REPORT

STATE OF HUMAN-WILDLIFE CONFLICTS IN THE LAHAUL LANDSCAPE



nature conservation foundation

HCL FOUNDATION

State of Human-Wildlife Conflicts in the Lahaul Landscape

Submitted to

HCL Foundation

September 2022

By

The Himalaya Lab

Nature Conservation Foundation

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Suggested citation:

Bhatnagar, Y.V., Nagpal, T., Rana, R.S., Chugh, K., Gokhale, A., Jalihal, S. (2022). *State of Human-Wildlife Conflicts in the Lahaul Landscape.* Nature Conservation Foundation, Mysore, Report submitted to the HCL Foundation, Noida, India.

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Acknowledgments

We would like to sincerely thank the HCL Foundation, Mr. Robin Thomas, Deputy Manager and all the evaluators for recognising the importance of our work and supporting the successful completion of the project. In the HCL-Foundation team we would especially like to thank the constant advise and support of Ms. Shreya Bisht, Program Officer, who had been patiently guiding us during our quarterly document submissions till the closure of the project, supported by Mr. Anuj Srivastava, Deputy Manager, HCL Grant.

We would like to extend our gratitude to the Himachal Pradesh Forest Department, especially the Forest Department, Keylong, and Mr. Dinesh Sharma, D.F.O Lahaul, for helping us with field-related logistic support, especially in facilitating the training workshops with his staff. We would also like to acknowledge and strongly appreciate UNDP-India's SECURE Himalaya programme and Mr. Abhishek Kumar for sharing his incredible knowledge about Lahaul and supporting us with valuable resources when needed. We owe our appreciation to the Forest Department and UNDP-India Delhi (especially Dr. Ruchi Pant, Chief, Climate Change, Resilience, Natural Resources & Chemicals Management) and State office (especially Dr. Manoj Thakur, State Project Officer, SECURE Himalaya, HP) for partnering with NCF-India to implement the recommendations emerging from this project. We would also like to thank the line departments in Keylong, namely, Departments of Agriculture, Horticulture, Animal Husbandry and Livestock Health, Forest, Rural Development, Tourism, Irrigation and Public Health, and the DC Office for cooperating with us in willingly providing us with relevant historical information and datasets from their respective offices to enable us to meet our project objectives.

Most importantly, we are extremely grateful to the local communities of Lahaul who gave us their precious time and warmly welcomed us to hold relatively long discussions and interviews with them. All our community engagement and data collection activities were conducted during the peak agricultural season, and therefore, we cannot appreciate the communities enough, especially the *Mahila Mandals*, in supporting us in the same. Our fieldwork could not have been possible without the sincere and consistent efforts of our local Field Assistants, Mr. Vikram Singh and Mr. Jigmet Wangchuk, who offered their invaluable support and companionship throughout our time in Lahaul.

We would also like to acknowledge Himachal Pradesh Road Transport Corporation and their state buses for making our travel between remote villages possible.

We are extremely thankful to Dr. Koustubh Sharma for extending his valuable expertise on matters related to data collection and analyses on multiple occasions.

We would like to end by thanking NCF-India's Accounts team for helping and advising us on critical matters throughout the course of the project.

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List of abbreviations

ABC	Animal Birth Control
AIC	Akaike Information Criteria
AIR	Active Infrared
ALOS	Advanced Land Observation Satellite
ANIDER	Animal Intrusion Detection and Repellent System
ATMA	Agriculture Technology Management Agency
COVID	Coronavirus Disease
DCHB	District Census Handbook
DSA	District Statistical Abstract
FGD	Focus Group Discussion
FRD	Free Ranging Dogs
GIS	Geographic Information System
GLM	Generalised Linear Model
GREF	General Reserve Engineer Force
HWC	Human Wildlife Conflict
INR	Indian National Rupee
KVK	Krishi Vigyan Kendra
LPS	Lahaul Potato Society
LULC	Land Use and Land Cover
MAP	Medicinal and Aromatic Plants
NBAGR	National Bureau of Animal Genetic Resources
NCF	Nature Conservation Foundation
NREGA	National Rural Employment Guarantee Act
NTFP	Non-timber Forest Products
NWAP	National Wildlife Action Plan
ODK	Open Data Kit
PIR	Passive Infrared
PMFBY	Pradhan Mantri Fasal Bima Yojana
PRA	Participatory Rural Appraisal
SECURE	Securing Livelihoods, Conservation, Sustainable Use and Restoration of High Range Himalayan Ecosystems
SES	Social Ecological System
UNDP	United Nations Development Programme

Executive Summary

The higher reaches of Himalaya offer a continuum of wildlife habitat where they have coinhabited with marginal agropastoralists for millennia. This large interface of people and wildlife can result in enhanced interaction among them, some of which is negative and leads to conflicts.

The uppermost catchment of the Chandrabhaga or Chenab River constitutes the Lahaul region of Himachal Pradesh. This beautiful valley that mostly occurs above 2500 m asl is sandwiched between two branches of the Greater Himalaya, the Pir Panjal and the Zanskar, thus forming a transition zone between the mesic Greater and the more arid Trans Himalayan cold deserts. This is reflected in relatively more abundant plant diversity and cover, including patchy conifer and mixed forests as also sage steppe and meadows. Also, there is a rare richness of large mammals with over ten species - including Asiatic ibex, snow leopard, Tibetan wolf, and Himalayan brown bear of the Trans Himalaya and the Himalayan tahr, goral, musk deer, serow, Himalayan black bear, and common leopard of the Greater Himalaya. With only one wetland protected area in the northeastern corner of this *ca*. 7000 km^2 region, most of this wildlife share the habitat with people in revenue and common lands.

Like most high-altitude areas, arable land in Lahaul is limited to valley bottoms along alluvial fans near the side streams where staples such as barley, buck wheat, corn, and black peas were grown. The agricultural economy of the region shifted towards cash crops since the 1960s, which began with potato and then a variety of other cash crops. The enterprising Lahauli farmers acquired more land for cultivation, often away from the settlements and frequently changed their cropping patterns based on market forces. Over 10 cash crops grown here now include cauliflower, broccoli, *kuth*, but importantly green peas, apple, other fruiting trees and iceberg lettuce. Some of these happen to be palatable to the native wildlife and especially the brown bear and black bear.

Along with some other wild species, brown bears and black bears have always foraged on some crops. However, the incidence of such attacks reportedly increased since the mid-2000s often causing concern among the farmers who pressure the District Administration and the Forest Department to control it. While conflicts were present and perhaps increasing, there was little information on questions such as – Are all areas of Lahaul vulnerable to crop depredation and conflicts? What makes a village more vulnerable to crop depredation? Is it related to the crops grown there or the nearby habitat? What can be done to mitigate losses – especially with the approach to prevent, offset, and spread better awareness among the stakeholders. With this background the project aims:

1. To generate knowledge on patterns, processes, and drivers of human-wildlife conflicts so that more robust mitigation measures can be designed for securing local livelihoods in the future.
2. To create baselines for socio-economic indicators of the resident communities, and for distribution and occupancy of the wildlife.
3. To use the above information and develop an awareness and outreach strategy to disseminate the key messages on prevention and safety to relevant stakeholders, especially the local communities.

The project followed a three-pronged approach to obtain information – Information was obtained from literature and government records about the current status, understand village-level and then household-level patterns and processes.

Literature was thoroughly searched for information on conflicts and socioecological transformations of the region. This was accompanied with thorough consultations and data gathering from key government Departments including the District Administration, Agriculture, Horticulture, and Tourism on topics such as their schemes, key metrices, and beneficiaries.

Using stratified random sampling, we sampled 78 of about 200 inhabited villages that were representative of the spatial spread in all the seven sub-valleys of the Lahaul sub-division, village size and access. Focal Group Discussions (FGD) were held with representative groups within the villages to understand the vulnerability of villages and to stratify them as per the level of conflicts with bears. The semi-structured questionnaire administered during FGDs included questions on the challenges to cultivation and animal husbandry, and the nature, type and extent of crop damage and livestock loss. Further, village-level socio-ecological and terrain characteristics that could explain and stratify conflicts were also obtained using QGIS 3.22 software (see Table 1.1).

Representing each stratum of conflict level with bears, a total of 26 villages were randomly selected for household-level interviews where 179 households were sampled following a snowball and convenience approach to understand how the conflicts influenced their attitudes and tolerance towards the bears and conservation in general.

Generalised linear modeling was used to identify factors governing the vulnerability of villages based on key socio-ecological and terrain covariates determined through the village-level surveys and derived using QGIS software by demarcating 2km X 2km grids around the villages. A set of individual-level variables determined through household-level surveys was used to understand respondent attitudes and tolerance towards bears and conservation. Further, descriptive and non-parametric tests were used to explore differences in the values of variables between the conflict and non-conflict villages.

As per responses from the FGDs, human-wildlife conflicts were present in all parts of Lahaul from species such as the diminutive pika damaging cauliflower seedlings, to brown bears damaging apple. Losses also included an increasing free-ranging dog population that caused damage by trampling and digging at different crop stages. Similarly, livestock losses also were present in all areas where local livestock as well as that belonging to the transhumant Gaddi community fell prey to predators such as the snow leopard, wolf and brown bear.

The amount of crop produce lost to bears was highest among all reported species. The Himalayan brown bears occur throughout the Lahaul Valley, and the black bears occur towards the south-western end neighbouring Chamba. However, of the of the 78 sampled villages, conflicts were prevalent only in 24 of them, most of which were on the left bank of the Chandrabhaga River, in the Pattan belt. The levels of conflict in these 24 villages varied, from very low (3 to 140 Kg of overall losses to crops per village), to medium (41.6 to 320 Kg) and high (403 to 1958 Kg). Despite these losses, it was interesting to find that farmers in Lahaul perceived weather-related calamities, market access and diseases as greater challenges to cultivation than human-wildlife conflicts, even in the conflict hotspots in the Pattan region. The coarse monetary losses estimated amounted to only about 1% of the agricultural income (which is estimated to be Rs 94.38 crores in Lahaul) but for some affected households it could be significant.

Our results showed that the villages vulnerable to conflicts were surrounded by patches of forests and rugged canyons. Further, it was evident that the amount of agricultural land and even the quantity of palatable crops such as green peas and apple did not differ between the conflict and non-conflict villages. This suggests that palatable crops were present in all villages but those that were close to the rugged forests, which are likely to offer better food in terms of berries and herbs, shelter in the warm part of the day, security from disturbance and denning in the rocky crevasses contribute to making them more attractive and thus more vulnerable to crop foraging by bears.

Agriculture has led to significant transformations in local livelihoods in Lahaul and it is evident that an increase in acreage under highly palatable crops such as apple and iceberg lettuce may have been at the root of the reported increase in conflicts since the mid-2000s. While apple acreage and production in conflict and non-conflict villages is similar, we speculate that the advent of apple has enhanced the risk

of crop depredation by bears near suitable habitats. This is evident from the reported increase in instances of conflicts since about 2004 when apple acreage grew by about 20 times in the landscape.

Although people seem to have a slightly negative attitude towards the presence of bears in their immediate village surroundings, they are more ambivalent towards its presence in Lahaul in general. People also seem to have an ambivalent attitude towards bear when asked about its utility in tourism. Examining tolerance, or the willingness of an individual to absorb the extra costs of living with wildlife, suggests that even though people in Lahaul were ambivalent towards bears, they have a slightly lesser tolerance towards them. In other words, people are less willing to tolerate bears in events of crop or livestock depredation in and around their village and most people prefer them to be restricted to wildlife sanctuaries and national parks.

Among all explanatory variables, only age was negatively correlated with attitudes. In other words, older people are likely to be more negative. Interestingly, those who had seen the bear had a more positive attitude towards it than those who had not. Tolerance is negatively correlated with age of the respondent and females in general tend to be less tolerant towards bears. As opposed to conventional wisdom, monetary losses, and experience of conflict do not seem to determine tolerance.

Since human-bear conflicts are complex and diverse, there is no one solution to effectively minimise losses and the mitigation strategy should accommodate multiple and diverse sets of approaches. It is reiterated that a simultaneous use of approaches to *prevent* losses, *offset* the losses that still take place and then institute a better *outreach* and *awareness* among all relevant stakeholders is the key to managing this issue. We elaborate on these multi-pronged measures and highlight the importance to follow a landscape-level approach with concerted and converged efforts from the local communities, government departments and programmes like UNDP's SECURE Himalaya project, NGO's and other civil society groups.

Our key recommendation develops with the understanding that some villages will always remain vulnerable due to the presence of suitable bear habitat in their vicinity. While measures such as erecting barriers, deterrents, and guarding can continue to be tried, most of these have considerable limitations. It is thus important to replacing the crops palatable to bears with non-palatable ones. Fortunately, with existing remunerative cash crops such as potato, cauliflower, and broccoli there are other new ones such as asafoetida and value-added traditional crops such as barley, that cannot just match, but increase farmer incomes. This, accompanied by the use of technology to develop early warning measures (e.g., Animal Intrusion Detection and Repellent System) and rapid response teams can help manage conflicts more effectively. Accompanied with responsible community-based wildlife tourism and targeted awareness campaigns suggested in the report, it is hoped that lasting coexistence between people and wildlife can be achieved in Lahaul.

The project recommendations have been deliberated with the Departments of Agriculture, Horticulture, District Administration, Tourism, Forest, and farmers from affected villages whose suggestions have been incorporated. Along with these, other agencies such as UNDP's SECURE Himalaya Programme, which have a longer-term presence in the landscape are already implementing some interventions for conflict mitigation and are willing to try and sustain some of the key suggestions of this project.

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INTRODUCTION





Credits: Rashmi Singh Rana, Kartik Chugh

1.1 Introduction to the Lahaul landscape

The trans-Himalayan region is characterised by a dynamic system of interactions between bio-physical, social, and ecological processes that makes life possible in this otherwise harsh landscape (Wester et al., 2019). The human community is primarily dependent on a mixed crop-livestock agro-pastoral system for their livelihoods and sustenance (Aryal et al., 2014; Singh et al., 1997; Mishra et al., 2001). Other than that, people in these landscapes also rely upon natural resources and forest produce to supplement their livelihoods. In these dynamic social ecological systems (SESs), humans, livestock, and wild predators share common resources, and human activities such as resource extraction and agriculture overlap with that of wild animals. As a result, human-wildlife interactions are pervasive throughout this landscape (Anon, 2008).

A community's interactions with wildlife are not homogenous but can take a multitude of forms (Oommen, 2021). These entanglements could range anywhere on a continuum of positive, negative, and ambivalent. The relationships between humans and non-humans are hardly constant and can deviate based on the context, social relations, lived experiences, history, politics, and geographies. Similarly, human relationship with different animal species or at times even individuals is usually not the same (e.g., Govindrajan, 2018). While some animal species involved in 'misbehaviour' may be villainized invoking antagonism, others involved in the same may be granted more tolerance. In other cases, one can feel animosity towards some species and yet continue to tolerate them because of their cultural, societal, and religious values (e.g., Saraswat et al., 2015; Oomen, 2021).

Negative interactions between humans and animals often result in situations of conflict between the two. Forms of human-wildlife conflict (HWC) are pervasive throughout the world and can vary from species to situations ranging from crop depredation by tiny lagomorphs such as pika (e.g., Khan & Smythe, 1980) to human casualties by leopards (Naha et al., 2018). HWC can also vary in terms of its impact from severe to minor, and in frequency from rare to common (Nyhus, 2016). In case of Upper Spiti Landscape, for instance, livestock depredation by feral dogs and Snow leopards is common but less concerning, whereas conflict with wolves is relatively infrequent but can provoke stronger reactions (Suryavanshi et al., 2013). While HWC is usually produced from negative interactions, it is important to remember that it could also be rooted in power differentials between groups having divergent aspirations and perceptions towards nature (Hill, 2004).

HWC can inflict severe costs upon both the humans and the animals involved. People cohabiting the landscape with wildlife might suffer from crop loss, livestock depredation, damage to property, disease transmission to livestock, lethal attacks, and hidden or opportunity costs (Barua et al., 2013) involving decreased physical and psychological well-being, increased workload, and decreased nutritional status (Ogra, 2008). The disruption of livelihoods and psychological well-being coupled with financial losses and food insecurity, can prompt people to react violently. People often turn to lethal control of the conflict species by indulging in retaliatory killing, hunting, and poaching. As a result, HWC poses a significant threat to the population of many wildlife species (Dickman, 2010).

HWC has been recognized as a global challenge requiring multidisciplinary and trans-disciplinary endeavour (Game et al., 2014; NWAP, 2017). Understanding and resolving conflicts is no longer limited to conservation sciences but also requires active inputs, perspectives and methods from humanities. Geographers, sociologists, and anthropologists, for instance, can unravel the underlying drivers and causes of conflict by documenting changes in socioeconomic metrics and cultural values. They can evaluate the intensity of the conflict by assessing spatial and social distribution of crop and livestock damage (Naughton-Treves & Treves, 2005). And they can also illuminate the socio-psychological drivers that shape people's perceptions towards conflict animals.

The conflicts between humans and animals have been increasing in many parts of the developing world and in the coming years, this, and its impacts are likely to intensify (Manfredo, 2015). The same is also

true for the Himalaya. Unsurprisingly, scientific research referring to Human-wildlife conflict in Himalaya (Sharma et al., 2021) and globally (Nyhus 2016) has also seen an exponential growth over the last two decades.

The drivers behind HWC are myriad and complex, and include ecological and biological factors such as age and sex of the individual, resource availability, distribution of food, water and shelter, and spatial distribution of the species. Anthropogenic factors comprise increasing human population, urbanisation, agricultural intensification, and land use change which have resulted in habitat loss for animals.

Over the last few decades, large swathes of Himalayas have undergone massive transformations in terms of land use change, cropping patterns, and market accessibility (Wester et al., 2019). There has been a surge in agriculture, and farmers have shifted from cultivating subsistence crops such as buckwheat and barley, towards more lucrative, high-value cash crops such as fruits and potatoes (Singh et al., 1997; Wangchuk & Siebert, 2013). Factors such as improved access to markets, infrastructural development, technology, and expansion of cooperatives have facilitated these transformations. Livestock herding is also experiencing drastic changes in this landscape in terms of spatiotemporal migratory patterns, stock abundance and composition (Singh et al., 2015; Dolker, 2022).

While a shift towards high-value agriculture can enhance local livelihoods, the transformations in social-ecological systems can also create vulnerabilities and affect livelihoods negatively. An escalation in human-wildlife conflict owing to a shift towards cash crops is also documented by Hill (2004). Recent transformations in the intricate and delicate SES have produced novel threats to agriculture and livestock management regimes as well. These problems include climate change, failing soil fertility, infestation by pests and diseases, labour deficiency, and shrinking pasturelands (Katoch, 2022; Poudel, 2020; Sharma, 2011; Wester et al., 2019). Although HWC is not the only challenge faced by the dynamic crop-livestock agricultural system of the Himalaya, it is perceived as one of the most pressing issues for livelihood security and biodiversity conservation (Mishra, 1997).

It is crucial therefore to mitigate this issue for the welfare of both the humans and the ecosystem. A wide range of technical solutions consisting of lethal and non-lethal approaches have been proposed to prevent conflict or to reduce its frequency and severity. These measures have largely proven useful but remain inadequate in promoting long-term resolution and coexistence (Osborn & Hill, 2005). This is because the drivers of conflict have multiple facets, and their non-linear interaction is fraught with complexity (Dickman, 2010; Game et al., 2014).

To understand the complexity of HWC more comprehensively, it is important to engage with the human/social dimensions of conflicts. As argued by Hill (2004), mitigation of HWC requires an exhaustive understanding of the perceptions and viewpoints of various stakeholders including those affected by it. Equally important is to understand the perception of the problem in terms of its extent, risk, and loss as there is often a mismatch between perceived risk/loss and the actual magnitude of risk/loss (Dickman, 2010). And finally, to better understand conflict, an attempt should be made to address deeper relationships with animals, determine attitude and tolerance of stakeholders and discern the factors driving these attitudes and tolerance (Kansky et al, 2016; Manfredo, 2015).

While several attempts have been made to understand multiple facets of HWC in the Himalaya (Sharma et al., 2021), little attention has been paid to the region of Lahaul because of its relative inaccessibility. But with the opening of Atal tunnel underneath the Rohtang Pass in Himachal Pradesh (Bodh & Mehta, 2018), Lahaul has not only become more connected and accessible, but it has also undergone massive transformations in terms of livelihoods, development, and markets. During the same time, conflict with wildlife has started to become prominent. So, to arrive at a profound understanding of myriad aspects of HWC in Lahaul, and to develop a mitigation plan to reduce this conflict, an interdisciplinary approach was utilised to design an exhaustive study combining ecological as well as social components of conflict. This study would help us develop socio-economic baselines to better understand the community's dependence on agriculture and livestock, transformations in livelihoods, and the current challenges to the crop-livestock agriculture system. It would further enable us to understand the extent, magnitude, spatiality, and seasonality of conflict with different animals, the socio-economic and ecological drivers behind conflict, people's attitudes, perceptions, and tolerance towards conflict

species, socio-psychological factors that shape these attitudes, current state of awareness and knowledge of various schemes and policies, and mitigation strategies used by the community and their effectiveness.

1.2 Study Objectives

To understand the current state of HWC in Lahaul and its various aspects, following objectives were identified:

1) To generate knowledge on patterns, processes and drivers of human-wildlife conflicts so that more robust mitigation measures can be designed for securing local livelihoods in the future.

2) To create baselines for socio-economic indicators of the resident communities, and for distribution and occupancy of the wildlife.

3) To use the above information and develop an awareness and outreach strategy to disseminate the key messages on prevention and safety to relevant stakeholders, including local communities.

1.3 Study Area

Only a few places in the Himalayas can match the grandeur of what the mystical mountainscape of Lahaul offers. Situated between the Greater Himalaya and the trans-Himalaya, Lahaul is a transition zone characterised by valleys with steep and undulating terrain, snow-covered peaks, torrential *nullahs*, and harsh climate. A subdivision of the frontier district of Lahaul & Spiti, Lahaul is separated from Spiti by the Kunzam range in the East. The Baralacha range (Zanskar Range) in the North disjoints it from Ladakh while the Pir Panjal range in the South and its offshoots extending to the Southwest set it apart from the districts of Kullu and Chamba (Bajpai,1987).

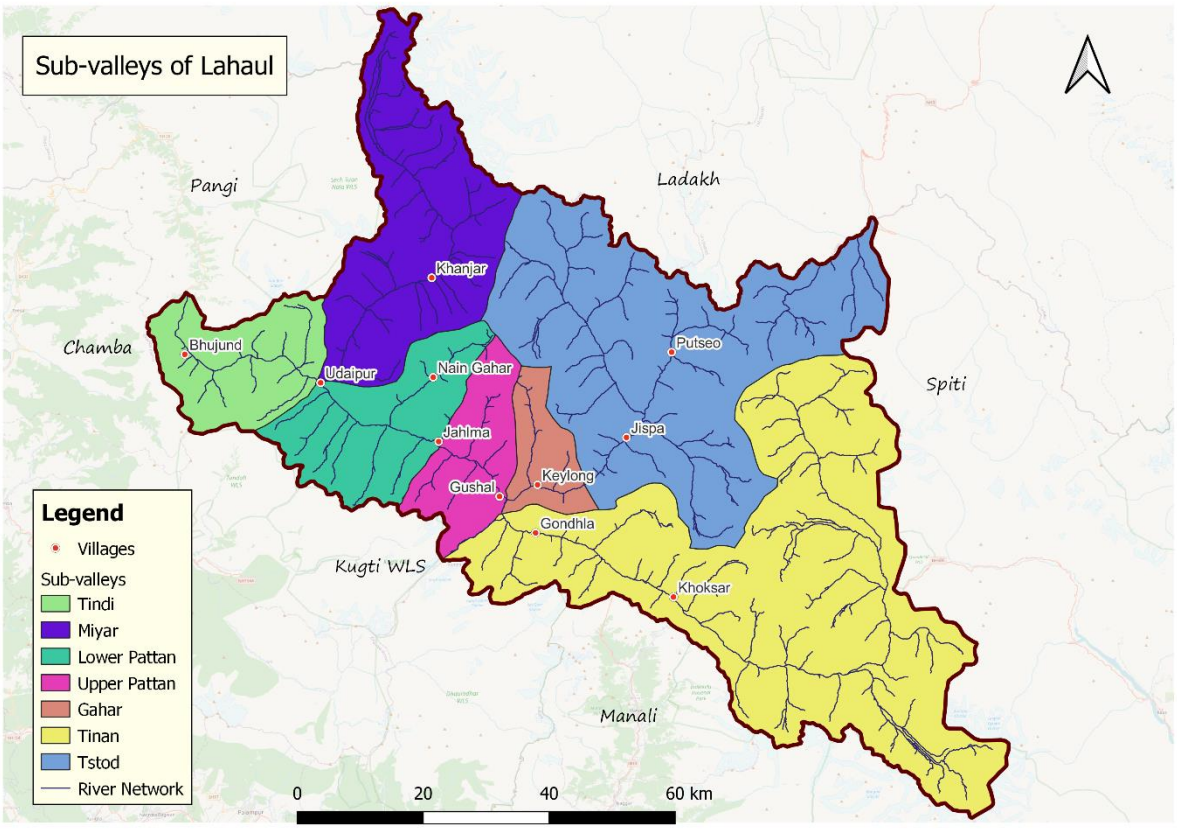
The Lahaul valley comprises a grid of mountains which criss-cross each other in every direction. The average elevation of the terrain is 4717 metres with most peaks ranging between 5480 metres and 6400 metres while most villages are situated at an average elevation of 3082 metres.

There are three major valleys in Lahaul, i.e., Chandra valley, Bhaga valley, and Chandrabhaga valley. Both Chandra and Bhaga rivers originate from the opposite sides of Baralacha Pass. Chandra river first flows to the South-East till Shigri glacier after which it turns North-West and flows near Tandi where it meets the Bhaga River to form Chandrabhaga, popularly known as Chenab further downstream in Jammu & Kashmir (Map 1.1). Also known as Tinan or Rangloi, the valley of river Chandra is considerably barren, and uninhabited towards its emergence. This region has scanty vegetation and largely consists of glaciers, mountain peaks, and icefields. It is only after 75 odd Kms in the valley that the habitation begins. The first village here is called Khoksar. After Khoksar, several villages are located on the right bank of river Chandra with ample pastures and croplands.

Akin to Chandra valley, the upper parts of Bhaga valley are largely barren. From Baralacha Pass, the river Bhaga descends in a narrow gorge until it reaches Darcha, the first village in this valley. Here, the riverbed becomes much wider, and the size of the river increases as it converges with the Zanskar river coming from the North-West. The river then passes through Keylong - the district headquarters – and

flows to its junction at Tandi where it merges with the river Chandra. The part of the valley from Darcha up to Stingiri is locally called Tstod, and beyond that it is known as Gahar.

The valley formed by the confluence of Chandra and Bhaga is called Chandrabhaga valley, locally known as Pattan. Compared to other valleys, the Pattan valley is wider and more fertile. The population is more abundant, and the region abounds with large tracts of cultivation including fruit orchards. Pattan can further be segregated into four segments. The portion of the valley from Tandi up to the village Jahalma is referred to as Upper Pattan and from there up until Udaipur, it is referred to as Lower Pattan. At Udaipur, the river Chandrabhaga is met by one of its major tributaries – the Miyar nallah – from the North. Although the Miyar valley extends up to a 100 Kms until the Kang La (Pass) which connects Lahaul to Zanskar, there are only a few habitations closer to Udaipur in this valley. Moving westwards along the river Chandrabhaga from Udaipur until Bhujund, which is the last inhabited village of Lahaul, the valley is popularly known as Tindi (see Map 1.1), downstream of which is the Pangi region of the Chamba District of HP.



Map 1.1 The seven sub-valleys of the Lahaul block, Himachal Pradesh. Our study design ensured sampling of villages across all the seven sub-valleys.

The climate of the region is dry temperate to alpine (Aswal & Mehrota, 1994) with temperatures ranging between a maximum of 27 °C in summers to a minimum of -13 °C in winters (Sharief et al., 2020). Being in a rain shadow area, the summer is largely rainless, and the monsoon receives scanty showers. The winter lasts longer and receives heavy snowfall. Early winters and heavy snowfall also mean that the cultivation period is small, and the cropping cycle is limited to sowing of one crop. However, moving westwards into the Pattan valley, the elevation decreases and with it the rigours of climate. This allows farmers in Pattan to sow their fields twice in one season.

Due to its harsh climatic conditions and poor soil, the vegetation cover in Lahaul is sparse (Rawat et al., 2010). In the Chandra sub-valley, the vegetation cover comprises meadows and steppe, especially

on the drier south facing slopes of the right bank. It is only after Sissu that a few *shur* or Juniper *(Juniperus recurva syn. J. macropoda)* trees begin to appear. On the left banks, *chiat* or pine *(Pinus wallichiana)* and *bhiy* or birch *(Betula utilis)* occur in scattered patches. On the moister northern aspects, mostly on the left bank of Chandrabhaga, the soil is more fertile encouraging denser patches of forests, and these parches become larger as one goes downstream. Consequently, the northern aspect has a greater biodiversity and density of vegetation than its southern counterpart. In the main Chandrabhaga valley, between Tandi and Udaipur, the northern slopes (left bank) are forested with *diyar* or *deodar (Cedrus deodara), rie (Abies pindrow), tosh (Picea smithiana), chiat or kail* and birch, whereas open woodland of *shur* (*Juniperus spp*) is dominant on the southern slopes (right bank) (Singh et al., 1997). There is a marked difference between the left (northern) and the right (southern) bank of Chandrabhaga, not only in terms of vegetation but also terrain. The left bank is more rugged with steeper slopes, contains more ridges, and retains more snowfall. Apart from the forests, the land cover of Lahaul also hosts patches of rich grasslands and alpine vegetation. The alpine zone (above 3300m) hosts scanty vegetation of pine, birch, juniper and *Rhododendron campanulatum.*

Sea buckthorn (*Hippophae rhamnoides*) is another important shrub species that can be found pervasively along the Miyar and Bhaga sub-valleys. The products made of sea buckthorn have recently started providing economic benefits to the locals. Locals also grow several species of *beli* or willow (*Salix spp*) and *safeda* or poplar (*Populus spp)* plantations in and around the villages, especially along the agricultural fields to help meet fuel and fodder needs.

Lahaul is also rich in faunal diversity. Prominent mammalian species present here include the Himalayan Red Fox (*Vulpes vulpes montana*), Snow Leopard (*Panthera uncia*), Himalayan Palm Civet (*Paguma larvata*), Himalayan Brown Bear (*Ursusarctosis abellinus*), Himalayan Black Bear (*Ursus thibetanus laniger*), Yellow throated Marten (*Martes flavigula*), Himalayan Ibex (*Capra sibrica*), Bharal (*Pseudois nayaur*), Himalayan Musk Deer (*Moschus leucogaster*), Himalayan Tahr (*Hemitragus jemlahicus*), etc. (Sharma et al., 2019).

The local communities in Lahaul practise an agro-pastoral livelihood with reliance on forests and grasslands. Livestock rearing is carried out for sustenance mostly as it provides essential produce such as milk, wool, manure, and labour. Agriculture is the main source of income and in the last few decades, it has turned commercial with the introduction of cash crops such as green peas, cauliflower, and iceberg lettuce. With the construction of Atal tunnel, tourism has also picked up in the last few years as an alternate source of livelihood.

1.4 Methods

To minimise negative human-wildlife interactions and to develop mitigation strategies, it is important to first develop socio-economic baselines of the local agrarian communities, and then to understand the patterns, processes, and drivers of conflict. To achieve that, a mixed method approach was employed wherein social surveys were conducted and secondary data was collected by the project team. An overview of the Study design in the form of a flowchart can be found in Figure 1.1.

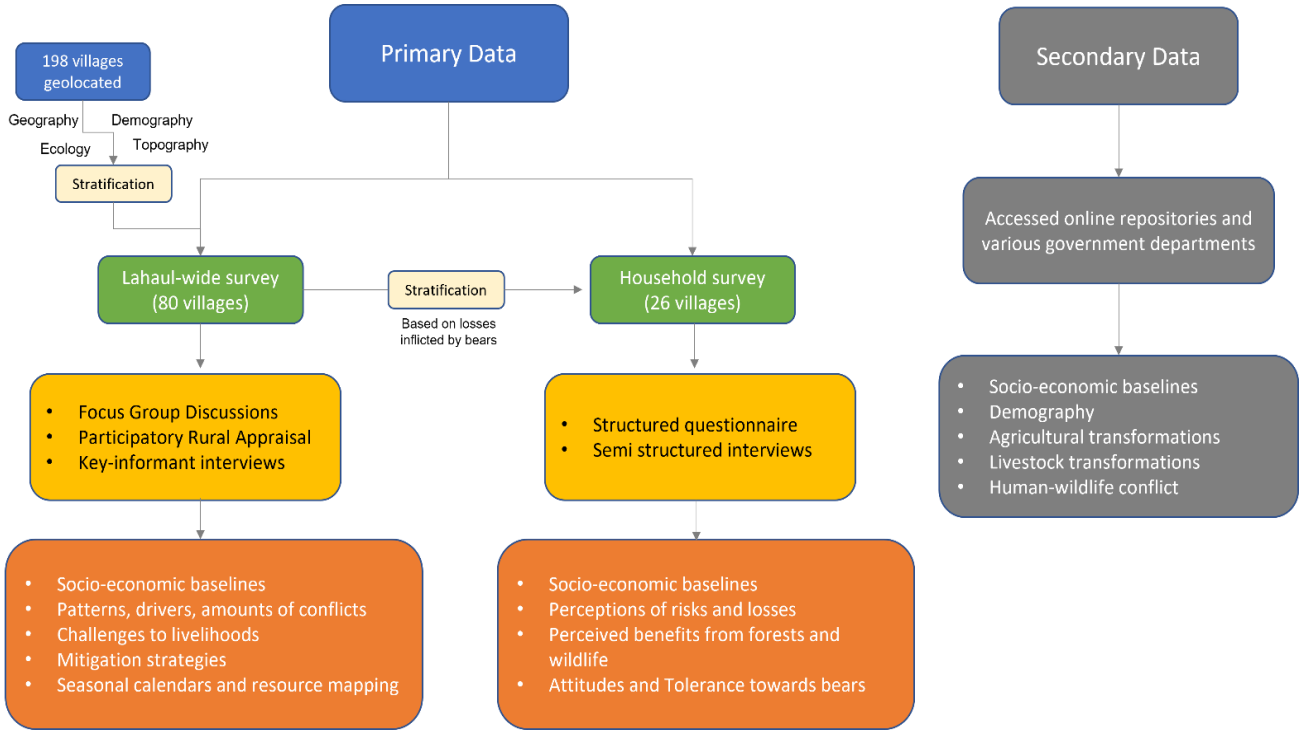


Figure 1.1 An overview of study design. A systematic approach was followed to first collect secondary data from online repositories and government departments, after which villages in Lahaul were stratified for landscape level survey. Based on a preliminary analysis, a third of these villages were sampled again for household survey.

1.4.1 Data Collection

1. Secondary Data: Various government and nongovernment data repositories were accessed online to collect socio-economic, demographic, as well as historical data on agricultural production and livestock reliance. Line departments such as the Horticulture department, Agriculture department, Statistics department, Forest department, and Animal husbandry department were approached to collect relevant socioeconomic data including their official mandates, schemes, and trends in agriculture and livestock management. We also gathered all available data on instances of conflicts with wildlife between 2000 and 2021.

2. Primary Data: A toolkit consisting of Focus Group Discussion (FGD), structured questionnaire, key-informant interviews and unstructured conversations was utilised to collect primary data from 78 villages in the landscape between July and December 2021. The primary data was collected in two phases. The first phase of the survey was conducted at a landscape level where individual villages acted as data points, whereas the second phase involved collecting more granular data at the household level.

First phase: Lahaul-wide survey

The primary objective of the Lahaul-wide survey was to get information on socio-economic baselines, and patterns, drivers, and amounts of conflicts. To carry out this phase of fieldwork, around 198 inhabited villages in Lahaul were first geolocated using QGIS 3.22.2 software. Out of these, 40% of

villages (80 in total) were selected for the social survey based on stratified random sampling. The villages were sampled based on the following stratification criteria:

i) Stratification based on topographical and ecological features:
The landscape was first divided into seven broad valleys. A representative percentage of villages were selected from each valley contingent to its size, i.e., the total number of villages it contained. For each valley, the villages were further stratified based on topographical and ecological variations such as the left and the right bank of rivers and *nullahs*, proximity to forests, elevation, and accessibility.

