ellipticus Sm.	69.61	87.51	70.00

Species	Disturbance		
	High	Moderate	Low
Rubus niveus Thunb.	44.75	79.55	44.55
Rubus paniculatus Schltdl. ex Link	27.84	14.32	12.73
Smilax spinosa Poir.	18.89	11.14	-
Thamnocalamus spathiflorus (Trin.) Munro	-	-	534.58
Viburnum cotinifolium D.Don	0.99	1.59	-
Vitis jacquemontii R.Parker	24.86	63.64	50.91
Woodfordia fruticosa Kurz.	1.99	-	12.73
Total shrub density	1122.65	1196.43	1756.46

TABLE S3 Density (number/ha) of seedlings and saplings across different disturbance classes.

Species name	Disturbance		
	High	Moderate	Low
Albizia lebbeck (L.) Benth.	0.99	1.59	15.91
Alnus nepalensis D.Don	17.90	19.09	-
Bauhinia variegata L.	5.97	-	-
Betula alnoides Buch. Hanm ex D.Don	-	1.59	-
Carpinus viminea Wall. ex Lindl.	27.84	9.55	6.36
Cedrus deodara (Roxb, ex D.Don) G.Don	0.99	4.77	9.55
Celtis australis L.	6.96	3.18	6.36
Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm.	1.99	22.27	63.64
Engelhardtia spicata Lechen ex Blume	15.91	225.92	6.36
Ficus nemoralis Wall.ex Miq.	11.93	-	15.91
Ficus roxburghii Steud.	5.97	1.59	38.18
Ficus subincisa Buch.-Ham.	14.92	17.50	3.18
Fraxinus micrantha Lingelsh.	1.99	-	6.36
Glochidion velutinum Wight.	0.99	-	-
Ilex dipyrena Wall.	-	-	9.55
Juglans regia L.	-	3.18	-
Lindera pulcherrima (Nees) Hook. f.	-	1.59	31.82

Species name	Disturbance		
	High	Moderate	Low
Litsea umbrosa (Nees) Nees	51.71	33.41	12.73
Lyonia ovalifolia (Wall.) Drude	71.60	85.91	73.19
Mallotus philippensis (Lam.) Mull. Arg.	0.99	3.18	19.09
Morus alba L.	-	1.59	-
Myrica esculenta Buch.-Ham. ex D.Don	19.89	25.46	3.18
Neolitsea cuipala (Buch.-Ham. ex D.Don) Kosterm.	0.99	114.55	31.82
Pinus roxburghii Sarg.	37.79	17.50	66.82
Prunus cerasoides Buch.-Ham. ex D.Don	0.99	3.18	3.18
Pyrus pashia Buch.-Ham.ex D.Don	111.37	151.15	79.55
Quercus floribunda Lindl. ex A. Camus	24.86	11.14	3.18
Quercus glauca Thunb.	3.98	31.82	19.09
Quercus leucotrichophora A.Camus ex Bahadur	170.04	154.33	140.01
Quercus semicarpifolia J.E.Sm.	1.99	-	22.27
Quercus serrata Murray	-	-	3.18
Rhododendron arboreum Sm.	95.46	120.92	111.37
Rhus wallichii Hook.f.	14.92	27.05	28.64
Sapium insigne Benth. & Hook.f.	1.99	11.14	9.55
Symplocos chinensis (Lour.) Druce	35.80	27.05	15.91
Symplocos ferruginea Roxb.	28.84	65.23	12.73
Symplocos theifolia D.Don	69.61	11.14	70.00
Syzygium cumini (L.) Skeels	16.90	190.92	9.55
Toona ciliata M.Roem.	13.92	52.50	-
Toona serrata (Royle) M.Roem.	1.99	-	-
Zanthoxylum armatum D.C.	0.99	-	3.18

TABLE S4 Tree species density, total basal area, importance value index, and regenerating species at 3 landslide sites.

Species name	Density (number/ha)			Total basal area (m2/ha)			Importance value index*	Regenerating species		
	Bandwara	Jugansu	Jaggi	Bandwara	Jugansu	Jaggi	Bandwara	Bandwara	Jugansu	Jaggi
Alnus nepalensis D. Don	138.00	374.20	334.39	19.17	7.64	6.14	134.48	-	√	√
Albizia chinensis Merr.	-	-	-	-	-	-	-	-	√	√
Bauhinia variegata L.	-	-	-	-	-	-	-	-	-	√
Carpinus viminea Wall. ex Lindl.	26.51	-	-	0.50	-	-	24.28	-	-	-
Cornus macrophylla Wall.	10.62	-	-	0.12	-	-	7.18	√	-	-
Deutzia compacta Craib	-	-	-	-	-	-	-	√	-	-
Ficus nemoralis Wall. ex Miq.	-	-	-	-	-	-	-	√	-	-
Ficus roxburghii Steud.	-	-	-	-	-	-	-	√	-	-
Litsea lanuginose (Nees) Nees	5.31	-	-	0.06	-	-	5.44	√	-	-
Lyonia ovalifolia (Wall.) Drude	37.15	-	-	3.79	-	-	32.43	√	-	-
Myrica esculenta Buch.-Ham. ex D.Don	15.91	-	-	0.39	-	-	13.44	√	-	-
Pyrus pashia Buch.-Ham.ex D.Don	37.15	-	-	0.99	-	-	29.20	√	-	-
Quercus leucotrichophora A.Camus ex Bahadur	31.85	-	-	0.57	-	-	22.37	√	-	-
Rhododendron arboreum Sm.	37.15	-	-	0.51	-	-	19.97	√	-	-
Toona ciliata M.Roem.	5.31	-	-	0.15	-	-	5.78	-	√	√
Zanthoxylum armatum D.C.	5.31	-	-	0.51	-	-	5.41	√	-	-

* The other two sites had adult individuals of only one species, thus no Importance Value Index has been provided.

TABLE S5 **S**hrub and herb species density (number/ha)at 3 landslide sites.

	Bandwara	Jugansu	Jaggi-Bagwan
Shrubs			
Berberis lycium Royle	84.93	-	-
Debregeasia saeneb (Forssk.) Hepper & J.R.I.Wood	21.23	222.93	191.08
Indigofera heterantha Wall. ex Brandis	-	63.69	-
Origanum vulgare L.	21.23	-	-
Prinsepia utilis Royle	42.46	-	-
Pyracantha crenulata (Roxb. Ex D.Don) M. Roem.	63.69	-	-
Himalrandia tetrasperma (Wall. ex Roxb.) T.Yamaz..	212.31	-	-
Rubus ellipticus Sm.	169.85	159.24	191.08
Rubus niveus Thunb.	21.23	222.93	382.17
Sarcococca saligna (D.Don) Muell.-Arg.	445.86	-	-
Herbs			
Anaphalis contorta (D.Don) Hook f.	-	2	2
Achyranthes aspera L.	-	2	-
Ajuga brachystemon Maxim.	0.75	-	-
Arenaria serpyllifolia L.	-	8.5	-
Bidens pilosa L.	-	2.6	2
Boehmeria macrophylla Hornem.	169.85	63.69	-
Cardamine impatiens L.	2	-	-
Dicliptera bupleuroides Nees	2	-	-
Erigeron karvinskianus DC.	-	-	5
Eupatorium adenophorum Spreng.	15% of plots	70% of plots	30% of plots
Fragaria indica Jacks.	1.75	-	-
Girardinia diversifolia (Link) Friis	-	796.18	127.39
*Polygonum persica*ria L.	-	2.75	-
Pteracanthus urticifolius (Wall. ex Kuntze) Bremek.	0.25	-	-
Reinwardtia indica Dumort.	573.25	2	2
Rumex hastatus D.Don	-	4	4
Scutellaria scandens D.Don	1.25	-	-
Senecio rufinervis DC.	0.75	-	-
Streptopus simplex D.Don	0.25	-	-
Thalictrum foliolosum DC.	0.5	-	-
Viola serpens Wall.	3	-	-

TABLE S6 Plant species that were recorded at landslide sites but were not recorded during sampling.

Species name	Habit	Distribution
Cyathula tomentosa (Roth) Moq.	Herb	All 3 sites
Rumex hastatus D.Don	Herb	All 3 sites
Apluda mutica L.	Grass	All 3 sites
Themeda arundinacea Hack.	Grass	All 3 sites
Capillipedium assimile (Steud.) A.Camus	Grass	All 3 sites
Saccharum rufipilum Steud.	Grass	All 3 sites
Crassocephalum crepidioides (Benth.) S.Moore	Herb	All 3 sites
Urena lobata L.	Herb	All 3 sites
Digitaria sp.	Grass	All 3 sites
Pilea umbrosa Wedd.	Herb	All 3 sites
Pouzolzia zeylanica (L.) Benn.	Herb	All 3 sites
Solanum nigrum L.	Herb	All 3 sites
Solanum torvum Sw.	Herb	All 3 sites
Isodon sp.	Herb	All 3 sites
Strobilanthes purpurea Hook. Ex Nees	Herb	All 3 sites
Leptodermis lanceolata Wall.	Shrub	All 3 sites
Urtica dioica L.	Herb	All 3 sites
Cissampelos pareira L.	Climber	Bandwara only
Ficus scandens Lam.	Climber	Bandwara only
Hedera nepalensis K.Koch	Climber	Bandwara only
Rubus paniculatus Sm.	Climber	Bandwara only
Smilax aspera L.	Climber	Bandwara only
Tetrastigma serrulatum (Roxb.) Planch.	Climber	Bandwara only
Vitis parvifolia Roxb.	Climber	Bandwara only
Arundinaria falcata Nees.	Grass, hill bamboo	Bandwara only
Eriophorum comosum (Wall.) Nees	Shrub	Bandwara only

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HUMAN WILDLIFE CONFLICT IN INDIA: A REVIEW OF ECONOMIC IMPLICATION OF LOSS AND PREVENTIVE MEASURES

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ABSTRACT

In a developing economy like India where majority of human population depends heavily on natural resources, the forest-dwellers have co-existed with the wildlife for long. However, the growing human dependency on natural resources and degradation of wildlife habitats, have resulted in a conflicting situation between humans and wildlife, and authorities involved in wildlife management. With significant conservation and economic consequences, human wildlife conflict (HWC) undermines well-being of both the parties and threatens the conservation goals. It impacts the people's food security and livelihood and psychosocial wellbeing. We reviewed articles that deal with monetary loss incurred by involved communities and discuss the effectiveness and the short comings of measures taken to address the issue and prevent the loss, in the Indian scenario. There is a lack of studies dealing with monetary cost associated with HWC and no realistic estimates are available for involved species. Majority of the studies are from protected areas with un-protected forests represented poorly. It is imperative that action plans, which target offsetting economic loss of locals and enhance public participation, are put in-place to meet the integrated conservation and development goals in a landscape where human and wildlife can coexist.

Key words: Carnivores, Human Wildlife conflict, Opportunity cost, Primates, Ungulates.