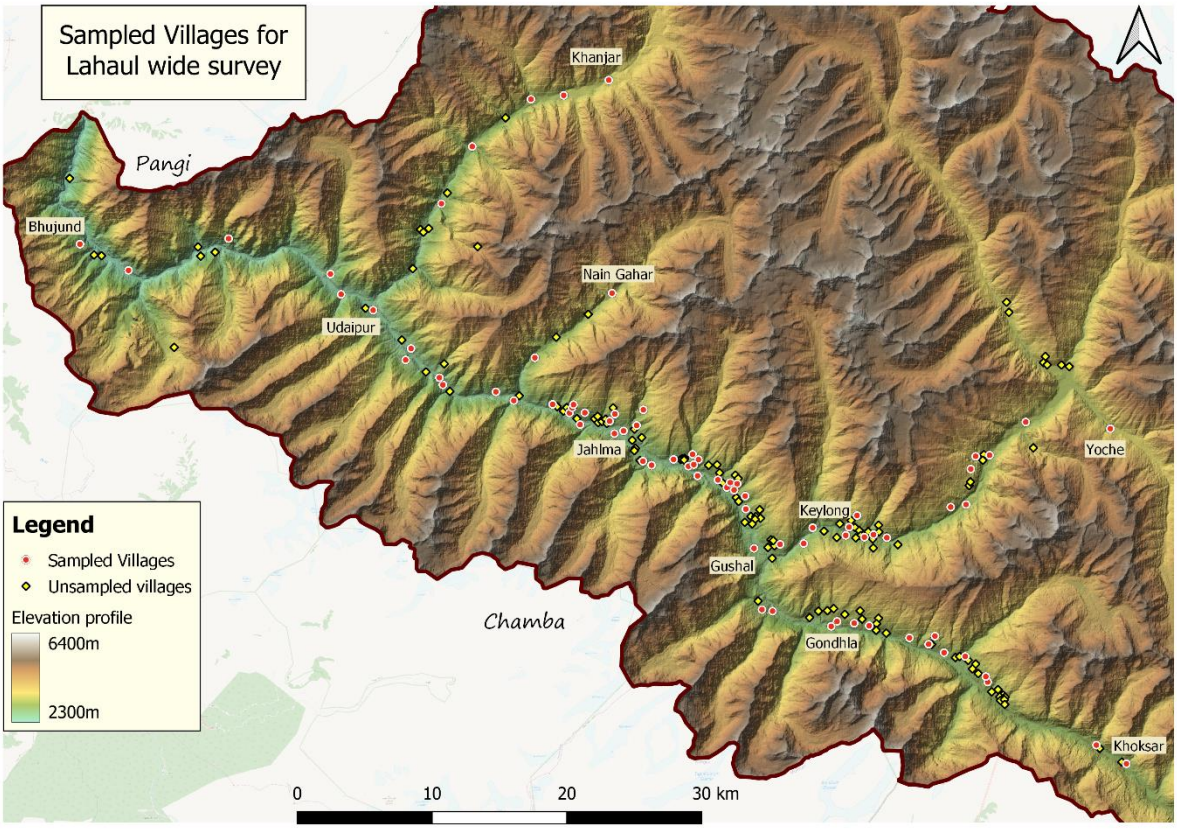
ii) Stratification based on village demography:
The villages were further stratified based on the size of the village (total households), caste composition, and religious diversity.

The stratification done using this approach ensured that the entire spatial, topographical, ecological and demographic extent of the landscape was represented.

Focus Group Discussions (FGDs): The first phase of the fieldwork involved collecting coarser village-level data for the landscape. Two teams consisting of two researchers and a field assistant each were formed. The field assistants were familiarised with the questionnaire and trained to assist the researchers in conducting FGDs. The team piloted mock FGDs with the community to evaluate the feasibility, and duration of the questionnaire and to identify design issues. With the help of community feedback, the questionnaire schedule was improved and fine-tuned to be more effective. The sampled villages were approached and accessed by the two teams with the help of local field assistants. The members of the *mahila mandal* of the respective villages along with the field assistants helped in mobilising groups and organising meetings. Great care was taken to ensure that the group was representative of the entire village in terms of gender composition, age, and social structure. However, there were instances (two) when we could not achieve the desired representation because of the unavailability of villagers owing to the cropping season.

A total of 93 FGDs were conducted in 78 census villages (Map 1.2), with a participation of 823 people out of which 51% were males and 49% females. The average duration of an FGD was 95 minutes (± 28 minutes). Of the shortlisted 80 sampling villages, two villages could not be covered because of unavailability of people during our time there. The details of the sampled villages can be found in the Annexure 1.

For any given village, the participants were asked questions regarding agriculture, livestock, transformations, migration, challenges to livelihoods, conflicts, and mitigation. Participatory Rural Appraisal (PRA) tools (Cavestro, 2003) such as resource mapping, ranking, key-informant conversations, and seasonal diagrams were employed to gain insights about the villages, their cropping seasons, and the problems they faced in agriculture and livestock management.



Map 1.2 Locations of all the 78 sampled villages in the first phase of Lahaul-wide survey.

Second phase: Household-level survey

The second phase of the survey was carried out at the scale of a household. Of the 78 census villages sampled for landscape level survey, the household level questionnaire was administered to 26 villages (33%). The objective of this survey was to gain more granular information on household level losses, and to gauge attitudes and tolerance of people towards bears, their perceptions of risks and losses from bears, perceptions of benefits from wildlife and forests, mitigation measures and their efficacy, and challenges to livelihoods. From each village, we aimed to interview 25-30% of the total households. Snowball and convenience sampling methods were used to select the households in any given village. This sampling approach was utilised since a lot of people were unavailable during that time sowing to the harvesting season. From each household, only one member was interviewed. A total of 179 interviews were conducted between 14 November 2022 and 30 November 2022 where females constituted 31% of the respondents, and males 69%.

The 26 villages for the household survey were selected based on the following sampling criteria (also see Figure 1.2 and Map 1.3) Details of these villages can be found in Annexure 1.

i) From the preliminary analysis of FGDs, the 78 villages were first categorised into 4 levels of conflict – High, Moderate, Low, and None. The categorisation was based on monetary losses caused by bears in agriculture in the year 2020 in each village. The thresholds for each category were drawn based on the percentile distribution of data. The villages where the monetary loss data was missing or incomplete were subjectively placed in these categories by the researchers based on their collective experiences in these villages (Figure 1.2). A total of 8 high crop-damage related conflict villages, 5 moderate conflict villages, and 11 low conflict villages were

recognised. 51 villages faced no conflict with bears and the remaining 3 had only suffered livestock losses.

ii) All the high and moderate conflict villages were selected for the household level survey. Five low conflict villages, and five no conflict villages were selected. And finally, all the three villages which faced only livestock losses in the last 5 years were selected as they formed a unique category of conflict where interactions with bears were only limited to spaces outside the village.

iii) The low conflict and zero conflict villages were randomly stratified from different valleys to ensure that the spatial extent of the landscape was represented.

iv) Villages where bear conflict was limited to only one or two hamlets were not entirely sampled. Instead, only the hamlets which faced conflicts were interviewed.

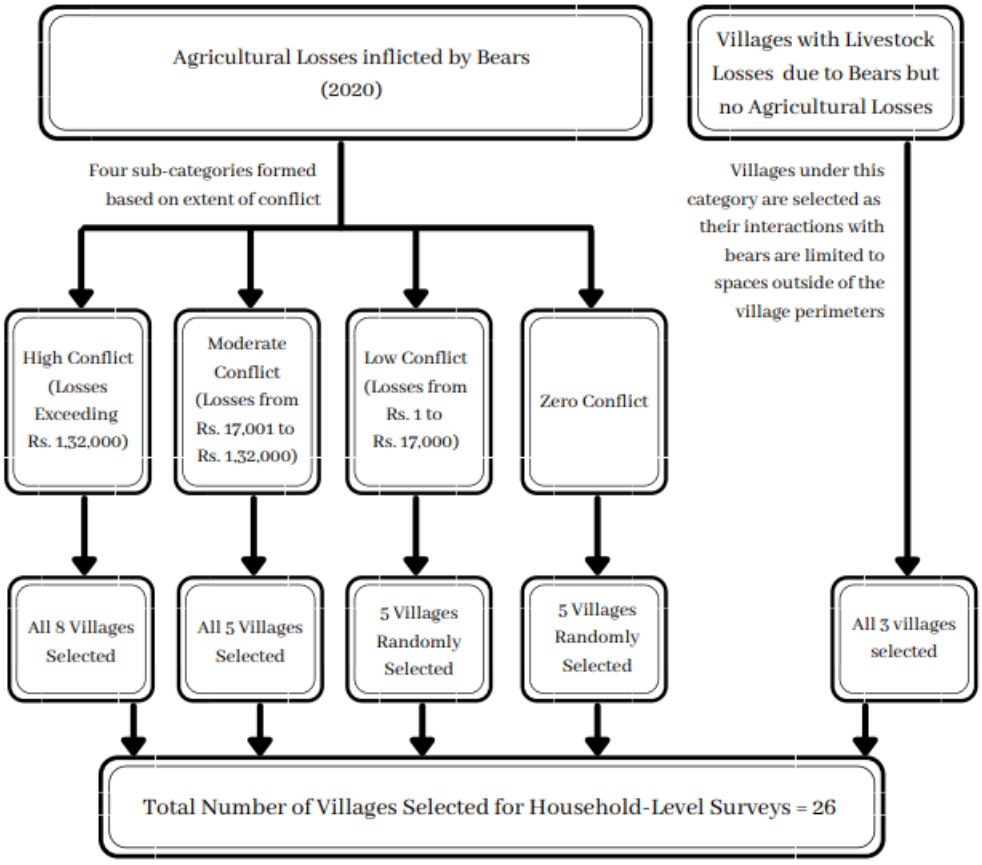
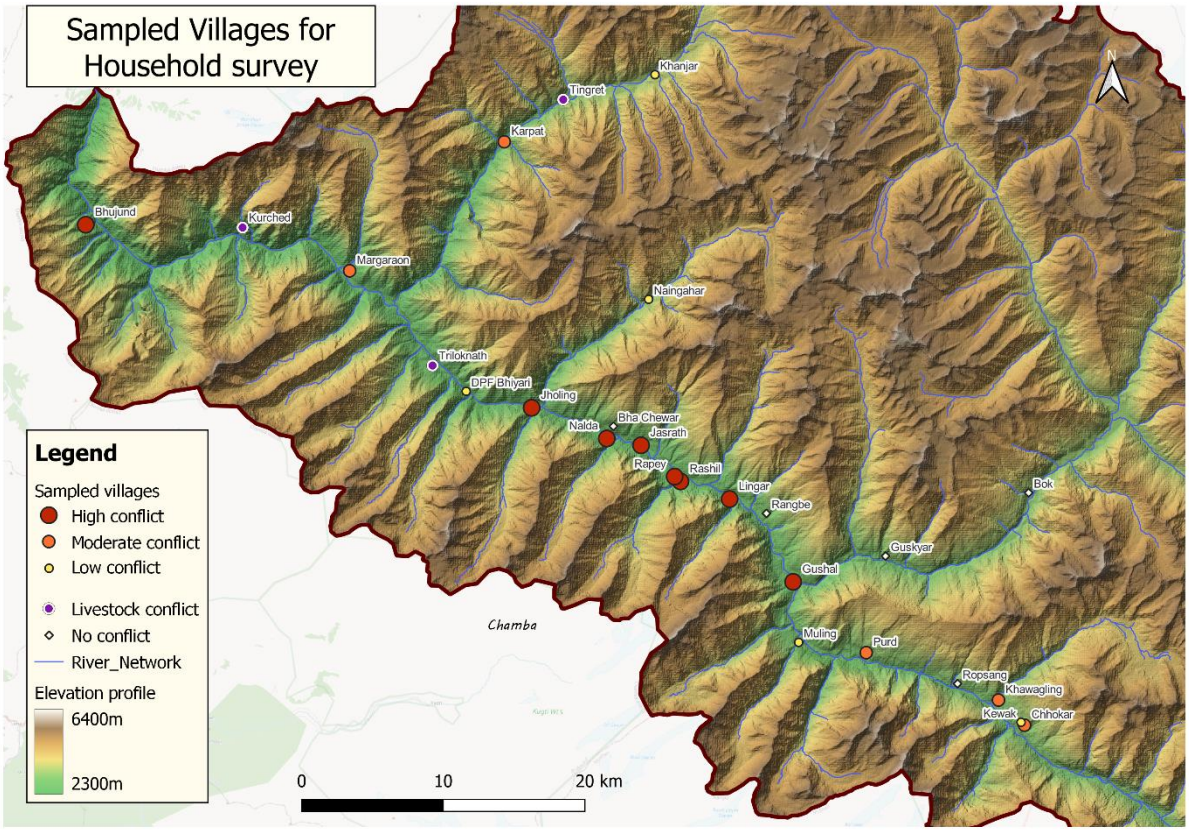


Figure 1.2 Sampling criteria for Household level survey.



Map 1.3 Locations of the 26 villages sampled during the second phase of household-level survey.

Apart from the survey questionnaire, the household level survey also deployed open-ended, in-depth, semi-structured interviews to qualitatively understand the intangible as well as historical and cultural aspects of human-wildlife interactions, forests, resource use, encounters with bears, and to gain insights about local knowledge about wildlife. The data for the household level questionnaire was recorded on a mobile application called KoboCollect (KoBo Toolbox www.kobotoolbox.org).

1.4.2 Data processing and analyses

For the purpose of reliable data analyses, some data inputs had to be derived as follows:

a) The information on total acreage of a given village was asked during the FGDs since the census data for the same from 2011 was outdated. However, many times the respondents couldn't come up with an accurate figure. Therefore, agricultural area was digitised for each village using QGIS 3.22.2 software. For some villages, however, it was difficult to demarcate boundaries. To solve this problem, the FGD data on acreage was triangulated with both the digitised data from QGIS and when needed, with census 2011. In cases where we found stark differences between the reported figures and the digitised figures, an attempt was made to reconfirm the acreage from the village. The acreage reported by any village community served as the primary data source.

b) An effort was made to standardise reported losses of apples and damage to trees in kilograms. In many cases of bear-related damage, losses to apples were reported in unit trees. This could range from the complete damage of a tree to damage of a few branches or just a few fruits. Loss

of branches can affect the productivity of a tree for numerous years. Accounting for these externalities in the amount of loss was beyond the scope of this study. In cases where people could not report losses in terms of quantum of apple, but reported number of trees damaged, we used a maximum estimate of 18.5 kg (of apple) following Sharma and Chauhan (2008). This estimate was also close to the average output of a tree reported by our respondents. But in cases where the reported loss was only of a few branches, we used an estimate of 25% of the potential output, i.e., 4.6 kg (25% of 18.5 kg). It is important to note, however, that the breakage of branches have repercussions extending beyond a single year.

c) To estimate crop-related monetary losses, we have used the product of the reported selling price of each crop in the year 2020 with the reported or estimated quantity of loss (in kg) for the crop. But in cases where the respondents were able to report the monetary loss for a crop, the reported monetary estimate was used.

d) To calculate monetary losses for livestock depredation by wildlife, we used the average rates of two different years (between 2015 and 2020) provided by the Animal Husbandry Department in Lahaul.

e) While collecting information about transformations in agriculture, we found that it was more intuitive for respondents to answer in percentages of total village area or their own ownership, rather than Hectares of Bighas. Respondents could tell the percentage of a particular crop grown in a village for a given year more easily than the acreage of land on which that crop was cultivated that year. The proportions were converted to acres based on the total agricultural land reported by respondents for a given year.

f) To understand the drivers of conflict, some ecological and topographical layers had to be derived using QGIS 3.2.22 software (Table 1.1).

Table 1.1 Ecological and topographic GIS layers used as covariates to understand human-bear conflicts, human attitudes towards bears, and their respective sources.

Layer	Source
River Network	Open Street Maps
Forest layer	Esri Global LULC Sentinel 10m
Digital Elevation Model	ALOS World 3D 30m
Ruggedness index	ALOS World 3D 30m
Agricultural land	Digitized using Sentinel-2 imagery 10m
Orchard land	Digitized using Sentinel-2 imagery 10m
Maximum temperature in warmest month	WorldClim 1km
Annual precipitation	WorldClim 1km

The Esri Global LULC model captures “any significant clustering of tall (~15 feet or higher) dense vegetation, typically with a closed or dense canopy” with an overall model accuracy of 86% (Kara et al., 2021). The forest layer was further improved by manually digitising any patches of dense trees that were otherwise missing for our area of interest using Google Earth Pro. Similarly, patches which were

misclassified were also corrected. Wherever there was some doubt regarding the classification, a verification was carried out by the means of ground truthing. It is important to note that the open and young Juniper woodlands, which are prevalent on the right bank of Chandrabhaga, were not classified as forests by Kara et al. (2021) or by us. These woodlands were extensive, with sparse and spread-out Juniper trees and were difficult to map using any available technique. We didn't consider these patches because they are not optimal bear habitat.

Using these layers, various topographical and ecological covariates that were essential to modelling bear conflict in agriculture were derived (Table 1.2). To achieve this, 2kmx2km (or 4 km^2) grids were first laid around the 78 village centroids. The purpose of this step was to characterise each village in terms of the covariates of interest. It was hypothesised that the rivers would act as barriers for bears to cross over to the other bank. Moreover, there was a considerable difference between the topography and ecology of the right and the left bank. Therefore, the grids were manually adjusted in such a manner that they were restricted to the respective bank of the village in question, without spilling over to the other side. A number of covariates–summarised in the table below–were then derived for each village grid using the zonal statistics tool in QGIS.

Table 1.2 List of topographical and ecological covariates derived for characterising the 78 sampled villages.

Covariate	**Statistic**
Forest Area	Sum
Forest Perimeter	Sum
Number of forest patches	Count
Size of forest patches	Mean, Median, Maximum
Farm Area	Sum
Orchard Area	Sum
Total agricultural area	Sum of Forest Area and Orchard Area
Annual precipitation	Mean, Standard deviation
Maximum temperature in the warmest month	Mean, Standard deviation
Elevation	Mean, Median, Standard deviation
Ruggedness index	Mean, Median, Standard deviation
Slope	Mean, Median, Standard deviation
Aspect	Mean
Rugged forest	Sum

Microsoft Excel and R Studio (R Studio team 2021) were used to generate descriptive and summary statistics. R Studio was used to visualise data, run quantitative tests, generate biplots, and build general linear models. Spatial analysis was carried out using QGIS 3.22.2. Qualitative data from the interviews was coded and analysed using QDA Miner Lite.

1.4.3 Ecological Survey

To identify individual bears present in the landscape, to determine their abundance, and to analyse their diet and feeding habits, an ecological survey was planned at the landscape level. The original plan involved forging a partnership with the Forest Department to collect the samples in a more systematic manner. The entire landscape was divided into 5kmx5km grids. The habitable zones for bears were identified and based on that 103 sampling grids were selected for a 5-km search within each. This proposal, however, could not materialise and had to be reconsidered because of field logistic limitations related to covid restriction on movement in 2021 summer and extreme climate events.

The original plan was recalibrated to an opportunistic sampling survey which was carried out by the research teams in and around the 78 sampled villages in Lahaul. The aim was to collect as many samples as possible from the vicinity of these villages. After each FGD, the researchers and field assistants inquired and searched for bear scat and hair samples in and around the village, the agricultural fields, and sometimes in the forest patches nearby. Such an effort ensured that we collected scat samples that could help us identify the nature and proportion of bear feed coming from agricultural crops. An attempt was made to increase the effort by seeking help from volunteers from the Forest Department. To this end, a workshop was conducted in Keylong in July 2021 to train the volunteers.

Team kits and sampling bags (Annexure 1.3) with all necessary equipment were prepared well in advance and distributed among the team members and volunteers. Two samples were collected from each scat: first, for individual identification, and second, for diet analysis respectively. All the details corresponding to the sample like its size, location, and age were recorded on the label of the sampling bag as well as on an ODK data collection form using a mobile application called KoBoCollect. Utmost care was taken not to contaminate any sample.

A total of 111 samples were collected from the landscape between July and November 2021. These were preserved in vials of 95% ethanol for individual identity of bears using genetic tools and in silica gel for diet analysis using metabarcoding. These analyses would be carried out in collaboration with the genetic lab of IISER-Tirupati in the coming months.

1.4.4 Challenges in methods

a) While conducting FGDs, it was difficult, at times, to mobilise people, arrange meetings, and to get proper representation of the village in terms of age, gender, class, and caste since most of the people were unavailable owing to peak cropping season. To overcome this, FGDs had to be arranged late in the evenings or early mornings. The agricultural season in Lahaul is limited to a few months and is extremely intensive. We could not have carried out our survey in winter months because of restricted mobility due to harsh climate and unavailability of inhabitants, most of which out-migrate during winters.

b) Although we utilised PRA tools and FGDs to collect data at the village level, people still found it difficult to remember, and evaluate losses inflicted by bears and other animals at the village level. We thus relied on the discussions among the respondents until a consensus figure was reported. Although this approach compromised the robustness of data, there was no other way to collect this information in such a short time.

c) Estimating the amount for apple loss was a major challenge. We could not get robust figures based on FGDs and interviews as it was difficult for people to estimate the quantity of apples lost as well as assigning monetary value to the loss due to breakage of branches. We attempted to standardise

this error by developing a metric (explained in subsection 1.4.2), but a separate study is warranted to make an accurate assessment of apple loss due to bears.

d) The scope of the project was limited to decipher the direct impacts of human-animal interactions. However, as Ogra (2008) and Barua et al. (2012) have pointed out, there are other 'hidden' or opportunity costs like psychological well-being, and externalities that are uncompensated that should be addressed while understanding human-wildlife conflicts. Although an attempt was made to understand intangibles such as fear and risk perception, a better understanding of opportunity costs is warranted.

CH 2

LIVELIHOODS, TRANSFORMATIONS & CHALLENGES



Credits: Rashmi Singh Rana

2.1 Transformations in Agriculture-Horticulture practices in Lahaul

Like for most mountain-dwelling communities, agriculture has been the backbone of the *Lahaulis*. Commercial agriculture that began in the 1960's was the beginning of Lahaul's prowess into a quick-profit, agriculture-based economy. Every household in the region partakes in agricultural activities throughout the short and strenuous agriculture season of six to eight months. Lahaul is well-known for its off-season production of a variety of exotic and non-exotic vegetables like broccoli, iceberg lettuce, romaine lettuce, leeks, cauliflower, green peas and potatoes. Over the last two decades, horticulture has also come to the forefront of farmers' interests which has materialised as orchards of a variety of apples-Gala, Golden, Dwarf, Spur. Floriculture has also begun but is still in its nascent stages. The present-day scenario of Lahaul's successful and diverse agriculture systems can be credited to the enterprising nature of these people, as well as encouraging incentives and schemes introduced by the government. It is now difficult to imagine that only some decades ago their agricultural land could only grow sustenance crops like barley, buckwheat, wheat and black peas. From 1950's till present-day, Lahaul has witnessed a tremendous transformation from a sustenance agro-pastoral to a largely agricultural cash crop economy. In this section we document the timelines and some of the key processes in this transformation.

2.1.1 Timeline of traditional and introduced crops

Three varieties of barley/ *jaun* and two varieties of buckwheat /*kathu* were the traditional grains that constituted a staple part of the diet in this region. Found across Lahaul, these two crops have thrived in the harshest environment and soil conditions and find their rightful mention in the earliest records of trade from Kullu to Ladakh dating back to 1st millennium A.D. (Diack, 1897 as in Widmer, 2017). These grains formed an integral part of the barter system of *Lahauli* folks in exchange for sustenance essentials like vegetable oil, pulses, rice, sugar, tea etc. Another important traditional grain, namely wheat or *gehun*, was only restricted to the warmer Pattan belt-the fertile valley. Cultivation of black peas or *kala mattar*, *rajmash* and maize were also common preferences in Lahaul in the past. According to the official settlement records of 1912, out of the 1764 sq miles (4569 km^2 or 11,28,960 acres) of the geographical area of Lahaul (which excluded the present-day Udaipur sub-division), only five percent was under cultivation which represented 2900 acres of arable land and 3300 acres of meadow land (Whistler, 1924). Depending solely on the produce and exchange of these grains from meagre cultivable lands must have been indelibly challenging for comfortable sustenance.

It was in 1925 when some progressive farmers of Lahaul brought the seeds of a wild medicinal herb called *Kuth* (*Saussarea lappa*) from Kashmir and successfully domesticated it in their agricultural fields (Kuniyal et al., 2005; Anand, 1961). Kuth became the first cash crop of Lahaul. At the end of a three-years long (two-years in some regions) cultivation cycle, the roots of this perennial herb were removed and sold for as high as Rs. 200 per *maund* (40 kg) in those days. A valuable export since 1935, its high demand in international markets of China, Hong Kong, United Kingdom, Canada, France, Switzerland, Japan and Malaya lead to the establishment of the Lahaul Kuth Growers Co-operative Marketing Society in 1959 (Annexure 2 Table 2.1), and subsequently a research station for kuth was set up in Keylong in 1960 (Anand, 1961; Negi 1981). Manu or *Inula racemose* was another perennial medicinal herb that gained interest from Lahaul's farmers. Although the source of a critical turning point in the agriculture system of Lahaul, the economic returns from kuth and manu could be reaped only after a three- or two-year cultivation period.

Potatoes brought about a revolutionary change in the economy of Lahaul. Introduced for the first time by the Moravian mission stationed in Keylong, the world-renowned disease-free, quality potato was

heralded in 1965 by K.S. Bains, a deputy commissioner, when he brought improved, high yielding varieties of seed potatoes, namely Kufri Jyoti and Kufri Chandramukhi, to Lahaul. To boost potato cultivation and economy, the Lahaul Potato Growers Co-operative Society (or Lahaul Potato Society, LPS) was formed in 1966. This pushed Lahaul's potato production to be as high as 470 quintal per hectare in some progressive farms by 1982-83 (Thakur et al., 1991), with 1166 Ha dedicated to its cultivation. From 1994 till present, potato cultivation showed a slow decline, averaging at 717 Ha. This reduction can be attributed to the eager uptake of newer cash crops like green pea and hops (Figure 2.1).

By late 1980's, cash crops like green pea (replacing the traditional black pea), and hops gained immense popularity in Lahaul. While green pea was sold to the *mandis* in far off Delhi, hops was bought by Mohan Meakins Breweries in Solan within the state. Owing to the high hopes attached with the profitable returns from hops, Hops and Chicory Growers Cooperative cum Processing Society Limited was established in 1975. The year 1994 saw its peak in hops cultivation at 169 Ha, but ever since India began to import hybrid hops varieties from China and USA at significantly cheaper rates, demand for Lahaul's hops crashed, and so did its cultivation over the years. On the other hand, green pea acreage has more than doubled (720 Ha to 1770 Ha) from 1990's to 2010's. Like potato, green peas have continued to thrive as a major cash crop across Lahaul until very recently.

Commercial-level cultivation of cauliflower began in the early 2000's at a very small scale of 13 Ha. By 2015 cauliflower had successfully replaced green pea as the main cash crop, which till present day is reflected in its expansive cultivation averaging at 685 Ha (Figure 2.1). Cauliflower gives significantly higher production of 25 Metric Tonnes per Ha (MT/Ha) with better market prices, compared to green peas (11 MT/Ha). Along with cauliflower, farmers of Lahaul also experimented with exotic crops like broccoli, iceberg lettuce, romaine lettuce, Chinese cabbage, leaks, leafy greens etc. An astounding estimate of 900 Ha of Lahaul was under the cultivation of exotics alone in 2015.

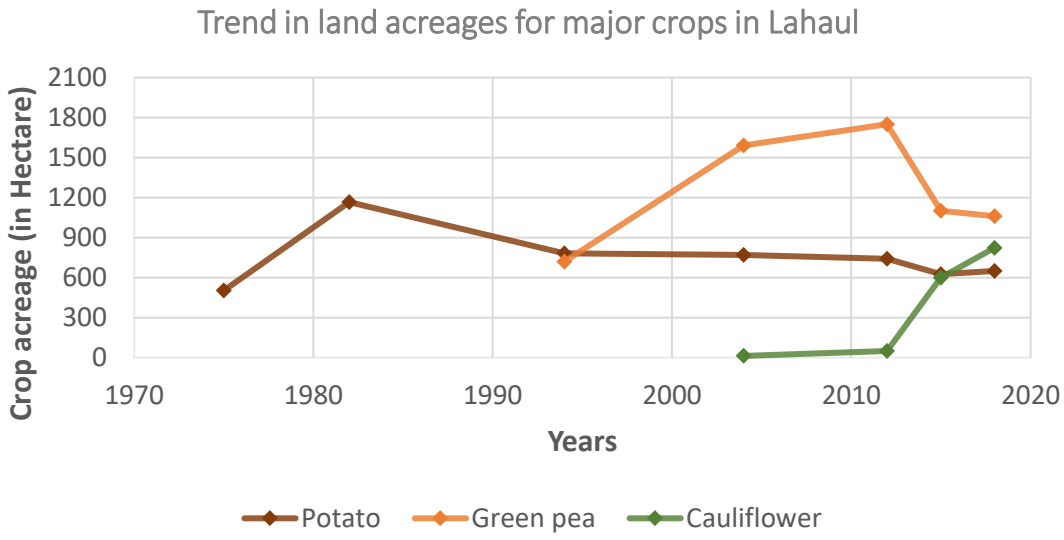
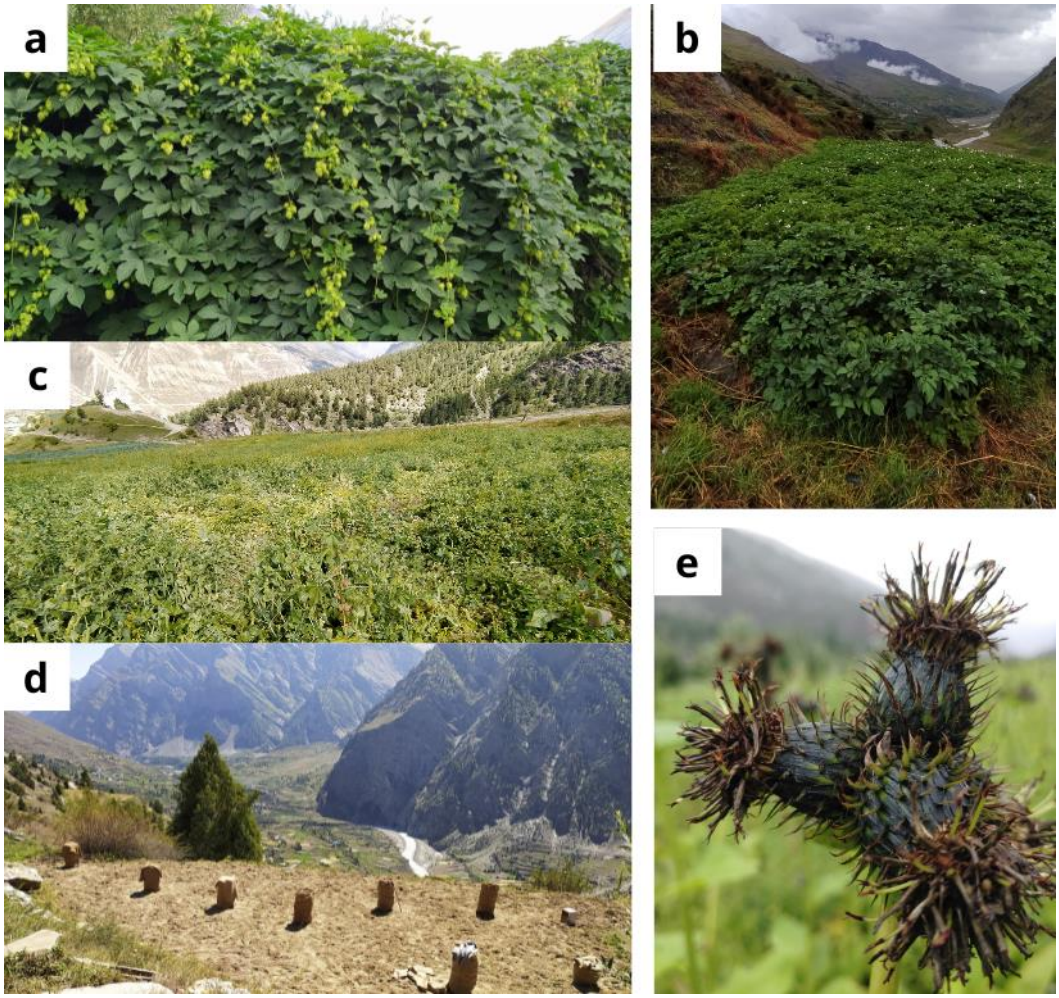


Figure 2.1 Trends in land acreages of major crops like potato, green pea and cauliflower in Lahaul. Introduction of green peas led to a decline in acreage of potato cultivation. Similarly, the popularity of cauliflower over green pea in 2015 can be seen in the sharp increase in cauliflower acreage with a simultaneous decrease in that of green pea. (Source: Distract Statistical Abstracts, and Agriculture department, Keylong)



Credits: Rashmi Singh Rana and Tanuj Nagpal

Image 1. Some of the cash crops introduced in Lahaul between late 1920s and 1980s: a) hops, b) potato, c) green pea, d) potato packaged in gunny bags for sale, and e) kuth.

Following the success of Kinnaur's apples, orchards of apples sprouted in Lahaul in 1975 at a modest scale of just 24 Ha. But in the last two decades (2001-2020), acreage under apple orchards has sky-rocketed by a 20-fold increase, whereas apple production has seen a five-fold increase (Figure 2.2). With the strong support from the state's and district's horticulture sector, and introduction of dwarf (Spur) varieties, the orchards have almost quadrupled in less than a decade (from 2004 to 2011), which has been the steepest jump in apple orchard areas in Lahaul. Although presently Lahaul has about 1500 Ha under apple orchards, its demand in the market is yet to meet its anticipated potential. Moreover, the older varieties of trees are yet to yield their full potential as it takes around 12-15 years for them to mature fully.

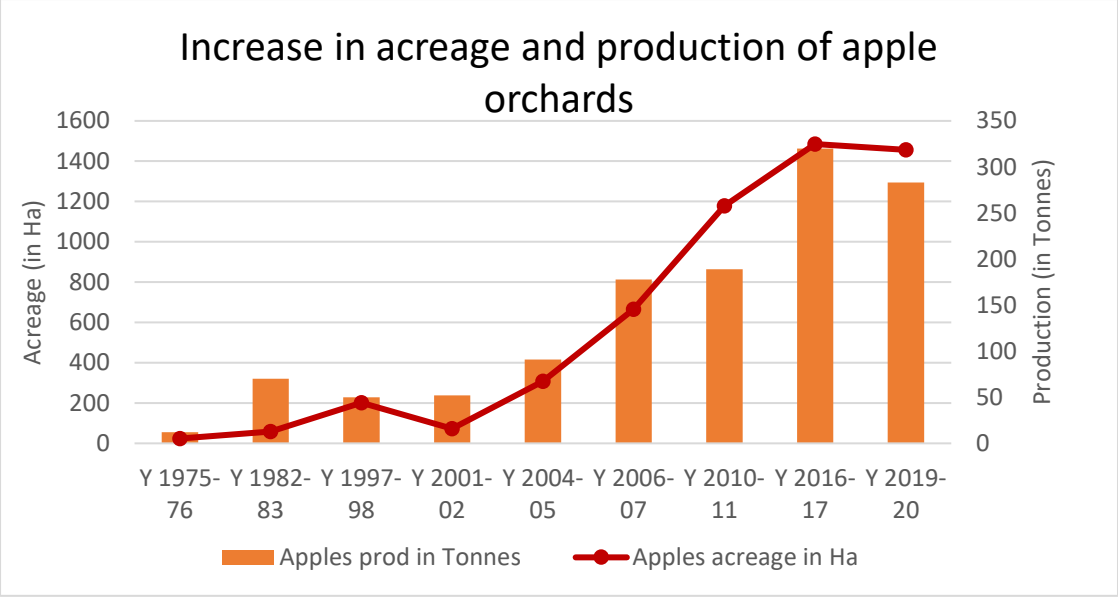


Figure 2.2 Stark increase in the acreage and production values of apples in Lahaul. In the last two decades alone, there has been a 20-fold increase in the orchard acreage and a five-fold increase in production estimates. (Source: District Statistical Abstracts and Agriculture Department, Keylong)

In conclusion, *Lahauli* farmers have always responded in tandem to the market demands of cash crops. So much so that they have almost entirely replaced their traditional crops with economical cash crops, at the same time ensuring diversity in the crops cultivated in any given year (Figure 2.3, also see Annexure Table 2.2 & 2.3). Substitutes for staples like barley and buckwheat are readily available in the local markets- wheat and rice being the common choice. The only traditional sustenance crops that continue to be preferred by farmers in lower, fertile belts are *rajmash* varieties and maize, which are grown at a subsistence scale of about 20 Ha (District Statistical Abstract, 2020 & District Agriculture Department).

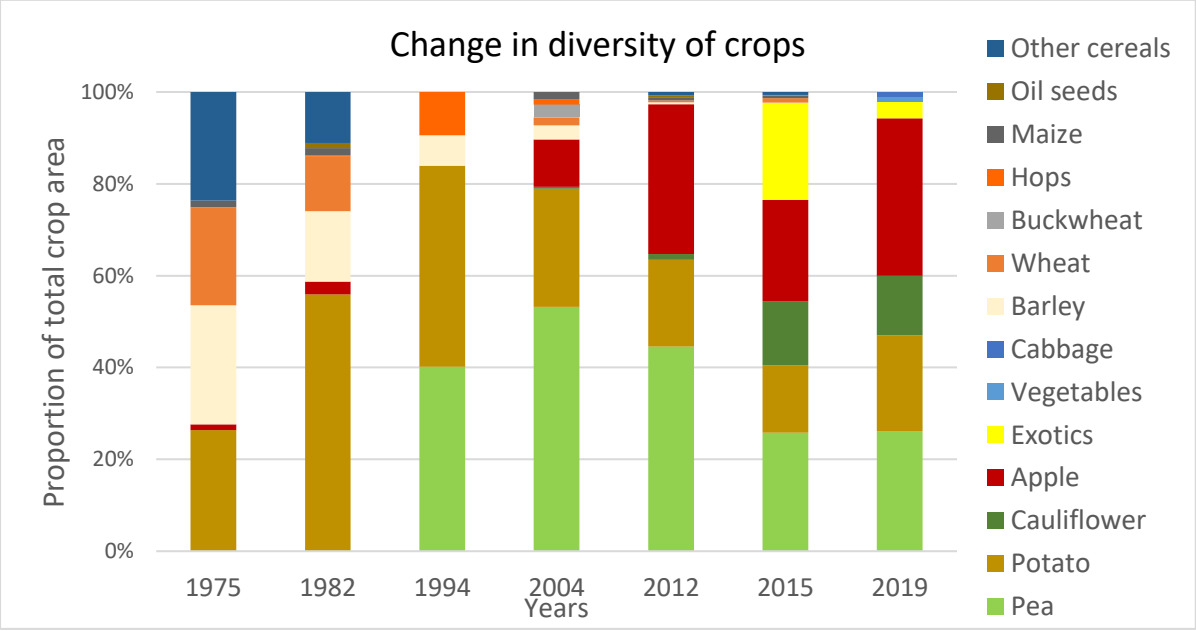


Figure 2.3 Trends in acreage proportions of crops over last decades. There has been a shift in the cropping diversity. Earlier, crops like cereals, barley, wheat and potato were cultivated in comparative proportions. Potato was the dominant cash crop till green peas replaced it. In 1994, large-scale cultivation of green peas and potato was at par. Potato and green pea acreages have reduced to about half in the last two decades. Introduction of apple, exotics and cauliflower has increased crop diversity of crops grown at large-scale. Since 2016, apple

orchards have occupied a dominant portion of agricultural land, although other crops are intercropped with apple. (Source: District Statistical Abstracts and Agriculture Department, Keylong)

Government schemes have strongly supported the enterprising farmers of Lahaul. From subsidised distribution of high yielding variety (HYV) seeds, fertilisers, pesticides, insecticides, farming equipment like power tiller etc., to making land available as *nautod* for household with less than 5 *bigha* agricultural landholding- all this has had a remarkable effect on the intensification of commercial agriculture. It should be noted that arable land is limited by the availability of deep soil, suitable slope, and irrigation in Trans Himalayan areas, which is true for Lahaul too. It is thus challenging to increase arable land. Even so, the net sown area in Lahaul has increased by 20% from 1940 Ha to 2347 Ha between 1982 and 2019 (Figure 2.4). There was a 9% increase in the two decades from 1982 to 1999, and another major increase of 8.6 % in the last decade from 2010 to 2019. There was just a minor increase of 1.5% in the net sown area from 1999 till 2010. These schemes have led to a significant decline (76.5%) in the 'barren unculturable land' and 'fallow land' (82%) since 1982 (Annexure Table 2.4). A reason could be that some of these areas that were previously not used for agricultural purposes have been converted to agricultural land. Singh et al. (1997) mention that due to the shortage of suitable agricultural lands, even relatively unstable areas (with more than 45° slope) were converted for commercial cultivation.

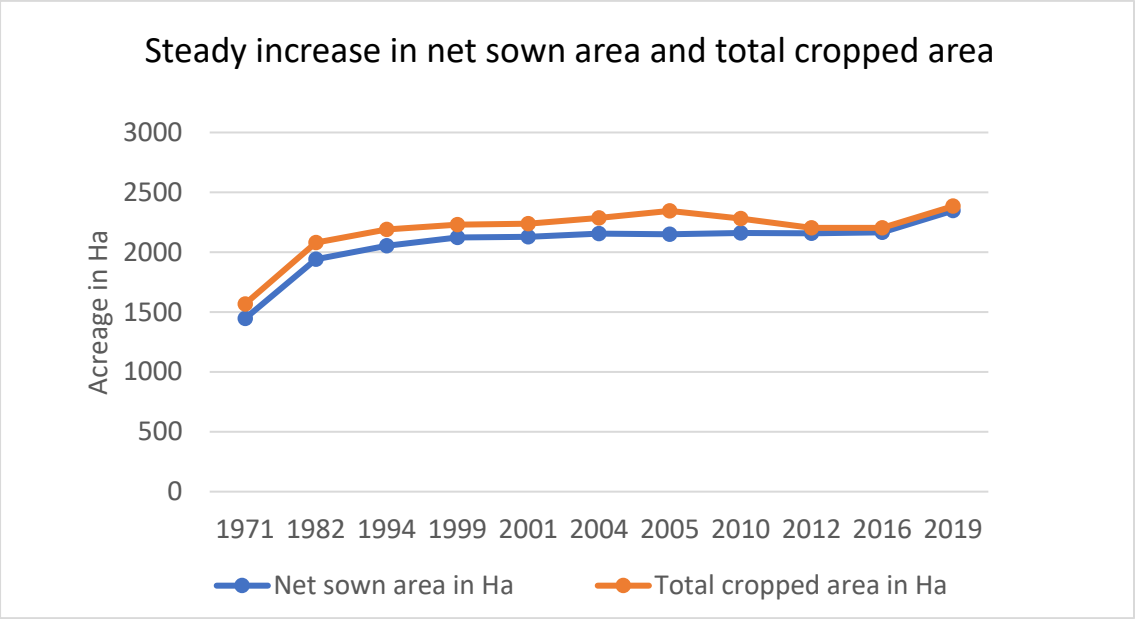


Figure 2.4 Trend in net area under cultivation 'net sown area' and 'total cropped area' which is agricultural area including area required for cultivation twice in one season. Overall, the net sown area and the total cropped area have increased by 20% from 1982 till 2019. (The year 1971 excludes data from Udaipur sub-division as it was not yet part of the Lahaul & Spiti district). (Source: District Statistical Abstracts and District Census Handbooks)

2.1.2 Contemporary scenario of agricultural system

Major cash crops like green pea and potato have shown sharp changes even in the last decade. From 2012 to 2015 green pea production drastically reduced (67%), and overall, in the last decade green pea production has declined by 24% (from 18900 MT to 14335 MT), while its acreage has reduced by 37% (from 1770 Ha to 1110 Ha) (Figure 2.5). In stark contrast, in a short span of three years cauliflower production increased by about 12-fold from 2012 to 2015 (from 1270 MT to 15000 MT), and between 2012 and 2019, there was a massive increase of 1707% from 1140 MT to 19460 MT. Naturally, this is due to the sudden and extant increase in its cultivation area from 50 Ha in 2012 to 824 Ha in 2018

(increase of 1648%. However, there was a slight decline of 33% in this acreage from 2018 to 2019 (Figure 2.6). Interestingly, despite an overall decline in preference to grow potatoes (Figure 2.3), the last decade has seen an increase in acreage as well as production of commercial potato. From 2012 to 2019 potato acreage has increased by 19%, and its production has increased by 43% between 2018 and 2019 (See Annexure Table 2.5 and 2.6 for crop-wise acreage and production estimates).

Farming of exotic vegetables like different types of lettuce are a quick source of good income. These exotics are in high demand by the hotels and restaurants in the tourism belts within the state such as, Manali and Shimla (Anonymous, 2013). Area under cultivation of these exotics had increased by more than 7 times from 20 Ha in 2003 to 150 Ha in 2015, and slight increase by 2 Ha by 2019 (Annexure Table 2.5). However, the published District Statistical Abstracts show a significantly reduced trend in exotic cultivation from the highest recorded estimate of 900 Ha in 2015 to 152 Ha in 2019 (Annexure Table 2.7). Cabbage is a minor cash crop grown in some villages with an average estimate of 46 Ha since 2015, which is nonetheless an increase from the average estimate of 17 Ha in the previous decade (Annexure Table 2.5). Sustenance crops like buckwheat, barley, wheat, maize, *rajmah*, oil seeds and garden vegetables are grown at a very small scale (Annexure Table 2.7). Baseline data for the contemporary agricultural patterns, land holdings, crop-wise acreages, agricultural incomes and village demographic indicators for the 78 sampled villages can be found in Annexure 5.

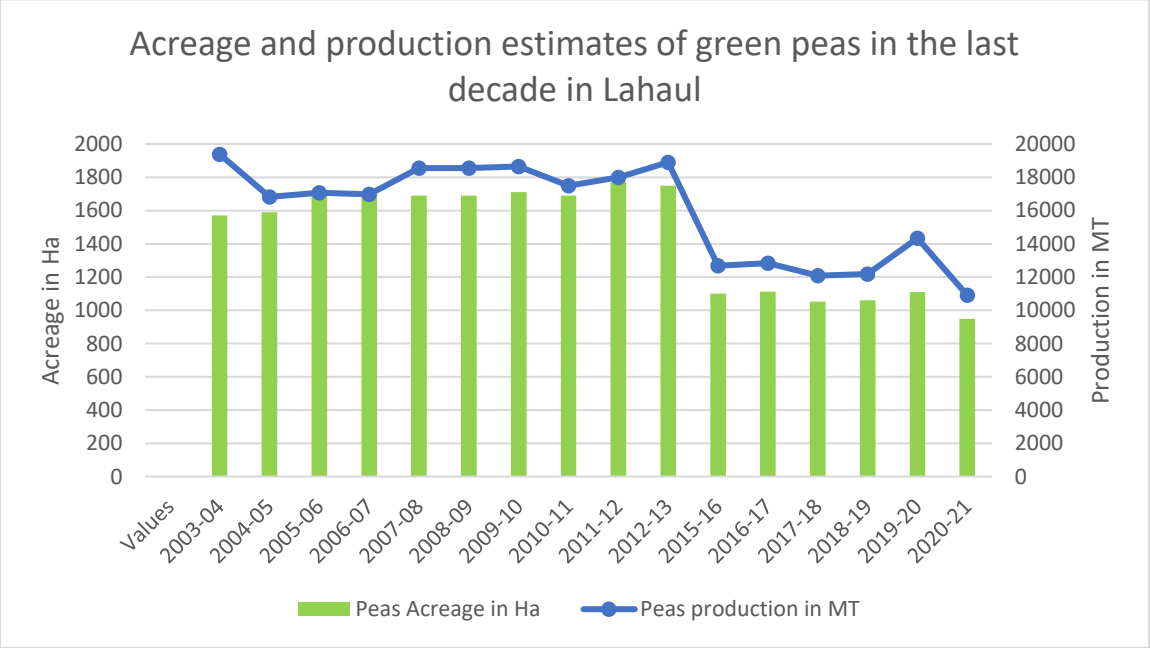


Figure 2.5 Acreage under green pea has steadily reduced by 29%, and production has declined by 26% in the last 20 years from 2003 to 2019. (Source: District Statistical Abstracts and Agriculture Department, Keylong)

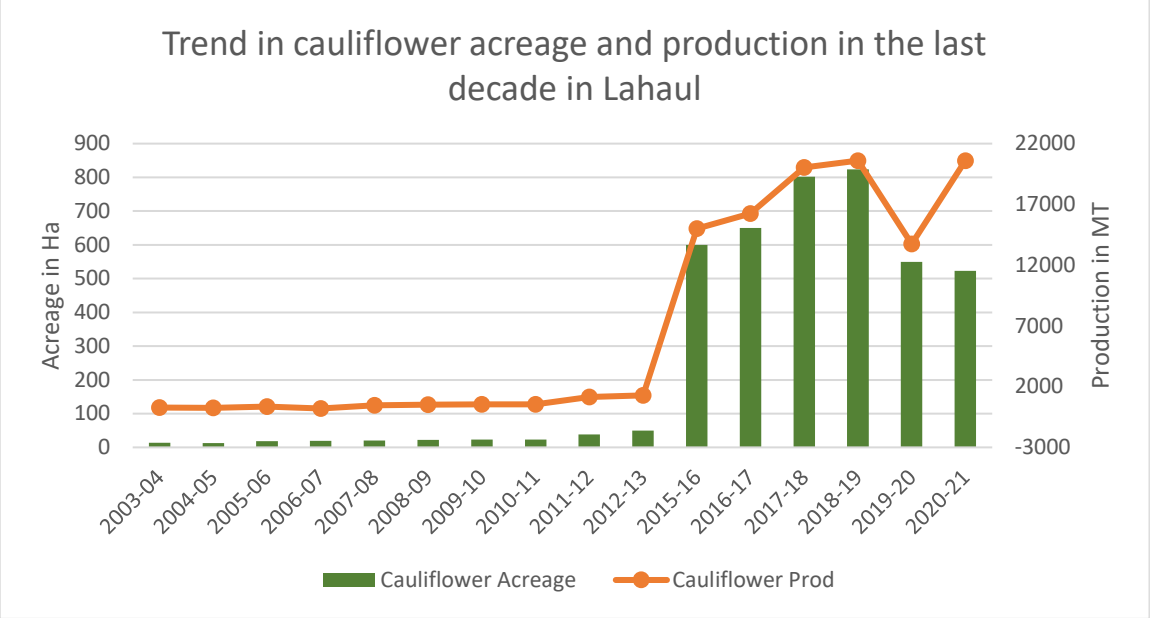


Figure 2.6 Acreage under cauliflower has expanded by 1648%, and its production skyrocketed by 1707% in the last 10 years from 2012 to 2019. A sharp increase in both acreage and production took place between 2012 and 2015. (Source: District Statistical Abstracts and Agriculture Department, Keylong)

Contract farming in Lahaul

Contract farming is seen as a secure, guaranteed remuneration for crops. This is typically done by private entities that forge a contract with a group of villages for a crop(s) with a mutually agreed rate of sale for that crop. The seeds for the contracted crop(s) are usually provided by the procuring party, who come to procure the produce in the village itself. There are several private companies that deal with the variety of cash crops produced in Lahaul (Table 2.1).

Other than contract farming, *Lahauli* farmers greatly depend upon middlemen from Himachal, Punjab or Haryana to buy their agricultural produce for sale in the *mandis* of Himachal and Delhi. Cash crops like cauliflower, broccoli and other exotic vegetables are sold directly to these middlemen. Some people also illegally lease out their agricultural land to migrants in lieu of a pre-decided amount of claim or compensation for the landowner from the overall monetary returns from the leased agriculture land.

Table 2.1 List of companies or societies that engage in contract farming of some cash crops in Lahaul as reported by respondents.

Contract farming companies	Crops
Lahaul Potato Society (LPS), McCains Foods Pvt Ltd, Balaji Foods, Bhagwan Singh and Company, HyFun Foods Pvt Ltd, Fruit & Vegetable Society, Gondhla	Potato
LPS, McCains Foods, Balaji Foods	Green pea
Agro company	Iceberg lettuce
Dabur, Himalaya Company, Nanda medicals, Aamchi Aromatics Society	Kuth & Manu



Credits: Rashmi Singh Rana

Image 2. Contemporary cash crops in Lahaul: a) cauliflower, b) fennel onion (exotic), c) broccoli, romaine lettuce, d) apple.

Monetary returns from cash crops in 2020

At present, all the crops generate varying scales of income which are highly dependent on the on-going market values. In 2020, Lahaul witnessed profitable market rates for crops like cauliflower and green pea due to the demand-supply shift brought about by COVID-19. From our primary data, monetary returns from cauliflower were the highest at Rs. 44.5 crores (Cr), followed by potato at Rs. 23.5 Cr, green pea at Rs.15.4 Cr, iceberg lettuce at Rs. 5.1 Cr, and lowest for broccoli, apple and *kuth* and *manu* at Rs. 3 Cr, Rs. 1.2 Cr, Rs. 1 Cr and Rs. 0.37 Cr, respectively (Table 2.2). These were calculated using the average rates reported for each village (Annexure Table 2.8). The crop production naturally followed the same trend, where cauliflower's production output was highest at 14,769 MT, and *kuth's* production was lowest at 28 MT in 2020 (Table 2.2).

Among all the seven valleys, villages in the upper Pattan area received highest returns as well as production output for iceberg lettuce, apple, cauliflower, potato, green pea and *manu*, whereas Tinan villages received highest for broccoli, and Tindi for *kuth* (Annexure Table 2.9 & 2.10).

Table 2.2 Total monetary returns and total production output from each cash crop in the year 2020, as reported in our Focus Group Discussions in 78 villages across Lahaul. (These monetary returns are not the realised or actual incomes for people as it doesn't include the costs of production).

Cash crops	Monetary returns in 2020 (INR in Cr units.)	Total output in 2020 (in MT)
Cauliflower	44.52	14,769
Potato	23.5	8,721
Green pea	15.49	2,968
Iceberg	5.12	710
Broccoli	3.08	174
Apple	1.2	284
Kuth	1.1	28
Manu	0.37	37

A crucial point to highlight is that the reported agricultural monetary returns are not the realised incomes for people. Farmers have to bear costs of agricultural inputs in terms of material resources (like seeds, fertilisers, pesticides, packaging material, power tiller, water sprinklers), as well as human resources by hiring migrant labourers. Some villages that lack access to *pucca* roads have to incur additional transportation costs for renting tractors or pack animals to transport their crop produce to the main roads. Therefore, the actual or realised agricultural income of farmers will be less than the reported monetary returns.

2.1.3 Challenges faced in contemporary agricultural system

By the means of reviewing literature, and with the help of our exposure to the landscape of Lahaul previously, we summarised the challenges faced by local communities in agriculture into six broad categories namely, (a) Access to supporting inputs such as seeds and fertilisers (b) Climatic problems related to erratic rain and snow, (c) Infestations by pests, insects and diseases, (d) Lack of labour and human resources, (e) Crop depredation by wildlife, and (f) Problems related to sale of produce, transport, and market. The nature of these problems and their relative magnitude of importance were understood by the means of FGDs. Let's discuss each of these categories in the context of Lahaul in some detail.

i) Problems related to sale of produce, transport, and market

In our discussions during FGDs, a lot of farmers highlighted the problems related to sale of produce, transport, and market. Many complained about the volatility of market forces and how it deters them from growing high value crops like broccoli and iceberg lettuce in abundance. The participants narrated how the middlemen usually exploited the markets by coming together and dictating the market prices. These *thekedaars,* usually take large cuts and buy the produce at lower prices. The farmers having very little control over the market have no other choice but to sell their produce to them since farmers can't access the markets in Delhi and Punjab directly. A common suggestion put forth by the respondents was the creation of a sabzi mandi (government sponsored big marketplace) and few cold stores in Lahaul. This infrastructure would make the market more accessible and competitive by giving more leverage and control to farmers.

ii) Climatic problems related to erratic rain and snow

Both the lack of, and excess of snow and rain can pose serious problems to agriculture and horticulture in Lahaul. The 2018 episode of widespread destruction of apple trees due to an untimely heavy snowfall in September is still fresh in the memory of Lahauli farmers. Some preliminary estimates suggested that more than 90% of the apple trees were damaged because of snow (Chauhan, 2018). The lack of snow and rain are equally challenging.

During our discussions, many farmers noted that their cropping calendars are shifting, and irrigating farms is becoming more and more challenging because of scarcity of water. The major reason being erratic rainfall and receding snowfall in winters. The team also witnessed major floods in August-September 2020 that cut off many roads during the harvest season and thus substantial losses to the farmers.

iii) Access to supporting inputs such as seeds and fertilisers

Another major problem that many farmers face has to do with the quality of seeds. The common narrative across Lahaul is that the quality of seeds provided by the agricultural department is not good because of which the yields are not adequate. Farmers, therefore, have to acquire these inputs privately.

iv) Infestations by pests, insects and diseases

Cash crops such as green peas, and cauliflower are getting susceptible to diseases, and pest infestations. Unfortunately, this is leading to a major increase in their investments in chemicals and pollution of the pristine mountain environment.

v) Lack of labour and human resources

In the last decade or so, many people from Lahaul have out-migrated for reasons such as education and better healthcare. The number of members in any given family have reduced. Moreover, the extended families have now dissolved into nuclear families. With the advent of cash crops, and with a decrease in the number of helping hands, there is a huge demand for agricultural labour. However, this demand is not always realised, as noted during the pandemic.

vi) Crop depredation by wildlife

Crop depredation by wild animals is a major problem affecting agricultural practices in Lahaul. Animals responsible for inflicting agricultural losses include dogs, pika, bears, red fox, marmots, and macaques. Respondents claim that the frequency of such instances have increased over the last decade. Prolonged instances of crop depredation can not only disrupt the livelihoods of the community but also affect their attitudes culminating into increased human-wildlife conflict.

While these six categories encompass most of the problems that the agrarian community of Lahaul faces, there are some other site-specific challenges that came to light during FGDs. Some of these problems include lack of basic infrastructure such as roads, irrigation infrastructure, and poor quality of soil.

In each FGD, participants were asked to rank these six categories of problems in order of their severity. They were allowed to give the same rank to more than one category. The ranks were then analysed using Friedman's test and a post-hoc Bonferroni correction was carried out. Friedman's test is used to determine whether there is a statistical difference between the ranks of the groups which in this case are the six categories of challenges faced in agriculture (Table 2.3).

Table 2.3 Ranks of challenges to agriculture in Lahaul: An overview of the summary statistics of ranks (highest to lowest) for each challenge category. Low value means a higher rank.

Rank	**Challenges**	**Mean (rank)**	**Standard Deviation (rank)**
1	Sale of produce and market	2.58	1.67
2	Snow and Rain	2.76	1.73
3	Access to inputs	3.42	2.06

4	Pests and Diseases	3.49	1.43
5	Wildlife	4.17	1.76
6	Human Resources	4.23	1.56

Although the Friedman test indicated that there is a significant difference between the six categories (χ^2 =62.1, df = 5, p <0.05), Kendall's W statistic (0.135) revealed that the difference between mean ranks for these categories is very small. Further, to analyse which categories are significantly different from the others, we carried out a pair-wise t-test with Bonferroni correction. The results are summarised in Table 2.4.

Table 2.4 Table showing which categories of challenges to agriculture are statistically different from others. If p-value < 0.05 = Significant (*); If p-value < 0.1 = Close to significant (.); If NS = Not significant.

	Sale of produce	**Snow and Rain**	**Access to inputs**	**Pests and disease**	**Human resources**
Sale of produce	-	NS	*	*	*
Snow and Rain	NS	-	NS	.	*
Access to inputs	*	NS	-	NS	*
Pests and disease	*	.	NS	-	*
Wildlife	*	*	*	.	NS

From this analysis, we can confidently say that Sale of Produce, Transport, Market, and Erratic Snow and Rain are the biggest challenges to agriculture in Lahaul, followed by Access to inputs and Pests and Diseases. Crop depredation by wildlife and shortage of labour are relatively less severe, but nonetheless important challenges that need to be addressed.

The challenges posed by wild animals in agriculture are not evenly distributed across or within villages. Some villages and some households bear the brunt of animal induced losses more than the others. Those who suffer losses, might have to bear them disproportionately. This can result in the disruption of their livelihoods and food security, which can ultimately lead to negative attitudes culminating into behaviours of retaliatory killing. To secure the livelihoods of people, and to conserve animals such as bears, it is important to address the issue of crop depredation.

With human-wildlife conflict, it is not just the direct impact of crop depredation that needs to be addressed but also the opportunity costs incurred in the form of crop guarding at nights and diminished psychological well-being.

2.1.4 Challenges due to COVID-19 pandemic

The unprecedented times created during the pandemic in 2020 were filled with confusion and uncertainty. Movement and transportation were disrupted, education came to a halt, and markets and economies were hampered worldwide. Reeling under the effects of the lockdown, the farmers in Lahaul had an important decision to make - whether to grow cash crops during these uncertain times or shift to traditional crops. Many decided to take the risk and grew cash crops. But the risk was calculated. They reduced the proportions of cash crops such as cauliflower and increased potato. While cash crops are perishable, potatoes can be buried underground and stored for much longer. The cultivation of exotic vegetables like broccoli and iceberg lettuce was significantly reduced. Those who were unsure, decided

to grow more of traditional crops such as *rajmah*, maize, barley, and buckwheat as they can be stored and consumed locally. As discussed above (Table 2.2), the farmers who cultivated cash crops could get better prices due to reduced supply from the region.

The change in the cropping pattern from the COVID-19 year of 2020 to a non-COVID-19 year of 2021 is presented in Figure 2.7 and discussed below.

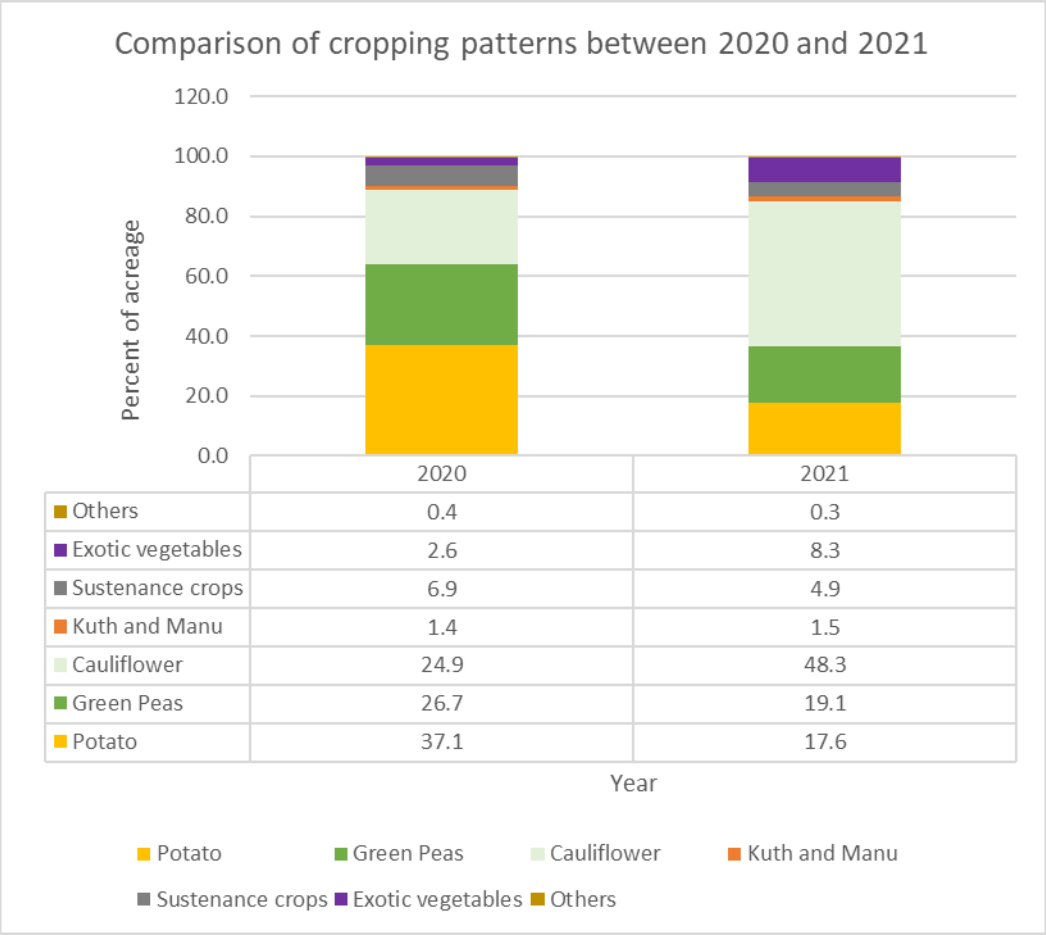


Figure 2.7 Comparison of cropping patterns between 2020 (impacted by COVID-19) and 2021.

One can discern how in the year 2020, farmers in Lahaul shifted towards potato as a cash crop while cutting down on the perishable cauliflower, and exotic vegetables. In 2021, cauliflower acreage doubled in comparison, and it was sown in almost half of the agricultural land. Those who grew cauliflower, green peas, and exotics in 2020, reaped great profits because of their high demand and short supply.

Even though many people in Lahaul benefitted from the pandemic, many others had to face adversity. For instance, in 2020, Lahaul faced an acute shortage of human resources to labour in the fields because of which up to 50% of the land was left uncultivated in many villages. While the more prosperous farmers managed to somehow procure helping hands for their farms, marginal farmers who heavily relied on migrant labour struggled. However, there were some less prosperous villages that typically do not employ migrant labour for their agricultural activities, and for this reason these villages were not impacted by the lockdown-induced shortage of migrant labour.

The agricultural practice in Lahaul has transformed immensely from the mid-20th century when it was sustenance oriented to the present time where it has largely become commercial. The introduction of cash crops such as cauliflower, iceberg lettuce, broccoli, and strawberry have on hand ameliorated

incomes and changed the socio-economic structure of the landscape, and on the other presented novel challenges. Some of these prominent challenges include stresses related to climate, market, wildlife, diseases, and human capital. To overcome some of these challenges, the community has adapted new mechanisms (see section 2.3.2), and changed cropping patterns and calendars, which in turn has again transformed agricultural practices.

2.2 Transformations in animal husbandry in Lahaul

Although agriculture has been a dominant source of economy in Lahaul, like all mountain communities, livestock husbandry has been a crucial part of life and sustenance. Livestock composition in Lahaul has also seen a dramatic shift over the last decades, in tandem with its changing agronomy. Typically, livestock is composed of small-bodied livestock like sheep and goats needed for wool, meat and hair; large-bodied livestock like *desi* cows and *churi* (female yak-cow hybrid) for milk; *churu* (male yak-cow hybrid) and bulls for ploughing agricultural fields; horses, donkeys and mules as beasts of burden; and one male yak per village kept for the purpose of maintaining the cross-bred lineage of *churu* and *churi.* In addition to being an asset for livestock-holders for lifestyle sustenance, these domestic animals played an important role in the agriculture system for manure as fertilisers. A good portion of land was kept for forage areas called *dhang*, and many villages also grew fodder grass on their land in the second or third shift. However, with an increasing attention to the highly profitable agriculture sector, there has been a growing disinterest in the less-profitable livestock husbandry.

2.2.1 Transformation in livestock-holdings and animal husbandry practices

Total livestock holding has been in a steady decline since the 1980s (Annexure Figure 2.2). There was a peak in livestock holding in 2012 due to efforts made by the Animal Husbandry department to distribute improved varieties of livestock including Jersey cows, sheep and goats (DCHB, 1991). But overall, a 47% decline in total livestock holding from 1977 (post the merger of Udaipur subdivision with Lahaul) has taken place. Sheep numbers have halved from 1977 till present, and goat numbers have declined by 69% (Figure 2.8). Large livestock numbers seem to have slightly increased, especially cattle including *desi* and jersey cows jumped up by 30% from 1977 till 2012, but again declined after 2012 till 2019 by 23%.

The cattle composition is important to note. Cattle for milk now majorly comprises the introduced Jersey cows, and very few *desi* cows and *churi* remain. The Animal Husbandry department has been distributing Jersey cows and bulls since 1973 under programmes to promote improved, high milk-yielding cattle varieties in Lahaul (Annexure Table 2.13). To further encourage this purpose, artificial insemination facilities have also been provided to six veterinary institutions since 1987 (DCHB, 1991). Pack animals like horse, donkey and mule have increased in numbers by 20% from 1977 till 2012. Although the department was also distributing improved varieties of yak bulls in Lahaul since 1978, yaks have crashed down by 80% from 1977 till 2012. This can be attributed to people's preference of introduced jersey cows over the traditional yak-hybrids. Data for pack animals and yaks was unavailable for the 20th Livestock Census obtained from the Animal Husbandry department (Annexure Table 2.11)

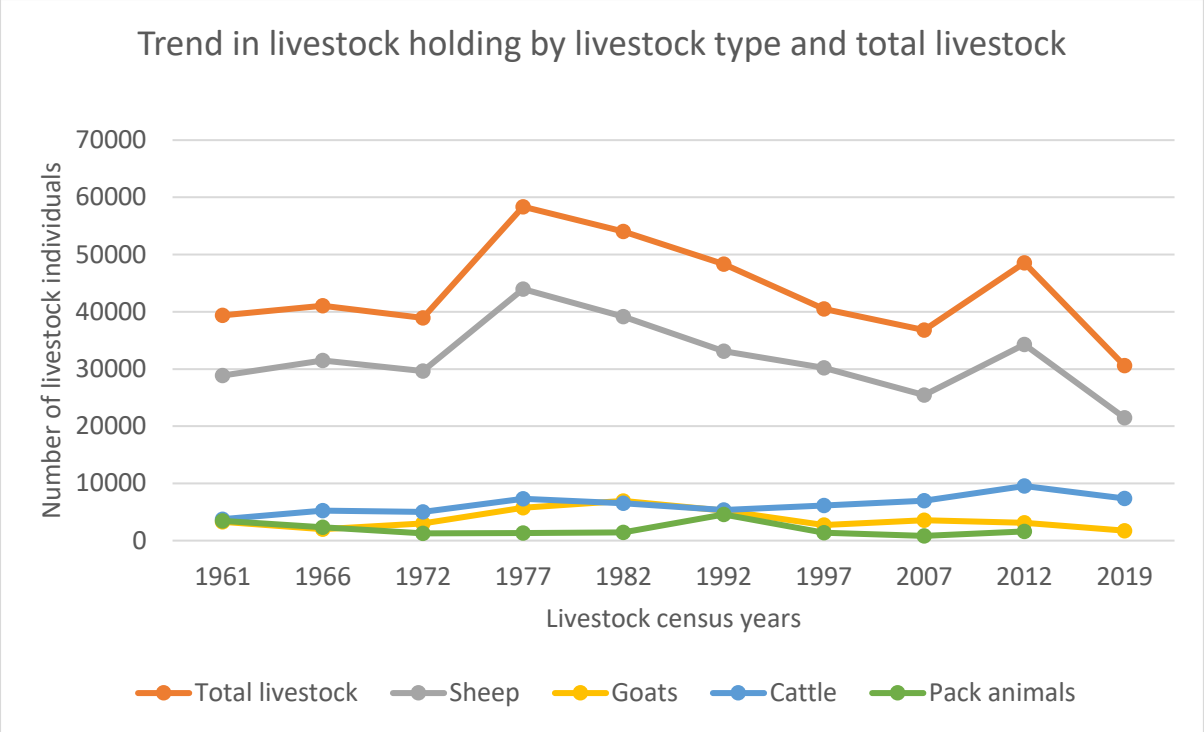


*Figure 2.8 Trend in livestock holding by livestock type. Sheep and goat numbers have declined by 51% and 69%, respectively from 1977 till 2019; on the other hand, cattle and pack animal (beast of burden) numbers have increased by 30% and 20%, respectively from 1977 till 2012, but then declined substantially. No data available for 'pack animals' for 2019. (*Source: *DSA, Livestock Census data & datasheet from Animal Husbandry Department, Keylong)*

Overall, the livestock population growth rate has seen a drop from 1977 till present, but there has been a steeper decline of growth rate in small-stock (-0.53) compared to large-stock (-0.14) (Annexure Table 2.12). This is reflected in the present-day livestock composition of Lahaul. The proportion of sheep and goat to total livestock-holding has declined by 14%, and the proportion of cattle has increased by 11% (Figure 2.9). In other words, in 1977, for every 6 sheep there was 1 cattle, whereas now, for every 3 sheep there is 1 cattle. Moreover, the per capita livestock has declined from a value of 2.8 to 1.6 (Figure 2.10).

Poultry farming was introduced by the Moravian mission by importing country birds from Kullu district. The Animal Husbandry Department also encouraged poultry farming from 1987 by distributing 2,000 one-day old broilers. Although poultry farming has been on a decline since 1992 (-38%), with increasing tourism the demand for poultry products is expected to increase, and this may reflect in increased poultry farms and numbers in near future.

Baseline data for the contemporary livestock holding patterns, and livestock densities for the 78 sampled villages can be found in Annexure 5.