Introduction

Human - Wildlife Conflict (HWC) is defined as 'interaction between humans and wildlife where negative consequences, whether perceived or real, exists for one or both the parties when action of one has an adverse effect on the other party' (Conover, 2001; Decker *et al*., 2002). It has been in existence for as long as wild animals and humans have co-existed and shared the same resources. Historical records from Nile Delta revealed that hippopotamuses raided crops while crocodiles attacked livestock in Egypt while elephants had been raiding crops all across Africa and other parts of world (Barnes, 1996). The famous "Taung skull" discovered in South Africa in 1924 belonged to a child victim of an eagle attack that occurred some two million years ago (Berger, 2006). Such conflicts have negative impacts on conservation of wildlife populations or of their environment; and social, economic or cultural life of humans (WWF, 2005). The negative consequences for local communities include attacks upon humans (Löe and Röskaf, 2004; Packer *et al.*, 2005; Jadhav and Barua, 2012), depredation of livestock or game (Thirgood *et al.*, 2005; Banerjee *et al.*, 2013), destruction of stored harvest or crop-raiding (Pimentel *et al.,* 2005; Perez and Pacheco, 2006; Karanth *et al.*, 2012) and spread of zoonotic diseases to humans or stock (Daszak *et al.*, 2000; Singh and Gajadhar, 2014; Hegglin *et al.*, 2015). At times people have to make lifestyle choices and bear opportunity costs due to presence of wildlife or protected areas (Woodroffe *et al.*, 2005; Barua *et al.*, 2013). Species involved may vary from grain eating sparrows or rodents to man-eating tigers; affecting from marginal agro-pastoralists of developing countries to elite section of developed world. Consequences are no better for wild species which bear the brunt in the form of retaliatory killing and lethal control (Liu *et al.*, 2011; Mateo-Tomás *et al.*, 2012; Northrup *et al.*, 2012; Bergstrom *et al.*, 2014). The intensity of the problem is increasing because of a number of factors such as increase in human populations, anthropogenic encroachment into wildlife habitats resulting in transformation of wildlife habitats into urban and sub-urban areas and agrarian ecosystems and fragmentation of wildlife habitat causing constriction of wildlife populations into marginal habitat patches (Siex and Struhsaker, 1999; Conover, 2001; Sillero-Zubiri and Switzer, 2001; Nyhus and Tilson, 2004; Hegel, *et al.*, 2009; Estes *et al.*, 2012; Yadav *et al.*, 2012). Recovery of declining populations of many large mammals due to efficient wildlife management and large network of protected areas worldwide has also lead to increased conflicts (Saberwal *et al.*, 1994; Fall and Jackson, 2002; Vijayan and

Growing human dependency on natural resources and degradation of wild life habitats have resulted in human wild life conflict.

Patil, 2002; Woodroffe *et al.,* 2005). Stochastic events such as fire and climatic change also augment conflict situations *e.g.* higher number of cases of livestock depredation by wild predatorsduring seasonal rains in Kenya while during dry season in Zimbabwe (Butler, 2000; Nyhus and Tilson, 2004; Patterson *et al.*, 2004).

Indian scenario

India is a mega-diverse country owing to its large climatic and topographic gradient. With only 2.4% of the world's land area, it harbors around 8% of all recorded species including 91,000 species of animals and 45,000 of plants (MoEFCC, 2014). Out of 34 global 'Biodiversity Hotspots', four fall fully or partly within Indian political boundaries. With more than 100 National Parks and more than 500 Wildlife Sanctuaries, the country has an extensive network of protected areas and wildlife reserves. The protection of forests and wild life by the State has been mandated by the Indian Constitution through its article 48A of part IV as Directive principles and as citizens of India it is also one of our fundamental duties as laid down by the Constitution of India in article 51A of part IVA (Bakshi and Kashyap, 2012). As the country is a fast developing economy and among most populous countries with around 17% of the world's human population, the protected area landscapes are not untouched of human presence. High rate of human population growth put the wilderness areas under threat due to increasing interference, deforestation, fragmentation of natural habitats and expansion of agricultural lands in the forested landscapes. As human settlements expand and protected areas become conservation islands surrounded by human-dominated landscapes, the negative interaction between human and wildlife species, particularly large mammals, increases. The situations are no better outside protected areas, as humans continue to encroach natural habitats and become prone to conflicts as wild animals seek to fulfil their nutritional, behavioural and ecological needs (Sukumar, 1991). A close interface between large mammals such as tigers, elephants, lions and others with humans and their land use has caused serious conflicts countrywide over space and resources (Sukumar, 1994; Madhusudan and Mishra, 2003; Banerjee *et al.*, 2013; Karanth *et al.*, 2013). Overgrazing by livestock in the wildlife habitats results in decline or local extinction of wild herbivore populations (Mishra *et al.*, 2003) while a disproportionate presence of wild and domestic ungulates amplifies cases of livestock depredation by wild predators (Mishra, 1997). The attacks on human and livestock and incidences of crop raiding have significant consequences for people's food security and livelihood and psychosocial wellbeing (Barua *et al.*, 2013). Most of the studies done on HWC in India are either single species oriented or area oriented. For the present study we conducted an extensive review of the current situation of the negative interaction between human and wildlife in the country and its impact on the livelihood security of the affected community. We also discuss here the effectiveness and the short comings of measure taken to address the issue, and suggest possible strategy.

Methodology

Literature on the Human wildlife conflict and associated economic cost was gathered through online web based search engines using keywords such as Human wildlife conflict, crop raiding, livestock depredation and names of problem species. Studies were restricted to India and search was made with the key words based on biogeographic zones, states and country name. Online technical databases which were searched to download relevant literature, primarily included Science Direct, JSTOR, Wiley Online Library and Google Scholar. The collected literature was then thoroughly reviewed for major conflict animals, economic loss to humans due to various conflict events and amount spent on preventive measures. Study primarily focused on conflict associated with large-bodied mammals.

Results and Discussion

Species involved

Livestock depredation is globally the most common form of human–wildlife conflict and can involve a variety of taxa including *felids, canids, ursids* and raptors (Thirgood *et al.*, 2005). In India, human population densities are high while populations of several large mammals reside outside protected areas that result in frequent negative interaction between human and many mammalian species (Karanth and Madhusudan, 2002). Almost all large carnivore species are known to attack and kill people and attack domesticated ungulates whenever an opportunity arise (Karanth *et al.*, 1999; Karanth and Gopal, 2005). Besides livestock depredation, crop damage is another form of human-wildlife conflict. Agricultural crops and fruit orchards are often raided by wild ungulates, primates and granivores and frugivores birds which cause damage to both food crops and young shoots of other crops and plantations (Jhala, 1993; Sekhar, 1998; Dave, 2010; Gubbi *et al.*, 2014). Conflict-prone species include tiger (*Panthera tigris*), leopard (*Panthera pardus*), Asian elephants (*Elephas maximus)*, sloth bear (*Melursus ursinus*), Himalayan black bear (*Ursus thibetanus*), wild pig

(*Sus scrofa*), nilgai (*Boselaphus tragocamelus*) and gray wolves (*Canis lupus*) (Table 1). Conflicts between large carnivores and humans have always been a serious issue since historic times. The conflict involving carnivore species particularly conflict-prone large felids is considered having potentially catastrophic consequences for both wildlife and humans (Karanth *et al.*, 2012; Dhanwatey *et al.*, 2013; Athreya *et al.*, 2016). In the Gir landscape, livestock of *Maldhari* community form an important part of lion's diet. The restricted distribution of the animal has led to frequent attacks on humans and livestock in the region (Saberwal *et al.*, 1994; Banerjee *et al.,* 2013). Both Tiger and Leopard have wide ranging behavior due to large habitat requirements resulting in increased chances of becoming involved in conflict with humans residing in adjoining areas (Rastogi *et al.*, 2012; Dhanwatey *et al.,* 2013; Karanth *et al.,* 2013; Athreya *et al.,* 2016). In the fragile Trans-Himalayan ecosystem where humans compete for limited resources with wildlife, Snow leopard causes huge economic loss to the local communities through livestock predation (Bagchi and Mishra, 2006; Jackson *et al*., 2010). Though, wild dog (*Cuon alpinus*) has its range across Indian sub-continent, but it's involvement in livestock depredation is mainly reported from north-east India where species has been reported to prey upon mithun (*Bos frontalis*) (Lyngdoh *et al.,* 2014). Similarly, livestock depredation and attacks on humans by Indian wolf (*Canis lupus pallipes*) has long history in the country which has escalated in recent times (Krithivasan *et al.*, 2009; Agarwala *et al*., 2010).

Among all the crop-raider ungulates, Asiatic elephant is most studied and is known to cause large scale damage to crops and human lives across its range in India (Gubbi, 2012). In north-east India, the incidences of conflict with the species have increased due to reduction of forest cover below 30-40% in the area (Datta-roy *et al.*, 2009; Chartier *et al.*, 2011). A number of ungulate species including wild pig, nilgai, barking deer, spotted deer, and wild ass cause damage to both food crops and young shoots of other crops and plantations (Rao *et al.,* 2002; Madhusudan, 2003; Chauhan *et al.*, 2009; Dave, 2010; Karanth *et al.,* 2012; Meena *et al.,* 2014). Both sloth and black bears cause human casualties and have been reported to attack without apparent provocations. Along with attacks on humans, bears have been reported to cause crop raiding and livestock depredation (Rajpurohit and Krausman, 2000; Bargali *et al.*, 2005; Charoo *et al.*, 2011).

Primates, primarily Rhesus Macaques and Hanuman Langur are also nuisance species that share food and space with humans in the rural and urban areas and are known to cause distress and economic loss by means of crop raiding and looting and attacks on humans (Imam *et al.*, 2002; Chauhan and Pirta, 2010a; b). Apart from large mammals, small animals like insects (locusts and

Table 1: Monetary value of loss incurred by local communities due to Human Wildlife Conflict

Species	Location	Extent of loss/ monetary loss	Reference
Blackbuck	Gujarat	48,600 kg of Sorghum crop in two villages of value ~ US$ 558	Jhala, 1993
Snow leopard	Kibber Wildlife Sanctuary, Himachal Pradesh	18% of household's livestock holdings with economic loss that equaled to 25% of annual income/ household	Mishra, 1997
Wild ungulates, tiger and leopard	Sariska Tiger Reserve, Rajasthan	6 - 27% of total crop yield per ha, valued at US$ 48 to 67/ household/ year	Sekhar, 1998
Snow leopard and wolf	Hemis National Park, Jammu & Kashmir	492 cattle in 14 months valued at US$ 23,500	Jackson and Wangchuk, 2001
Ungulates, leopard and Himalayan black bear	Nanda Devi Biosphere Reserve, Uttarakhand	40% of sown area with crop loss of US$ 50 while livestock loss of US$ 5/ household/ year	Rao *et al.*, 2002
Elephants, tiger and leopard	Bhadra Tiger Reserve, Karnataka	11% of the annual production from agriculture and animal husbandry in the area lost, valued at US$ 5404	Madhusudan, 2003
Tibetan wolf, snow leopard and lynx	Proposed Gya-Miru Wildlife Sanctuary, Jammu & Kashmir	2.9% of household' livestock holdings, valued at US$ 190/ household/year	Namgail *et al.*, 2007
Wild ungulates	Kanha National Park, Madhya Pradesh	US$155 from crop loss/ household/ year	Karanth *et al.*, 2013
Wild ungulates	Ranthambore National Park, Rajasthan	US$ 264 from crop loss/ household/ year	Karanth *et al.*, 2013
Wild ungulates	Nagarahole National Park, Karnataka	US$ 546 from crop loss/ household/ year	Karanth *et al.*, 2013
Wild dog	Arunachal Pradesh	20.3% of the total monetary value of livestock valued at US$ 134,493 for two years in 48 sampled villages	Lyngdoh *et al.*, 2014

caterpillars) and rodents, hares, birds and porcupines can be involved in conflict with humans over game species, crops, apiaries, poultry and fish and have devastating impacts on harvest (Rao *et al.,* 2002; WWF, 2005). The inherent fear of snakes in humans has caused a lot of negative interactions between the two. As the two taxa live in close association in rural and urban areas and human encroach more into natural habitats, the cases of snake bite victims are on rise (Nath *et al.*, 2012).

Threatened livelihood security - Humans at the receiving end

HWC results in damage to crop, water sources and property and livestock depredation, which threaten the livelihoods of millions across the globe and costs lives of both human and wildlife, thus, jeopardizing wildlife conservation goals (Oli, 1994; Sekhar, 1998; Rajpurohit and Krausman, 2000; Ogra and Badola, 2008). The research on HWC has primarily been focused around natural science with a resultant well-understood ecology of some conflicts (Woodroffe *et al.*, 2005). However, it involves people, and it is very essential to understand attitudes, beliefs and values of stakeholders to mitigate conflicts (Redpath *et al.*, 2004; Ogra, 2008). In rural areas where livestock holdings and agriculture are an important part of household's livelihoods and incomes, competition between local communities and wild animals for the use of natural resources is intense thus escalating conflict (Mishra *et al.*, 2003).

In Kibber Wildlife Sanctuary, pastoralist communities incurred a loss of 18% of their livestock holdings to snow leopard and wolf attacks, an economic loss equaled to 25% of annual income per household (Mishra, 1997). Snow leopard and wolf killed 492 animals within a period of 14 months around Hemis National Park, valued at US$ 23,500 (Jackson and Wangchuk, 2001). In another study from Trans-Himalaya of Ladakh, Namgail *et al*. (2007) estimated that livestock depredation, particularly of valuable livestock such as yak and horse, by Tibetan wolf, snow leopard and lynx resulted in an annual monetary loss of US$ 190/household/year or approximately US$ 12,120/ year for the three study villages combined. Local communities of Bhadra Tiger Reserve lost an approximate 11% of their crop to elephants and 12% of livestock to large cats annually (Madhusudan, 2003). The overall annual loss to sampled households was 11% of the monetary value of annual production, estimated at INR 243,167 (US$ 5404). Similar was the case of Sariska Tiger Reserve where agriculture and livestock rearing are main economic activity of 117 villages situated in and around the reserve. Damage to crops of chickpeas, maize, mustard, wheat etc. from wild ungulates was 6 - 27% of total crop yield per ha. The total economic loss from crop damage and livestock depredation by tiger and leopard was INR 2500 (US$ 48) to INR 3500 (US$ 67) per household (Sekhar, 1998).

Situations are no different when it comes to crop raiding, as studied by various workers. A small population of blackbuck around two villages in Gujarat caused loss of 48,600 kg of Sorghum crop in a single season accounting for economic loss of INR 29,000 (US$ 558) (Jhala, 1993). In Nanda Devi Biosphere Reserve, more than 40% sown area was damaged with an average monetary loss of INR 2590 (US$ 50) per household, annually. Locals in the reserve also suffered from livestock depredation with an average loss of INR 272 (US$ 5) per household annually. The projected total values of livestock and crop losses for buffer zone villages were estimated at INR 10,24520 (US$ 29272) and INR 538620 (US$ 15389), respectively (Rao *et al.,* 2002). Karanth *et al.* (2013) reported an annual loss of US$ 155, 264 and 546 from crop loss per household in Kanha, Ranthambore and Nagarahole National Parks, respectively as annual household incomes averaged US$ 300 per household. Livestock depredation by wild dog in Arunachal Pradesh resulted in loss of around 20.3% of the total monetary value of livestock in sampled villages which was around US$ 134,493 for two years in 48 sampled villages (Lyngdoh *et al.*, 2014).

Such financial losses are particularly damaging if occurring in regions with underdeveloped economies (Mishra *et al.,* 2003). The relative impact of damage caused on household's income varies greatly according to the economic dependence on agriculture and livestock and for households with subsistence economies even small losses can be significant (Oli, 1994; Rao *et al.,* 2002). Costs are escalated if investments are made in fencing or mitigating measures or if the conflict is severe, families abandon cultivation of otherwise profitable land (Naughton-Treves *et al.,* 1998).

Ways to mitigate Human Wildlife Conflict

Prevention of conflict between humans and wildlife has been a challenge for management authorities and local community and very less success has been documented. Thus, it becomes imperative to examine the preventive measures such as putting barriers or *post facto* options including compensatory measures to manage the conflict.

Preventative measures: A number of studies have discussed preventive measures to deal with HWC (Sukumar, 1991; 1994; Mishra, 1997; Karanth and

Madhusudan, 2002; Madhusudan, 2003; Mishra *et al.,* 2003; Jayant *et al*., 2007; Karanth *et al.*, 2013). Here, measures which might either put extra economic burden on households or improve their economic conditions are discussed. However, the cost benefit analyses of various mitigating measures are rare. In Sonitpur, Assam, an investment of INR 10,00,000 (US$ 19,231) in Human-elephant conflict mitigation strategy saved value worth more than 80 times of the investment made (Fernando *et al.*, 2008). Following are few examples of preventive measures:

Physical barriers: Barriers, whether natural (rivers and mountain ranges) or man-made (stone-walls, chain-fence, electric fencing and hedge) spatially separate wild population and adjacent communities and have been proved successful (Mishra, 1997). Fencing is not feasible and does not provide satisfactory solution for the problem always (Choudhury, 2004). Electronic fencing has been proved successful in reducing human - elephant conflict in many places in India (Gubbi, 2012) but fails due to inadequate or poor maintenance (Chauhan and Chowdhury, 2002). It has been successful in limiting elephant incursions into farm lands in some parts of Coorg and Anamalai hills in Karnataka (Fernando *et al.*, 2008). In case of Gir National Park, Gujarat, fencing was proved economically impractical (Vijayan and Patil, 2002). In Rajasthan, farmers claimed that wild boar were able to dig beneath stone wall while nilgai could jump over 1.5 m fence (Sekhar, 1998). Similarly, digging trench has also been proved unsuccessful due to human error or environmental factors (Nath and Sukumar, 1998; Choudhury, 2004; Jayant *et al.*, 2007). In Tamil Nadu, the cost of digging a trench was estimated to be around US$ 2,160 per km (Fernando *et al.*, 2008). Jayant *et al*. (2007) rated a trench built alongside an electric fence as highly effective in eliminating human-elephant conflict in Karnataka. Both Nath and Sukumar (1998) and Jayant *et al.* (2007) found private and individually owned fences to be effective than the government owned fences in reducing crop raiding by elephants in Karnataka. In Hemis National Park, villagers' nighttime livestock pens or corral were predator-proofed through Appreciative Participatory Planning and Action or APPA. The imported materials including wire mesh, cable fasteners, poles, etc. were provided by Snow Leopard Conservancy (US $ 400 to $ 800 per village) while mud and stones were brought by villagers along with their time and labor for constructing the corral. Though the initial costs were high, however, it prevented the mass-attacks on livestock particularly sheep and goats by snow leopard and the associated economic impact on households (Wangchuk and Jackson, 2004).

Disrupting stimuli: Use of electronic devices which produce stimuli such as sounds, chemicals or light annoying to animals when they approach a protected resource has been tested but are very expensive and complicated to use. However, their use in Indian scenario needs to be tested (Chaudhury, 2004). In Tamil Nadu, the Forest department distributed high power search lights to farmers worth INR 1.5 lakh (US$ 3,250) to scare away the elephants straying into farm lands (Fernando *et al.*, 2008). In Sonitpur, Assam, Zimmermann *et al.* (2009) found hand-held spotlights to be popular and effective in reducing events of crop raiding by elephants when used with other methods such as noise, fencing and chili smoke. In villages around Manas National Park in Assam, a mix of methods including use of torch lights and fire and making noise through shouting and beating drums have been found to give good results to prevent elephant movement (Fernando *et al.*, 2008).

Taking out the problem party - translocation of problem animal or human population resettlement: The process of eliminating problem animal and releasing it to other site has been practiced in India for few species (Fernando *et al.*, 2008; Athreya *et al.*, 2011). However, it has been found that this does not mitigate the problem in many areas, even increasing the conflict in release sites (Nath and Sukumar, 1998; Athreya *et al.,* 2011). In Karnataka, the cost of translocation of 20 elephants from different regions to Bhadra Wildlife Sanctuary was estimated to be around US$ 375,000 (Fernando *et al.*, 2008). Displacement has been suggested as an alternative to segregate people and wildlife spatially to reduce conflict (Ogra and Badola, 2008), however shifting families to locations with livelihood options new to them e.g. providing agricultural land to pastoralists or forest dwelling communities, might prove futile (Gubbi, 2012). Relocation of communities to areas with better socio-economic opportunities, substantial benefits, no cultural, political or social opposition and low or no risk of losing property, provides adequate solution and can be successful in long run (Madhusudan, 2003; Treves and Karanth, 2003). However, such resettlements are limited to small homogenous communities who have been living inside the protected areas.

Buffer of multiple use areas or unpalatable crops: Gubbi (2012) suggested addition of multiple use forest as buffer of Nagarhole National Park in India to reduce conflict with elephants. Rao *et al.* (2002) in a study in and around Nanda Devi Biosphere Reserve, suggested replacing agricultural

crops with medicinal plant species which will also enhance household's income. In Chirang-Ripu Elephant Reserve in Manas National Park, Assam, experiments are being carried out to study the viability of cultivating alternate crops such as capsicum, beetle nut, lemon and Patchouli plants or other economically viable crops as elephant deterrents and to improve income of affected community (Fernando *et al.*, 2008). However, in many parts of the country the agriculture lands around the elephant habitats are owned by small farmers who are not willing to adopt practices different to the traditional farming of subsistence crops.

Compensatory measures: In the absence of tangible economic gains, local communities are often unable to support conservation - friendly production and consumption practices, thus, programs are required to offset their economic loss (Mishra *et al.,* 2003). Tools for mitigating financial loss of locals involve direct cash compensation and indirect compensation through insurance schemes, integrated conservation development programs and alternative source of income such as ecotourism or wildlife tourism (Sillero-Zubiri *et al.*, 2006).