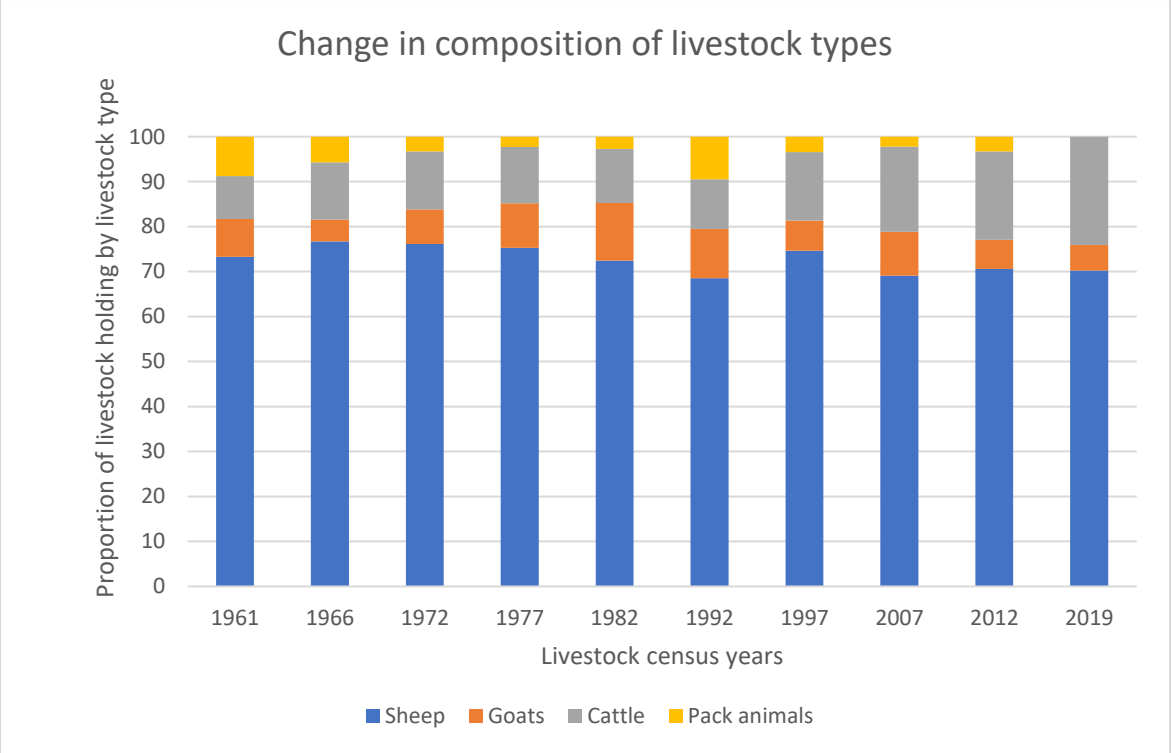


*Figure 2.9 Change in the composition of livestock type to total livestock holding. From 1977 till 2019, the proportion of sheep and goat to total livestock-holding has declined by 14%, and the proportion of cattle has increased by 11%. Data was unavailable for 'pack animals' from the 2019 Livestock Census. (*Source: *DSA, Livestock Census data & datasheet from Animal Husbandry Department, Keylong)*

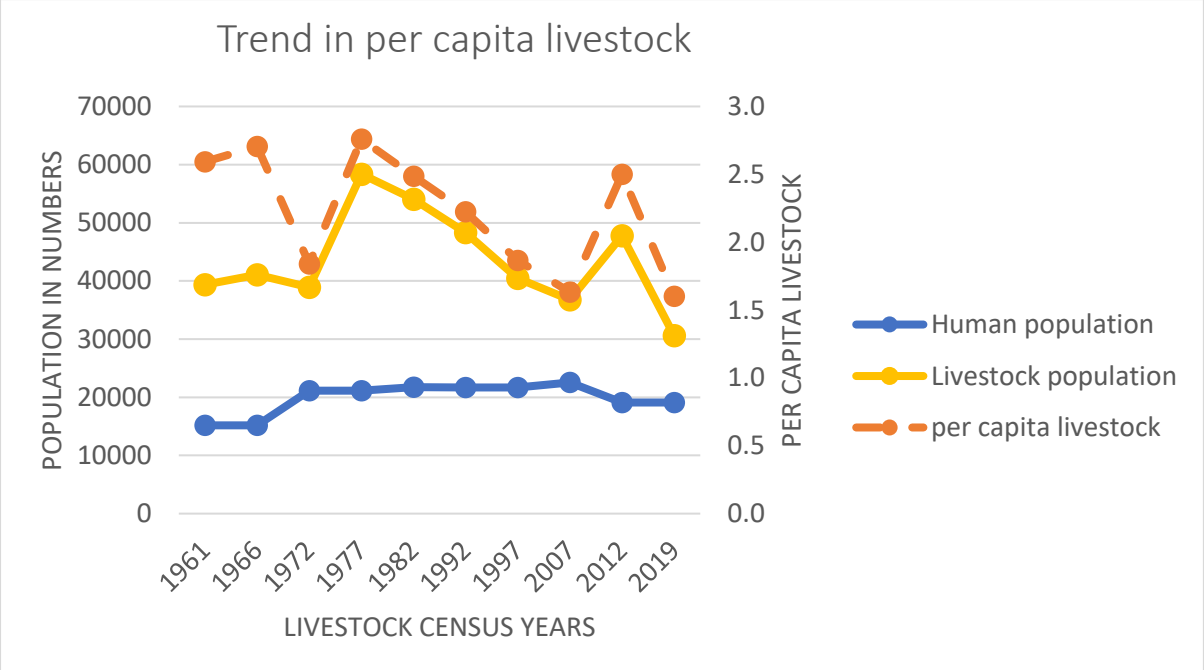


Figure 2.10 Trend in per capita livestock figures. From 1977 till 2019, per capita livestock has declined from a value of 2.8 to 1.6. (Source: *DSA, Livestock Census data & datasheet from Animal Husbandry department, Keylong)*

Recently, due to the efforts by the CSK Himachal Pradesh Agriculture University an indigenous breed of cow called *Himachali pahadi* has been recognised by the Breed Registration Committee of National Bureau of Animal Genetic Resources (NBAGR) in Haryana. Recognising the adaptability of these

disease-resistant breeds to the topography, cold climate and fodder scarcity, this breed was distributed in many districts including Lahaul & Spiti (Puri, 2020).

Seasonal grazing cycle of livestock

In Lahaul, the livestock group of an entire village are taken together to the village pastures for grazing daily from May to October. Small-livestock are grazed separately from the large-stocks like cows. In the past, livestock-owners themselves would take turns to take the entire village livestock to the higher pastures. However, now the entire village (all livestock-owners) hires a grazier, usually a migrant labour from Nepal, every season. The grazier responsible for taking small livestock to the pastures is locally called *pawaal*, while the grazier for cows is called *gwaalaa*. Lack of availability of interested local manpower in the village has necessitated employing migrant labourers for the daily task of livestock grazing. This grazier(s) is paid collectively by the livestock-owning households. Unable to afford the demand for increased wages by the grazier, many households have sold off their small livestock.

In the winter months starting November till April, the livestock are stall fed inside the sheds by the livestock owners (Image 3). Another reason for the depleting interest in livestock husbandry is the lack of manpower in villages during the winter months. Come winters, most *Lahaulis* prefer to move outside of Lahaul in their winter homes in Kullu and Manali. This means that there are no caretakers for the livestock in winters, and the livestock have to be sold or given away.



Image 3. Livestock seasonal calendar for small livestock (sheep and goat) and cows.

Livestock products and sale

Livestock are also a modest source of income for some villages. Villages close to market areas are able to sell livestock produce such as milk, curd or ghee made in surplus (Table 2.5). With increase in tourism demand for such local produce may increase if promoted well. However, with increased market connections, many people prefer opting for readily available substitutes for curd and butter. Use of wool from sheep is restricted to very few villages that use it for self-use by making woollen socks and *pattu*. Similar preference is seen for more durable colourful synthetic wools in the market. It is well-acknowledged that mechanisation in agriculture practices, such as use of power tillers, has made the utility of drought animals like bulls and *churu* redundant. Changes in animal husbandry practices in Lahaul can serve as a model to trace the changes in the lifestyle of *Lahaulis* in terms of their attire, diet and livelihood activities.

Table 2.5 Livestock products and rates in Lahaul. Products like milk are occasionally sold in case of surplus production, usually by farmers who own more than one Jersey cow.

Livestock	Livestock product	Avg output	Avg rate in INR
Jersey cow	Milk	7.5 L/day/cow	Rs. 30/L
Local cow	Milk	2.5 L/day/cow	Not sold
Dzomo/ Churi	Milk	5 L/day/cow	Not sold
Sheep	Wool	1.3 kg/year/sheep	115/kg (range Rs. 80 – 350 per kg)
Goat	Meat	NA	NA
Poultry	Meat & eggs	NA	NA



Credits: Rashmi Singh Rana

Image 4. a) Jersey cows grazing in village pastures; b) a churu (yak-cow hybrid) reared in remote villages for agricultural activities like ploughing the field; c) a lone jersey cow grazing in dhangs near village.

2.2.2 Challenges to livestock husbandry practices

Livestock rearing forms an essential component of the livelihoods of people in Lahaul by complementing the dominant agrarian economy. As discussed already, Lahaul has experienced an overall decline in the numbers of livestock over the last few decades. Some of the reasons for this decline also translate to the problems that herders face in managing livestock. The challenges to livestock management in Lahaul can be broadly classified into six categories as discussed below. The nature and magnitude of these challenges were understood by the means of FGDs.

i) *Problems posed by climate change, rain, and snow*

The most evident effect of climate change is in the form of unpredictable frequency and usually increased intensity of precipitation – both rain and snow. Unseasonal summer rains

can increase disease risk in animals grazing in the high pastures and early or late snowfall can restrict access of the livestock to pastures at a critical time (especially in late spring season), resulting in starvation. Further, respondents felt that low winter snowfall can reduce forage biomass in the coming summer season. The challenges posed by climate change to herders have been discussed in detail by Poudel (2020).

ii) Shortage of human resources/graziers

As discussed previously, the outflow of people from Lahaul in the last decade has created a deficiency of working hands. And with an increase in the production of cash crops, the few available family members can only afford to practise agriculture. As a result, Lahaul saw a considerable reduction in livestock abundance in the last two decades. For what's left, an arrangement is usually made at the village level where a grazier is hired for an entire grazing season. However, participants note that it is getting increasingly difficult to find one. And in a situation where only a few people in a village are holding livestock, the expenses per person to hire a grazier shoot up making it an economically unviable option. In such a scenario, a domino effect can be noticed where people are forced to sell their remaining livestock.

iii) Pests and diseases

Infestation by pests and diseases is one of the major problems in livestock rearing. Although there are provisions of veterinary staff in many panchayats, they are usually not well equipped with necessary medicines and equipment. Moreover, there is a scarcity of veterinary hospitals in Lahaul, and sometimes people have to travel long distances to get the right medicine and treatment for their livestock.

iv) Access to market

There is no market or cooperative for livestock produce such as wool, and milk. For villages far off from Keylong, and Udaipur, the market is inaccessible. This is not a major problem, however, since most of the produce is consumed locally within the house or village.

v) Pastures and fodder

The availability of grazing lands and natural feed is constantly decreasing throughout the Himalayas (Katoch, 2022). The same is true of Lahaul. In a study conducted by Dev at al. (2009), lack of quality fodder, and poor herbage collection came out to be the major problems associated with livestock rearing in the Miyar sub-valley of Lahaul. During our Focus group discussions as well, many participants resonated with the problem of shrinking pasturelands.

vi) Livestock loss by wildlife

In the trans-Himalayan region of Lahaul, livestock and predators often share common resources which results in human-wildlife interactions. Livestock predation by animals such as bears, snow leopards, and wolves is common and can disrupt the livelihoods of people. During our interactions with the community, we heard many instances where entire herds of livestock were lost because of wild animals.

During Focus group discussions, participants in each village were asked to rank these six categories of challenges to livestock rearing in order of their importance (Table 2.6). The most severe problem was given the rank 1 and the least severe problem was given a rank 6. The ranks were then analysed using Friedman's test and a post-hoc Bonferroni correction was carried out.

Table 2.6 Ranks of challenges to livestock rearing in Lahaul: An overview of the summary statistics of ranks (highest to lowest) for each challenge category. Lower the value, higher is the rank.

Rank	Challenges	Mean (rank)	Standard Deviation (rank)
1	Grazier/Labour scarcity	2.97	1.96
2	Pastures and fodder	3.53	1.99
3	Livestock loss by Wildlife	3.75	1.87
4	Pests and Diseases	3.78	1.84
5	Snow and Rain	3.85	1.83
6	Access to market	4.65	1.67

Although the Friedman test indicated that there is a significant difference between the six categories (χ^2 =40.8, df = 5, p <0.05), Kendall's W statistic (0.089) revealed that the difference between mean ranks for these categories is very small. To analyse ranks in more detail and to pinpoint which categories are significantly different from others, a pair-wise t-test with Bonferroni correction was carried out. The results are summarised in Table 2.7 below.

Table 2.7 Table showing which categories of challenges to livestock rearing are statistically different from others. If p-value < 0.05 = Significant (*); If p-value < 0.1 = Close to significant (.); If NS = Not significant

	Snow and Rain	Grazier	Pest and Disease	Access to market	Pasture and fodder
Snow and Rain	-	*	NS	*	NS
Grazier	*	-	*	*	NS
Access to market	*	*	*	-	*
Pasture and fodder	NS	NS	NS	*	-
Wildlife	NS	.	NS	*	NS

Clearly, scarcity of human resources, and graziers is the biggest problem for livestock rearing in Lahaul, closely followed by the unavailability of pastures, fodder, and stall feed. Although the former is a slightly larger problem, it is important to note that there is no significant difference between the ranks of these two. In other words, both these problems can be considered of equal significance. These problems are followed by the categories of Wildlife, and Snow and rain which are not statistically different from each other. And lastly, the problem of access to markets is considered the least significant problem of all, as perhaps, they don't see this as a viable livelihood option given the commercial value of agriculture.

Although livestock loss by wildlife is not the most acute problem to livestock rearing, it is still essential to address it. As highlighted by Suryavanshi et al. (2013), livestock depredation by carnivores such as snow leopard and the wolf can result in human-wildlife conflicts that can hinder the conservation of these species and pose a threat to local livelihoods (Hussain, 2003).

2.3 Tourism and other livelihoods and dependencies

2.3.1 Tourism in Lahaul

Lahaul has been experiencing an increasing attraction as a tourist destination, especially by domestic tourists. Over the last few years, the number of tourists visiting Lahaul, mostly on the way to Leh, have been increasing. As seen in Table 2.8, more than a three-fold increase in domestic tourists visiting Lahaul shows the promising boost in the tourism sector for people of Lahaul. This trend of tourists in 2020 has been due to the opening of the Atal tunnel in October 2020 that has not only reduced the time travel between Manali and Lahaul by from 5 hours to little over an hour, but also made the landscape accessible throughout winters. With the ease of access into the landscape, Lahaul is turning out to be a key tourist destination and the enterprising local people are already preparing for the anticipated tourism by establishing homestays, camping sites and new hotels. As of 4 June 2022, the number of registered and approved homestays in Lahaul are 485. These registrations have been made from across Lahaul including the remote valley of sub-valley Miyar. A total of 46 hotels and guest houses are also registered.

Table 2.8 Number of tourists in Lahaul since 2019. Source: Sub-Division Magistrate Office, Keylong. (Estimated numbers are an approximate)

Year	Domestic tourists	Foreign tourists
2019	3.7 lakhs	13,000
2020	2.6 lakhs	155
2021	12.8 lakhs	331
2022 (till April)	42,717	8

The nascent tourism sector will bring viable livelihood options for the local people in the near future. The inhabitants are already preparing to host the increasing number of tourists. However, it should be flagged that there is a definite need to strictly monitor this sector. The increasing footfall will put tremendous pressure on the natural resources of this fragile mountain system. During 2021 itself, Lahaul experienced heavy water shortage owing to increased demand and reduced supply due to the climate change-fuelled receding glaciers. Increasing ingress and numbers of tourists is only going to exacerbate the problem of water shortage. Additionally, the present status of unmonitored and unmanaged garbage disposal will lead to grave problems like soil water toxicity, soil toxicity, diseases and increased population of stray animals like dogs and more domino-effects. As has been seen in the neighbouring Kargil region of Ladakh, brown bears may also aggregate on these garbage dumps posing a serious threat to both local communities and tourists. This problem will only escalate with increasing tourism and its infrastructure.

This industry is poised at a budding stage, and it is critical to make the rapidly expanding tourist sector responsible and more sustainable for the environment and local people. Both, the administration and the local people, stakeholders who will be most benefited or harmed by it, must take proactive and collaborative action to systematically create nature-based, sustainable tourism in Lahaul that simultaneously aims for improving and diversifying livelihoods, promote traditional culture, and conserving and sustainably managing the natural resources. Such initiatives are beginning to be undertaken by UNDP-India SECURE Himalaya supporting eco-tourism activities, and by environmentally sensitised local people who are promoting agro-based tourism in their farmsteads.

2.3.2 Migration in Lahaul

A common megatrend observed throughout the Himalaya is the out-migration of youth from the rural to the urban areas for better employment opportunities. Migration, on one hand results in a scarcity of farm labour, affecting rural livelihoods, while on the other it reduces poverty by creating new livelihood opportunities (Siddiqui et al., 2019). The drivers of out-migration are many and the decision to leave is influenced by socio-economic, political, and environmental factors. For instance, Joshi et al. (2018) lists poverty, lack of livelihood opportunities, marginalisation, climate change, and lack of facilities as the major drivers of migration.

A similar trend can be observed in the region of Lahaul. That people were migrating out of Lahaul was confirmed by the respondents in 88% of the FGDs. A large proportion of the original population was believed to have settled within the state, in places like Kullu and Manali. The primary driver for moving out of the valley was the harshness of winters coupled with a lack of healthcare infrastructure. Before the inception of Atal tunnel, Lahaul was inaccessible and disconnected from the rest of the state over 6 months of winters. Moving in and out of the valley was difficult due to heavy snow on Rohtang pass. These conditions proved difficult especially for the elderly with medical conditions. To access better healthcare facilities during winters, many decided to settle in Kullu while others practised seasonal migration. Nowadays, a lot of people migrate down to Kullu during winters and return to Lahaul for the cropping season.

The other cited reasons for migration included education and economic opportunities. People employed in government and corporate sectors such as army, police, education, finance, etc tend to settle down around places of work. To provide better higher education opportunities, a lot of families send their children to study in Kullu and Chandigarh. After completing their education, the youth usually aspire to find a job in the urban centres and settle there. As a result, the number of people permanently living in Lahaul are decreasing.

The practice of out-migration in Lahaul has had profound ramifications on agriculture and livestock management. As people are moving out, joint families are dissociating into nuclear families. As a result, the number of helping hands in a family are also reducing. Traditionally, families within a village would help each other during the sowing and harvesting period. Now with a lack of manpower, many families have to rely on migrant labourers to do the work. During unprecedented times like that of the pandemic, practising agriculture becomes challenging because of the scarcity of working hands. For the same reason, many people who cannot afford labour are now reducing the proportion of green peas (see figure 2.5) as it is relatively more labour intensive.

The lack of labour also created problems for livestock management. Lesser members meant that families could not tend to agriculture and livestock simultaneously. Managing livestock is an intensive full-time job which requires herding and collecting fodder for lean periods. With no one to assist, many families decided to reduce their livestock holdings. Over the last decade, the livestock abundance in Lahaul has seen a dramatic decline (see figure 2.10). Many people have sold their livestock completely and others who have reduced it collectively hire a shepherd to graze them.

While outmigration created a scarcity of labour, it also created a need for the crop-livestock agricultural system to adapt and transform in light of these changes. To compensate for the reduced working hands, people not only hired labourers, but they also adopted the use of technology. For instance, instead of using cattle for tilling, people resorted to power tillers and tractors. Sprinkler systems were installed for irrigation and grass cutters and other mechanised tools were used for weeding and harvesting. At times, *Lahaulis* also made arrangements with migrant labourers where they leased them their lands for agriculture. In summary, out-migration in Lahaul has played an instrumental role in the transformation of agriculture and livestock management.

2.3.3 Forest-based livelihoods

Like any other mountain region, people in Lahaul are dependent on forest resources for their everyday lives. Before the year 2000, people were highly dependent on forests for collecting fuelwood, dried pine needles, fodder, and NTFPs like medicinal plants, herbs and *Guchhi or* morel mushrooms. The need for fuelwood was essential to survive winters and to cook. Similarly, wooden logs were needed for constructing houses and fences. Since there were no checks and regulations, forests were overharvested. Many people feel that the forests had declined throughout Lahaul because of overharvesting. Other prominent reasons for this decline include climate change, natural disasters, overgrazing by locals and Gaddi herders.

To overcome that, local institutions such as *Mahila Mandals* started imposing restrictions on forest use. Since the last decade, harvesting fuelwood has been banned in many parts of Lahaul and certain rules have been put in place to regulate forest use and allow regeneration. Although the Forest Department is also actively putting efforts in reviving and increasing forest cover, the locals opined that this effort seldom sees any fruition due to the inefficiently planned of plantations, for example, planting young trees in water scarce regions with limited access to water to sustain the plantations. On the other hand, the forest department is often denied water from streams by villagers who prefer to use this scarce resource for their irrigation.

Lately, there has been a significant transformation in forest-based livelihoods. The dependence on forests has significantly reduced since LPG cylinders and electricity became accessible. Fuelwood is now provisioned from depots, and NTFPs are mostly collected by migrant shepherds. To meet fuelwood and fodder demands, people rely on *beli* (Salix) plantations around the village. Forest now usually opens for only about a week every year. During this window, people are allowed to collect dried, fallen wood and pine needles. These pine needles are used to cover the floor of the livestock and cow sheds to keep the sheds warm and dry. This also ensures relatively cleaner and more hygienic conditions for the livestock inside the sheds.

2.4 Conclusion

Over the last few decades, Lahaul has witnessed considerable socio-economic, environmental, and infrastructural changes. Whereas traditionally, the community was dependent on a closely knitted interaction among agricultural, livestock and forest systems for their sustenance, the agrarian means of production have become the primary source of livelihood in the present. Sustenance crops such as barley, buckwheat, and maize have largely been replaced by cash crops such as cauliflower, exotic vegetables and apples. The potential of cash crops in ameliorating incomes has also resulted in a gradual increase in cropping area and many new farms have sprung in close proximity to forests. Consequently, wildlife interactions with agricultural crops have increased. At the same time, changes in climate such as reduced snow and erratic rainfall have affected the cropping calendar, as well as fodder availability for livestock. Social changes in family structure owing to out-migration of people for better health, education, and lifestyle opportunities have created a scarcity of human capital. The scarcity of working hands has had huge ramifications on *Lahauli* livelihoods. Not only has it resulted in a significant reduction in per capita livestock holding (Figure 2.10), but it has also been partly responsible for the reduction in green pea acreage (Figure 2.5).

In the last few years, the advent of the Atal tunnel has provided local communities with better connectivity and accessibility to markets. The tunnel has also opened new possibilities in terms of livelihoods by paving the way for tourism in Lahaul. These new opportunities in commercial agriculture

and tourism are attracting people back to Lahaul. Youthful populations have started reverse migrating to Lahaul to take advantage of these opportunities.

CH 3

HUMAN-WILDLIFE INTERACTIONS



Credits: (Clockwise) Amir Jaspa, Tinkal Bhatt, Rashmi Singh Rana

3.1 Patterns, processes and drivers of human wildlife interactions

Like most of the landscapes in our country and across the world the study area of Lahaul exhibits multiple uses of land. Characteristic of multi-use landscapes is that human settlements and activities associated with the anthropogenic sphere overlap with that of the wildlife (Moilanen et al., 2005). Wild animals have always co-occurred along with the local communities without any well-defined physical boundaries, and there seems to be a reciprocal resource extraction of one from the other's primary habitat. Natural resource extraction by humans can be in the form of agriculture, both subsistence and commercial, livestock grazing on pasture lands, and extraction of NTFPs for fuel, fodder as well as medicinal and aromatic plants (MAPs). While wild animals extract anthropogenic resources like crops and livestock as food resources. In such multi-use landscapes where people and wild animals live in overlapping habitats, human-wildlife interactions are inevitable. Fortunately, there are no human injuries or fatality caused by wild animals in Lahaul. Our study focussed on the negative human-wildlife interactions or human-wildlife conflicts in the form of crop damage and livestock predation.

3.1.1 Nature and extent of human-wildlife interactions of crop damage

From our sample of 78 villages for FGDs, 77 villages (98.7%) reported crop damage by wild animals, including free-ranging dogs (FRDs).-Reported by 96% of sampled villages (Table 3.1), pika was the most widespread animal causing damage to crops, followed by free-ranging dogs (56%), *chakor* or chukar partridge (50%), red fox (41%), bears including both brown and black bear (33%), macaque (23%), marmot (17%), and musk deer and ibex (3.7% each).

Table 3.1 Animals reported for causing crop damage in 78 sampled villages across Lahaul.

Animals reported	% of sampled village (no. of villages)	Crops foraged	Crops trampled or broken
Pika	96 (75)	Apple, cauliflower, broccoli, green pea, potato	-
Free-ranging dogs	56 (44)	-	Cauliflower, green pea, maize, potato
***Chakor* partridge**	50 (39)	Potato, green pea, cauliflower	-
Red fox	41 (32)	Green pea, potato	-
Brown and black bear	33 (26)	Apple, green pea, iceberg lettuce, maize, rajmah	Cauliflower, potato, green pea, iceberg
Macaque	23 (18)	Apple, cauliflower, green pea, potato	-
Marmot	17 (14)	Green pea, potato	-
Musk deer	3.7 (3)	Apple (buds)	-
Ibex	3.7 (3)	Apple (buds), green pea, potato, cauliflower	-

i) Extent of crop damage by animals

In the year 2020, Lahaul farmers from sampled villages experienced a reported loss of about Rs. 92 lakhs on account of crop damage by wild and stray animals. Although bears were reported in less than half of the sampled villages, the amount of reported crop damage caused by them in the year 2020 substantially surpassed the damage caused by any other reported animal in the same year (Figure 3.1). With a total reported monetary loss of nearly Rs. 28 lakhs (32% of total crop monetary loss), green pea, apple and iceberg lettuce were the most common cash crops damaged by brown bear and black bears combined. Dogs did not forage on any crops, and yet their digging and trampling behaviour resulted in a loss of Rs. 16 lakhs. Pika–a small lagomorph–caused an estimated loss of Rs. 14 lakhs, while the recently arrived macaques accounted for crop loss of Rs. 12 lakhs. The third most prevalent or reported species, the *chakor* partridge, caused an estimated loss of Rs. 11 lakhs. The shy mammals, namely red fox and marmot, lead to comparatively lesser loss of Rs. 7 lakhs and 2 lakhs, respectively. Musk deer and ibex caused negligible monetary loss.)

(An important point to highlight is that these monetary estimates have been calculated using the reported market rate of the respective crop in the year 2020. We know that crops like green pea and cauliflower had an unusually higher market rate in 2020 owing to high demand-low supply balance caused by the COVID-19 pandemic. Also, people found it difficult at times to report the exact quantity lost due to wildlife. In case of apple, for instance, the damage was on branches. We used a standardised value to compute such losses (see Section 1.4.2). The monetary loss values, therefore, can be an overestimate for some crops. These monetary estimates have been used as a means of comparison between crop losses by all reported animals, as the crop damage by different animals could not be reported in common units. For example, cauliflower and apple damage by pika could only be reported in number of saplings and number of trees damaged, respectively, and not in the common metrics used for reporting crop damage by other animals (in Kgs). Therefore, we urge the readers to use these reported estimates only as an indicative measure of comparative losses caused by these animals to the crops, and not take them as absolute figures of 'actual' losses.)

Note: For all the 78 sampled villages baseline data on quantity and monetary losses caused due to crop damage by bears can be found in Annexure 5.

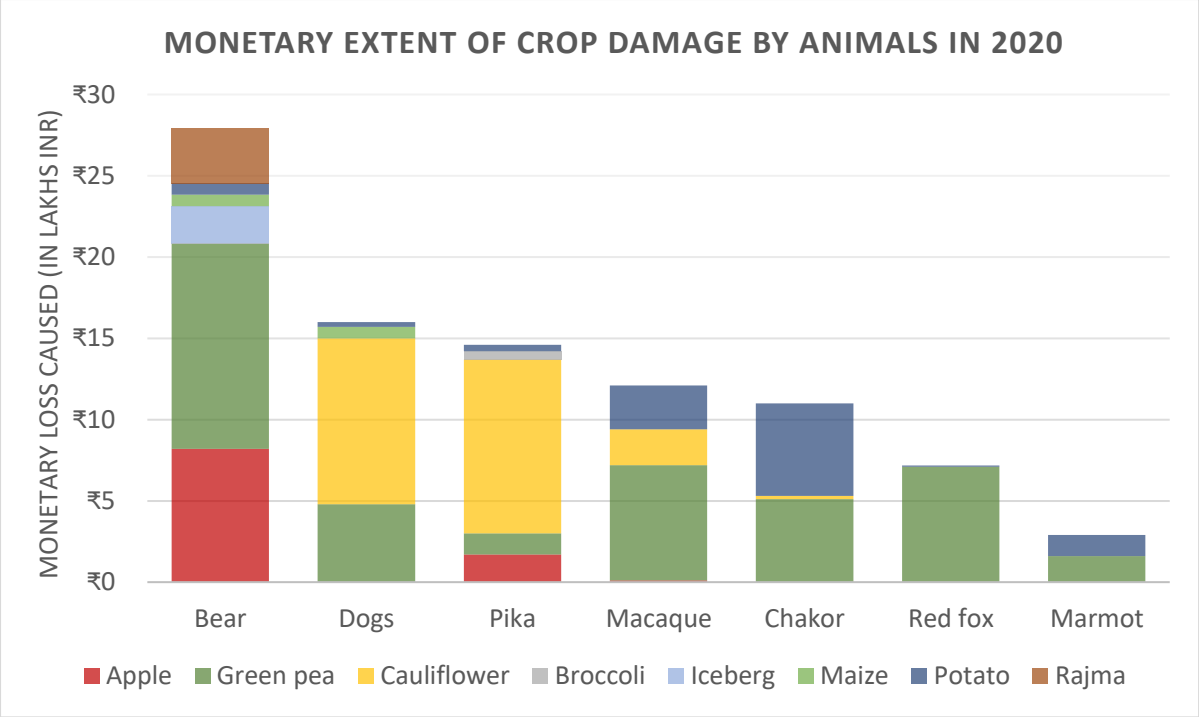


Figure 3.1 Reported monetary loss caused by each animal to crops in the year 2020 in 78 sampled villages. Bears have caused the most damage to all crops that they forage upon.

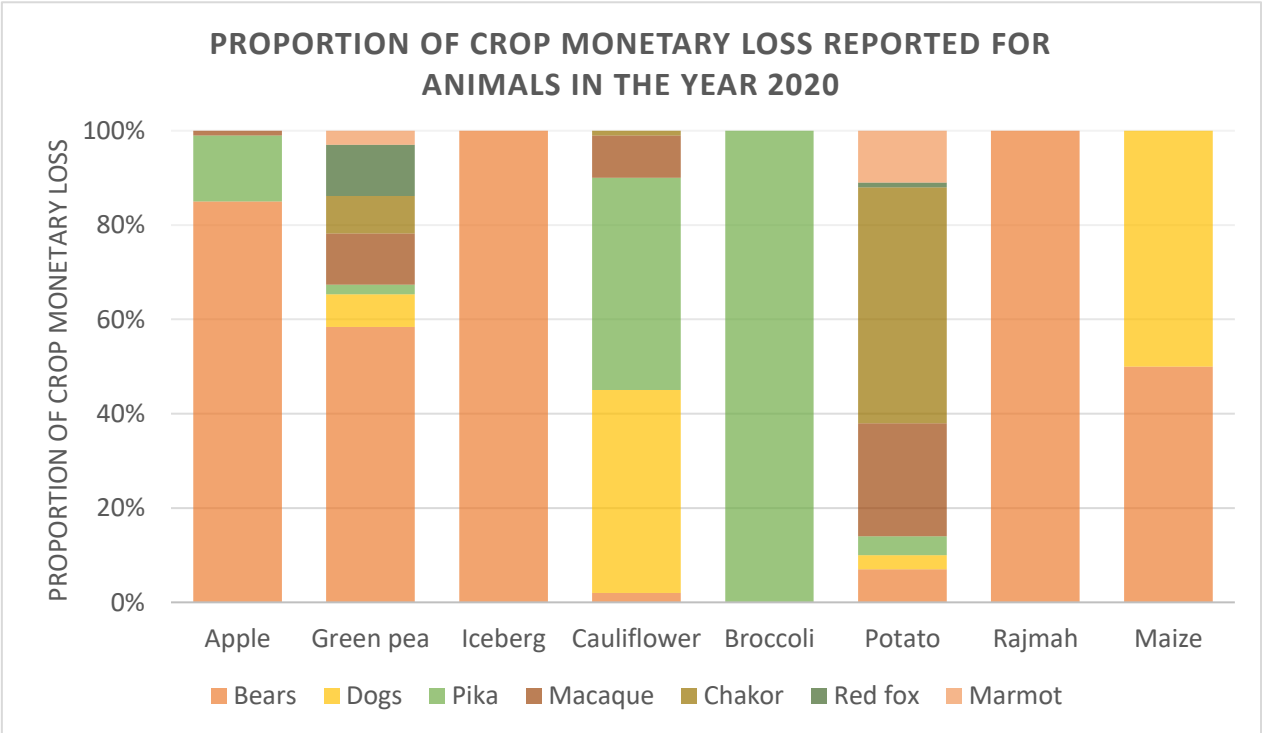


Figure 3.2 Proportion of crop monetary loss reported for animals in the year 2020. Bears cause a significant loss to apple, green pea, iceberg lettuce, rajmah and maize.

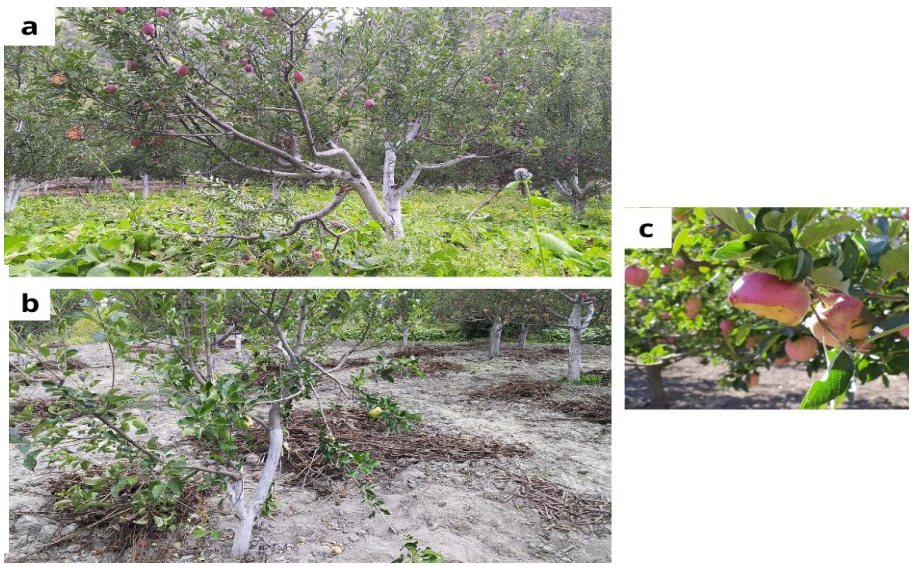
Figure 3.2 shows that bears account for more than 50% of monetary damage for apple, green pea, maize, and are entirely responsible for damage of iceberg lettuce and *rajmah*. Pika significantly account for monetary damage to broccoli and cauliflower, while dogs account for significant damage to cauliflower and maize. Birds like *chakor* partridge account for the most monetary damage for potato, followed by macaque. And other animals account for about 10% (and less) of the total monetary damage to any crop. For details on crop-wise and animal-wise estimates on monetary damage refer to Annexure 3 (Annexure 3 Figure 3.1 to 3.5 & Table 3.1).

Overall, in the year 2020, the monetary losses incurred because of crop damage by wild animals and stray animals have amounted to about 1% of the total monetary returns from cash crops (Annexure Table 3.2). It is also important to repeat that the reported agricultural monetary returns are not the realised incomes for people. Farmers have to bear costs pertaining to agricultural inputs in terms of material resources (like seeds, fertilisers, pesticides, packaging material, power tiller, water sprinklers), as well as human resources by hiring migrant labourers. Some villages that lack access to *pucca* roads have to incur additional transportation costs for renting tractors and pack animals to transport their crop produce to the main roads. Therefore, the actual or realised agricultural income of farmers will be less than the reported agricultural monetary returns.

ii) Extent of crop loss by brown and black bears

Both the bears combined foraged the most on cash crops like green pea, apple and iceberg lettuce amounting to estimated loss of 31.6 thousand kg, 19.6 thousand kg and 4.2 thousand kg, respectively. Maize and *rajmah* were the subsistence crops foraged by bears and resulting in a total loss of 5.2 thousand kgs and 2.5 thousand kgs in 2020. Although not sold by the farmers, the monetary values of these crops were calculated using the average purchase market rate in Lahaul-Spiti district. Lastly, crops like potato and cauliflower were only damaged by trampling behaviour (Figure 3.3).

Overall, of the total monetary returns from bear-preferred crops (~Rs. 90 crore), bears caused a loss of about 0.2% (~Rs. 23 lakhs) in the year 2020. These estimates do not include non-cash crops like *rajmah* and maize (Annexure 3 Table 3.3).



Credits: Rashmi Singh Rana

Image 5. All images above show damage caused to apple trees due to bear foraging on apples.

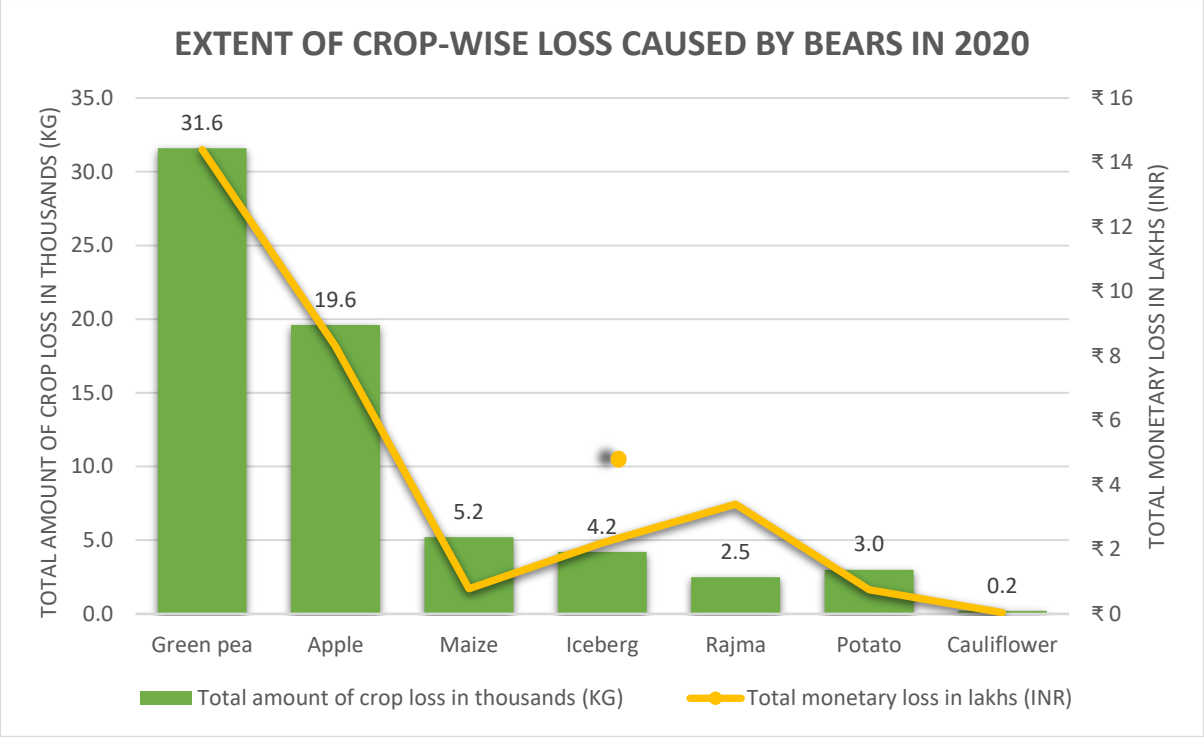


Figure 3.3 Reported quantity as well as monetary loss caused by bears to each crop in the year 2020.

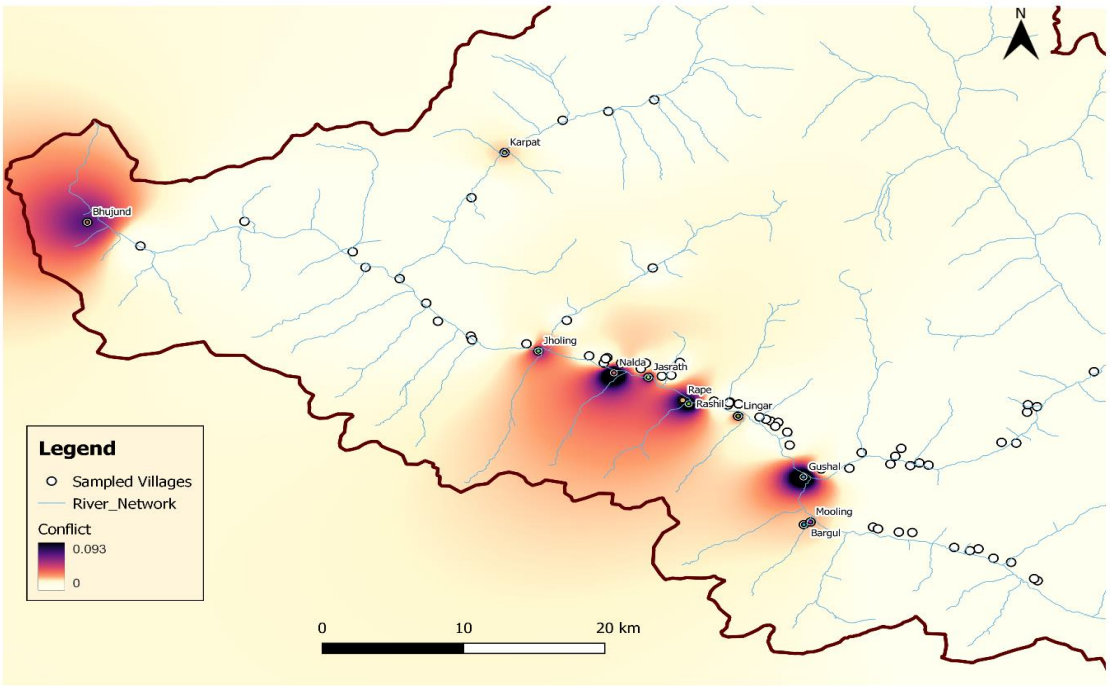
iii) Patterns of crop damage by animals

These patterns of crop loss by different animals are not uniform across Lahaul, and in fact show spatial variations in all the seven sub-valleys (Table 3.2; see Map 1.1 for the map of the valleys). Over half of the proportional monetary loss takes place in the fertile belt of lower and upper Pattan (54%), while the inner, remote sub-valley of Miyar accounts for the lowest 5% of the total loss. Significant crop loss by bears is only restricted to the Pattan and Tindi sub-valleys, and the Gahar sub-valley does not suffer any crop loss by bears. Pika has been reported for crop loss across Lahaul in all the seven sub-valleys, although the monetary losses have been relatively smaller. Dogs have been reported for crop damage in all sub-valleys, except for Tindi. Macaques, reported in all valleys except upper Pattan, Gahar and Miyar, have shown a rise in population and consequent crop-related damage. For details on valley-wise extent on loss of crops refer to Annexure 3 (Figure 3.6, 3.7 & Table 3.4, 3.5).

Table 3.2 Sub-valley-wise patterns of crop loss by reported animals.

Sub-valleys	Proportion of total monetary loss	Reported animals in descending order of proportional monetary damage	Reported crop loss in order of descending order of proportional monetary damage
Lower Pattan	30%	Bears, macaque, *chakor*, dogs, red fox, pika	Green pea, apple, cauliflower, potato
Upper Pattan	24%	Bears, *chakor*, pika, red fox, marmot, dogs	Green pea, potato, apple, cauliflower, iceberg lettuce
Tinan	13%	Pika, dogs, bears, macaque, marmot, red fox, pika	Cauliflower, green pea, apple, maize, broccoli, potato
Gahar	11%	Dogs, pika, marmot	Cauliflower, green pea, potato
Tindi	9%	Bears, macaque, red fox, pika	Rajmah, maize, green pea, apple
Tstod	8%	*Chakor*, pika, dogs, marmot, macaque	Green pea, potato, cauliflower
Miyar	5%	Red fox, bears, pika	Green pea, cauliflower

The reported crop damage caused by bears is primarily restricted to the left bank of the river Chandrabhaga (Map 3.1), with relatively less severe instances of crop damage in villages on the right bank. Moreover, 85% of our respondents from household-level interviews explained that crop predation by bears is relatively new and has greatly increased in the last 10-15 years. Most of the crop damage occurs at the time of ripening or fruiting of the crops. In Lahaul, many respondents admitted that they were forced to stop cultivating iceberg lettuce for fear of bears raiding the crop. Crop damage by bears is very common and has been reported in other parts of Himachal Pradesh and the Himalaya (Charoo, Sharma, & Sathyakumar, 2011; Rathore, 2008; Sharief et al., 2020).



Map 3.1 Spatial extent of crop damage by bears across the sampled villages in Lahaul. The darker shades of purple, blue and red show areas of high bear crop damage and conflict, while the remaining uncoloured villages indicate areas of no bear-related crop damage and no conflict.

Macaques are regarded as a menace to crops in many parts of Himachal. Many respondents from our study mentioned that the population of macaques have been rising since last 5 to 10 years, and that they are either coming from the adjacent Pangi area in Chamba or have been forcefully brought in trucks by authorities from lower regions of Manali or Shimla to get rid of the macaque menace there.

The extent of crop damage by pika is spatially limited to agricultural fields close to stonewalls and rocks that act as a perfect micro-habitat. Damage to apples only occurs in the winters when there is little else for pika to forage upon. Similar crop loss by pika, especially due to debarking of apples, has been previously noted in Baluchistan area (Khan & Smythe, 1980).

To our knowledge, this extent of damage to crops by free-ranging dogs has not been reported from the Himalayan region. Although unmonitored, the respondents mentioned that the FRD population is on the rise since the last decade owing to a variety of reasons such as increase in unmanaged garbage disposed of by hotels, *dhabas*, tourist camps and army camps. Many reported that Gaddi or shepherd guard dogs owned by the migratory Gaddi community are left behind in the landscape leading to an increase in dog population.

Although comparably widespread, crop damage caused by red fox is considered a minor problem, in terms of quantum as well as economic value, in all Lahaul. Marmots, on the other hand, show restricted spatial range of crop-foraging activities, and mostly reported in villages located at higher elevations where marmots find suitable habitat.

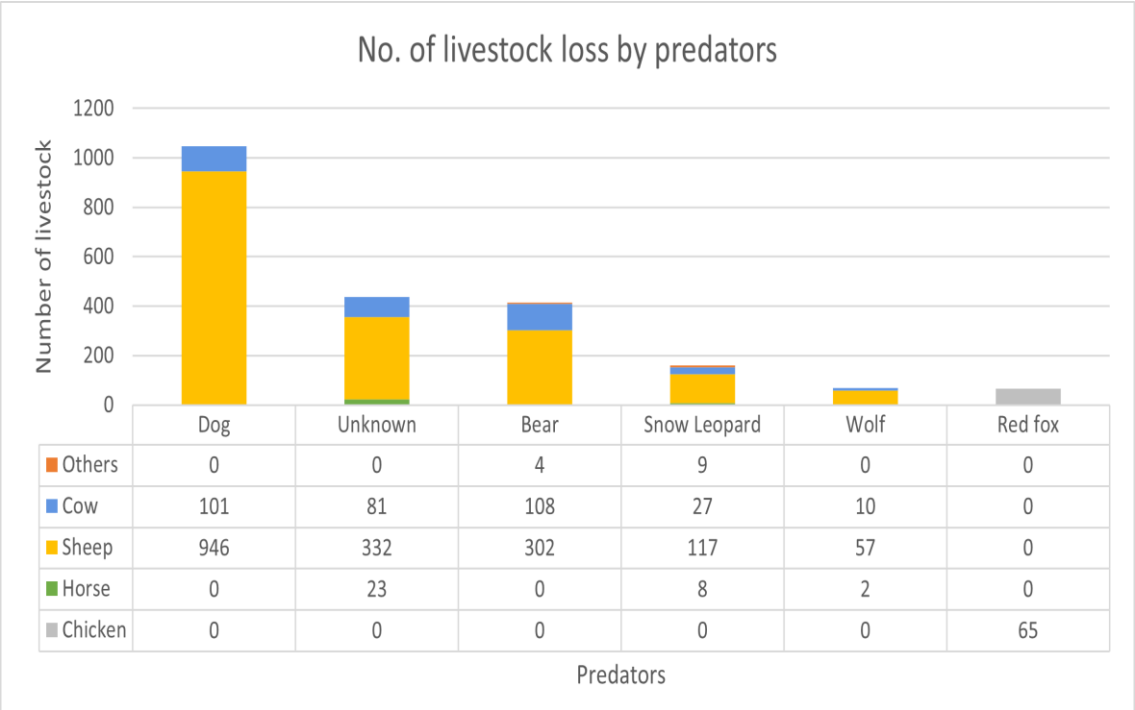
3.1.2 Livestock depredation by predators

In the trans-Himalayan landscape India, livestock rearing forms an essential component of the local agro-pastoral economy. Depredation of livestock by predators is a pervasive concern that inflicts economic losses, affects local livelihoods, and causes negative attitudes towards conservation and co-existence. It is important, therefore, to understand the issue of livestock depredation more comprehensively as resolution of such conflict is critical. Efforts have been made to study the extent of livestock depredation by large carnivores and to quantify these losses in the region of Kargil (Maheshwari & Sathyakumar, 2020), Spiti (Mishra, 1997; Suryavanshi et al., 2013), Ladakh (Namgail et al., 2007), Kashmir (Charoo et al., 2011), and Great Himalayan National Park (Chauhan, 2003). However, such efforts have not been replicated in the region of Lahaul. To better understand the extent, patterns, seasonality, and amounts of livestock conflict with predators in Lahaul, we asked the participants in each sampled village the details of such losses. The results are summarised below.

i) Number of livestock lost in the last 5 years (2016-2020)

From 2016 to 2020, a total of 2192 livestock casualties were reported from 78 villages in Lahaul. Sheep (80%) were the most affected livestock, followed by cow (15%), and the rest attributing to the remaining 5 percent. Out of the 327 casualties of cows, 84% were calves.

Of all the predators, dogs were responsible for almost half of the livestock losses and their most selected prey was sheep (94%; Figure 3.4). Such a great impact of dogs on livestock depredation is also documented by Home et al. (2017) in the upper Spiti landscape. Following dogs were bears (18.8%). Livestock depredation by snow leopard (7%) and wolf (3%) were relatively lesser, and red fox predated exclusively on poultry. The predator in about 20% of losses couldn't be determined by the respondents.



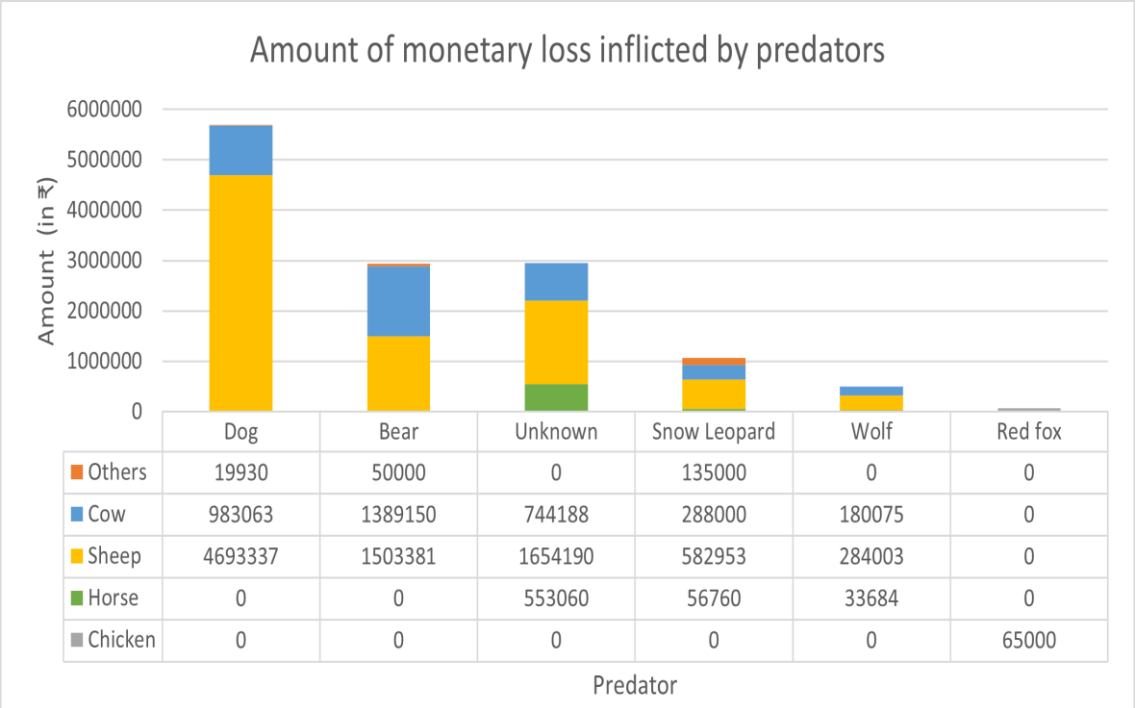
	Dog	Unknown	Bear	Snow Leopard	Wolf	Red fox
Others	0	0	4	9	0	0
Cow	101	81	108	27	10	0
Sheep	946	332	302	117	57	0
Horse	0	23	0	8	2	0
Chicken	0	0	0	0	0	65

Figure 3.4 Number of livestock lost to all predators

ii) Monetary losses due to livestock depredation (2016-2020)

For a duration of five years from 2016-2020, a total monetary loss of INR 1,32,15,771, or ca. INR 26,43,154 per year, was caused by livestock depredation from 78 sampled villages in Lahaul. Loss of sheep accounted for 66% of the monetary losses, followed by cows (27%).

Unsurprisingly, dogs inflicted most of the monetary losses (43%) followed by bears (22%). The losses inflicted by snow leopard (8%) and wolf (4%) were relatively lesser. The average loss of 26.43 lakhs in one year accounted for 0.33% of average village income for that year for 57 affected villages. In other words, 0.33% of total income in every affected village was lost to livestock depredation. Although this might not seem like a huge amount at the village level, the effects of livestock depredation are disproportionately distributed at the household level, where a few houses might have to bear the entire brunt of the losses. It is important to note that the village income that we have calculated amounts to the sum of the selling price only and does not consider the costs incurred on human capital, transportation, packaging, ad inputs. Therefore, the percentage of average village income lost to livestock depredation should be slightly higher than the reported figure. But the essence of argument remains, i.e., the monetary losses incurred due to livestock depredation in any given village are only a small fraction of the total village income.



	Dog	Bear	Unknown	Snow Leopard	Wolf	Red fox
Others	19930	50000	0	135000	0	0
Cow	983063	1389150	744188	288000	180075	0
Sheep	4693337	1503381	1654190	582953	284003	0
Horse	0	0	553060	56760	33684	0
Chicken	0	0	0	0	0	65000

Figure 3.5 Monetary losses (in INR) inflicted due to livestock depredation

iii) Seasonality of attacks on livestock

The seasonal patterns of attacks on livestock suggest that for bears, snow leopard, and wolf, the number of instances of livestock predation peaked during summer as compared to other seasons. During winters, there is very little to no livestock loss as most livestock are stall-fed and mostly well protected indoors. The instances start to increase during the onset of spring which coincides with the time livestock start to go out for grazing. The instances are maximum at the peak of the grazing season, and they begin to

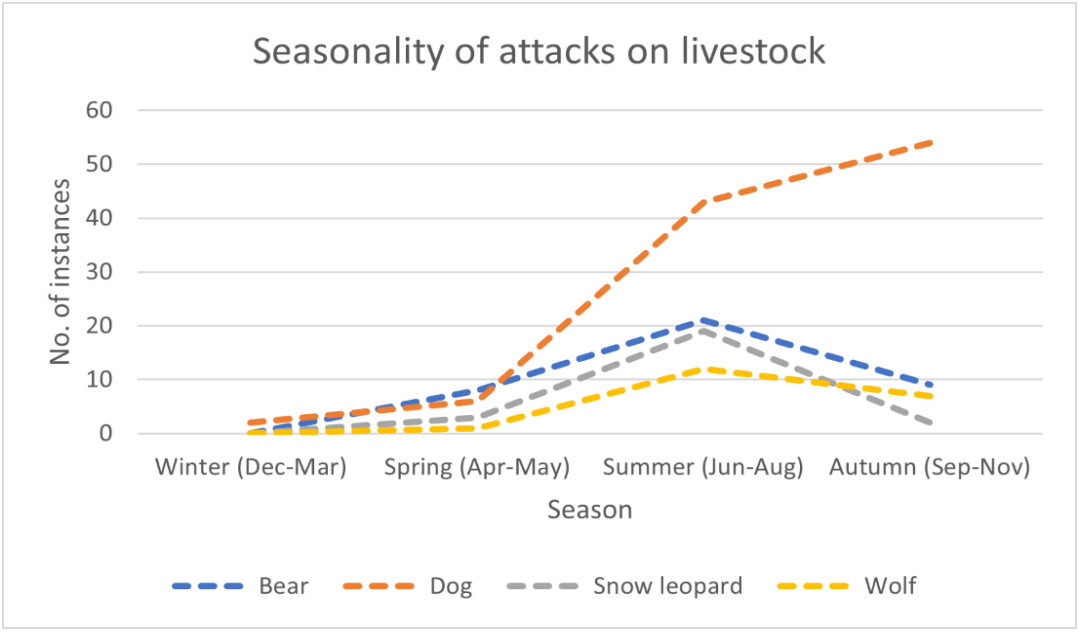


Figure 3.6 Seasonality of attacks on livestock by various predators

reduce again as the grazing season comes to an end with autumn. During this time, most of the livestock is present in the agricultural fields and it is easier to protect them against predators.

Dogs, however, present a slightly different case wherein the number of instances of attack form a peak during autumn. This could be because a number of hotels and restaurants on which dogs usually rely upon, start to shut in October. Facing an acute food resource crunch, all the dogs living around hotels and restaurants start migrating towards villages where smaller livestock like sheep and lambs grazing on agricultural stubble become an easy target. It was also found from the interviews that the majority of the events of livestock depredation take place during nights and early mornings.



Credits: Tinkal Bhatt

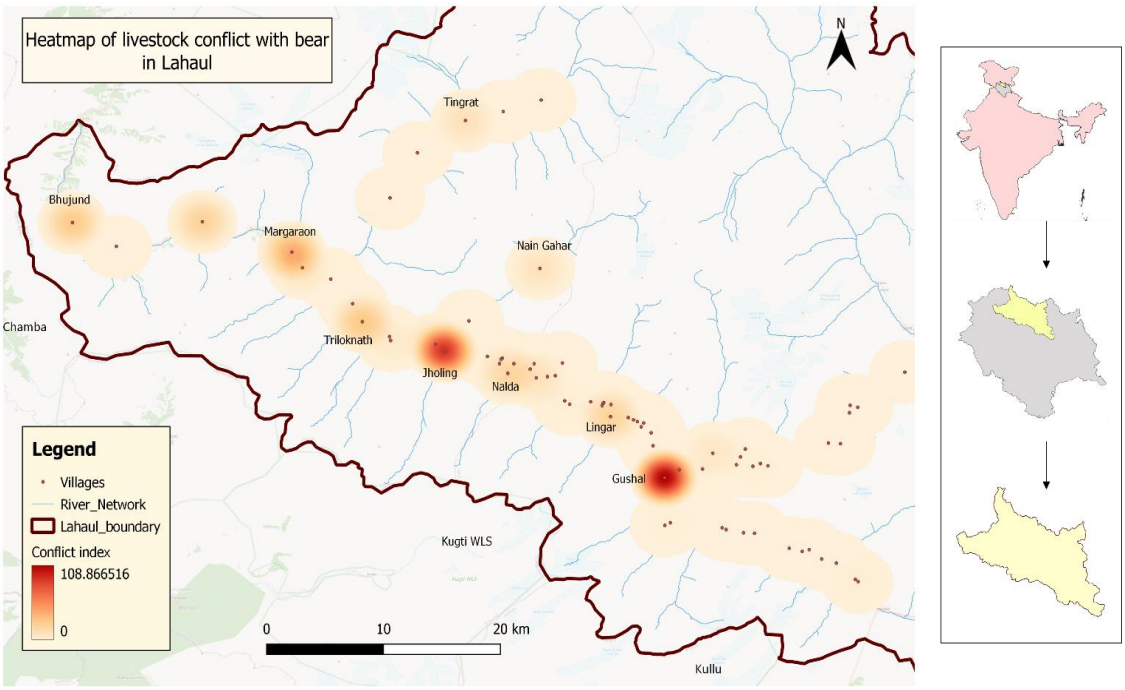
Image 6. A livestock herd attacked by an unknown predator (snow leopard or a wolf suspected) in the pastures while grazing. a) a grievously injured adult sheep, b) neck of the sheep punctured by the predator.

iv) Patterns of conflict

Livestock depredation by bears

Instances of livestock depredation by bears are not distributed uniformly throughout the landscape of Lahaul. Out of the 78 sampled villages, only 19 reported some amount of livestock loss to bear. To understand the spatial pattern of livestock related conflict with bears, a heatmap (Map 3.2) was generated using Kernel Density estimation with the help of QGIS 3.22 software. The radius of influence was chosen to be 3 Kms around the village centre and the weight was assigned based on the number of livestock killed in any given village. The hotspots around Gushal and Jholing suggest that these two villages are most vulnerable to livestock predation by bears. Hotspots of slightly lesser intensity are also formed around villages Lingar, Nalda, Triloknath, Margaraon, and Bhujund. From the heatmap, one can infer that the conflict by bear is almost absent in Gahar, Tinan and Tstod sub-valleys. Another important point of discussion has to do with the spatial context of conflict. Almost all the instances of

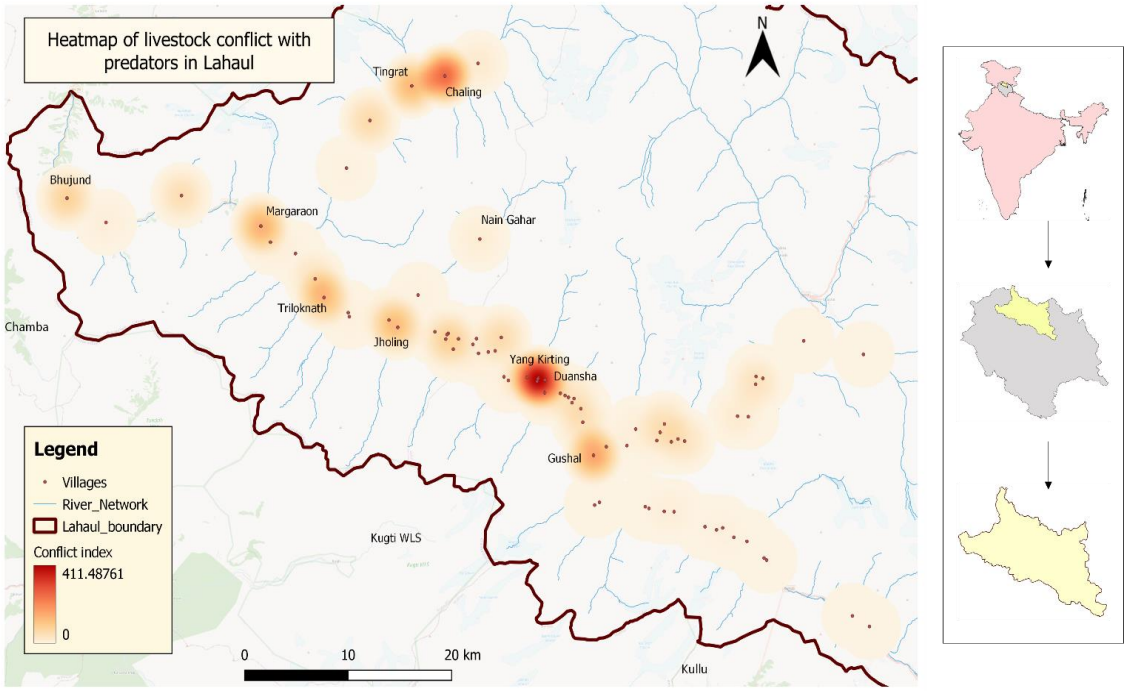
livestock depredation happen in the forest or pastures around the affected villages. And in the majority of these cases, either the livestock is left behind during the day or they are placed there for a long duration without supervision.



Map 3.2 Heatmap of livestock conflict with bear in Lahaul

Livestock depredation by all predators

To understand the full extent of conflict with all the predators present in the landscape, another heatmap was generated using Kernel Density estimation in QGIS (Map 3.3).



Map 3.3 Heatmap of livestock conflict with all predators in Lahaul

The hotspots of conflict are centred around the villages of Gushal, Yang Kirting, Jholing, Triloknath, Margaraon, Bhujund, and Chaling. The conflict is relatively lesser in Southeast, in the sub-valleys of Gahar and Tstod, and almost absent in the Tinan sub-valley. Again, it is important to note that most of the instances of livestock depredation happen when livestock are kept in the forest/pasture without supervision.

Table 3.3 Percent of livestock lost each year in various sub-valleys of Lahaul

Valley	Villages sampled (a)	Number of livestock killed 2016-20 (b)	Average livestock killed per village per year (c)	Total Livestock owned in 2021 (d)	Average livestock owned per village in 2021 (e)	Percent livestock killed per village per year (f)
			c=b/(a*5)		e=d/a	f=(c/e)*100
Gahar	7	77	2.2	715	102	2.2
Lower Pattan	17	435	5.1	3336	196	2.6
Miyar	5	420	16.8	1683	337	5.0
Tinan	15	24	0.3	712	47	0.7
Tindi	5	299	12.0	2330	466	2.6
Tstod	8	98	2.5	518	65	3.8
Upper Pattan	21	839	8.0	2025	96	8.3

As seen in Table 3.3, the highest number of average livestock lost per village per year is in Miyar sub-valley, followed by Tindi, and Upper Pattan. Tindi and Miyar sub-valleys are the remotest valleys in Lahaul and accessing them is relatively more challenging. Other than being less developed in terms of infrastructure, these two sub-valleys also hold the greatest number of average livestock per village. These numbers are almost six to seven times more than that of Tinan and Tstod sub-valleys, where most of the people have sold their livestock owing to opportunities presented by tourism and employment. A greater number of average livestock owned per village in Miyar and Tindi sub-valley could be one of the reasons why livestock predation is more intense in these regions.

Even though Miyar and Tindi sub-valleys face a greater number of livestock loss per village, they are relatively less vulnerable than Upper Pattan where 8.3% of livestock is reported to be lost each year. Villages in Tinan are the least vulnerable facing less than a percent of livestock depredation each year.

3.1.3 Nature and extent of human-wildlife interaction w.r.t human safety

Respondents were inquired about any incidents of human injury or fatality caused by wild or stray animals in the last 10 years. About half of the surveyed villages reported concerns to human safety from wild and stray animals like brown bear, black bear, dogs, macaque and snow leopard. Fortunately, there has not been any incident of fatality of humans from these animals.

Brown bear and black bear: About a third (33%) of sampled villages (n=78) reported concerns about threat to humans by bears. Although there have been no reported cases of human injury or death by bears, there is always a lingering fear as reported in individual interviews in 26 villages. This fear of bears has a definite psychosocial impact on villagers who cannot venture out alone early morning or late evening. This impacts important livelihood activities such as visiting and opening the water sources at higher elevations to release the water into the irrigation channels called *kuhls*. The water source needs to be accessed as early as 3 or 4 am, and this is the time when the chances of encountering a bear visiting the village are high. Similarly, villagers, especially women and kids are fearful of staying out of the house after sunset. Areas or agricultural fields near forest, near riverbanks or *nallah*, near irrigation water sources were reported to be the areas where the chances, and consequently threat, of encountering bears is the highest.

Dogs: A total of 7 incidents of human injury by pack of dogs were reported from 5 villages. In all cases, dogs attacked people inside the village itself. There was one extreme case of dogs mauling a man, following which he had to be taken to the hospital, one case of dogs injuring a young girl outside her house. Except for one incident of attack that happened at night, no specific time of the day was reported for such attacks. However, all villages reported fear of dog packs in the night and identified them as a threat to kids. Some also mentioned that they need to carry sticks with them at night for protection. Some villages reported the problems and fear of the increasing dog population to the Animal Husbandry and Livestock Health department, but lack of infrastructure, facilities and manpower in the department limits any solution yet.

Macaques: One village reported an incident of a troop of 15 macaques chasing a woman in the agricultural fields in the survey year of 2021. The villagers, therefore, perceived a sense of threat from the increasing number of macaques in their village.

Snow leopard: Only one village reported a sense of fear from snow leopards when there is news of snow leopard moving around their village.

3.1.4 Processes and drivers of crop damage by bears

The Himalayan brown bear and Himalayan black bear have become noticeably dependent on agricultural crops as a food resource in Lahaul in the last decade. Our study shows that presently, bear-related damage is not widespread in the study landscape, but serious in only some villages. Out of the 78 sampled villages only 24 reported crop damage by bears in the year 2020 (Map 3.1). Moreover, bears do not forage on all crops indiscriminately, but rather have preferences for certain crops. Among the bear-preferred crops (henceforth referred to as palatable crops) green pea, apple, and iceberg lettuce are grown in majority of the villages across Lahaul, and yet damage to these crops by bears is not comparable between villages. Similarly, maize and *rajmah* are grown in many in the lower Pattan and Tindi belt but bears do not cause damage in all villages. It was established that despite a similar availability of food crops for bears across all villages, bear movement and resultant crop damage was restricted to some hotspots. It was, therefore, important to disentangle the potential factors that drive this restricted range of bear-related crop loss.

In this context, we wanted to understand vulnerable villages as defined by socio-ecological, topographical, physical and bioclimatic characteristics, stratify them (no loss, low, medium and high loss) according to their vulnerability to damage by bears, and within these strata, understand the patterns of losses and individual attitudes towards bears.

The entire Lahaul landscape is a mosaic of crop land and natural vegetation which makes for a suitable habitat for bears. Lahaul can be characterised and classified into 10 habitat types (Kumar et al., 2022; Rathore, 2008) (Table 3.4):

Table 3.4 Some characteristics of physiognomic habitat types found in the Lahaul Valley.

HABITAT TYPE	DESCRIPTION
Agriculture land	Consists of crops like green pea, iceberg lettuce, carrot, apple orchards, maize, *rajmah*, potato, cauliflower, buckwheat, barley, wheat etc. These agricultural lands span from areas around habitation to isolated areas far away from habitation, near the alpine areas or close to forest. Spread in all valleys.
Mixed forest with conifers and broad leaf species	Consists majorly of blue pine, cedar and birch trees. Patches mostly in the left bank of Chandrabhaga.
Himalayan moist temperate forest with conifers	Consists of blue pine, cedar, spruce, fir trees. Patches mostly in the left bank of Chandrabhaga.
Dry alpine Juniper scrub/woodland	Consists of scattered trees and shrubs of Juniper species with dry, barren patches in between. Mostly in the Gahar and Tstod Valley and the right bank of Chandrabhaga.
Grassland with scattered trees	Pastures on higher elevations (usually above 3000m) lush with grass species and few scattered trees.
Exposed rock with slope grasses	Highly rugged areas of mountains with exposed rocky mountain walls, with some grass species and scrub including *Rosa* and *Caragana*, scattered around.
Barren land	Barren land with no vegetation cover
Riverine forest	Consists of patches of birch, poplar and willow on riverbanks.
Water bodies like river, spring, *nallah*	Rivers, spring and *nallah* often with willow, poplar or juniper.
Plantations	Willow and poplar plantations around villages.

Habitat use by bears is highly dependent on availability of food resources, variety of food plants as well as shelter in different habitat types (Rathore, 2008). Some studies have shown that occurrence of bears is positively associated with agricultural land and grasslands with no clear preference or avoidance for other habitat types (Sharief et al., 2020; Rathore, 2008). In contrast, another study by Dar et al. (2021) indicates that agricultural land may act as disturbance for brown bears and found that brown bear occurrence to be highest in areas with low density of agriculture land. Moreover, the study also found occurrence to be highly significant in areas with moderate amounts of barren land, low amounts of mixed forest, scrubland, grassland and moderate to high amount of conifer forests (Dar et al. 2021).

Like any other wild species, bear should prefer to use areas that offer reliable food, water, and shelter. We thus predicted that in Lahaul, bears should be attracted to any village with palatable crops but would prefer to use those that not only offer food from these crops but in addition have forests close by that offer secure cover from being detected and a relatively cool area during the warm periods of the day, and wild food in terms of its preferred grasses, berries, herbs, and wild prey. Water may be crucial, but all villages are assumed to have reliable water supply close anyway.

For this study, we have reported our attempt to explore how 'conflict' and 'non-conflict' villages differed regarding their attributes (Table 3.5) to understand how these conflict patterns w.r.t bears in these villages could be explained by similar village-level attributes.

Table 3.5 Description and a priori prediction of socio-ecological, physical and topographical predictor variables used for modelling bear conflict in Lahaul. Variable codes are within the brackets. The full list of predictor variables can be found in Annexure 3 Table 3.6.

VARIABLES	*A PRIORI* PREDICTION	SOURCES
a) Socio-Ecological Variables		
Livestock density (LS.dens)	Livestock also serve as prey for bears, and therefore a larger availability of livestock in an area may act as an attractant.	Livestock census, 2019 + DCHB, 2011
b) Physical Variables		
Maximum forest patch size (Patchsize_max)	A higher area of conifer or mixed conifer forest may serve as preferred habitat for food and shelter for bears.	QGIS 3.22.2
No. of forest patches (Patches)	Number of fragments of forest patches around a village may influence bear movement for food and shelter, especially during the warm day time with high movement of people.	QGIS 3.22.2
c) Topographical Variables		
Ruggedness (Rugg_50)	Higher rugged area around village may serve as shelter for bear during the day in the form of caves and crevices.	QGIS 3.22.2
Elevation variation (elev_stdev)	Elevation is a known factor influencing bear presence and movement	QGIS 3.22.2
d) Bioclimatic variables		
Maximum temperature (MaxT)	Optimal brown bear habitats have relatively cold and wet climatic conditions.	QGIS 3.22.2

It was established that villages that experienced crop damage by bears in the year 2020 have been experiencing crop damage in the past. These villages vulnerable to crop damage by bears have been termed as 'bear conflict' villages. Whereas villages that faced no crop loss in the year 2020 are the villages that have never experienced crop loss even in the past. We used this data on 'bear conflict' villages and no conflict villages, with a value of '1' and '0', respectively, as a measure to understand the factors affecting this vulnerability of villages to crop damage by bears. To see which variables influence the vulnerability of the 'bear conflict' villages we fitted a generalised linear model with a logit link function in R programming environment (version 1.4.1717) (RStudio team 2021). Multicollinearity was tested between predictor variables to ensure that highly correlated variables (with correlation coefficient >0.6) were not used in the same model. Table 3.5 enlists details about variables that came out to be significant. The full list of predictor variables can be found in Annexure Table 3.6.