Compensation schemes: Monetary compensation is provided by several state governments in India to conflict affected people, to balance their economic loss. However, these payments are often insufficient, delayed and involve time-consuming procedures and fail to reduce anti-wildlife sentiments (Madhusudan, 2003; Ogra and Badola, 2008; Gubbi, 2012). Verification of losses and final payment take time and payments are so measly (rarely meeting market value of lost crop or animals, at times 3% of total loss; Mishra *et al.,* 2003) that people do not apply for compensation (Saberwal *et al.,* 1994; Gubbi, 2012). However, factors like wealth, gender, social networks and pre-existing expectations also influence one's decision of applying for compensation (Ogra and Badola, 2008). In Bhadra Tiger Reserve, payments made to villagers were equal to only 14% of crop losses and 5% of the livestock losses which were accompanied by extended delay (Madhusudan, 2003). The forest department spent around INR 53,090 (US$ 1,021) as compensation for crop loss from elephant raiding in three years which was only 14% of the claimed monetary value of crop loss by the villagers. In Nagarhole National Park landscape, households received a compensation of US$ 30 for crop loss by elephants (Gubbi, 2012). Compensation schemes also put pressure on already limited budget of Forest Departments. The Wildlife Department in Hemis National Park found itself spending 60% of its annual budget as compensation that too when claimants were being paid only 10-30% of animal's market value (Jackson and Wangchuk, 2001). Such compensation schemes cannot do much to reduce HWC and strong institutional support is required to make compensation schemes successful along with clear guidelines, quick and accurate verification of damage, fair payment and sufficient and sustainable funds with concerned authorities (Mishra, 1997).

Insurance programs involving locals: The basic idea of compensation scheme in most of the countries is that forest department is entirely responsible for losses caused to neighbouring human settlements and resultant compensations. However, locals dependent on forest resources in certain areas are contributing or are ready to contribute a small amount to safeguard their crops and livestock through protective measures and to reduce their losses through insurance programs (Madhusudan, 2003; Mishra *et al.,* 2003). In Ladakh, village council left approximately 500 ha area free of livestock grazing and human use for 5 years and in return got a yearly sum of INR 20,000 (US$ 385) from Nature Conservation Foundation for collective work and village development schemes. Livestock insurance program was also initiated in the area with a monthly contribution from villagers and initial funds from International Snow Leopard Trust. Up to 100% of livestock losses are provided depending on total number of livestock killed and the total size of insurance fund. Work is going on for programs to develop and market handicrafts and achieve sustainability of the grazing on set-aside land (Mishra *et al.,* 2003). Madhusudan (2003) suggested a similar insurance scheme in Bhadra Tiger Reserve for mitigating monetary loss to local community due to conflict. Under the scheme, the premium that the interested party (villagers interested in securing their livestock and crops) would have to pay annually could be as low as INR 125 (US$ 2.60) per head of livestock and INR 223 (US$ 4.60) per acre of paddy.

Conclusion - short comings and possible strategies

The review indicates that though Human Wildlife Conflict is well studied in India, however, not many workershave looked into monetary losses to the affected community. There are sporadic studies on certain species (Table 1) but no realistic estimates are available for any species across its range. The economic loss incurred by households put an additional burden on rural households, particularly marginalized sections of society. It is to be understood that the negative interactions between the wildlife and humans undermines well-being of both the parties and threatens the conservation of wildlife, particularly of large-bodied mammals which happen to be problem animals all over their range (Madhusudan, 2003;

Madhusudan and Mishra, 2003; Mishra *et al.,* 2003). Conflict and associated loss lessen the public support and increase hatred towards wildlife and wildlife managers with a decrease in cultural tolerance of locals towards wildlife (Madhusudan, 2003; Ogra and Badola 2008). Intentional and retaliatory killings of carnivores have also increased which pose a threat to carnivore population viability (Jhala and Giles, 1991; Mishra *et al.,* 2003; Maclennan *et al.*, 2009; Lyngdoh *et al.,* 2014).

It was also observed that almost all the studies were done in and around protected areas or proposed protected areas. The protected areas represent a little over 5% of country's geographic area while the forest cover of the country is 21.34% of total area (FSI, 2015). Thus, a large part of country's natural habitat is not under any protection. With increasing human population, the pressure on natural systems will also increase leading to augmented magnitude of such negative incidences. While declaring more of the forest cover as protected might seem as a potential measure to prevent further anthropogenic pressure and degradation, however, without assessing the dependencies of the surrounding local communities and ensuring alternatives it might lead to further conflicts. This will further amplify the negative repercussions for biodiversity conservation and human well-being and livelihoods, thus posing a challenge for policy-makers (Young *et al.*, 2010).

For many state governments, wildlife conservation is considered a non-priority sector with delayed or meager flow of funds. Lack of resources with the authorities to compensate loss of local communities is one major challenge (Jackson and Wangchuk, 2001). In Karnataka alone, over 100,000 compensation claims due to various wildlife conflicts were filed from 2000 to 2010 (Sidder, 2016). Insufficient compensation provided to locals and often time-consuming procedures are considered responsible for augmenting anti-government and wildlife sentiments (Madhusudan, 2003; Gubbi, 2012). Though, compensation could be only a partial strategy to reduce hostility of local communities but timely payment and supportive staff would improve relationships between management authorities and communities and can reduce retaliatory activities of locals. With the little help from technology the whole process of compensation, deemed as time-consuming and costly, can be fastened up as recently illustrated by the WildSeve project in Bandipur-Nagarhole National Parks, Karnataka (Sidder, 2016). The project uses cell phone technology to help the claimants to file and track their claims to get timely compensation and is funded by the National Geographic Big Cats Initiative, Oracle, and The Rufford Foundation. Possibly, such innovative measures could be adopted by forest department of other area and state, along with allocation of more funds so that sufficient compensation is provided.

Studies are also lacking to improve herding practices. Free ranging livestock is more vulnerable to predation which is also partly responsible for the conflict. In Kibber Wildlife Sanctuary of Himachal Pradesh, the livestock density is ten times of Bharal (*Pseudois nayaur*) which results in high levels of livestock depredation by wild carnivores and consequent retaliatory persecution by the herders (Mishra, 1997). It was suggested that inviolate areas should be created for wild herbivore while livestock stocking density should be regulated in other areas. Cultivation of crops unpalatable or repelling to wild herbivore as a buffer to food crops has been suggested as an option to reduce the crop raiding by wild ungulates. However, often there are constraints in marketing of such produce (Maikhuri *et al.*, 2001) thus farmers tend to not prefer such crops. Thus, civil organizations and government departments should work towards creation of market and training of locals in marketing of such produce. Also due to lack of alternative livelihood, such incidents of livestock predation and crop depredation by wildlife hits the local communities hard. Hence, it is crucial that the local institutions, central government and civil society bodies work together in tandem to ensure that not just the ecological diversity but economic diversity is also maintained for a holistic conservation.

Some of the commonly used preventive and mitigative measures are listed in Table 2. But no one mitigative/ preventive measure can be 100% effective everywhere given the diversity of the country. Hence, it is desirable that in various permutations and combinations the measures are used to ensure maximum safety possible. At the end, it is imperative to mobilize and educate the community about the wildlife values and significance of an intact natural habitat. Local youth could be trained to monitor wildlife signs in and around villages and report sightings to local officials so that timely actions could be taken to prevent conflict (Dhanwatey *et al.,* 2013). A participatory strategy where affected community is involved while drafting and initiating a project leads to a sense of project ownership by local stakeholders and results in communal empowerment, self-reliance, and willingness to co-exist with problem species (Wangchuk and Jackson, 2004). It is important to bring down Human Wildlife Conflict and programs are required to offset economic loss of locals to achieve an integrated conservation and development goal.

Table 2: Examples of preventive and mitigation measures used during Human Wildlife Conflict in India

Animal	Loss type	Preventive measures used	Mitigation measure used	Reference
Elephants	Crop Raiding, Property Damage, Killing cattle and people, disruption of daily activities	Guarding, fencing, anti-depredation squad, community based participatory wildlife monitoring, trip wire alarms, barriers, elephant proof trenches (EPT), walls, punji sticks, bio-fences, habitat enrichments, chemicals, artificial water sources, chilies, satellite tracking, scaring squads, translocation, culling, capturing for captivity, alternative livelihood such as bee keeping.	Compensation for loss, relocation of villages	Williams *et al.*, 2001; Singh *et al.*, 2002; Choudhury, 2004; Jayant *et al.*, 2007; Fernando *et al.*, 2008; Lenin and Sukumar, 2008; Datta-roy *et al.*, 2009; Barua *et al.*, 2010; Zimmermann and Ladle, 2011; Gubbi, 2012; Jadhav and Barua, 2012; Palei *et al.*, 2015
Lions	Human attack, livestock damage	Thorn enclosures for livestock, translocation	Compensation for loss	Saberwal *et al.*, 1994; Banerjee *et al.*, 2013
Tigers	Human killing, livestock depredation	Eradication, translocation, preservation, stopping coupe operations, introduction of human face masks and clay models wrapped with energizers connected to electricity, patrolling, nylon net fencing, use of crackers, drums, education and awareness programs, alternative livelihood	Compensation for loss, Voluntary resettlement	Madhusudan, 2003; Ogra and Badola, 2008; Gubbi *et al.*, 2008; Rastogi *et al.*, 2012
Leopards	Livestock depredation, Human Killing	Translocation, lethal control	Compensation for loss	Athreya, 2006; Athreya *et al.*, 2007; Athreya *et al.*, 2011
Snow leopards	Livestock depredation	Lethal control, alternative livelihood such as handicraft and wildlife tourism, predator-proof corrals, guarding, anti-predator livestock management, creating grazing set-asides, wild prey recovery.	Incentive program to reduce grazing in conflict area, livestock insurance program, Compensation, training programs, Promote community-based wildlife stewardship	Mishra, 1997; Jackson and Wangchuk, 2001; Mishra *et al.*, 2003; Bagchi and Mishra, 2006; Namgail *et al.* 2007; Jackson *et al.*, 2010
Sloth Bears	Crop damage, Human Attack	Education and awareness programs, restriction in agricultural practices, alternative livelihood, change in activity pattern	Compensation for loss	Rajpurohit and Krausman, 2000; Bargali *et al.*, 2005
Black Bears	Human attack, livestock damage, crop damage	Retaliatory killing, drumming empty metal containers, use of guard dogs, barbed wire fencing, scarecrow, burning red chilies mixed in cow dung	Compensation for loss	Charoo *et al.*, 2011
Macaques and Langurs	Human Attack, Property Damage	Removal and relocation, surgical sterilization or immune-contraception of macaques, garbage management, development of monkey sanctuaries.	Insurance schemes, compensation	Imam *et al.*, 2002; Chauhan and Pirta, 2010a, b
Wolves	Livestock depredation, human attack	Lethal control, translocation	Incentive program to reduce grazing in cpnflict area, livestock insurance program, compensation, training programs, Promote community-based wildlife stewardship	Krithivasan *et al.*, 2009; Agarwala *et al.*, 2010
Wild pig	Crop raiding, career of infectious diseases, human attack	Fencing, trapping, guarding, pig-proof barriers, loud music.	Compensation for loss	Chauhan *et al.*, 2009
Snakes	Human attack	Removal and relocation, lethal control, awareness programs	Not available	Nadu *et al.*, 2011; Nath *et al.*, 2012; Vyas, 2013
Crocodiles	Human attack, livestock depredation	Removal and relocation, caged-bathing ghats, warning sign boards.	Education program, compensation for loss	Whitaker, 2007

Table 3: Cost of various preventive measures used to combat Human Wildlife Conflict

Species involved	Location	Preventive measure	Cost	Agency bearing the cost	Outcome	Reference
Elephant	Sonitpur, Assam	Conflict mitigation strategy including fences, spotlights and training to locals	US$ 19,231	Forest Department and civil agencies	Value 80 times of the investment made was saved.	Fernando *et al.*, 2008
Elephant	Tamil Nadu	Trench around villages	US$ 2,160 per km	Tamil Nadu Forest Department	Various environmental factors and human errors resulted in failure of trench.	Fernando *et al.*, 2008
Elephants	Tamil Nadu	High power search lights	US$ 3,250	Tamil Nadu Forest Department	Efficacy remains to be scientifically tested.	Fernando *et al.*, 2008
Snow leopard	Hemis National Park, Jammu & Kashmir	Predator-proof livestock corral	US $400 to $600 per village	Snow Leopard Conservancy	Mass-attacks on livestock by snow leopard were prevented.	Wangchuk and Jackson, 2004
Elephant	Bhadra Wildlife Sanctuary, Karnataka	Translocation of 20 elephants	US$ 375,000	Karnataka Forest Department	-	Fernando *et al.*, 2008

भारत में मानव वन्यजीव संघर्ष : क्षति एवं निवारक उपायों की आर्थिक जटिलता का एक पुनरीक्षण

उपमा मनराल, श्रुति सेनगुप्ता, सईद एनुल हुसैन, साक्षी राणा और रूचि बडोला

सारांश

भारत जैसी विकासशील अर्थव्यवस्था में जहां अधिकांश मानव आबादी बहुत अधिक प्राकृतिक संसाधनों पर निर्भर है। वन निवासियों का दीर्घकाल से वन्यजीवों के साथ सह-अस्तित्व रहा है। तथापि, प्राकृतिक संसाधनों पर बढ़ रही मानवीय निर्भरता और वन्यजीव आवासों के निम्नीकरण के फलस्वरूप वन प्रबंधन में लगे अधिकारियों तथा मानव एवं वन्यजीव के मध्य संघर्षात्मक स्थिति पैदा हुई है। महत्वपूर्ण संरक्षण और आर्थिक परिणामों के साथ, मानव वन्यजीव संघर्ष दोनों पार्टियों के कल्याण को क्षति पहुंचाते हैं तथा संरक्षण लक्ष्यों के लिए संकट खड़ा करते हैं। यह लोगों की खाद्य सुरक्षा एवं आजीविका तथा मनोसामाजिक कल्याण को प्रभावित करता है। हमने शामिल समुदायों द्वारा उत्पन्न आर्थिक क्षति पर विचार किए गए शोधपत्रों को पुनरीक्षित किया और भारतीय परिदृश्य में क्षति को रोकने एवं विषय के समाधान हेतु किए गए उपायों की प्रभावकारिता एवं कमियों पर विचार किया। मानव वन्यजीव संघर्ष के साथ सम्बद्धआर्थिक लागत से संबंधित अध्ययनों का अभाव है तथा शामिल प्रजातियों के लिए कोई वास्तविक आकलन उपलब्ध नहीं है। अधिकांश अध्ययन संरक्षित क्षेत्रों से संबंधित है, जिसमें गैर संरक्षित वनों का पर्याप्त प्रतिनिधित्व नहीं है। यह अनिवार्य है कि ऐसी कार्य योजना को मूर्त रूप दिया जाए, जो स्थानीय लोगों की आर्थिक क्षति की पूर्ति कर सके और जन सहभागिता को बढ़ाए ताकि ऐसे भूदृश्य में एकीकृत संरक्षण एवं विकास लक्ष्यों को पूरा किया जा सके, जहां मानव और वन्यजीव साथ-साथ रह सकें।

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Kedarnath Wildlife Sanctuary: Nature-Cultue linkages in a sacred landscape in Indian Himalayan Region

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Abstract

Kedarnath Wildlife Sanctuary is among the largest protected areas in Western Himalaya. The vast variability in climate, geology and topography results in rich biological diversity with varied floral and faunal assemblages. The landscape has many sacred elements which include famous *Kedar* circuit comprising of five *Shiva* temples, and many other Hindu shrines. Forest patches, alpine meadows and trees associated with shrines or local deities are also considered sacred. The landscape has around 172 villages with local communities holding traditional rights of phyto-resource use from the area; 12 villages are located inside the Sanctuary. In recent decades, various natural and anthropogenic challenges are threatening the nature-culture mix that forms the foundation of sacredness of the landscape. It becomes imperative that policies and action programs to enhance the ecological sustainability are appropriated and local cultural beliefs with embedded conservation ethics are integrated in the environmental governance and management of landscape.

KEY WORDS: Conservation challenges, local communities, Mandakini River basin, protected area, Western Himalaya

1. Introduction

1.1 Overview of the heritage site

The Kedarnath Wildlife Sanctuary (hereafter KWS) is situated largely in the catchment of Mandakini and Alaknanda Rivers, and form a large sub-catchment of River Ganga. It is located between 78°54'E and 79°27'E Longitudes and 30°25'N and 30°45' N Latitude and has a wide elevational range from 1100 m to 7068 m asl.

With an area of 97517.80 ha, KWS is among the largest protected areas in western Himalaya and in the state of Uttarakhand. The landscape has around 172 villages with local communities holding traditional rights of livestock grazing, lopping and grass cutting from the Sanctuary area. The inhabitants of these villages depend largely on the Sanctuary forests for their day-to-day sustenance. Forests in the region have had a long history of commercial tree felling since pre-independence era as part of British *Garhwal*.

1.1 Brief description of the sacred landscape

The KWS landscape is home to Kedarnath temple, one of the most revered and holiest Hindu shrines of lord Shiva and part of *Char Dham* pilgrimage in Uttarakhand. *Shiva* is among the principal deities of Hinduism and is considered the 'destroyer and transformer'. The exquisitely architectured temple structure is believed to be more than 1000 years old, dating back to 8th century and draws thousands of visitors every season. The landscape houses famous *Kedar* (*Shiva*) circuit comprising of *Kedarnath, Madhmaheshwer, Tungnath, Rudranath* and *Kalpeshwer* temples (Figs 1, 2). All the temples except *Kalpeshwer* are situated above 3500m elevation and are open only between April to November (from *Akshaya Tritriya* to *Kartik Purnima*, Hindu auspicious days) due to extreme weather conditions. The deities are brought to various *Shiva* temples at lower elevation during winters.

There are many symbols of *Pandavas*, kings from the *Mahabharata* Sanskrit epic, scattered in and around KWS. The *Garhwali* people perform a dance form called '*Pandav Nritya'* that tells the story of *Pandavas*. Other temples include *Mandani, Kalimath, Triyugi Narayan, Ansuya Devi* and many smaller shrines. All these temples draw thousands of pilgrims from across the India. These temples support local economy greatly, as men from neighbouring valleys and even from Nepal work as guides, porters or run shops and lodges around these temples. Nature and wildlife tourism is also gradually gaining momentum among tourist in the landscape. Famous treks include *Deoriya-Tungnath-Chopta, Madhmaheshwer, Nandi Kund* and *Mandani*, to name a few.

[Fig. 1]

[Fig. 2]

2. Significance of the heritage place including natural and cultural values

2.1 Natural values

KWS is neither a world heritage site nor in the tentative list, however, is recognised as a 'Habitat/Species Management Area' by the IUCN and is reputed among the world's richest bio-reserves. Sanctuary falls under the Himalayan Bio-geographical zone (2) and West Himalayan Biotic province (B) with alpine, temperate coniferous and broadleaf and subtropical forests as biomes (Rodgers and Panwar 1988). Permanent ice and snow line has been demarcated at or above 5000 m within the Sanctuary. The diverse climate, geology and topography of the region result in a varied floral assemblage in the sanctuary. It is estimated that about 44.4–48.8% of the area is forested, 7.7% is alpine meadows and scrub, 42.1% is rocky or under permanent snow and 1.5% is degraded which was formerly forested (Prabhakar et al. 2001).

A total of 886 dicotyledons and 253 monocotyledons have been recorded from the area (Rai et al. 2017). A number of endangered plant species including *Acer caesium, A. oblongum, Aconitum ferox, Allium stracheyi, Coelogyne cristata, Dendrobium normale, Kobresia duthiei, Saussurea roylei and Schizandra grandiflora* are recorded from the Sanctuary (Singh and Rai 2008). Twenty eight mammal species have been confirmed with Himalayan musk deer (*Moschus leucogaster*), an 'endangered' species in IUCN Red list, being the flagship species of KWS (Sathyakumar 1994). Other mammals include common leopard (*Panthera pardus*), Himalayan weasel (*Mustela sibirica*), Himalayan yellow-throated martyn (*Martes falvigula*), Himalayan black bear (*Selenarctos thibetanus*) and Himalayan Pika (*Ochotona roylei*). With a wide elevational gradient and rich habitat-diversity, the KWS offers a potential for rich avian diversity. According to a partial checklist, the Sanctuary has 244 species of birds including three 'threatened' species (Lepage 2017).

2.2 Cultural values

The forests and alpine meadows around the shrines and high elevation lakes in the landscape have deep cultural significance (Figs 2, 3). Alpine meadows around the temples and few community forests in and around the KWS landscape (in Chamoli and Rudraprayag districts) are considered sacred. Plant species like *Saussurea* spp., *Brassica* spp., *Ficus* spp., *Zanthoxylum armatum* etc. are highly valued and used in various religious ceremonies. *Saussurea obvallata* or *Brahma Kamal* (Fig. 4) is one such plant which is highly revered and finds its place in many mythological stories associated with Hindu Gods. It grows in high alpine areas in KWS and is offered to Hindu deities, particularly lord *Shiva.* It is collected by pastoralists and brought to villages at lower elevation and are distributed among devotees as deities' blessings. In villages, one or two trees (*Ficus* spp., *Prunus cerasoides* and *Quercus* spp.) are dedicated to local deities, which are worshipped and are not lopped.