The top-ranking model (with the lowest AICc value; see Table 3.7) indicates that the likelihood of a village being vulnerable to bear conflict is influenced by topographical characteristics of the village: high number of forest patches, the maximum forest patch size positively increased the likelihood of bear conflict (Figure 3.7), while variation in elevation, and the interaction of maximum forest patch size with ruggedness negatively influenced the likelihood of bear conflict in villages (Figure 3.7 and Table 3.6). Contrary to our expectations, socio-ecological variables like agricultural land, crop-wise acreages,

apple orchard area, livestock density and village size had no significant influence on a village's likelihood of experiencing crop damage by bear (Figure 3.8).

It is important to note that these results only show the likelihood of bear conflicts in villages in terms of prevalence of crop foraging, and do not reflect on the intensity or frequency of bear conflicts or crop foraging in a village. Additionally, our scale of analysis is at a finer village level scale of 2x2 sq. km, and not at the landscape scale. However, all our sampled villages account for variations across the demographic, ecological and topographical characteristics of the Lahaul landscape.

Table 3.6 Coefficient estimates for each parameter and corresponding significance based on the most parsimonious model. Please see Table 3.5 for details of the variable codes.

	Estimate	**Std error**	**Z value**
Intercept	2.15	1.82	1.17
Patches	2.31**	0.71	3.23
elev_stdev	-2.09**	0.79	-2.63
Patchsize_max	10.65	5.54	1.92
rugg50	-0.98	1.22	-0.80
Patchsize_max:rugg50	-8.41*	3.65	-2.30
			*p **p ***p<0.05

Table 3.7 The five best models based on their AICc scores. Please see Table 3.5 for details of the variable codes.

Model structures	**K**	**AICc**	**DeltaAICc**	**AICcwt**	**Cum.Wt**	**logLik**
Patches +elev_stdev +Patchsize_max*rugg50	6	52.20	0.0	0.39	0.39	-19.51
Patches + elev_stdev + LS.dens + Patchsize_max*rugg50	7	52.95	0.75	0.27	0.66	-18.67
Patches + elev_stdev + MaxT + Patchsize_max*rugg50	7	53.54	1.34	0.20	0.86	-18.97
Patches + elev_stdev + LS.dens + MaxT +Patchsize_max*rugg50	8	54.31	2.11	0.14	0.99	-18.11
Patches + Patchsize_max*rugg50	5	61.24	9.05	0.00	1.00	-25.20

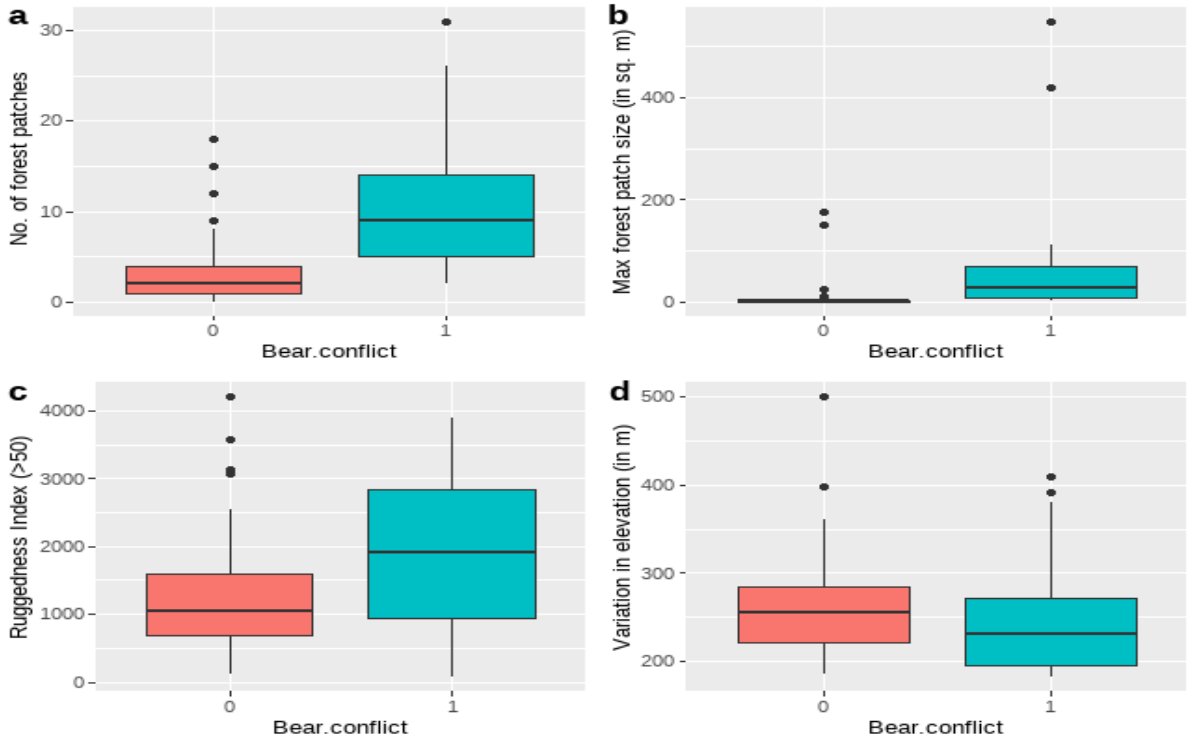


Figure 3.7 Variables significantly and positively influencing the likelihood of vulnerability of a village to experience bear conflict (0=no bear conflict; 1=bear conflict). Villages with (a) higher number of forest patches, (b) bigger forest patch size, (c) higher ruggedness index, and (d) larger variation in elevation have a higher likelihood of being vulnerable to bear conflict.

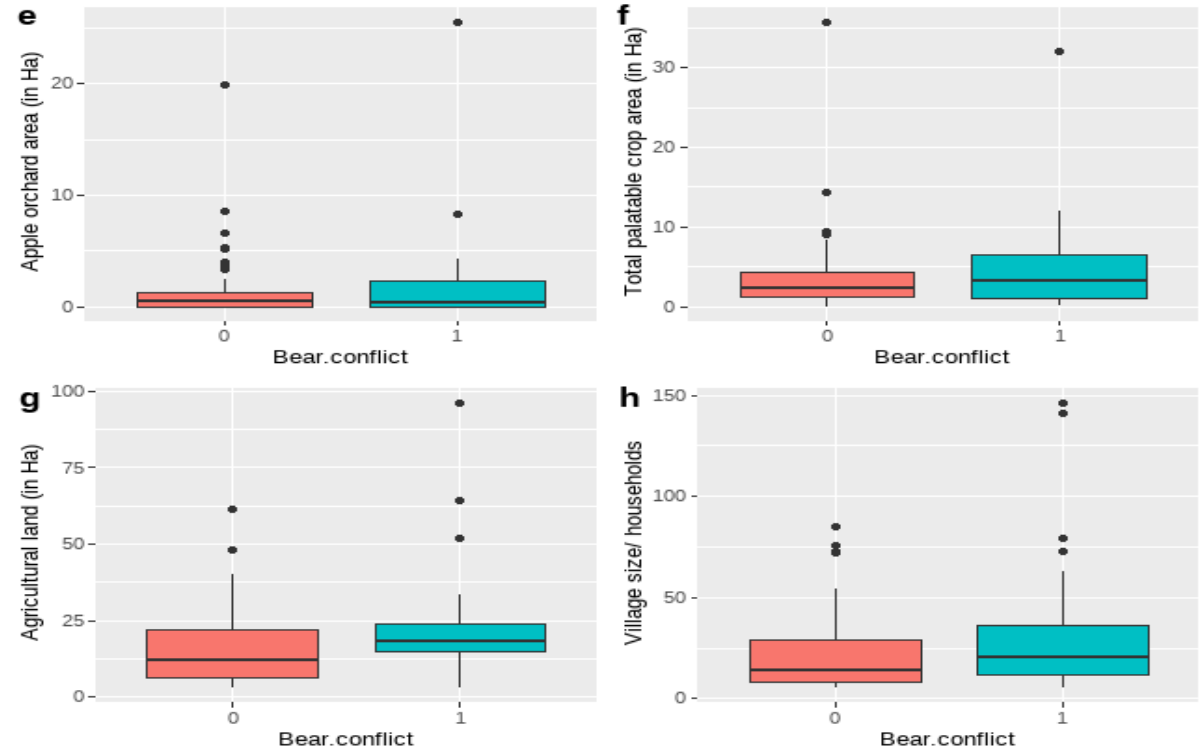


Figure 3.8 Variables that were initially thought to have an effect on a village's likelihood of experiencing bear conflict (0=no bear conflict; 1=bear conflict) *but proved to have no effect in our analyses: e) apple orchard area, f) total bear palatable crop area, g) village agricultural land, and h) village size or number of households.*

Studies on Himalayan brown bear occurrence in Lahaul (Sharief et al., 2020) and in adjacent habitat of Kugti (Rathore 2008) show bear's preference for agriculture and alpine grassland, and not a significant preference or influence of forests. Our results indicate that at the village-level scale, just the availability or access of agriculture land and bear-palatable crops did not influence crop-related bear conflicts since the extent of agriculture land and palatable crop acreages were comparable between conflict and non-conflict villages. Topographical features at the scale of the village explain the vulnerability of crop damage by bears in villages. The interaction of forest patch size and ruggedness around the village together seems to have a strong role in driving the likelihood of bear conflict, which suggests that, at finer scales, bear conflict is restricted to areas that provide large patches of conifer and mixed forests on rugged terrain. But this negative interaction term indicates that the increase in both forest patch size and ruggedness around a village are associated with an increased likelihood of bear conflict in that village, however, the influence of either of these variables (for e.g., forest patch size) decreases as the other variable (for e.g., ruggedness) increases, and vice-versa. So around areas where ruggedness increases, the effect of forest patch size on probability of bear conflict decreases, and on the other hand, around areas where forest patch size becomes larger, the role of ruggedness becomes mild or less significant. Many of our sampled villages in the lower Pattan valley have larger patches of forest cover, but perhaps owing to the gentle, undulating terrain tend to not provide required shelter and resting spaces for bears, and therefore, villages in this region are less likely to be frequented by bears, and less likely to result in bear conflict. Similar results were found by Nelleman et al. (2007) where they highlighted that both male and female brown bears used rugged forest terrain significantly more than flatter forest terrain. This preference for rugged terrain is understood to be because of greater availability of cover and denning sites for females, along with lower access to these areas by humans. Additionally, rugged terrain and aspect variations affect the composition and phenology of the plant resources for bears (Nellemann et al., 2007).

Studies have shown the significant positive influence of forests on habitat preferences of both brown bears (Kobler & Adamic, 2000; Mateo Sánchez, Cushman, & Saura, 2014; Posillico et al., 2004) and black bears (Hagani et al., 2021; Manen, 1997). While confirming the ecological importance of forests for brown bear habitat, some studies noted that these forests serve more as a protective cover than a rich source of food. Pine forests, such as the ones found in our study area, have lower food resource opportunities compared to deciduous forests (Clevenger, Purroy, & Campos, 1997).

Elevation or less variation in elevation around a village also increases the likelihood of bear-related crop damage. Many studies have also highlighted the significant and direct effect of elevation on bear habitat preference (Hagani et al., 2021; Kobler & Adamic, 2000; Manen, 1997; Martin et al., 2010; Posillico et al., 2004). Female brown bear may prefer areas with steeper slopes as they provide higher relative security to avoid direct anthropogenic disturbance and threats to cubs from other carnivores.

In a study assessing brown bear habitat selection, Mateo Sanchez et al. (2014) suggested that patch cohesion and canopy cover were strong predictors of habitat quality. And although results from our study may indicate that increase in number of forest patches (decreased patch cohesion and canopy cover) increases the likelihood of bear conflict in a village, we are not entirely convinced by this interpretation. This is because in our study landscape, the fragmentation of forest patches is not due to anthropogenic activity but due to the nature of the terrain. Moreover, patchiness in forest cover allows a larger diversity of forage vegetation for the bears, and therefore should not be interpreted as a habitat of poor quality. On the contrary, smaller and multiple forest patches on rugged slopes may provide a better mix of cover and locally available wild forage in the forest edges compared to large, contiguous pine forested areas with little or no forage.

A critical point to add here is that many of our non-conflict villages on the south-west facing slope were not characterised to have forest cover or forest patches as they did not have conifer or mixed forests, but rather had only dry scrubland characterised by scattered patches of *Juniperus* spp. that may be avoided by bears due to lack of access to food and protective cover. The avoidance behavioural tendency of bears towards *Juniperus spp.* has been noted in other studies too (Clevenger et al., 1997; Posillico et al., 2004).

As observed by others (e.g., Martin et al., 2010), bears in Lahaul also tend to show a spatio-temporal avoidance to human settlements such as villages. They do not visit the village for crop foraging during the daylight hours of high human activities and disturbance. It is only from the time of dusk till dawn when they enter a village and forage on their preferred crops. During the day, they remain inactive and hidden from human sight, which means they are occupying and utilising the protective resting or shelter grounds in their home ranges.

The analysis of conflict and non-conflict villages shows that the amount and proportion of agricultural area and palatable crops itself didn't seem to matter, perhaps since all villages were not very different in this regard – all had apple, peas and other palatable crops – but it was the habitat within which the village was located that made a greater difference. As mentioned above, villages that had forested and rugged terrain and canyons close by appeared to be more vulnerable to crop damage by brown bears. We propose that this was because the bears in such areas had access to more secure and shaded cover in the forests with some amount of wild forage in the forest edges and additional, high-quality food from crop fields close by.

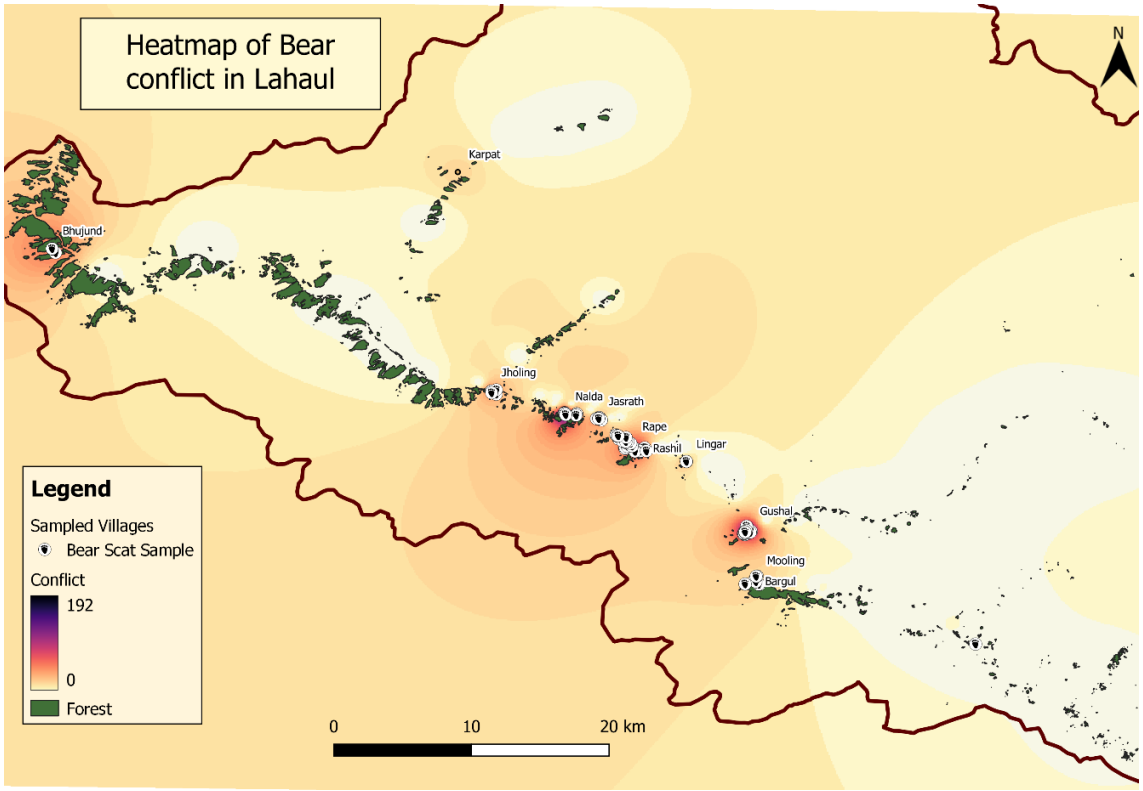
It should also be noted that brown bears are reported from all valleys of Lahaul, including in the more open and rolling areas of the right bank of Chandrabhaga, but their abundance appears to be higher in the left bank. Respondents also said that often it was females and her young that were seen in these crop fields. Another hypothesis we propose here is that lactating females taking care of their young may prefer to remain in such rugged, forested secure sites with additional forage from crops as this could restrict their search effort for food and thus be able to survive in a smaller home range through the summer season.

3.1.5 Ecological survey for bear diet ecology and individual identification

The delay in the initiation of project, the pandemic, and weather proclivities like the cloudburst event, and flash floods during the initial phases of the fieldwork reduced the time available for effectively carrying out all the research activities. For the same reason, we decided that we could not invest substantial time in conducting the ecological survey as initially planned. The team prioritised conducting Focus Group Discussions and household-level interviews in 80 villages before December. Therefore, the ecological survey was recalibrated (see Section 1.4.3) to focus on brown and black bears for their abundance near villages (using genetic tools) and diet analyses to understand the importance of crops in their diets relative to wild plants (Activity 4). Separate funds were generated to complete the genetic component of the study and collaborations were forged with IISER-Tirupati's genetics laboratory for the analyses.

Further, we had prepared a proposal for including the larger biodiversity survey, with an emphasis on estimating bear abundances across the entire Lahaul Valley, with the state's Forest Department. In this regard, we had also conducted a training workshop for the department's field staff in bear monitoring techniques in July 2021. For individual identity of bears near villages and understanding bear diets, we propose to use genetic analysis for which the team collected 111 bear faecal samples and 3 hair samples (Map 3.2). All the scats were collected from the vicinity of twelve villages- in agricultural fields and forest areas near these villages. To aid in plant identification in bear diet analysis, some plant samples known to be part of the bear diet were also collected to be used as reference. The lab analyses of the samples are presently underway. This would allow us to attain a better understanding about the abundance of bears around conflict villages as well as the proportion of agricultural crops in their overall diets.

As a result of our continued engagements with the Himachal Pradesh Forest Department, ecological survey and monitoring for wild animals in Lahaul has been successfully adopted by UNDP-India SECURE Himalaya as part of their management plan.



Map 3.4 Location of bear faecal (scat) sampling in Lahaul as part of ecological survey. A total of 112 bear scats were collected from the vicinity of 12 villages.

3.2 Drivers of attitudes, perceptions, and tolerance towards bears

3.2.1 Attitudes, perceptions, and tolerance towards bears in Lahaul

Resolving human-wildlife conflict related to crop depredation and livestock loss cannot be achieved using a singular approach but requires the use of multiple and adaptive tools (Madden, 2004). People's perception of crop loss inflicted by an animal might not be an accurate indicator of actual financial loss as perceptions can be shaped by factors such as emotional attachments towards crops, and a lack of control over addressing the problem. As highlighted by Gillingham and Lee (2003), retaliation towards conflict species is often shaped by the perception of losses rather than the actual losses. Moreover, attitudes towards conflict species, and tolerance towards damages are governed by factors such as frequency and intensity of instances of conflict, socio-economic background of affected farmer (Naughton-Treves & Treves, 2005), cultural and religious significance of conflict animal (Saraswat et al., 2015), and wider societal experiences and cultural norms (Dickman, 2010). Therefore, to mitigate human-wildlife conflict, it is vital to first understand the attitudes, and perceptions of people towards these offending species and then take up measures to minimise negative perceptions.

To understand people's perceptions of risks, attitudes, and tolerance towards bears in Lahaul, a questionnaire schedule was administered on 179 households in 26 villages from villages that had no (n=5), low (n=5), medium (n=5), high (n=8), and livestock only (n=3) conflict. Attitude index and tolerance index were constructed by adding responses from short statements dealing with several aspects of living with bears.

Out of the 179 household-level interviews, 65% (117) respondents reported to have faced some sort of conflict with bears. While 44% of the respondents experienced crop loss because of bears, 31%

experienced livestock depredation. More than half (58%) of the respondents had seen a bear in or around the village in the last 2 years. The rest of the results from interviews are summarised below.

a) Perceived risks and losses from bears

Perceptions towards bears varied largely from person to person (Figure 3.9). Almost half of the respondents perceived an extremely high risk from bears. 20% of the respondents felt that the risk was moderate and almost an equal proportion felt that the risk was low. Around 15% felt that there was no risk involved in cohabitating with bears.

When asked about the frequency of livestock loss from bears, 69% of the respondents felt that bears never attacked their livestock, whereas only 9% felt that the bear attack on livestock was frequent. Similarly, more than half of the respondents (55%) believed that bears never frequented their farms and caused no damage. Around a fifth of the respondents (22%) felt that bears depredated crops in their fields very frequently and inflicted extremely high damage (20%). A similar proportion (10% each) felt that episodes of bear inflicted crop loss were frequent and occasional. While 6% perceived the damages inflicted by bears to be high, 11% felt it was moderate, and 8% viewed it as low.

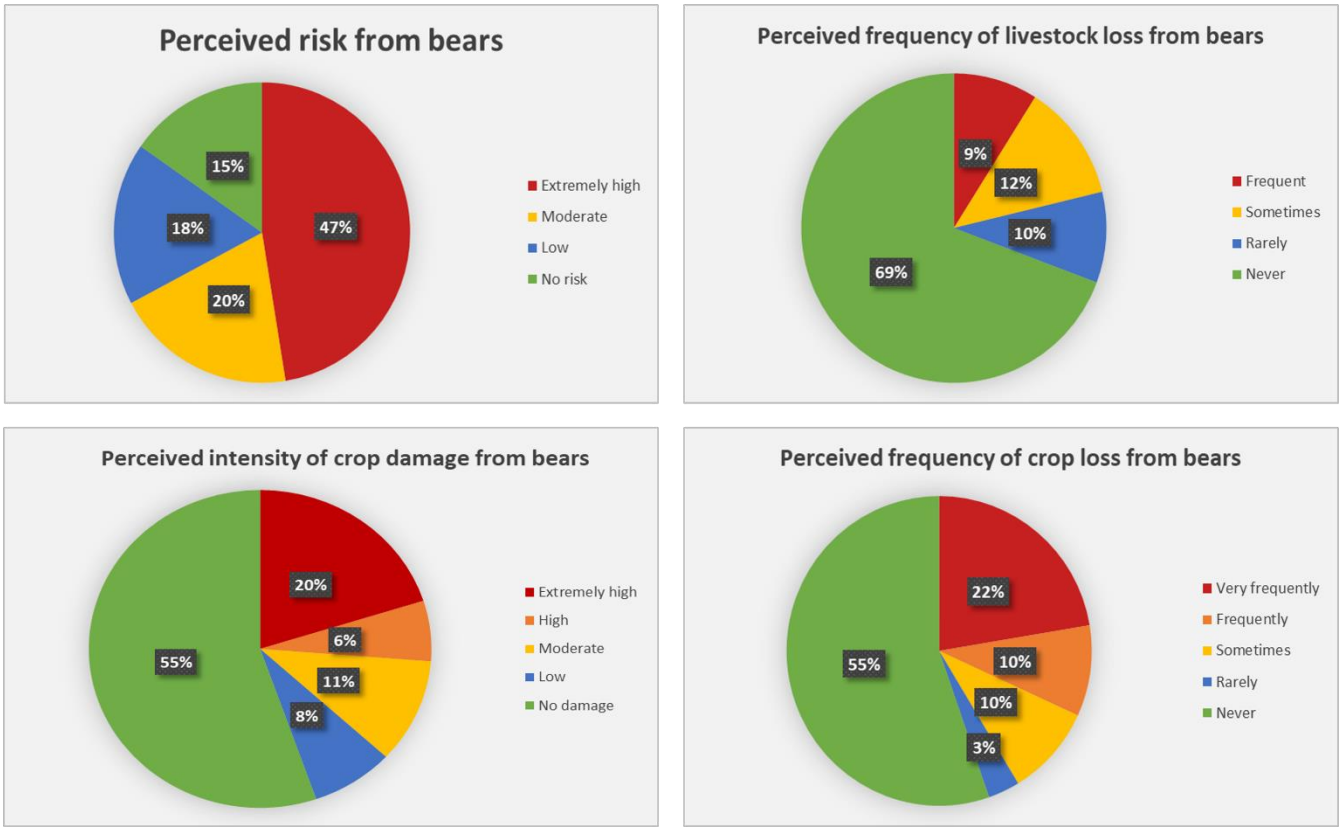


Figure 3.9 Perceived risks and losses from bears in Lahaul

Even though almost half of the respondents felt that the risk of living with bears was extremely high, more than half of the respondents also perceived the intensity and frequency of crop and livestock damage by bears to be negligible. This means that the risk perceived from bears was not entirely dependent on perceived losses.

b) Attitude towards Bear

The attitude of people towards bears was evaluated using several attitude statements dealing with various aspects of cohabiting with bears. Likert scale ranging from Strongly Disagree to Strongly Agree was used to record responses against each statement. Based on the nature of the statement, the responses were then scored from 1 to 5, where 5 depicted the most positive attitude and 1 depicted least positive. Mean scores for each attitude statement were calculated. The results are summarised in Table 3.8.

Table 3.8 Summary table of attitudes towards bears. (Green coloured statements are positive in nature and the pink ones are negative.)

S.no.	Attitude statements	Percent (%) of responses					Mean Score
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
a	**It is important to have a healthy population of bears in the forest around village.**	42	30	7	15	7	2.15
b	**Whether or not bears cause agricultural/livestock damage, it is important that they exist in Lahaul.**	20	20	8	41	12	3.04
c	**It is okay to hurt a bear to prevent agricultural damage.**	17	33	9	27	14	3.13
d	**Bear hunting should be allowed in moderation in Lahaul.**	37	20	7	22	13	3.46
e	**Having a healthy bear population is important for tourism in Lahaul.**	22	21	13	28	15	2.93
f	**It is acceptable if bears eat apples from your orchard.**	30	34	9	20	6	2.38
g	**Bears should only be restricted to wildlife sanctuary and national parks.**	6	16	6	26	46	2.09

As pointed out by various scholars, a community's relationship with animals is not homogenous but contingent on circumstances and factors such as social relations, history, geography, etc. Therefore, it is important to view these relationships as a spectrum ranging from positive to negative, and ambivalent (Oommen, 2021; Bhatia et al., 2020). And even though we have not specifically focused on the positive

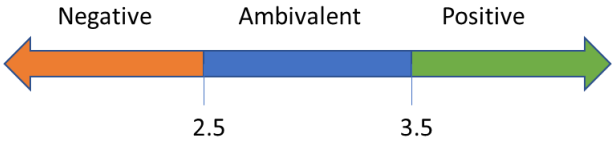


Figure 3.10 Visual representation of the attitude scale towards bears in Lahaul

aspects of human-wildlife interactions in our study, we would like to acknowledge that we came across a range of such interactions during our study. In our case, we have defined attitudes having a mean score greater than 3.5 to be positive, and less than 2.5 to be negative. Between 2.5 and 3.5, the attitudes are considered to be ambivalent.

Some interesting insights develop from the summary of the attitudes table. Although people seem to have a slightly negative attitude towards the presence of bears in their immediate village surroundings, they are more ambivalent towards its presence in Lahaul in general. People also seem to have an ambivalent attitude towards bears when asked about its utility in tourism. Having said that, most people prefer bears to be restricted to wildlife sanctuaries and national parks. This means that people in general have an ambivalent attitude towards the presence of bears in Lahaul, but it shifts slightly negative when this presence becomes localised.

The attitudes towards managing bears are also largely ambivalent with most respondents having reservations about hurting and hunting bears.

Using the attitude statements presented in Table 3.8, we constructed an index for attitudes and tolerance each. As attitudes represent mental constructs like thoughts and feelings, statements a, b, c, d, and e were combined to form the attitude index. Tolerance, on the other hand, can be defined as "the ability and willingness of an individual to absorb the extra potential or actual costs of living with wildlife"

(Kansky et al, 2016). Since tolerance is about the everyday interactions with the animal and is a 'passive restraint' on the human part, we chose the summation of statements a, c, f, and g to best represent the tolerance index.

The mean score for the attitude index came out to be 2.94 and that for tolerance index was 2.44. These results suggest that even though people in Lahaul have an ambivalent attitude towards bears, they have a slightly lesser tolerance towards bears. In other words, people are less willing to tolerate bears in events of crop or livestock depredation in and around their village. During our time in the field, we learnt that people resorted to a number of ways to retaliate. For instance, in the village of Nalda, a man used live wire around his field to electrocute and fend off bears.

3.2.2 Drivers of attitude and tolerance

An attempt was made to understand the factors that could influence the attitudes and tolerance of people towards bears in Lahaul. To explain attitudes and tolerance, Generalised Linear Models (GLMs) were constructed. Studies show that attitudes towards wildlife is influenced by socio-economic and demographic factors such as age, gender, income, education (Ambrali, 2016), cost of damage, livelihood diversity (Dickman, 2010; Lindsey, 2013), socio-psychological factors such as subjective norms, moral obligations, perceptions of costs and benefits (St John et al., 2010; Kansky et al., 2016), and ecological factors such as visibility of animals (Dickman, 2013).

After reviewing literature, and after carrying out preliminary analysis of variables using biplots, correlation plots, and boxplots, seven significant explanatory variables were shortlisted for each model. A summary of selected covariates for modelling is presented in Table 3.9 below.

Table 3.9 Description of covariates used for modelling attitudes and tolerance

S.no.	Covariate code	Description	Type	Range/Categories	Used for Model
1	Age	Age of the respondent	Numerical	18-88	Attitude and Tolerance
2	Gender	Gender of the respondent	Categorical	Male or Female	Attitude and Tolerance
3	Education1	Education level of the respondent	Categorical	No education/Primary education/Secondary or Higher education/ College	Attitude
4	WL_benefits1	Perceieved benefits from Wildlife	Categorical	Yes/No	Attitude and Tolerance
5	Ag_rank_bear	Problems related to agriculture were ranked. This covariate is the rank that bears recieved among all other problems. Rank 1 is the highest and rank 7 is the lowest.	Numerical	1 to 7	Attitude
6	Seen_bear	Whether seen a bear in the last 2 years	Categorical	Yes/No	Attitude
7	Risk_perc1	Perceieved risk from bear	Categorical	Low/Moderate/High	Attitude and Tolerance
8	Liv_div	Livelihood Diversification. Number of occupations in a household.	Numerical	1 to 5	Tolerance
9	Crop_loss_freq	Perceived instances of crop loss by bears	Numerical	0-31	Tolerance
10	Crop_damage_perc1	Perceived intensity of crop depradation by bears	Categorical	No damage/ Low or Moderate damage/ High damage	Tolerance

All the possible combinations between the shortlisted covariates were used to generate Generalised linear models (GLMs) for attitudes and tolerance towards bears. A total of 128 models each were

automated using an R package called *glmulti* (Calcagno & Mazancourt, 2010). This function builds all possible unique models by involving all the explanatory variables provided and selects the best model among all candidate models. The corrected AIC values (AICc) were used as the information criteria for model selection.

a) Drivers of attitude towards bears in Lahaul

A summary plot of AICc values of all 128 fitted models was generated. In Figure 3.11, the red horizontal line separates the models whose value is AICc values are less than 2 units from the best model from those whose AICc values are more than 2 units from the best model. Models having values more than 2 units away from the best model are usually considered to be significantly less plausible than those within 2 units of the best model. From the output, we can see that there are two such competing models. The top 8 models were then retrieved. The details of these models along with their AICc values, and Akaike weights are presented in Table 3.10. The Akaike weights can be thought of as the probability that a given model would be the best model among all the fitted models. The best model in our case has a significantly lower AICc value and a much greater weight than the second-best model.

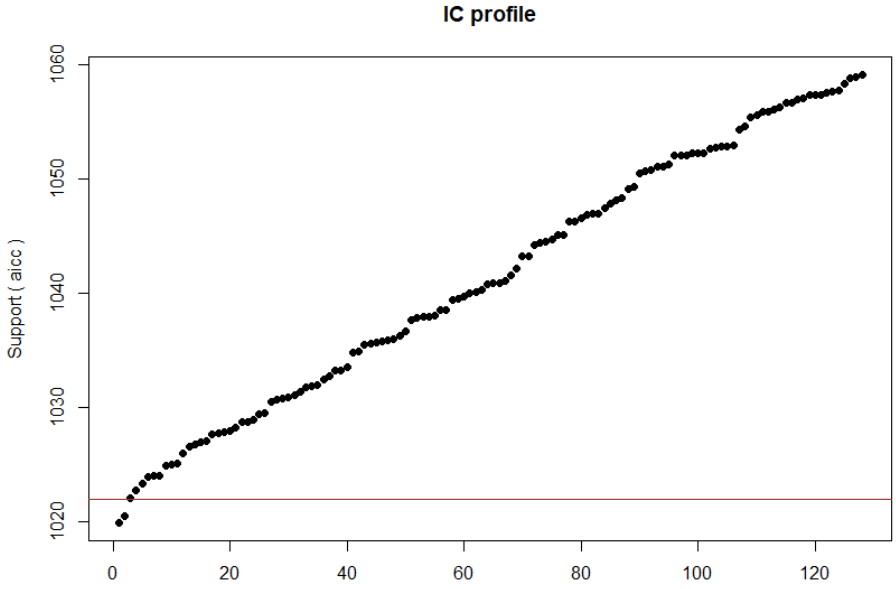


Figure 3.11 Summary plot of AICc values of all fitted models that explain attitudes

Table 3.10 Summary of best models that describe attitudes towards bears

S.no.	Candidate models that best explain attitudes towards bears in Lahaul	AICc	Weights
1	Att_ind1~Age+WL_benefits1+Ag_rank_bear+Seen_bear+Risk_perc1	1019.96	0.283362
2	Att_ind1~Gender+Age+WL_benefits1+Ag_rank_bear+Seen_bear+Risk_perc1	1020.541	0.21193
3	Att_ind1~WL_benefits1+Ag_rank_bear+Seen_bear+Risk_perc1	1022.091	0.097624
4	Att_ind1~Gender+Age+WL_benefits1+Ag_rank_bear+Risk_perc1	1022.804	0.06836
5	Att_ind1~Gender+WL_benefits1+Ag_rank_bear+Seen_bear+Risk_perc1	1023.349	0.052043
6	Att_ind1~Age+WL_benefits1+Seen_bear+Risk_perc1	1023.944	0.038652
7	Att_ind1~Age+WL_benefits1+Ag_rank_bear+Risk_perc1	1023.996	0.037658
8	Att_ind1~Gender+Age+WL_benefits1+Seen_bear+Risk_perc1	1024.053	0.036614

Attitudes towards bears in Lahaul are best described by a combination of age, perceived benefits from wildlife, rank of bears in agricultural problems, bear visibility, and perceived risk from bears. The summary statistics of this model are presented in the Table 3.11. The McFadden's R-squared value for this model came out to be 0.2327 which is decent. Among all explanatory variables, only age is

negatively correlated with attitudes. In other words, older people are likely to be more negative towards bears. The rank of bears among agricultural problems is positively correlated. This means that people who assigned a higher numerical value to bear related problems or in other words ranked them lowly (rank 1 being highest and 7 being lowest) were more likely to have a positive attitude towards them. Interestingly, those who had seen the bear had a more positive attitude towards it than those who had not. People who had not seen or encountered a bear, or experienced losses personally had a "hyperawareness" of the risk posed by bears which often culminated in more negative attitudes (Dickman, 2010). Contrary to the popular belief that experiencing damage, and monetary losses were the dominant factors in determining attitudes (Distefano 2003; Dickman 2010; Poudel et al., 2022), we found that those who experienced losses and those who didn't, exhibited a similar attitude towards bears. Put differently, experiencing conflict and monetary loss had no impact on people's attitude towards bears. Our argument is in line with Kansky et al. (2014) that damage and monetary losses are not the primary drivers of a community's attitudes towards bears. It is rather the perceived risks and benefits from the species (Kansky et al., 2016) that best describe attitudes.

In summary, older people who perceived no benefits from wildlife but perceived moderate to high risk from bears, who had not seen the bear, and who ranked bears highly (rank 1 or 2) among the list of problems associated with agriculture were more likely to have a negative attitude towards bears.