[Fig. 3]

3. Current management arrangements (Legislations, institutions, resources)

The sanctuary is currently managed and protected by Kedarnath Wildlife Forest Division of Forest department, Government of Uttarakhand, administered under Wildlife (Protection) Act, 1972. The inhabitants of villages situated within KWS and in immediate proximity have traditional grazing and resource extraction rights within the Sanctuary. Shepherds from these villages take livestock to alpine meadows every year during summer and monsoon months. Village councils or *panchayat* look after the local rights in these areas and also manage community forests in the landscape. The temple committee and village councils maintain temples and sacred meadows and tree stands in the landscape. Many civil society organizations working towards capacity development, ecological restoration and women empowerment, work with local communities towards biodiversity conservation and livelihood improvement. Block development offices, departments

related to agriculture, horticulture and animal husbandry are other stakeholders working towards development in the landscape.

3.1 *Management History*

The Sanctuary forests formed part of Alaknanda catchment in the British *Garhwal* since 1815, after they defeated *Gorkhas*. During the first two decades, they classified these forests into class-I and class-II forests. After independence, a 10-year ban (beginning 1953) on green felling was imposed in the hill region at or above 1000 m elevation that resulted in an end to green felling in hills. Various timber extraction practices including fuelwood and bamboo harvest were done as mentioned in the working plan of the Kedarnath Forest Division, however, the amendment in the Wildlife (Protection) Act, 1972 in 1991 brought all commercial activities in the area to a halt. Kedarnath wildlife sanctuary was created in 1972 under the rule 4 of General Hunting Rules UP for 10 years. With the enactment of Wildlife (Protection) Act 1972, the sanctuary came under preview and under dual control of wildlife wing (ensuring protection of wildlife) and territorial staff (Silviculture and other forestry activities).

4. Current State of Conservation and Challenges for Continuity

KWS landscape faces a number of natural and anthropogenic challenges which include landslides and flesh floods in narrow valleys and forest fires, and increased human population growth and development activities within the Sanctuary and in the fringes, increased religious and nature tourist inflow and requisite forest resource extraction and infrastructure development in fragile ecosystems, pressure from unsustainable harvesting of resources and wildlife offences. Studies have indicated forest degradation and change in regeneration patterns of native flora, and impact of disturbances on wildlife and its habitat in the Sanctuary (Manral et al. 2017; Misra et al. 2009; Singh et al. 2010; Thakur et al. 2011). There are also reports of dispersal of anthropogenic disturbance deeper into relatively undisturbed forests in the Sanctuary (Singh et al. 2010).

There are 12 villages inside the sanctuary and about 160 villages within 5km of the boundary of the sanctuary, which are located from sub-tropical to temperate region. Local communities have very few livelihood options and are highly dependent on natural resources and marginalized traditional agricultural practices (Fig. 4). Basic amenities such as primary education and health services are not uniformly available in remote villages. Area has seen frequent events of natural calamities in recent decades, resulting in loss of forests, human assets and lives. Heavy rainfall in June 2013 due to an early onset of monsoon rains in the Mandakini River catchment resulted in glacial lake outburst, landslides and flashfloods which claimed lives of thousands of locals and tourists and an economic loss going in millions. All these challenges have resulted in negative trends in economic and ecological well-being of mountain people. Consequently, the region sees a high migration of locals in search of good income sources and better prospect for children.

This outmigration of people, particularly youth from villages impacts local culture hugely. Many traditional art forms (preparing woolen items and containers from hill bamboos, playing traditional music instruments and folk songs about local deities and kings) are being lost. The ethno-medicinal knowledge in traditional health care system is also being lost gradually. Driven by a socio-cultural change from subsistence to market economy, local communities are preferring cash crops over traditional crops resulting in loss of many traditional varieties. This gradual alienation of people from their land and culture might result in loss of religious customs and cultural norms along with the indigenous knowledge with time.

Like rest of Himalaya, KWS is also prone to projected climate change and consequent changes in vegetation structure and composition. Adhikari et al. (2012) found variation in major plant phonological processes such as leaf bud break, leaf fall and flowering in timberline species in response to inter-annual climate variation. With a host of drivers such as infrastructure development, changing land-use, weak political will towards conservation; the projected climatic variation might bring complex changes in social-ecological systems of the landscape threatening its role as a rich repository of both natural and cultural values.

[Fig. 4]

5. Conclusion and recommendations

The KWS landscape is dotted with Hindu shrines, sacred alpine meadows and trees and biological resources that have high cultural, aesthetic and heritage values. These symbolize the essence and identity of local culture and traditions. While Oak forests of the area form the lifeline of local economy, many plant species form the foundation of religious and cultural systems. Local festivals, religious beliefs and rituals are associated with the landscape and often have embedded conservation ethics which underpins this relationship. These cultural linkages to the natural systems of landscape can greatly enhance the positive attitude of local communities and visitors towards conservation.

Further degradation of fragile mountainous ecosystem and its functions will increase the environmental, social-economic and cultural vulnerability of local communities in the landscape. There is a need of finding alternatives to natural resources to support local communities and increased tourist inflow. One such is to formulate long-term energy strategies by promoting renewable-energy technologies. This may include encouraging use of solar photovoltaic lights, solar cookers and water heaters, and improved cook stoves; and continuous need-based up-gradation of these products. It is also imperative to increase phyto-biomass production within human landscape by planting fast-growing native grasses and multipurpose tree species, which might reduce extraction pressure within forests.

In the pursuit of overall sustainable development and conservation of nature-cultural linkages in the sacred and biologically rich KWS Landscape, it is needed that appropriate policies and action programs to enhance the ecological sustainability in the region are put in place. Suitable spatial planning policies should be made to support the infrastructural development, particularly to support heavy pilgrimage to *Shiva* temples, in natural calamities prone areas. In the current scenario of continuous environmental degradation, the inclusion of local institutions into environmental governance has tendency to influence management and conservation of natural systems. The wide gap in managing the natural and religio-cultural values

of the KWS sacred landscape should be minimized by abolishing or minimizing the exclusionist policies and encouraging the bleongingness among the key stakeholders by involving them in governance and conservation of landscape and its resources.

Fig. 1: Location of prominent Hindu shrines, high elevation lakes and trekking routes within the Kedarnath Wildlife Sanctuary Landscape (Source: Rai et al. 2017)

Fig. 2: Sacred elements of the landscape: a) *Kedarnath*, b) *Madhmaheshwer*, c) *Tungnath* d) *Kalishilla* (a rock worshipped as a Hindu goddess), e) *Deoriya* lake (a lake where deities are believed to have taken bath) and f) A temple and associated sacred tree within a village

Fig. 3: Snow clad peaks, alpine meadows and a holy shrine: Nature and culture as encountered together in KWS landscape (at *Budha Madhmaheshwer*)

Fig. 4: Natural resources from forests of Sanctuary form the foundation of local rural economy: d shows pastoralists bringing *Saussurea obvallata* or *Brahma Kamal* to be distributed among devotees and (f) shows a woman crossing a landslide while carrying grass on her back

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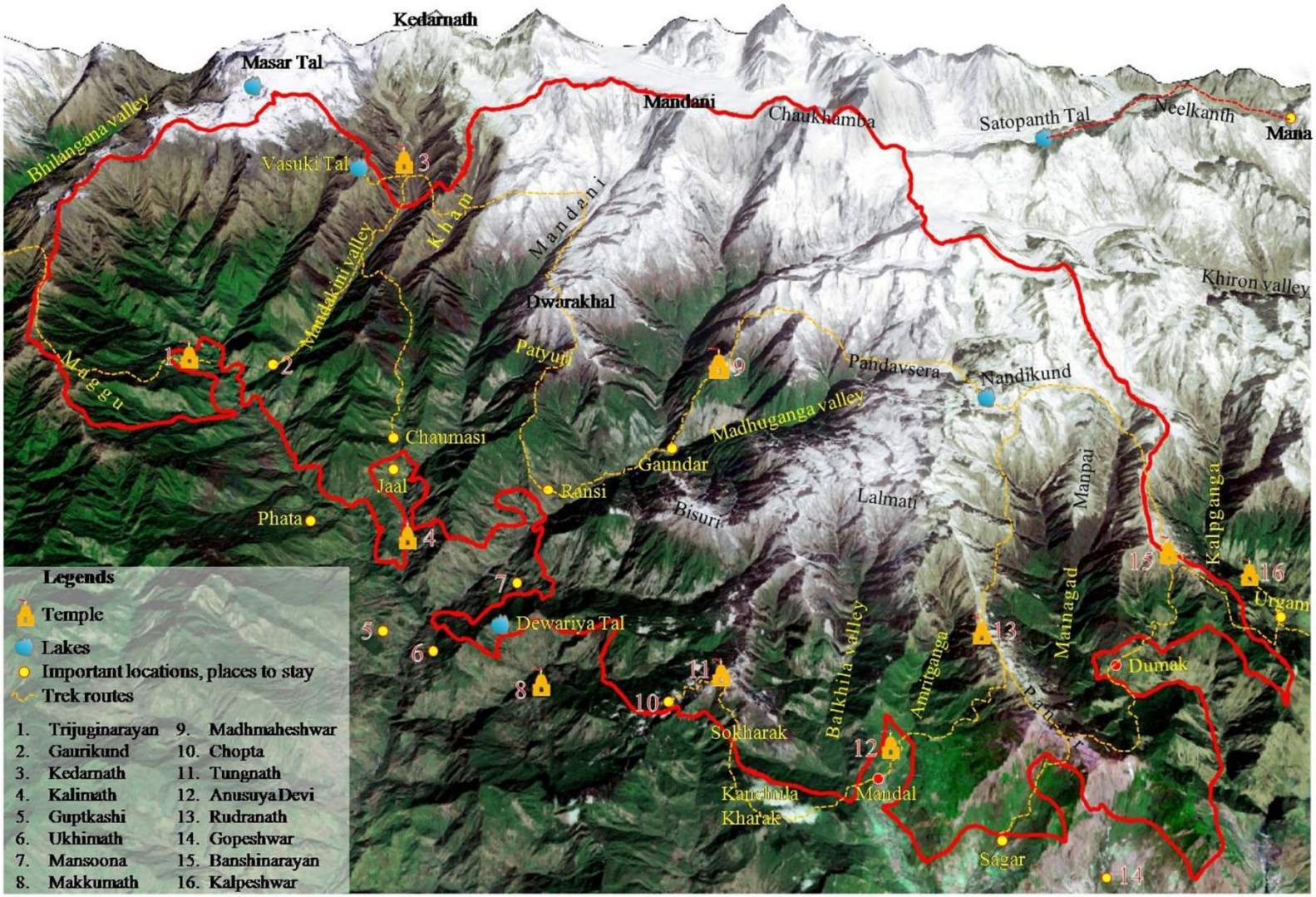
Kedarnath
Masar Tal
Mandani
Chaukhamba
Satopanth Tal
Neelkanth
Mana
Bhilangana valley
Vasuki Tal
3
Khiron valley
Dwarakhal
Patyuri
Pandavsera
Nandikund
Madhuganga valley
Chaumasi
Jaal
Gaundar
Ransi
Lalmati
Bisuri
Phata
Manpai
Kalpganga
Urgam
Dewariya Tal
Balkhila valley
Amriganga
Mainagad
Dumak
Sokharak
Kanchula Kharak
Mandal
Sagar
Legends
Temple
Lakes
Important locations, places to stay
Trek routes
1. Trijuginarayan
2. Gaurikund
3. Kedarnath
4. Kalimath
5. Guptkashi
6. Ukhimath
7. Mansoona
8. Makkumath
9. Madhmaheshwar
10. Chopta
11. Tungnath
12. Anusuya Devi
13. Rudranath
14. Gopeshwar
15. Banshinarayan
16. Kalpeshwar

Figure 1.



Figure 2.



Figure 3.



Figure 4.

Author: Upma Manral, First appeared in: Sanctuary Asia, Vol. XXXVI No. 8, August 2016.

Banj, Beasts And People – Life On The Fringe Of The Kedarnath Wildlife Sanctuary

While walking through the degraded Banj oak forests of the Kedarnath Wildlife Sanctuary in the company of villagers, Upma Manral worries that exclusionist forest policies are alienating communities from nature.



A troop of rhesus macaques raids a field. Villagers expressed much anger that these primates pick the sown seeds, young shoots and devour grains even before they can be harvested. Photo: Upma Manral.

When I opened my eyes, it was only seven a.m. but everyone seemed busy already. The rays of the sun filtered through the window of my room and just outside, a Himalayan Woodpecker ceaselessly knocked on a dry branch. It sounded like the drumming of a jazz musician. The sound of ringing bells on a pair of bulls in the neighbouring field and the unremitting piho-piho of a Great Barbet from a distant tree added to the symphony. I came out and took in the surroundings, gazing at mud-houses and freshly-sown fields with the oak forest framing the village. I was in Ransi, a Garhwali village in the Madhyamaheshwar valley, located inside the

Kedarnath Wildlife Sanctuary, one of Uttarakhand's largest Protected Areas (PAs) and home to the endangered Himalayan musk deer.



The magnificent Chaukhambha massif, named for its four prominent summits, as seen from the Buda-Madmaheshwar temple inside the sanctuary. Photo: Upma Manral.

The kalpavriksha of hill folks

My host, Kamla di and her daughter Meera, along with their neighbours, were about to enter the forest for fodder and wood and as we had agreed the evening before, I joined them. Walking along a narrow, dusty path, ours was a motley procession of young girls chatting excitedly, older women talking light-heartedly and me diligently noting down the names of all the birds I could see. Streaked Laughing Thrushes hopped about on the ground, while a lone Black-headed Jay looked down at us from its perch. A flock of Russet Sparrows and Yellow-breasted Greenfinches picked seeds in a field. Above us a White-eyed Buzzard was being harassed by a pair of Common Kestrels, as a few Himalayan Griffons glided over the valley on thermal currents. A sudden movement from behind a Berberis bush revealed, to my delight, a yellow-throated marten, which threw us a quick look before escaping into a maze of boulders and bushes.

We stopped at a point where a stone indicated that we were now entering the sanctuary. I chatted with the girls, asking them about their plans after completing

school. One of them replied, “Even after higher studies, we will have to go to the forest as we go today. What difference would battling books bring to our lives?” Her statement reflected the grim reality of the isolation and remoteness of many Himalayan villages that has resulted in an economy intimately associated with mountainous forests for subsistence and livelihoods. In such a scenario, Banj oak forests constitute a crucial component of the socio-ecological system for communities. During winter and summer, when next to no fodder is available for livestock, Banj leaves mixed with dried grass and agricultural by-products constitute the primary fodder source. In the early summer, the new leaves of Banj are collected in large quantities as fodder. With its associated vegetation, Banj also happens to be the primary energy source for locals who use the wood as fuel to cook and to heat their homes. The leaf litter serves as bedding material in cowsheds, and turns into excellent manure after being mixed with cattle dung. Banj forests are also a source of numerous springs and streams that hill folk depend on for their water needs.

Clearly Banj is the kalpavriksha (mythological tree from heaven capable of fulfilling all human needs) of legend for the locals here.

We had walked almost a kilometre from the forest edge. The forest that looked dense and healthy from the outside now appeared wounded and decidedly distressed from inside. Kamla di said to me: “I must travel further now to obtain fodder, compared to when I was a young bride. The village population has almost doubled and the young do not understand that if they cut trees mercilessly, there will be no fodder and fuelwood in the future.” Her statement accurately describes the current situation with regard to the degradation of Himalayan forests at the hands of both humans and a changing climate.



Banj forests are an important source of mountain streams - both big and little. Photo: Upma Manral.

As we reached the site of the resource extraction, my companions began work in earnest. Meera and her friends climbed huge Banj trees and began lopping branches, while their mothers gathered leaf litter from the forest floor. Meanwhile I kept a look out for the winged creatures that sprang from branch to branch. A Bar-tailed Treecreeper, an Eurasian Jay and a pair of White-tailed Nuthatches scurried up and down a tree trunk. A flock of White-throated Laughing Thrushes flew noisily past from a nearby perch. A pair of Verditer Flycatchers lured me off the track where I saw a Himalayan langur searching for Banj acorns on the forest floor. The tiny acorns are vital to wild herbivores as they are easy to find and highly nutritious. Once the women had gathered all they needed, it was time to walk back home.

Wildlife in the backyard

Without a shadow of doubt, a rising human population coupled with excessive extraction has created stress between wildlife and local communities in recent decades. I asked my women companions about this as we walked. One woman told me how a bear had eaten the corn and pumpkins from her kitchen garden the previous night. Another bemoaned the fact that wild pigs had raided her finger-millet fields just prior to the harvest, resulting in a loss of 20 per cent of her crop yield. On hearing the discussion, more women joined in, each with an unhappy story to tell involving losses at the hands, or rather jaws, of Himalayan black bears, wild pigs, porcupines, Himalayan langurs and rhesus macaques. Some years ago, such crop raids were restricted to fields relatively close to the forest, but with every passing year wild animals have taken to moving closer to their homes. An elderly lady said with both anger and sadness: "We sow the seeds and nurture the plants, but all is taken by the wild animals. Bears take our corn, wild pigs eat our millet and paddy and dig up our potatoes, and porcupines consume our lentils. We are left with nothing." Among all the animals, the women despised rhesus macaques the most. They come in troops, pick the sown seeds, pick off the young shoots and devour grains before these can be harvested.

The situation is no better when it comes to attacks on livestock. Half the women present there had lost some animal or the other to leopard attacks. Though most of the incidents took place in the forest, attacks inside cowsheds or in the fields were not unheard of either. In one incident, a leopard took three heads of cattle that were grazing in the fields at dusk. The monetary loss on account of the death of such

animals varies from Rs. 2,500 to 1,75,000 (in case of mules) per animal, per household. And the losses on account of crop raiding range from Rs. 300 to Rs. 4,500 per household, per year. These losses may seem small in an urban context, but can be a crippling burden on rural households who must subsist on a meager income.

Though the Forest Department compensates the loss of livestock, the women were less than impressed by the schemes said to benefit them. To some extent this may be a result of a communication gap between villagers and the Forest Department, as women complained of complicated procedures, delayed and inadequate compensation amounts, and the insensitive intimidation from forest staff members. Those who did in fact receive some compensation said that delays caused them much grief and in any event the amount was much lower than the actual value of their loss. Everyone agreed that the situation was getting worse and that human-animal conflicts were getting more frequent. Locals felt that this was a result of a combination of factors including increased human numbers, forest degradation and the ban on hunting. The lack of fuel and fodder alternatives has forced them to be even more dependent on forest resources than they once were.



Banj trees form a significant constituent of agro-forestry systems in villages at higher elevations. Photo: Upma Manral.

Turning the waves of disapproval

The general belief is that natural resources need protection from the destructive actions of people. But they are doing the best they can to manage their natural resources with very little effective, external help. In many rural communities of Uttarakhand, economic structures and social organisation is founded on a strong tradition of harmony with nature. But we have a problem here. The rationale of creating Protected Areas that seek to isolate communities from the resources upon which their daily existence depends is creating a phalanx of hostile communities around our most precious biodiversity areas. This is why, when a conflict situation arises, people refer to the problem animals as "your" (Forest Department's) wild animals and "our" domestic animals and "our very lives".

The formula is not working. The exclusionist policies are alienating local communities who must be recognised as potential allies in the joint objective of conserving forests upon which both people and wild species depend. It may not be easy, but unless a social wall is created to protect natural resources, with local communities at the centre of such plans, the sense of belonging that people shared with the forest will be lost forever.

Sitting there with the simple, life-loving women and men of the villages that so generously took me in, I listened to the words of just one among hundreds of Kumaoni folk songs that embody the sentiments of local communities. Resurrecting such ancient relationships could help us cut the Gordian Knot that currently defines the ill-fated people-park relationship that ends up harming both people and nature.

Oh girl, oh sister, do not cut Banj

How will you get cool breeze from Akhrot trees only

From where will you get water, so do not cut Banj

Treat them tenderly as your own children.



A line of village women, doubled over under the weight of their load, stream back into their village after collecting fodder from the forest. Photo: Upma Manral.

Paper presentations and awards

1. Paper entitled ‘Kedarnath Wildlife Sanctuary: A Himalayan Jewel’ presented in ‘Capacity Building Workshop on Nature-Culture Linkages in Heritage Conservation in Asia and the Pacific (CBWNCL) – 2017’ held from 15th to 26th September 2017 at Tsukuba, Japan.
2. Paper entitled ‘Park, People and Cattle: Forest resource availability within a protected area landscape in Western Himalaya’ presented at the Rufford India Conference, Rajasthan - 2017 held from 23rd to 26th April 2017.
3. Abstract published and paper entitled ‘Tree fodder availability and its use along elevational gradient in Kedarnath Wildlife Sanctuary Landscape, Western Himalaya’ presented in ‘10th Uttarakhand State Science and Technology Congress-2016’ held from 10th to 12th February 2016 at UCOST, Dehradun.
4. Abstract published and paper entitled ‘Vegetation recovery after landslide in the fringes of Kedarnath Wildlife Sanctuary, Western Himalaya’ presented in ‘8th Uttarakhand State Science and Technology Congress-2013’ held from 26th to 28th December 2013 at Dehradun.
5. Poster ‘Sustainable Development in Mountains: Embarking on Woman Empowerment’ presented in ‘Asia-Pacific Youth Forum 2013 on Mountain Issues and Post-2015 Development Agenda’ held from 30th September to 4th October 2013 at ICIMOD, Kathmandu, Nepal
6. Received honorable mentions certificate in the ‘Resilient HKH Photo Story Contest’, part of PhotoHKH: Capturing change across the Hindu Kush Himalaya.