Table 3.11 Summary statistics of the attitude model

Best model that explains attitudes towards bear

	Dependent variable:
	Att_ind1
Age	-0.045**
	(0.022)
WL_benefits1Yes	3.251***
	(0.717)
Ag_rank_bear	0.622**
	(0.253)
Seen_bearYes	1.687**
	(0.683)
Risk_perc1Low	2.480***
	(0.755)
Risk_perc1Moderate	0.783
	(0.839)
Constant	13.444***
	(1.283)
Observations	179
Log Likelihood	-502.556
Akaike Inf. Crit.	1,019.113
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 3.12 Summary statistics of the tolerance model

Best model that explains tolerance towards bear

	Dependent variable:
	Tol_index1
GenderMale	1.079**
	(0.517)
Age	-0.033*
	(0.017)
WL_benefits1Yes	1.886***
	(0.555)
Liv_div	-0.595**
	(0.242)
Risk_perc1Low	1.821***
	(0.536)
Risk_perc1Moderate	1.532**
	(0.651)
Constant	10.979***
	(1.257)
Observations	179
Log Likelihood	-456.426
Akaike Inf. Crit.	926.852
Note:	*p<0.1; **p<0.05; ***p<0.01

b) Drivers of tolerance towards bears

A summary plot of AICc values of all 128 fitted models for tolerance was generated. From the output we can see that there are only two competing models. A summary of top 8 models that best describe tolerance can be found in Table 3.13.

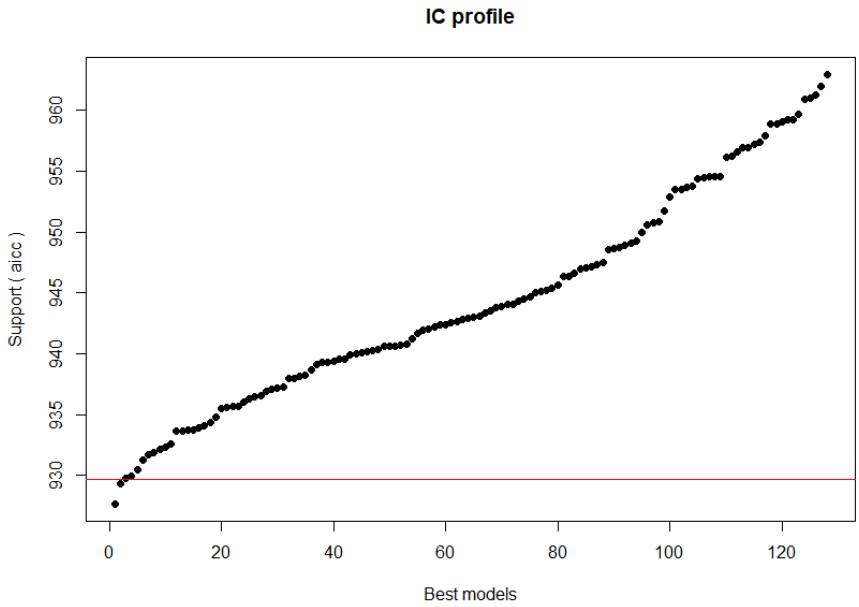


Figure 3.12 Summary plot of AICc values of all fitted models that explain tolerance

Table 3.13 Summary of best models that describe tolerance towards bears

S.no.	Candidate Models that best explain Tolerance towards bears in Lahaul	AICc	Weights
1	Tol_index1~Gender+Age+WL_benefits1+Liv_div+Risk_perc1	927.6988	0.27196177
2	Tol_index1~Gender+WL_benefits1+Liv_div+Risk_perc1	929.3058	0.12177361
3	Tol_index1~Gender+Age+WL_benefits1+Liv_div+Crop_loss_freq+Risk_perc1	929.7979	0.09520964
4	Tol_index1~Age+WL_benefits1+Liv_div+Risk_perc1	929.9819	0.08684506
5	Tol_index1~WL_benefits1+Liv_div+Risk_perc1	930.4939	0.06722904
6	Tol_index1~Gender+WL_benefits1+Liv_div+Crop_loss_freq+Risk_perc1	931.2492	0.04608284
7	Tol_index1~Gender+Age+WL_benefits1+Risk_perc1	931.6901	0.03696677
8	Tol_index1~Gender+Age+WL_benefits1+Liv_div+Crop_damage_perc1+Risk_perc1	931.8804	0.03361098

The top model has a significantly lower AICc value and a much greater Akaike weight than its competing models. The McFadden's R-squared value for this model was calculated to be 0.2309. According to this model, tolerance towards bears is best determined by a combination of gender, age, perceived benefits from wildlife, livelihood diversity, and risk perception. An overview of the summary statistics of this model is provided in Table 3.12. Like we discussed in the case of attitudes, perceived risks and benefits are important covariates that determine tolerance as well. Tolerance is negatively correlated with age of the respondent and females in general tend to be less tolerant towards bears. Again, as opposed to conventional logic, monetary losses, and experience of conflict do not seem to determine tolerance (Kansky et al., 2016). Interestingly, we found livelihood diversity to be negatively correlated with tolerance. According to Dickman (2010), a greater diversification in livelihoods should lessen the impact of conflict and increase tolerance. However, in this case, we found that people with lesser diversification tend to have a higher tolerance for bears.

In summary, younger men with limited livelihood options, who felt wildlife to be beneficial and bear related risk to be low were likely to have a greater tolerance towards bears.

3.3 Conclusion

Out of the 78 sampled villages, 77 villages experienced varying degree of crop damage by wild and stray animals including dogs, pika, chakor partridge, macaque, marmot, brown bear and black bear. Of all these animals, both the bears caused a significantly higher amount of crop loss in terms of quantity as well as monetary values. Despite these significant crop losses, we found that crop damage by bears is not pervasive across the landscape but is limited to some sub-valleys. Villages on the left bank of the Pattan and Tinan sub-valley, Tindi and Miyar sub-valley experienced crop loss by both the bears.

This spatial variation in crop damage by bears was assessed using several village-level characteristics, and our results indicated that a village's topographical features play a key role in making a village more vulnerable to crop damage by bears. Particularly, higher number of forest patches increases the likelihood of a bear crop damage, while higher variation in elevation decreases this likelihood. And although the increasing size of forest patch increases the likelihood of a village experiencing crop damage by bears, with increasing ruggedness the increasing forest patch size has little effect on bear crop damage. This indicates that the interplay between forest size and ruggedness around a village play a critical role in bear micro-habitat use and consequently its crop foraging activities in a village. Moreover, contrary to our expectations, the mere presence of crop-forage, and the extent of availability of palatable crops like apple and green pea had no significant effect in making a village more vulnerable to crop damage by bears.,

In terms of livestock loss, 73% of our sampled villages (57 villages) reported livestock loss in the last five years. Our results revealed that free-ranging dogs caused the most damage due to livestock predation, especially on small-bodied livestock such as sheep. Bears also predated on livestock like sheep and cows, while there were few reported incidents of livestock predation by snow leopard and wolf on cows, sheep and horses. For wild animals like bears, snow leopard and wolves, the livestock predation was limited to the grazing season from spring to summer, but for dogs such incidents were higher in post-grazing season when livestock tend to graze unattended around village fields. Indicating a clear spatial pattern in livestock predation, the Pattan, Tindi and Miyar sub-valleys were the hotspots for livestock predation. Many of the reported incidents took place in the village pasturelands.

The household-level interviews in 26 villages with varying level of conflict with bears showed that people's attitude towards bears was largely ambivalent, whereas their tolerance towards them in the village proximity was relatively lesser. Contrary to many studies, our findings revealed that experiencing conflict with bears or incurring monetary loss had no significant role in determining an individual's attitude and tolerance towards bears. Individuals who were older, and perceived no benefits from wildlife, but high risks from bears, despite never seeing or encountering them, had a more negative attitudes towards bears. A similar case can be made for understanding tolerance but with the addition of gender. Older females who perceived no benefits but high risk from bears were less tolerant towards them. Interestingly, households with higher diversity in livelihood options showed a lower tolerance as well. These findings suggest that although mitigation measures to prevent, reduce and offset losses may be important, in order to improve communities' attitudes and tolerance towards bears, we need to lay equal emphasis on understanding how communities perceive risks and benefits of co-habiting with bears in the landscape.

CH 4

MITIGATION & RECOMMENDATIONS





Credits: Rashmi Singh Rana, Kartik Chugh

4.1 Mitigation strategies used by the community

People in Lahaul utilise several techniques and strategies to safeguard their lives, and to mitigate crop and livestock loss against conflict species such as bears, wolves, dogs, pika, marmots, and snow leopards. Mitigation measures reported and suggested by the community (summarised in Table 4.1) range from lethal to non-lethal control of the conflict animal, from behaviour modification of humans to measures that promote human-animal coexistence.

To prevent crop depredation from bears, most of the farmers make use of audio and visual repellents like fire, lights, crackers, and banging utensils to produce noise. However, many complained that these measures become ineffective over time as bears get used to them. Other than that, guarding fields in small groups at night is also routine, but as many complained, it is tiring, time-consuming, and risky.

When asked about the potential mitigation measures against bears, the community suggested two possibilities. While some believed that installing solar fencing could be the way forward, others felt that capturing bears and relocating them was the only solution. Although farmers in Lahaul are positive towards getting solar fences installed, they also have their reservations about their efficacy. They often complained how solar fences were not resilient and would easily damage in an event of heavy snowfall. Once damaged, it was not easy to get it repaired either. In any case, any kind of repair needed for the parts such as the solar panel, energizer or wires was not possible locally and was expensive. According to some, bears were also capable of damaging the fence and getting through. As noted by Sharma et al. (2020), there is a growing need to test and improve the structure, design, and utility of the current model of solar fencing in Lahaul.

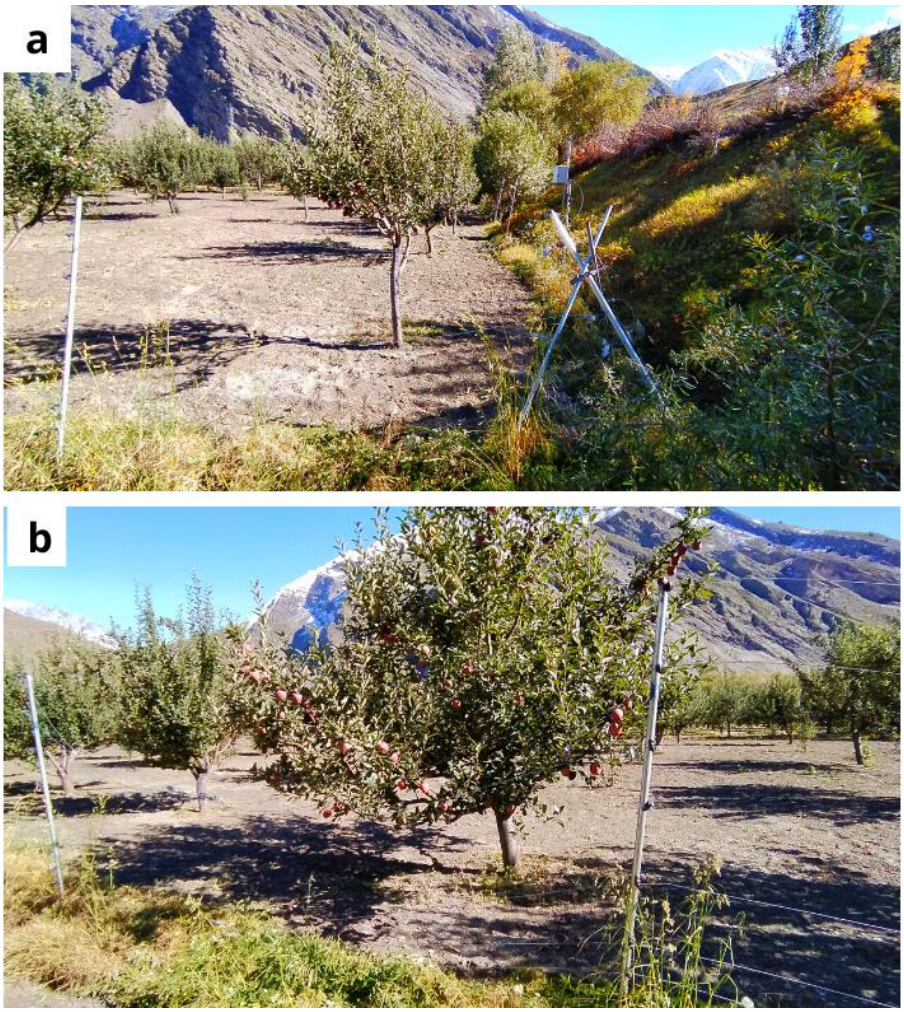
To prevent livestock depredation from all predators, the use of enclosures and corrals is common. Graziers are hired to assist livestock to pastures and to protect them from predators. Villagers also try to make sure that the livestock are not left alone in the village.

To prevent lethal encounters with bears, people in Lahaul usually go out in groups during dawn and after dusk. They usually carry torches, stones, and sticks in case of an encounter and create noise while walking to make the bear aware of their presence. These methods have largely been effective so far as there is no reported case of human harm or casualty from bears in Lahaul to date.

A lot of people in Lahaul believe that the population of bears have increased in the last decade. They also felt that it was the responsibility of the forest department to manage bear populations and to mitigate conflicts. There were many instances where people complained about the inaction of government departments in this regard.

Table 4.1 Mitigation strategies for crop loss, livestock loss and human safety as reported by respondents.

Mitigation approach	Techniques	Strategies used and suggested by community	Target animals	To safeguard
Physical separation of conflict animal and resources	Barriers/ Fencing	Fencing, Electric fencing	Bears, Livestock, Dogs	Crops
	Use of deterrents and repellents	Use of fire, lights, crackers, noise, smoke, and odour repellents	Bears	Crops and Humans
		Scarecrow, Fladry	*Chakor* partridge, Pigeons	Crops
		Use of cassette tapes to produce a gusting sound	*Chakor* partridge, Pigeons, Pika	Crops
	Enclosures	Livestock enclosures and corrals	Snow Leopards, Bears, Wolves, Dogs	Livestock
Guarding	Human guarding	Guarding fields at night	Bears	Crops
		Stone pelting	Bears	Crops and Humans
		Hiring Graziers	All predators	Livestock
	Animal guarding	Guard dogs to alert humans about the presence of predators	All predators	Crops and Livestock
Behaviour modification of humans	Changing cropping patterns	Reducing crops palatable to bears	Bears	Crops and Humans
	Others	Restricted movement in night		
		Walking in groups		
		Waving clothes, arms to look bigger		
		Making noise by banging utensils		
Use of buffer resources	Planting buffer resources	Planting buffer crops to reduce consumption of main crops	Bears, Pika	Crops
		Suggestion of maintaining some plots outside villages for bears	Bears	Crops
		Sowing extra seeds	*Chakor* partridge, Pigeon	Crops
Lethal control of conflict species	Killing of conflict species	Hunting	Bears, Dogs, Marmots	Crops and Livestock
		Use of live wires	Bears	Crops
		Glue traps	Pika	Crops
		Poison	Pika, Rats, Bear	Crops
		Setting fire	Marmot, Wolves	Crops and Livestock
Non-lethal control of conflict species	Removal of conflict animal	Suggestion of capturing bears, translocating or relocating them	Bears	Crops



Credits: Rashmi Singh Rana

Image 7. Electric fencing around apple orchard in a village, Gushal, with damage to poles and the electric wires. The heavy snowfall of winters was cited as the reason for this damage. Some people also cited bears damaging the fencing in order to access the apple orchards.

4.2 Mitigation plan for human-bear conflict

To successfully manage human-bear conflict in Lahaul requires an integrative approach. After **understanding** the patterns and processes of conflicts, we propose a 3-step mechanism of **preventing**, **offsetting**, and **informing** to minimise conflict. Such an approach would need to integrate not only the intervention mechanisms to mitigate conflict but also the participation and convergence of all stakeholders at various capacities.

4.2.1 Preventing access to anthropogenic food

The common pattern across Lahaul, according to local accounts, was that the bears responsible for crop depredation were usually females accompanied by their offspring. The same pattern can also be found in North America, Europe and parts of Asia. The reason why adult males and lone females are usually not present near human settlements could be because of *despotic distribution* wherein dominant adult bears tend to displace younger subordinate individuals from prime habitats rich in food and shelter (Elfström et al., 2014). Many times, these individuals living near human settlements become habituated to human presence and conditioned to anthropogenic foods.

The availability of anthropogenic food is one of the primary drivers of human-bear conflict (Krofel et al., 2020). Therefore, preventing bear's access to crops is perhaps the most effective measure towards mitigating and minimising human-bear conflict. Doing this would ensure that the bears are not positively reinforced every time they visit human settlements, thus impeding food conditioning and human habituation. There are many proactive ways of preventing bears from accessing croplands including the use of deterrents, electric/solar fencing, guarding, non-lethal removal of bears, behavioural conditioning of bears, and changing cropping patterns. Some of these approaches are discussed in greater detail below.

a) Shortcomings of animal translocations

People in Lahaul believe that capturing bears and translocating (capturing an individual and releasing it in a different location but within its geographic range) them might be an effective way to mitigate conflict. Translocation of 'problem animals' is widely considered a more humane and non-lethal approach for resolving conflicts worldwide (Bauder et al., 2020). But there are multiple problems associated with it. Not only is it logistically and financially complex to carry out, but the process of translocation can also have an adverse effect on the individuals who might experience lower reproductive rates, malnutrition, and even mortality in some cases (Massei et al., 2010). Moreover, new forms of conflicts might emerge at the release site.

The success of translocating bears is dependent on factors such as age and sex of the individual, distance between capture and release sites, and the context of the landscape (Bauder et al., 2020). A review of the efficacy of black bear and brown bear translocation in Europe and America suggest that the rates of return of translocated bears was more than 50% in most cases (Linnell et al., 1997). Similarly, a study conducted by Mukesh et al. (2015) in Dachigam National Park, Jammu and Kashmir found that 7 out 11 translocated Asiatic black bears returned to their capture sites. As pointed out by Massei et al. (2010), we believe that translocation is not the most effective nor the most humane way to mitigate human-wildlife conflict. Importantly, since the affected villages provide reasonable habitat and these are contiguous with other bear ranges in Chamba and Zanskar, new individuals are very likely to occupy the territories/habitat vacated by the translocated animals.

b) Solar electric fencing

Electric fences have been used throughout the world to deter bears from crop, livestock, homesteads, and aviary depredation. It is a proactive measure that creates an environment of aversive conditioning for bears whenever they make contact with electric wires. Over the last two decades, electric fencing has become a predominant method for minimising human-bear conflict in many western countries (Johnson, 2018). In their global review of 77 cases of interventions against bears, Khorozyan & Waltert (2020) found electric fencing to be the most effective. However, most of these cases were from Europe and North America and there was a species bias towards American black and brown bears. The trans-Himalayan landscape of Lahaul might provide a unique context with a different set of challenges. Acknowledging and incorporating them is essential for electric fencing to be a success here.

Based on the team's interactions, people of Lahaul are not satisfied with the efficacy of solar/electric fencing tried so far. This is because the current design of the electric fence is not resilient to withstand the harsh winters as there is no provision to disassemble the fence during snow. And once the fence sustains any damage, it is difficult to get it repaired. Moreover, there have been instances of bears getting through and damaging the fence.

Before implementing the current model of electric fencing, no research was carried out to test its effectiveness. The efficacy of electric fencing is contingent upon many factors such as design which might include height and weight, portability, and ease of use, mesh configuration which might include number of strands, distance between each strand, and material of wire, joule rating and output, and more importantly soil conditions such as particle size and moisture content (Smith et al., 2018). It is important therefore to consider these factors, as well as the local context and geography, before using solar fencing as an intervention in Lahaul as its ineffectiveness in deterring bears can produce scepticism against its use in the community.

We suggest that multiple fencing models should be tried and tested, and a practical study should be carried out to test the effectiveness of each model under different conditions of slope, substrate, and target species. Fence models should ideally be removable so that they can be wound back in autumn, to be reinstalled in the coming spring, thus avoiding damage during winter. Portable models can also be tried for palatable crops, so that the fences can be moved around by an owner to the bear-palatable crop fields. Presently, only the agriculture department gives composite and electric fences at subsidised rates, while efforts are being made by UNDP-India's SECURE project and the Forest department to collaborate with private companies for manufacturing electric fences for Lahaul. We further propose that a convergent endeavour be initiated by the Forest department, Agriculture department and Horticulture department to create a common platform for providing these improved fencing models to high bear-conflict villages at subsidised rates. A joint venture can be encouraged between these government departments and selected private companies. A joint effort like this may reduce the redundancy that comes with multiple departments making efforts independently towards a similar goal. In villages, with low or no bear conflict, Agriculture and Horticulture departments can continue to spearhead the existing schemes of providing subsidised fences to farmers. Lastly, workshops should be organised to inform the users about the best practices of implementation and management of electric fences. It will be useful to train a set of local youth and technicians in the skills of repairs of the fencing and energisers, that can improve continued use of the fences. A system for systematically storing spares locally should also be explored.

c) Use of deterrents and repellents

Visual, acoustic, chemical, and olfactory repellents can be used to aversively condition the behaviour of bears. Similarly, deterrents such as shooting with rubber bullets and firecrackers can be used to

condition the bears to avoid undesirable behaviour (Dickman, 2010). Alarms that can detect bear presence and produce high-pitched noise can be utilised in conjunction with flashing fox lights and bear-repellent odours. Animal Intrusion Detection and Repellent System (ANIDERS), in particular, can be useful towards this end. ANIDERS use a combination of Active Infrared (AIR) and Passive Infrared (PIR) sensors to detect animal presence, movement, and intrusion into the farm, following which they trigger an alarm – a combination of light and sound – to repel that animal away. Some advanced models can also process images or animations to identify the animal and produce customised combinations of coloured lights and sounds to deter that animal (Jeevitha & Kumar, 2020). However, the use of repellents and deterrents alone is not an effective measure to alter bear behaviour (Beckman et al., 2004; Khorozyan & Waltart, 2020). As noted by farmers in Lahaul as well, the efficacy of deterrents and repellents wanes over time as bears get habituated to them, rendering them ineffective.

d) Rapid Response Team

Crop depredation by bears usually takes place during night. Since the use of electric fencing is not widespread in Lahaul, the primary mode of mitigation is guarding the fields in groups at night. Guarding fields along with the use of deterrents such as firecrackers has proven to be somewhat effective in fending off bears. However, patrolling fields at night is a cumbersome task and cannot be carried out for extended times. The drudgery of guarding involves high opportunity costs (Barua et al., 2013) affecting sleep and mental well-being of those involved. And while the affluent families can afford to hire labour for the purpose of watching their fields, many others cannot.

To overcome the limitations posed by guarding, previous studies from Lahaul (Sharma et al. 2020) suggested a joint effort between communities and the Forest department to create a 'Temporary Watcher Facility' by hiring and training local youth from effected villages to guard the fields from wild animals, especially bears, during the peak harvest months. A similar suggestion was made by a veteran from Rashil who believed that if field-guarding by locals can be incorporated into other daily-wage activities as part of the existing NREGA scheme (National Rural Employment Guarantee Act), it will be successful as locals would be interested in the dual purpose of crop protection as well as income generation. In an appreciable effort, the Forest department is considering forming Rapid Response Teams. We further suggest that the pilot of such a team be formed initially for all the high bear-conflict villages. Moreover, the rapid response team can be additionally equipped with tools such as crackers, noise making speakers, rubber bullets, bear sprays, night vision equipment, torches, and camping gear.

However, a rapid response team by itself might not be effective, especially in larger villages with vast agricultural stretches. It might be difficult for a single team to cover the entire area effectively. To overcome this, technological interventions like alarm systems (ANIDERS) should, therefore, be incorporated in conjunction to aid the rapid response team in determining the location of bears within a village.

e) Changing cropping patterns

We found that bears in Lahaul prefer crops such as green peas, apple, maize, and iceberg lettuce. Green peas and apples are widely cultivated throughout the valley whereas maize and iceberg lettuce are more limited. We also found that farmers in Lahaul have started to reduce the acreage of green peas in favour of cauliflower due to ease of cultivation, quality of produce and marketing. There are other reasons for this shift away from green peas and include need for greater manpower during harvest, dwindling productivity, poor quality of seeds, and depredation by bears. At the same time, new crops such as *Ferula asafoetida* (Heeng) and floriculture are being tested and their potential looks promising.

Since green peas account for the majority of crop depredation by bears, we propose a further reduction in its acreage in a phased manner over the next few years. Green peas should be replaced by crops that are not preferred by bears. To make it a success, it is important to make sure that these new crops are equally remunerative with adequate market linkages. For this purpose, we recommend bringing back traditional crops such as barley, and black peas. With proper value addition at source, these crops can be sold for prices greater than ₹200/Kg as compared to ₹40/Kg for green peas and are comparatively less perishable.

With help from the Agricultural department and Krishi Vigyaan Kendra, Kukumseri (KVK), small processing units can be set up at village or panchayat level where the produce can be packaged and labelled. Workshops can be conducted, and farmer cooperatives can be taught the essentials of effective marketing. The departments and the farmer cooperatives can also help in creating and sustaining market linkages. With a demand in organic products increasing, the value of the produce can further be increased if grown organically or using sustainable and fair-trade practices. Block-level committee under the aegis of the ATMA scheme (Agriculture Technology Management Agency) has been working towards the goal of bringing Lahaul under organic farming by promoting the use of natural fertiliser mixes using cow dung, cow urine and organic manure and waste. We further encourage active engagement of ATMA with farmers groups to provide them technical training and advice to sufficiently equip them for the transition towards organic farming. Moreover, under the Geographical Indications of Goods Act, 1999, black peas from the district Lahaul & Spiti can be registered for a Geographical Indication (GI) tag for the district, which will further help towards the much-needed value-addition for the economic viability of these traditional crops

Another advantage of growing traditional crops is that they are not perishable, unlike green peas. In events of calamities such as the flash floods of 2021 which washed away roads and disconnected parts of Lahaul to markets, many of the contemporary cash crops like cauliflower and exotics like broccoli and lettuce spoilt either in the fields or inside their packages, causing severe economic losses to the farmers. These traditional non-perishable crops such as barley and black peas or their products can be safely stored for long durations in times of disconnection from markets. Similarly, when the markets are low, these crops can be held for extended times, giving farmers greater control.

Compared to green peas, traditional crops such as barley and black peas require much lesser quantities of water. Since lack of water and snowfall is a major problem in agriculture in Lahaul and it is likely to get worse in the coming years on account of the receding glaciers and unpredictable precipitation. Adapting traditional crops in a strategic and phased manner might provide the necessary safety net for securing livelihoods of farmers in the long run.

After creating adequate market linkages with the help of various stakeholders, this effort can be piloted in a high-conflict village like Nalda and Gushal, as the respondents in these villages showed their keen interest for the same.

Along with green peas, bears also inflict a considerable amount of loss on apple trees. Most of this damage is attributed to breakage of branches of mature trees. Although it is difficult to replace older varieties of mature trees, the Horticulture department should take cognisance of actively discouraging further proliferation of such varieties in the high-conflict villages. Instead, novel Spur or dwarf varieties (which take shorter time for first fruiting) that are not too tall or have long branches, can be alternatively grown to minimise the effect of damage on tree branches.

f) Implementing new horticulture activities with caution

Under the *Mukhya Mantri Madhu Vikas Yojana*, 2018, the Himachal Pradesh government and the state Horticulture Department are encouraging bee-farming or apiculture among the farmers of the state by providing them with multiple subsidies on bee-keeping activities and equipment. For Lahaul in

particular, we would strongly urge the concerned authorities and communities to be extremely cautious in employing such activities in areas vulnerable to bear conflict. Villages in sub-valleys of Tinan, Pattan, Tindi and Miyar already experience bear presence and conflict in varying degrees due to easy availability of palatable crops. Adding another palatable forage like honey may act as an additional attractant for bears, and thereby lead to increased incidents of conflict with bears.

Our recommendations to prevent crop damage

Since human-bear conflicts are complex and diverse, there is no one solution to effectively minimise losses. To steer towards success, the mitigation strategy or plan should accommodate multiple and diverse sets of approaches. In our opinion, the most proactive way to minimise conflict is to reduce the proportion of bear preferred crops and to gradually replace them with non-preferred traditional as well as emerging crops like Asafoetida. This process might be slow, however, as developing market linkages might take time. To protect patches of bear preferred crops and apple orchards, we recommend testing portable and removable models of electric solar fencing suitable for the conditions of Lahaul. Along with these improved models, ANIDER systems and fox lights should be installed in field patches vulnerable to bears. And finally, rapid response teams should be instituted, and deterrents should be applied in affected villages during the peak harvest months.

To understand the feasibility and practicality of some of these suggestions we also discussed with community members of 5 affected villages. A meeting involving all the concerned governmental departments was conducted in Keylong, where discussions were held around our suggestions on conflict interventions and building synergies. Most agreed that multiple methods need to be tested and upscaled and that an experimental approach will be ideal. The details of minutes of these meetings and feedback received can be found in the Annexures 4.1 and 4.2.

4.2.2 Offsetting losses caused by animals

Offsetting the economic impacts of conflicts by the means of financial compensation and insurance programs is a straightforward approach practised throughout the world (Dickman et al., 2011; Pettigrew et al., 2012). It is argued that alleviating the economic impacts of crop and livestock losses would result in an increased tolerance and resilience towards wildlife. Moreover, in frontier areas, compensation might provide an important safety net for the livelihoods of the community when they suffer economic losses by wild animals. By providing economic safety nets, compensation mechanisms aim to build resilience and reduce retaliatory killing of conflict species, thereby protecting them.

However, this approach has received heavy criticism in the scientific literature. Various studies have found that providing compensation does not increase tolerance of the affected community towards conflict species (e.g., Naughton-Treves et al., 2003). In most of the cases, the amount of compensation received does not reflect the market value of that commodity. Moreover, compensation usually does not account for the opportunity and transaction costs associated with depredation. For these reasons, Dickman et al. (2011) argues that there remains an incentive for the aggrieved for pre-emptive killing of the conflict species.

While recognising the potential pitfalls, we believe that the affected communities that are living with endangered wildlife need to be either compensated for the losses or have options to generate more incomes that can buffer these losses or generate incomes directly from wildlife such as wildlife-based tourism options.

a) Compensation for livestock depredation

An exhaustive review of the literature suggests that the use of compensation mechanisms to alleviate conflict have received mixed outcomes (Dickman et al., 2011; Rondeau & Bulte, 2007). These programs often fail because of a lack of adequate funding, slow processing, lack of transparency, lack of clear guidelines, complications involved in assessment and verification, and inability to measure success (Nyhus et al., 2003). Even if these problems are taken care of, adequate compensation might incentivise people to increase livestock and to become careless. For these reasons, it is not recommended to use compensation as the only approach to mitigate conflict. Compensation mechanisms should be part of an integrative approach, linked closely to preventative measures (Pettigrew et al., 2012).

While most of our respondents were aware of the existing compensation scheme for livestock depredation, they were unwilling to apply for it. In almost 42% of the FGDs, respondents said that they did not approach any institution for seeking compensation. In household interviews, 80% of the respondents affected by livestock depredation did not apply for any compensation. Of the 10 people who had applied, six were yet to receive compensation after 4 months to 2 years. From the records of the Forest Department, only 106 cases of compensation claims have been filed from 2011 to 2021. Various reasons were listed for the community's reluctance to apply for compensation.

1) The amount of compensation received is only a small proportion of the market value.
2) The procedure for compensation is complicated and tiresome involving too many formalities and paperwork, approvals and certificates from multiple institutions, and associated transactional cost of fulfilling these formalities.
3) Prolonged delay in release of compensation claims: Some claimed to have received compensation after 3 years of applying.
4) Confusion in assessment of the predator. For instance, a respondent mentioned about the rejection of compensation claim as there was confusion whether the livestock was killed by a wild animal like a wolf or by a dog.
5) Free-ranging dogs (FRD) are primarily responsible for livestock depredation in Lahaul. However, FRDs are not considered as ‘wild animals’ under the Wildlife (Protection) Act, 1972, and therefore FRD-related livestock depredation is not mandated to be compensated by the Forest department.

As suggested by Nyhus et al. (2003), a separate entity should be institutionalised that should take on the responsibility of streamlining the compensation procedure and processing compensation claims swiftly. Compensation procedures should be simplified and made more accessible by this entity. In that regard, a helpline number can be maintained to answer queries regarding compensation. Further, a field staff can be hired to assist the aggrieved on-ground through the course of compensation payment. A similar effort made by the Wild Seve program to assist aggrieved people in filing, monitoring, and receiving payments has achieved good results in Bandipur and Nagarhole National parks in Karnataka (Karanth & Vanamamalai, 2020). Along similar lines, previous studies from the landscape (Sharma et al., 2020) suggested institutionalisation of a compensation task force for facilitating and streamlining the process of applying for compensation claims. It is worth noting that the Forest Department, Keylong is considering adopting and piloting this suggestion in Lahaul.

As reasoned previously, compensation alone is not effective and has to be linked with better management practices. For instance, compensation might be denied in cases where livestock were left unattended in pastures for an extended duration. Finally, efforts should be made to monitor the success of using compensation tools in mitigating conflict and conserving wildlife.

To offset livestock losses, a locally managed communal livestock insurance can also be adopted. Depending on the size of the livestock and their risk to predation, villagers can contribute a monthly premium amount towards insuring livestock. Once a communal fund is established, compensation can be provided to the aggrieved from that fund. As demonstrated by Mishra et al. (2003), such an initiative

allows herders to own and regulate the program which can also offer better and more realistic rates of compensation.

b) Insurance of crops

Under *Pradhan Mantri Fasal Bima Yojna* (PMFBY), farmers are provided insurance coverage and financial support in an event of crop loss/damage due to natural calamities such as inundation, flood, hailstorm, drought, etc. or by pests and diseases. The farmers are required to pay a maximum rate of 5% on the sum assured (Information and Public Relations, Government of Himachal Pradesh, 2020). As a part of this policy, an optional add-on coverage was added for crop loss due to wild animals (Ministry of Agriculture & Farmers Welfare, n.d.). We propose that the state of Himachal Pradesh should consider providing this add-on coverage for select crops like green pea, apple, maize, *rajmah* and cauliflower in Lahaul. Since the add-on coverage is optional and the cost of the premium would be borne by the farmer, the scheme allows the state government to provide additional subsidy to the farmer on this coverage (Revamped Operational Guidelines of PMFBY, 2020). Adopting add-on coverage would not only provide monetary relief from crop loss due to erratic weather but also from crop depredation by animals such as bears.

We recognise that effective uptake and execution of this add-on requires several preconditional measures including digitisation of the threshold yield at insurance unit for the notified crops. For Lahaul, Krishi Vigyan Kendra (KVK), Kukumseri can assist the Agriculture and Horticulture departments in maintaining these records for selected annual as well as perennial crops.

From our survey, we found that less than half of the 78 villages (41%) were aware about PMFBY. Only about half (47%) of our sampled villages showed willingness to take crop insurance, while 31% were unwilling, and the remaining were unsure and wanted more information about the scheme. The primary reasons cited by the respondents for their unwillingness to take crop insurance schemes against animal loss included complex procedures, hidden details, incomplete information, high premiums, low returns, and a lack of trust and confidence in government departments. Therefore, multiple workshops by the agriculture extension wing of the departments need to be organised to disseminate complete information, answer queries, and to correct any misleading perceptions about the insurance scheme. We suggest awareness programs and outreach should be conducted by the agriculture department, horticulture department, KVK, Kukumseri with the help from bodies working under ATMA. The PMFBY scheme allocates 3% of the total budget for monitoring and Information Education and Communication activities. An alternate or simultaneous approach could be the testing and adoption of a community-financed insurance program.

c) Supporting traditional agriculture-based livelihoods

Like mentioned in previously (Section 4.2.1), promoting the cultivation of organically grown traditional crops like barley and black peas, by creating market linkages with efficient marketing of these value-added crops, can provide a significantly more remunerative, steady, and sustainable source of income for farmers. Many of these traditional subsistence crops are not palatable to bears, and therefore, creation of such high-return traditional crops has the potential to not only generate additional secure income, but also offset the crop losses or damage caused by bears. The more diversified crop income that is not vulnerable to be affected by bears may make the communities more resilient towards losses incurred due to wildlife. Villages most vulnerable to bears should be selected to pilot this. Particularly, respondents from Nalda and Gushal showed keen interest in experimenting with growing traditional crops at economic scales provided they get the support from the government departments and agencies to help market the produce.

d) Diversification of livelihoods

Communities can be made more resilient if they have a diversified source of income. With the advent of climate-induced weather calamities like cloud burst, flash floods, and drought, the agriculture economy and the farmers face huge losses. With the growing problems related to agriculture system (section 2.1.3), generating newer sources of sustainable livelihoods is of paramount importance. One such promising avenue is the tourism sector. Ensuring responsible and sustainable tourism, including wildlife tourism, can be a highly valued livelihood option that may offset losses faced by households due to wildlife. During our survey, many people found the utility of bear for wildlife tourism to be extremely useful, although many were also sceptical about its success (see Section 3.2.1). In adjacent areas of trans-Himalaya, wildlife-related tourism has not only been successfully welcomed by the community but has also improved the attitudes and tolerance towards wild animals like the snow leopard (Maheshwari & Sathyakumar, 2019). In this light, we would strongly urge the district administration and the Tourism department to work with communities and tour-operators to ensure responsible and sustainable tourism that only aids the local communities and the landscape of Lahaul and does not degrade it. One immediate suggestion is to incorporate proper garbage disposal and management rules as part of all tourism activities. This is important to control the free-ranging dog population but also the danger of providing yet another reason for the bears to be near human habitations, especially tourist facilities with unsuspecting tourists (see also Section 4.3).