United Nations Educational, Scientific and Cultural Organization

UNESCO Chair on Nature-Culture Linkages in Heritage Conservation University of Tsukuba, Japan

筑波大学 University of Tsukuba

CERTIFICATE

The UNESCO Chair on Nature-Culture Linkages in Heritage Conservation at the University of Tsukuba
ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property)
IUCN (International Union for the Conservation of Nature and Natural Resources)
ICOMOS (International Council on Monuments and Sites)
and the UNESCO World Heritage Centre

certify that

Ms. UPMA MANRAL

has attended the
Second Capacity Building Workshop on Nature-Culture Linkages in Heritage Conservation in Asia and the Pacific
Theme: Sacred Landscapes
From September 15-26, 2017 in Tsukuba, Japan

Professor Kyosuke Nagata
President of the University of Tsukuba

In cooperation with

United Nations Educational, Scientific and Cultural Organization

World Heritage Centre

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wild ungulates in the Tillari bioregion, an important conservation area of c. 350 sq.km, which is a vital link connecting forests in three states (Maharashtra, Goa, and Karnataka). We also evaluated local hunting patterns through questionnaire surveys with local hunters, villagers, and forest department staff to assess the impact of hunting on ungulates. This information would be useful to better protect this fragile region through local community support, trust-building activities, and improved management.

Park, People and Cattle: Forest resource availability within a protected area landscape in Western Himalaya
Upma Manral

The Himalayan forests play a multifaceted role in achieving Sustainable Development Goals in the region by balancing conservation and economic growth and interlinked development issues. With few livelihood options available, these form an essential life support system for local communities. As a result, even the protected area landscapes are not devoid of anthropogenic pressure, as people extract resources for sustenance and livelihood. The aim of this study was to assess the availability of major forest resources in Kedarnath Wildlife Sanctuary Landscape along an elevational gradient. In forests, vegetation characteristics were enumerated by laying 10 and 5 m radii plots for trees and regenerating individuals, at 200 m interval. Within the villages, transects were laid along the trails and agricultural areas to enumerate fodder species and biomass availability. Villages inside the Sanctuary and at higher elevation had higher livestock numbers/households and extracted more fodder from forests as compared to villages at a distance from the Sanctuary. Density and biomass of fodder trees in forest did not vary significantly along elevation; however forest area accessible to villagers varied, with villages at higher elevation having access to larger forest area. Low elevation villages had poor access to forests and had highest density and biomass of multipurpose trees within agro-forestry systems. With projected climate change and current rate of environmental

Certificate of Participation

Celebrating a Decade of S&T Success in Uttarakhand

Uttarakhand State Council for Science & Technology (UCOST), Dehradun

This is to certify that Uma Mamgai has actively participated in **10th Uttarakhand State Science & Technology Congress 2015-16, 10-12 February, 2016** at Uttarakhand State Council for Science & Technology, Vigyan Dham, Dehradun and presented a research pater entitled Tree fodder availability and its use along elevational gradient in Kedarnath wildlife Sanctuary Landscape, western HIMALAYA under the discipline Environmental Science & Forestry witness on behalf of the UCOST and University of Petroleum & Energy Studies, Dehradun

S J Chopra

(Prof. S.J. Chopra)
Chancellor
University of Petroleum & Energy Studies
Dehradun

(Dr Rajendra Dobhal)
Director General
Uttarakhand State Council for Science & Technology
Dehradun

VEGETATION RECOVERY AFTER LANDSLIDE IN THE FRINGES OF KEDARNATH WILDLIFE SANCTUARY, WESTERN HIMALAYA

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Disturbances such as fire, land clearing, landslide and development activities remove vegetation which has major influences on environment at site and regional level. Plant recovery and succession following such disturbances are poorly understood in temperate region of Himalaya. Understanding the dynamics of vegetation succession in such disturbed areas is of prime importance to plan restoration programs by facilitating the establishment of stable plant communities.

In the present study, observations were taken on natural restoration of plant components in three sites (aged 10 to >50 years) in fringes of Kedarnath Wildlife Sanctuary located in the Western Himalaya. The region has seen a number of landslides which have been accelerated by recent hydropower projects and road construction activities leading to loss of vegetation and original plant communities. Circular plots were laid in each of the site (10 m radius for trees; 5 m radius for shrubs and regenerating individuals; and four 1 m × 1 m quadrats within 10 m plot for grass cover and herbs). Name of the species and number of individuals were recorded for trees, shrubs, saplings, seedlings and herbs; in addition girth at breast height (GBH, 1.37 m) and canopy cover for trees were noted.

Twelve species of trees, 17 shrubs, 10 grasses and 24 species of herbs were recorded in total. *Alnus nepalensis* which is a pioneer tree species of the landslide area between 1200-2000 m asl was most common in all the sites. It formed pure stands in younger landslide sites with highest density of 374 individuals ha^{-1}, however, in older landslide areas, species like *Myrica esculenta, Lyonia ovalifolia, Pyrus pashia, Rhododendron arboreum* and *Quercus leucotrichophora* subsequently started appearing. Visits to these areas after recent landslides in 2012 and 2013 indicated that despite having high density, *A. nepalensis* fails to bind the soil in case of recurrent landslides. However, the species is known to add organic matter and nutrients through litter fall and increase nutrient availability to other species via Nitrogen fixation in its root nodules, thus facilitating growth of other species. Six species of shrubs and 7 species of herbs were recorded from younger sites while 16 shrub and 10 herb species were recorded from older site. Old landslides having species composition of *Q. leucotrichophora, R. arboreum, M. esculenta* and *L. ovalifolia* are comparatively more stable as seen in Ukhimath region in 2012. Therefore, interventions at earlier stages of succession would improve stability of affected sites. Such studies are important for restoration of ecological communities in Western Himalaya which is a landslide prone zone. This would improve the understanding of initial substrate conditions, propagule availability and suitability of a species for a site. Results of such studies would help in formulating mitigation strategies for efficient landslide disaster management in future.

Sustainable Development in Mountains: Embarking on Woman Empowerment

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Women: Backbone of hill economy



In mountain ecosystems, women have primary responsibility of the management of natural resource base and are custodians of indigenous knowledge
Sharon Capelieg Alakija

- Women contribute to the economy through collection of resources, small-scale entrepreneurial activities based on natural resources, agriculture and livestock rearing
- They have strong concerns for conservation actions as they are first to realize the sufferings as resources diminish
- They understand that healthy forests and grazing land, with firm tenure and user rights is important for a secure future
- Due to increased incidence of drought, flood, diseases or other changes in climate, they experience increased burden of water and fuelwood collection, and resulting health problems
- Loss or reduction of indigenous varieties of plants and animals have devastating consequences for food security, a responsibility of women
- Thus, they are important **allies to conservation initiatives**
- As caretaker of children, they are **agents of change**

Despite this, they are under represented at all levels of policy and decision making in natural resources and environment management

Conservation Programs: Gender biased shift in power and control

- Either high investment programs marginalize women or women-specific programs are marginalized itself
- Women neither consulted nor their existing management systems taken into account
- They are not adequately informed about conservation rules and regulations
- With increasing flow of funds, women effectiveness for forest conservation is questioned
- Disparity in remuneration of male and female workers
- Gender-based gap in school enrolment has narrowed: the gap of income is still wide

Getting started - Getting ahead

One young girl, just after completing her schooling, was asked about her persuading further study; and her reply was- *"Even after higher studies, I'll have to go to forest for fodder and fuelwood collection, as I go now. What difference will the study bring to me after spending years"*

- Recognizing their contribution in sustainable society
- Catch them young: younger generations learn faster, whether destructive resource extraction or conservation
- The workforce of educated girls should be encouraged to fill the void in education and health sector in mountains
- Strengthening Women Welfare and Self Help Groups
- Strengthening of mountain women's role in planning and decision making
- Improving livelihood opportunities: Promoting development of niche products



Principle 20 of Rio Declaration "women have a vital role in environmental management and development, and their full participation is therefore essential to achieve sustainable development"



Poster presented in 'Asia-Pacific Youth Forum 2013 on Mountain Issues and Post-2015 Development Agenda', ICIMOD, Kathmandu, Nepal

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Upma Manral

Honorable Mentions

of the **ResilientHKH Photo Story Contest**,

*part of **PhotoHKH**: Capturing Change across the Hindu Kush Himalaya*

November 2017

Organized by	Ministry of Population and Environment (MoPE), Government of Nepal, and International Centre for Integrated Mountain Development (ICIMOD)
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David Molden
Director General
ICIMOD

Photo-story in PhotoHKH - Capturing change across the Hindu Kush Himalaya

http://photo.icimod.org/node/304

Those who are left behind: A tale of augmented misery and dwindling cultural identity

November 27, 2017

Impacts of change

The current photo-series talks about the result of outmigration on those who are left behind and how these are affected more in case of various environmental changes and social-economic transitions.

The rural mountainous communities of Indian Himalayan Region have a long history of marginal agriculture-based economy that is intimately associated with the mountainous forests for subsistence as well income generation. These forest-resources based activities lay the foundation of human wellbeing in the region and are crucial components of traditional agro-system modelled on women's participation. Women, as the vital workers, are pillars that support and nurture these systems. Both agriculture and traditional animal husbandry practices are mostly subsistence in nature, and with increase in population and influence of market economy on traditional rural economy, the farm households are forced to seek nonfarm incomes. For long, the males of region have been migrating to urban centers of the country to find employment opportunities. This outmigration has acted as a driver of both demographic and cultural change in the region. Under the circumstances of male outmigration, women are crucial in providing labor to sustain hill economy.

The males working outside send money back home that gives greater purchase power to the household. However, on the other hand this also results in increased workload for family members who are left behind. In such scenario, women are most affected, particularly those living in a nuclear family. In a traditional Himalayan household, women play a crucial role in ensuring the well-being of

family members. They work on farms, bring resources from forests, and take care of children and elderly in the family. However, as the males go out to earn, women have to compromise with the leisure time that already is a luxury for hill women.

The photographs show how women are the ones who dominate the social-ecological scenery of these villages, as they bring fodder for livestock, many times back-breaking loads. They are the ones that you encounter when it is the season of preparing farmlands for sowing seeds or whether it's time to harvest the crop. After they feed lunch to the children, they are the ones taking livestock for grazing and bringing fuelwood and fodder. Large scale commercial exploitation of resources, continuous damaging harvest practices, accompanied by natural disasters, have degraded the forests of the region. This put extra burden on the ones responsible for collecting resources, as they have to go farther and work harder to ensure food-security and well-being of family members. In such scenarios, even age is no bar for women. Many times elderly women bring heavy loads on their backs. Situations worsen for them if the young women also migrate with their husbands leaving behind the aging parents. It also greatly impacts the education of children in the households with fewer adult members, as they take the responsibilities of bringing forest resources or taking cattle for grazing.

This outmigration of people, particularly youth from villages impacts local culture hugely. Many traditional art forms (preparing woolen items and containers from hill bamboos, playing traditional music instruments and songs which tell the stories of local deities and kings) are being lost. The ethno-medicinal knowledge in traditional health care system is also being lost gradually. Driven by a social-cultural change from subsistence to market economy, local communities are preferring cash crops over traditional crops resulting in loss of many traditional varieties. This gradual alienation of people from their land and culture might result in loss of religious customs and cultural norms along with the indigenous knowledge with time.