4.2.3 Community involvement, public awareness, and education

For any conflict management plan to be successful, it is important to actively involve the affected local stakeholders in the management process and in decision-making. As noted by Can et al. (2014), sharing responsibilities of planning and management with local stakeholders is a crucial component for success as it helps provide better perceptions of the project, partners, and outcomes (Treves et al., 2006). For effective intervention in Lahaul, an effort should be made to foster partnerships and synergies between various departments, conservationists, NGOs and locals.

Another important component for improving the efficacy of management programs is to increase public awareness about drivers of human-bear conflict, available policies, and preventive measures. Efforts should be made to demonstrate the proper use of preventive measures, and best practices to prevent conflict. Public education can also be an effective measure to improve attitudes, build tolerance, and reduce antagonism towards bears (Dickman, 2010; Ambrali, 2016). However, there are cases where educational programs have proved rather ineffective in changing attitudes (Can et al., 2014). Therefore, it is important to make education and awareness programs dynamic and interactive. Different approaches customised to the values of the community should be tried and their effectiveness should be evaluated.



Credits: Yash Veer Bhatnagar, Rashmi Singh Rana

Image 8. Stakeholder awareness and consultation workshops with relevant line departments in Keylong, and with affected villages of Lahaul.

Sustained stakeholder specific messages need to be conveyed using appropriate media such as visual fliers, posters, radio programmes. Some key recommendations and messages that can be appropriately conveyed to local communities as well as officials are summarised in the Image 9. Further, it will be important to inform tourists about not littering and keeping away from brown bears.



Image 9. Infographic: Recommendations for mitigating human-bear conflicts in the Lahaul landscape.

4.2.4 Research and Monitoring

To manage and resolve human-bear conflict in Lahaul, we have suggested an integrative approach constituting multiple preventives as well as compensatory measures. To test the efficacy of these measures in curbing conflict need to be assessed, and we strongly recommend monitoring and evaluating the results of these interventions. Treves et al. (2006) suggests that monitoring should include three measures to assess performance of interventions:

- To assess whether the intervention was applied as planned.
- To evaluate whether the level of conflict was reduced.
- To check whether the project goals were achieved.

While monitoring interventions is essential, efforts should also be made to fill gaps in knowledge about wildlife and socio-economic baselines. For instance, currently there are no records on wildlife population estimates, trends, and movements. To better understand and mitigate conflict, it is important to have clear estimates of wildlife abundance and its spatial distribution. This information would also help us manage and conserve wildlife. We recommend that long-term monitoring of wildlife and its ecology should be carried out and to achieve that, partnerships should be forged between various institutions involving researchers, local people, and government departments. Notably, the Forest department is collaborating with UNDP SECURE Himalaya and NCF-India to adopt a landscape-level wildlife monitoring exercise as part of the management plan where such measures can be institutionalised.

Additionally, to reduce redundancy and repeated efforts, the Forest department may also facilitate a common platform where all the relevant parties involved, including researchers and NGOs can maintain shared data repositories on wildlife population estimates, agricultural production, livestock population, and losses caused by wildlife at the village level.

4.3 Managing conflict with dogs and pika

Apart from bears, there is a considerable amount of conflict with pika and free-ranging dogs across Lahaul. Majority of the respondents we interviewed noted that the population of dogs has increased in the last two decades, whereas the conflict has surged in the last 8-10 years. Several reasons were indicated for this escalation in conflict: Gaddi nomads leave their dogs behind; ban on hunting; infrastructure like bridges making dogs access to villages easier. Spike in tourism has increased *dhabas*, hotels, and restaurants which help sustain dog populations by providing food. For the same reason, GREF camps and military camps also help sustain dog populations.

With dogs being responsible for most of the livestock depredation in Lahaul, not managing them can have a disruptive effect on the overall conflict management strategy and livelihood improvement. It is imperative therefore to manage and reduce dog populations. Among the various measures adopted worldwide to control dog populations, surgical sterilisation (Animal Birth Control, or ABC) is the most popular. However, performing this can be difficult in Lahaul due to a lack of facilities, staff and administrative support available to the Department of Animal Husbandry and Livestock Health. Moreover, this method of capturing, neutering, and releasing dogs renders ineffective if done for a short duration. Sustained efforts of several years are required for it to effectively control dog populations (Totton et al., 2010).

To control dog populations, we suggest that a concentrated effort should be made to remove dogs responsible for livestock depredation (Home et al., 2017). We strongly suggest the administration to develop garbage disposal and management plan to reduce food subsidies around hotels, restaurants and villages. This effort can be made in conjunction with the Tourism department to ensure that authorised hotels, restaurants, guesthouses and homestays strictly follow proper garbage disposal rules. Locals and tourists should be discouraged to feed free-ranging dogs. Efforts may also be made to ensure that tourists, locals, and Gaddi nomads do not abandon their dogs in the landscape.

Pikas are responsible for causing persistent damage on cauliflower saplings and young apple trees. Rock dwelling pikas usually make their nests alongside *dungas* (rock or boulder walls). Although, managing or removing these stone walls has proven effective in reducing pika induced damage to crops, this may not be a practical approach where these stone walls are used to keep out village livestock. A study by Khan & Smythe (1980), tested several measures for pika damage control on apple trees including applying poison-laden emulsion paints on the trunk and branches, glue-like repellent coating, as well as poison-baiting. All these methods had varying degrees of success and drawbacks. The intervention techniques used by the community to deter pika are largely effective. To prevent young apple trees from getting damaged, painting their trunks or wrapping them with a thick cloth has proven effective in many villages. Therefore, we would recommend these noted traditional measures to prevent and reduce damage by pika.

4.4 Conclusion

Crop losses caused by bears can be prevented using technology enabled barriers such as solar fencing, advance warning systems such as ANIDER systems (Animal Intrusion Detection and Repellent System), deterrents such as fox lights, the traditional method of creating noise through clanging vessels and crackers, guarding at vulnerable periods, and creating well equipped and trained rapid response teams consisting of local youth, forestry staff and others. However, in the vulnerable villages, it may be inevitable to gradually shift towards a greater proportion of remunerative cash crops unpalatable to bears such as *Ferula asafoetida* (hing) and value added local, climate resilient crops such as black peas and barley. This process might be slow, however, as developing market linkages might take sustained and multisectoral commitment.

The rationale for the suggestion of shifting to non-palatable crops is as follows. Lahaul farmers have always responded to market forces and quickly shifted their cropping patterns, any such shift should be acceptable to the farmers if viable alternatives are offered. Another key opportunity is offered by declining quality of green peas and its perishability that makes it vulnerable in the event of the increasing climate change related extreme weather events. Preventive methods are only partially effective as it is extremely difficult to maintain any kind of fencing, especially solar fencing during the heavy snow period that causes considerable damage to its structures. Deterrents such as fox lights reportedly work only till bears get habituated to it. Respondents suggested removal of ‘problem’ bears. However, this is unlikely to be effective as the good habitat around these villages, especially in the left bank of the Chandrabhaga, which is contiguous with prime bear areas in the Kugti Wildlife Sanctuary across the Pir Panjal range, will always attract new bears. Hence, reducing the attractants, the palatable crops in the vulnerable villages may be the best way to reduce losses in combination with the others mentioned above.

It is recognised that with value added, agriculture-based options for enhanced incomes complemented with community-based tourism, especially responsible wildlife tourism can be harnessed effectively for providing suitable offsets to any damage that does take place. With regard to tourism, it is also recognised that a comprehensive responsible tourism strategy for the region is urgently needed to

overcome serious pitfalls of cultural and ecological pollution that often accompanies any such boom in the economy. One area of particular concern is to manage solid organic waste that otherwise can promote free ranging dogs as also can attract bears, bringing them in dangerous proximity with unexpecting and unprepared tourists.

Since human-bear conflicts are complex and diverse, there is no one solution to effectively minimise losses and the mitigation strategy should accommodate multiple and diverse sets of approaches. Further, the conflicts are likely to change in its form and intensity based on agricultural cropping patterns, livestock husbandry and human behaviour towards these species. It is reiterated that a simultaneous use of approaches to *prevent* losses, *offset* the losses that still take place and then institute a better *outreach* and *awareness* among all relevant stakeholders is the key to managing this issue. Therefore, we urge to follow a landscape-level approach with concerted and converged efforts from the local communities, government departments and programmes like UNDP's SECURE Himalaya project, NGO's and civil society groups.

The project recommendations have been deliberated with the agriculture, horticulture, district administration, tourism, and farmers from affected villages whose suggestions have been incorporated. Further, other agencies such as UNDP's SECURE Himalaya Programme, which have a longer-term presence in the landscape are already implementing some interventions for conflict mitigation and are willing to try and sustain some of the key suggestions of this project.

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Annexure 1

Table 1.1 Details of the villages sampled for Lahaul-wide survey are furnished in the table below.

S.No.	Village	Valley	Households	
1	Biling	Gahar	46	
2	Cheling	Gahar	7	
3	Girmus	Gahar	8	
4	Guskyar	Gahar	8	7 villages
5	Gwajang	Gahar	18	
6	Kyor	Gahar	5	
7	Prasprag	Gahar	7	
8	Arat	Lower Pattan	13	
9	Bha Chewar	Lower Pattan	7	
10	Chokhang	Lower Pattan	28	
11	D.P.F.Bhiyari	Lower Pattan	6	
12	D.P.F.Lobar	Lower Pattan	6	
13	Haruka	Lower Pattan	54	
14	Jasrath	Lower Pattan	20	
15	Jholing	Lower Pattan	20	
16	Kamring	Lower Pattan	25	17 villages
17	Kuang	Lower Pattan	5	
18	Leh Baring	Lower Pattan	16	
19	Lomach	Lower Pattan	5	
20	Nain Gahar	Lower Pattan	12	
21	Nalda	Lower Pattan	38	
22	Othang	Lower Pattan	8	
23	Sindwari	Lower Pattan	63	
24	Triloknath	Lower Pattan	146	
25	Chaling	Miyar	28	
26	Chamrat	Miyar	29	
27	Karpat	Miyar	36	5 villages
28	Khanjar	Miyar	15	
29	Tingrat	Miyar	73	
30	Bargul	Tinan	18	
31	Chhokar	Tinan	6	
32	Dimphuk	Tinan	48	
33	Gondhla	Tinan	73	
34	Gopa Thang	Tinan	8	16 villages
35	Jagle	Tinan	9	
36	Kewak	Tinan	5	
37	Khangsar (12/8)	Tinan	17	
38	Khangsar (13/3)	Tinan	7	
39	Khawagling	Tinan	30	

40	Khoksar	Tinan	18	
41	Muling	Tinan	29	
42	Purd	Tinan	12	
43	Ropsang	Tinan	14	
44	Shuiling	Tinan	46	
45	Retil*	Tinan	9	
46	Bhujund	Tindi	35	
47	D.P.F.Lohni	Tindi	28	
48	Kurched	Tindi	15	
49	Margaraon	Tindi	141	
50	Salpat	Tindi	32	5 villages
51	Bok	Tstod	21	
52	Jispa	Tstod	51	
53	Kawaring	Tstod	19	
54	Khangsar (8/4)	Tstod	45	
55	Meh	Tstod	18	9 villages
56	Stingiri	Tstod	76	
57	Tinno	Tstod	29	
58	Yoche	Tstod	14	
59	Chikka-Be*	Tstod	16	
60	Bha Baring	Upper Pattan	5	
61	Bha Sumnam	Upper Pattan	5	
62	Duansha	Upper Pattan	13	
63	Gushal	Upper Pattan	79	
64	Jahlma	Upper Pattan	85	
65	Karing	Upper Pattan	5	
66	Kirting	Upper Pattan	41	
67	Kothi	Upper Pattan	5	
68	Krozing	Upper Pattan	9	
69	Lapshak	Upper Pattan	13	
70	Lindur	Upper Pattan	14	21 villages
71	Lingar	Upper Pattan	7	
72	Lot	Upper Pattan	36	
73	Rangbe	Upper Pattan	18	
74	Rape	Upper Pattan	28	
75	Rashil	Upper Pattan	14	
76	Ruring	Upper Pattan	9	
77	Shansha	Upper Pattan	72	
78	Thapak	Upper Pattan	7	
79	Wari	Upper Pattan	9	
80	Yang Kirting	Upper Pattan	8	

* Villages that could not be surveyed

Table 1.2 Details of the villages sampled for Household survey.

S.No.	Village surveyed	Hamlet	Valley	Conflict level	Reported Households	Households surveyed
1	Bhujund		Tindi	High	35	9
2	Gushal		Upper Pattan	High	80	20
3	Jasrath		Lower Pattan	High	18	6
4	Jholing		Lower Pattan	High	22	8
5	Lingar		Upper Pattan	High	6	3
6	Nalda		Lower Pattan	High	40	12
7	Rape		Upper Pattan	High	24	7
8	Rashil		Upper Pattan	High	14	5
9	Kurched		Tindi	Livestock only	9	4
10	Tingret	Udgose	Miyar	Livestock only	35	10
11	Triloknath	Hinsa	Lower Pattan	Livestock only	80	20
12	D.P.F.Bhiyari		Lower Pattan	Low	9	3
13	Kewak		Tinan	Low	6	3
14	Khanjar	Shukto	Miyar	Low	5	3
15	Muling		Tinan	Low	30	8
16	Nain Gahar		Lower Pattan	Low	14	4
17	Chhokar		Tinan	Moderate	4	2
18	Karpat		Miyar	Moderate	32	10
19	Khawagling		Tinan	Moderate	8	3
20	Margaraon	Namu, Dhawal	Tindi	Moderate	44	13
21	Purd		Tinan	Moderate	8	3
22	Bha Chewar		Lower Pattan	No	7	3
23	Bok		Tstod	No	24	8
24	Guskyar		Gahar	No	7	3
25	Rangbe		Upper Pattan	No	17	4
26	Ropsang		Tinan	No	20	5
	Total				598	**179**

Annexure 2

Table 2.1 Timeline and mandates of various agriculture-centred societies in Lahaul.

Name of co-operative/society	Year of establishment
Lahaul Kuth Growers Co-operative Marketing Society	1959
Lahaul Potato Growers Co-operative Society	1966
Hops and Chicory Growers Cooperative cum Processing Society Limited	1975
Fruit & vegetables growers society	NA

Table 2.2 Trends in acreages (in Ha) of crops in Lahaul. (Source: DSA and Agriculture Dept, Keylong)

	Barley	Wheat	Buckwheat	Pea	Vegetables	Cabbage	Cauliflower	Hops	Maize	Oil seeds	Other cereals	Exotics	Potato	Apple	Grand Total
Year															
1975	496	405						1	28		452		503	24	1909
1982	319	247						8	32	23	231		1166	58	2084
1994	119			720				169					783		1791
2004	92	51	85	1590			13	34	47				770	308	2990
2012	16	17		1750			50		27	14	31		742	1281	3928
2015	4	41		1100			600		23	7	27	900	625	940	3327
2016	4	35		1113	2	300	650		14	16	28	200	565	1485	4412
2018	6	9		1060	41	47	824		12	12	26	166	650	1405.5	4258.5
2019				1110	50	40	550					152	885	1456	4243

Table 2.3 Trends in production estimates of crops in last decade. (Source: DSA, Agriculture Dept)

	Peas (Production in MT)	Vegetables (Production in MT)	Cabbage (Production in MT)	Cauliflower (Production in MT)	Exotics (Production in MT)	Potato (Production in MT)	Grand Total
Year							
2003-04	19385	262	390	280	206		20523
2004-05	16812	147	82	244	190		17475
2005-06	17065	260	105	350	310		18090
2006-07	16980	230	95	200	255		17760
2007-08	18550	472	540	460	360		20382
2008-09	18550	456	560	506	335		20407
2009-10	18640	558	609	529	372		20708
2010-11	17500	558	609	529	372		19568
2011-12	18000	40	120	1140	600		19900
2012-13	18900	192	250	1270	1000		21612
2015-16	12690	506	1250	15000	3400		32846
2016-17	12840	506	1250	16250	3400		34246
2017-18	12080	486	1198	20050	3290	10500	47604
2018-19	12189	433	1173	20600	3768	9750	47913
2019-20	14335	608	850	13750	3500	15045	48088
2020-21	10902	486	1173	20600	3768	9750	46679

Table 2.4 Trend in different land-use types in Lahaul in the last few decades. (Source: DSA, Agriculture Department, Keylong)

Years	Net sown area in Ha	Rate of change in net sown area	Barren uncultur able land in Lahaul in Ha	Rate of change in barren land	Cultura ble wastel and in Ha	Rate of change in Cultura ble wastel and	Current fallow in Ha	Rate of chan ge in fallo w land
1982	1940		873		133		74	
1999	2124	9%	188	-78%	146	9.8	32	-56.8
2005	2149	1%	352	-87%	166	13.7	27	-15.6
2010	2160	0.5%	206	-41%	170	2.4	20	-26
2019	2347	8.6%	205	-0.5%	171	0.6	13	-35

Table 2.5 Trends in crop-wise acreages over the last two decades. Data for potato was only available for last decade from the Agriculture dept. datasheets.

	Peas (Acreage in Ha)	Potato (Acreage in Ha)	Cauliflower (Acreage in Ha)	Exotic vegetables (Acreage in Ha)	Cabbage (Acreage in Ha)	Total (Acreage in Ha)
Year						
2003-04	1570		14	20	13	1617
2004-05	1590		13	21	12	1636
2005-06	1690		18	32	17	1757
2006-07	1696		19	30	20	1765
2007-08	1690		20	30	23	1763
2008-09	1690		22	27	23	1762
2009-10	1710		23	30	25	1788
2010-11	1690		23	30	25	1768
2011-12	1770		38	20	5	1833
2012-13	1750	742	50	40	10	1850
2015-16	1100	625	600	150	50	1900
2016-17	1113	565	650	150	50	1963
2017-18	1052	700	802	145	48	2747
2018-19	1060	650	824	166	47	2747
2019-20	1110	885	550	152	40	2737
2020-21	948	978	523	102	28	2579

Table 2.6 Trends in crop-wise production in Metric Tonnes (MT) over the last two decades. Data for potato was only available for last decade from the Agriculture dept. datasheets.

	Peas (Production in MT)	Vegetables (Production in MT)	Cabbage (Production in MT)	Cauliflower (Production in MT)	Exotics (Production in MT)	Potato (Production in MT)	Grand Total
Year							
2003-04	19385	262	390	280	206		20523
2004-05	16812	147	82	244	190		17475
2005-06	17065	260	105	350	310		18090
2006-07	16980	230	95	200	255		17760
2007-08	18550	472	540	460	360		20382
2008-09	18550	456	560	506	335		20407
2009-10	18640	558	609	529	372		20708
2010-11	17500	558	609	529	372		19568
2011-12	18000	40	120	1140	600		19900
2012-13	18900	192	250	1270	1000		21612
2015-16	12690	506	1250	15000	3400		32846
2016-17	12840	506	1250	16250	3400		34246

2017-18	12080	486	1198	20050	3290	10500	47604
2018-19	12189	433	1173	20600	3768	9750	47913
2019-20	14335	608	850	13750	3500	15045	48088
2020-21	10902	486	1173	20600	3768	9750	46679

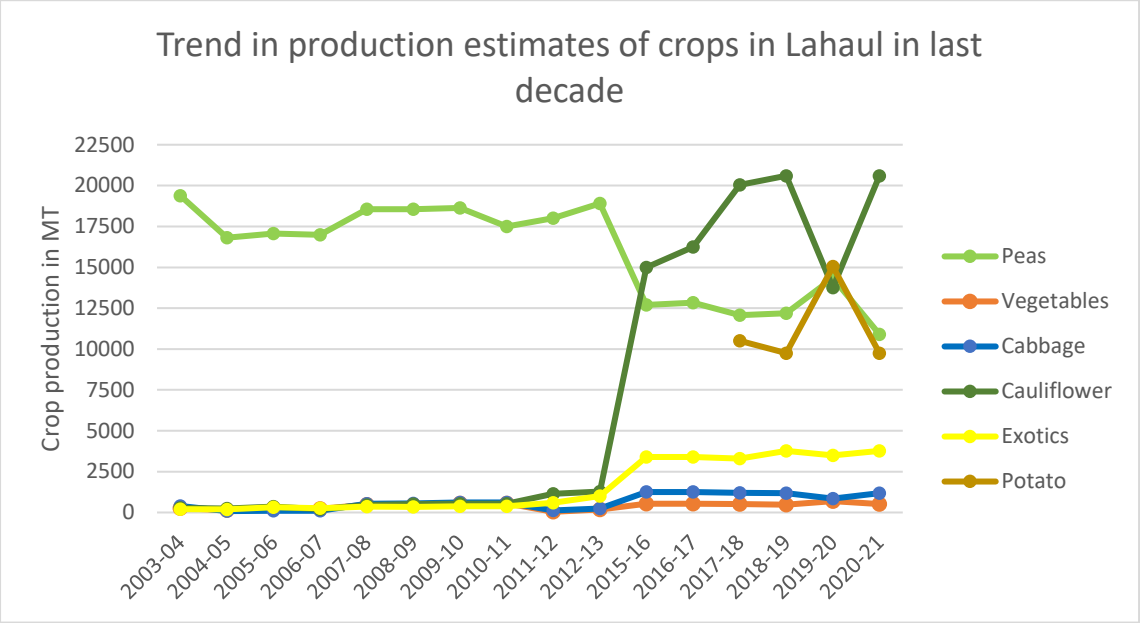


Figure 2.1 Trends in production estimates of cash crops in Lahaul in the last two decades. Production estimates for potato are unavailable before 2016. Source: Agriculture department letters.

Table 2.7 Crop-wise acreage in hectares. Data combined from District Statistical Abstracts and Agriculture department letters.

Year	Barley	Wheat	Buckwheat	Pea	Vegetables	Cabbage	Cauliflower	Hops	Maize	Oil seeds	Other cereals	Exotics	Potato	Grand Total
1975	496	405							28		452		503	1884
1982	319	247							32	23	231		1166	2018
1994	119			720				169					783	1791
2004	92	51	85	1590			13	34	47				770	2682
2012	16	17		1750			50		27	14	31		742	2647
2015	4	41		1100			600		23	7	27	900	625	3327
2016	4	35		1113	2	300	650		14	16	28	200	565	2927
2018	6	9		1060	41	47	824		12	12	26	166	650	2853
2019				1110	50	40	550					152	885	2787

Table 2.8 Average of reported selling rates of crop in the pandemic year 2020 in Lahaul.

Crops	Average rate in 2020 in Rs.
Cauliflower	29
Potato	25
Green pea	57
Iceberg lettuce	46
Apple	44
Broccoli	137
Kuth	394
Manu	134

Table 2.9 Estimated percent of monetary returns from each crop across the seven valleys, as reported for the year 2020 from our Focus Group Discussions in 78 villages across Lahaul.

Cash crops	**Upper Pattan**	**Lower Pattan**	**Tindi**	**Gahar**	**Tinan**	**Tstod**	**Miyar**
Apple	68	14	10	7	1	0	0
Broccoli	23	0	0	0	68	8	0
Cauliflower	49	15	4	2	19	4	7
Green pea	47	17	6	6	8	4	10
Iceberg	95	2	0	0	3	0	0
Kuth	8	5	52	0	11	0	24
Potato	49	10	1	2	17	13	6
Manu	65	9	0	1	0	7	19
Grand Total	**50**	**13**	**4**	**3**	**17**	**6**	**7**

Table 2.10 Proportion of production output from the total production output from each crop across the seven valleys, as reported for the year 2020 from our Focus Group Discussions in 78 villages across Lahaul.

Cash crops	**Upper Pattan**	**Lower Pattan**	**Tindi**	**Gahar**	**Tinan**	**Tstod**	**Miyar**
Cauliflower	50	16	4	2	19	3	6
Potato	45	11	2	2	20	14	6
Green pea	50	20	7	5	7	4	
Iceberg	85	6	0	0	9	0	0
Apple	66	16	11	7	1	0	0
Broccoli	26	0	0	0	67	7	0
Kuth	8	7	40	0	14	0	31
Manu	67	7	0	3	0	1	2
Grand Total	**49**	**15**	**4**	**2**	**18**	**6**	**6**

Table 2.11 Trends of livestock type-wise holding and total livestock holding over last few decades. Source: DSA + Livestock census data+ Datasheet from Animal Husbandry dept

Livestock Census year	Cattle	Donkey	Goats	Horses & ponies	Mules	Pack animals	Sheep	Yaks	Total livestock holding
1961	3756	306	3296	1036	1032	-	28851	1077	**39354**
1966-	5220	134	1973	485	13	-	31504	1716	**41045**
1972	5003	105	2992	256	283	-	29620	644	**38903**
1977	7313	717	5762	201	83	-	43969	323	**58368**
1982	6508	0	6945	0	0	1458	39144	0	**54055**
1992	5350	0	5265	452	-	4116	33117	0	**48300**
1997	2714	0	2714	474	0	899	30218	0	**40470**
2007	3585	0	3585	795	0	0	25426	31	**36790**
2012	9546	0	3118	733	0	802	34299	69	**48567**
2019	7364	NA	1743	NA	NA	NA	21481	NA	**30588**

Table 2.12 Trends of livestock holding, livestock type-wise holding, and their rate of change over last few decades. Source: DSA + Livestock census data+ Datasheet from Animal Husbandry dept

Livestock census years	**Sheep**	Sheep Rate of change in %	**Goats**	Goat Rate of change in %	**Cattle**	Cattle Rate of change in %	**Beast of burden**	Beast of burden Rate of change in %	**Total Livestock**	Total livestock Rate of change in %
1961	28851		3296		3756		3451		39354	
1966	31504	9.2	1973	-40.1	5220	39.0	2348	-32.0	41045	4.3
1972	29620	-6.0	2992	51.6	5003	-4.2	1288	-45.1	38903	-5.2
1977	43969	48.4	5762	92.6	7313	46.2	1324	2.8	58368	50.0
1982	39144	-11.0	6945	20.5	6508	-11.0	1458	10.1	54055	-7.4
1992	33117	-15.4	5265	-24.2	5350	-17.8	4568	213.3	48300	-10.6
1997	30218	-8.8	2714	-48.5	6165	15.2	1373	-69.9	40470	-16.2
2007	25426	-15.9	3585	32.1	6953	12.8	826	-39.8	36790	-9.1
2012	34299	34.9	3118	-13.0	9546	37.3	1604	94.2	48567	32.0
2019	21481	-37.4	1743	-44.1	7364	-22.9	NA	NA	30588	-37.0

Table 2.13 Efforts by the Animal Husbandry department to distribute improved breed and varieties of livestock. (Source: DSA)

Years	**No. of improved sheep**	**No. of improved yak bulls**	**No. of Jersey bulls distributed**	**No. of Jersey cows distributed**
1973	14	0	3	0

1974	47	0	5	20
1975	20	0	5	29
1976	32	0	9	34
1977	0	0	8	91
1978	72	18	7	75
1979	230	11	7	20
1980	191	9	10	31
1981	166	15	0	32
1982	72	13	10	159

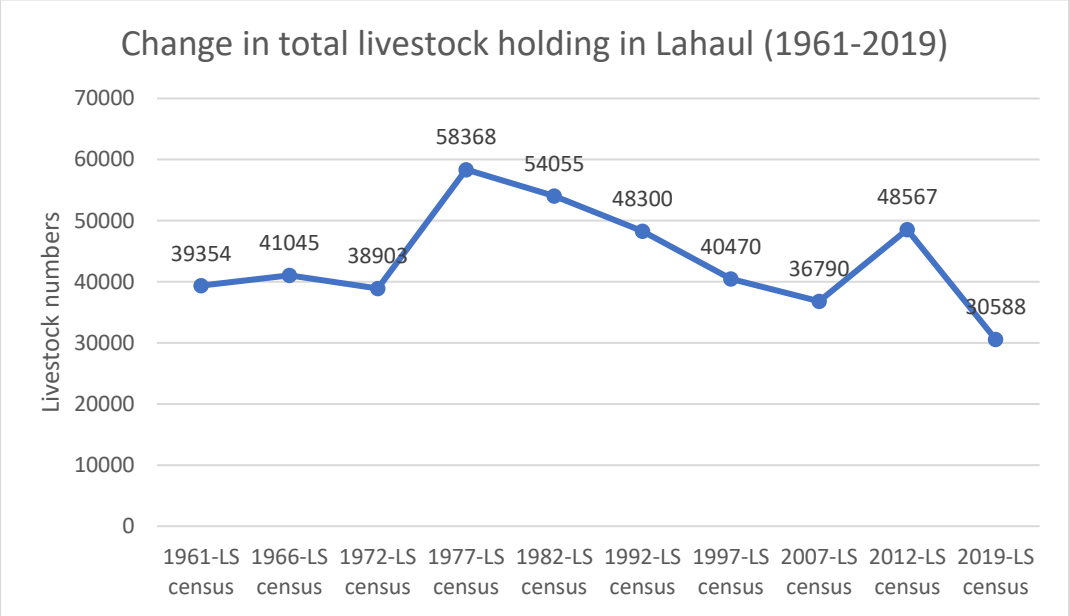


Figure 2.2 Change in total livestock holding in Lahaul (1961-2019). Source: DSA, Livestock Census data & datasheet from Animal Husbandry dept

Annexure 3

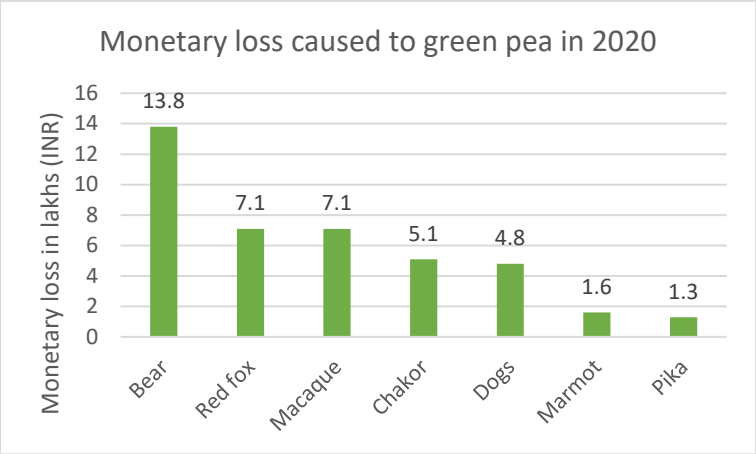


Figure 3.1 Monetary loss caused to green pea by all animals: Bears cause the highest amount of loss.

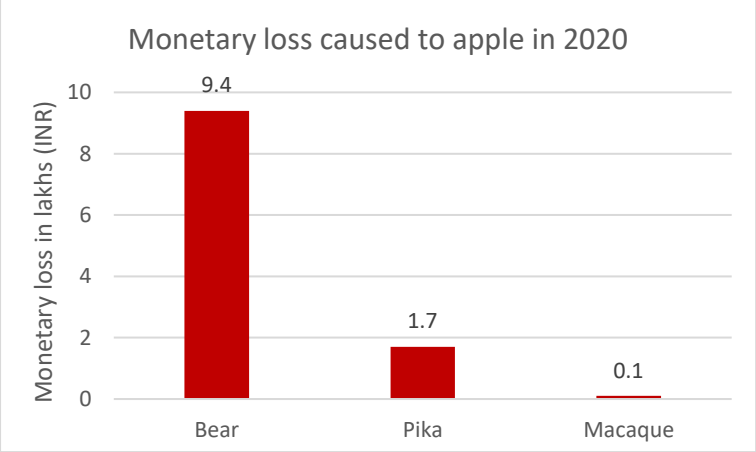


Figure 3.2 Monetary loss caused to apple trees by all animals: Bears cause a significantly high amount of loss.

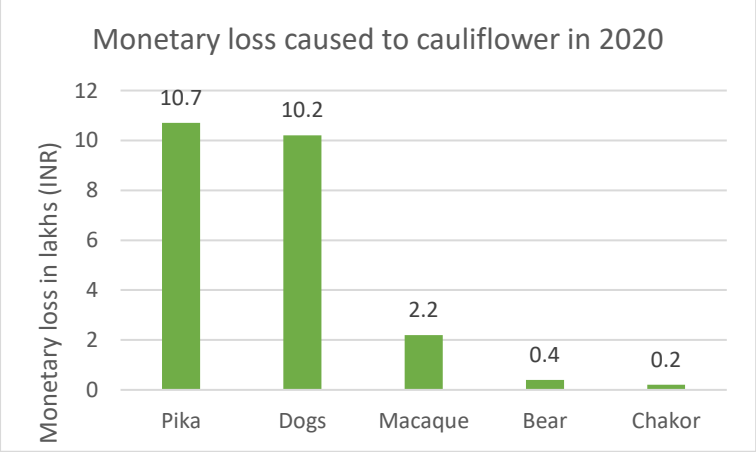


Figure 3.3 Monetary loss to cauliflower by all animals: Pika and dogs cause the highest loss

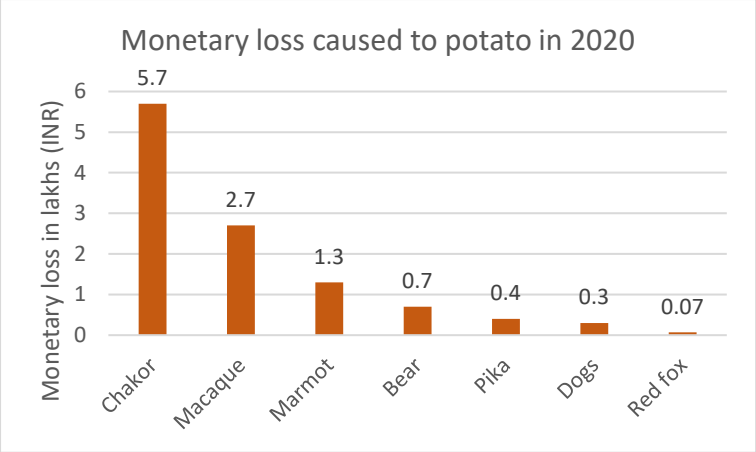


Figure 3.4 Monetary loss cause to potato by all animals: Chakor partridge causes the estimated highest damage of INR 5.7 L

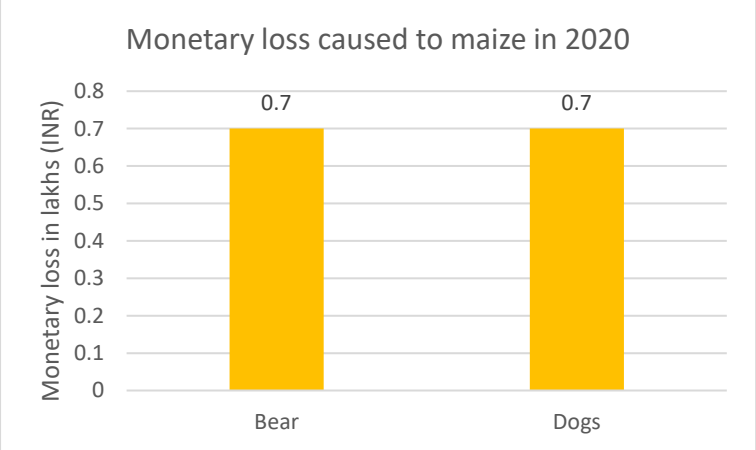


Figure 3.5 Monetary loss caused to maize by bears and dogs is comparable, and around INR 0.7 lakhs in 2020.

Table 3.1 Monetary loss caused to each crop by the reported animals. Monetary loss has been recorded in lakhs (Rs.)

Crops	Bear	Dogs	Pika	Macaque	*Chakor*	Red fox	Marmot	Total
Green pea	12.6	4.8	1.3	7.1	5.1	7.1	1.6	39.6
Apple	8.2	0	1.7	0.1	0			10
Broccoli	0		0.5		0			0.5
Cauliflower	0.04	10.2	10.7	2.2	0.2			23.7
Iceberg	2.3				0			2.3
Maize	0.7	0.7			0			1.4
Potato	0.7	0.3	0.4	2.7	5.7	0.07	1.3	11.17
Rajma	3.4				0			3.4
Grandtotal	28	16	14.6	12.1	11	7.17	2.9	92

Table 3.2 Amount and percent of monetary loss incurred by crop damage by all animals in 2020.

Cash crops	Monetary returns in 2020 (INR in Cr units.)	Monetary loss caused by animals in 2020 (INR in Cr units)	% of monetary loss from returns
Cauliflower	44.52	0.23	0.5
Potato	23.5	0.11	0.4
Green pea	15.49	0.40	2.5
Iceberg	5.12	0.02	0.3
Broccoli	3.08	0.005	0.1
Apple	1.2	0.10	0.8
TOTAL	**92.9**	**0.86**	**0.9**

Table 3.3 Amount and percent of monetary loss incurred by crop damage by all brown and black bears in 2020

Cash crops	Monetary returns in 2020 (INR in Cr units.)	Monetary loss caused by bears in 2020 (INR in Cr units)	% of monetary loss from returns
Cauliflower	44.5	0.004	0.008
Potato	23.5	0.007	0.02
Green pea	15.4	0.12	0.7
Iceberg	5.1	0.02	0.4
Apple	1.2	0.08	6.6
TOTAL	**90**	**0.23**	**0.2**

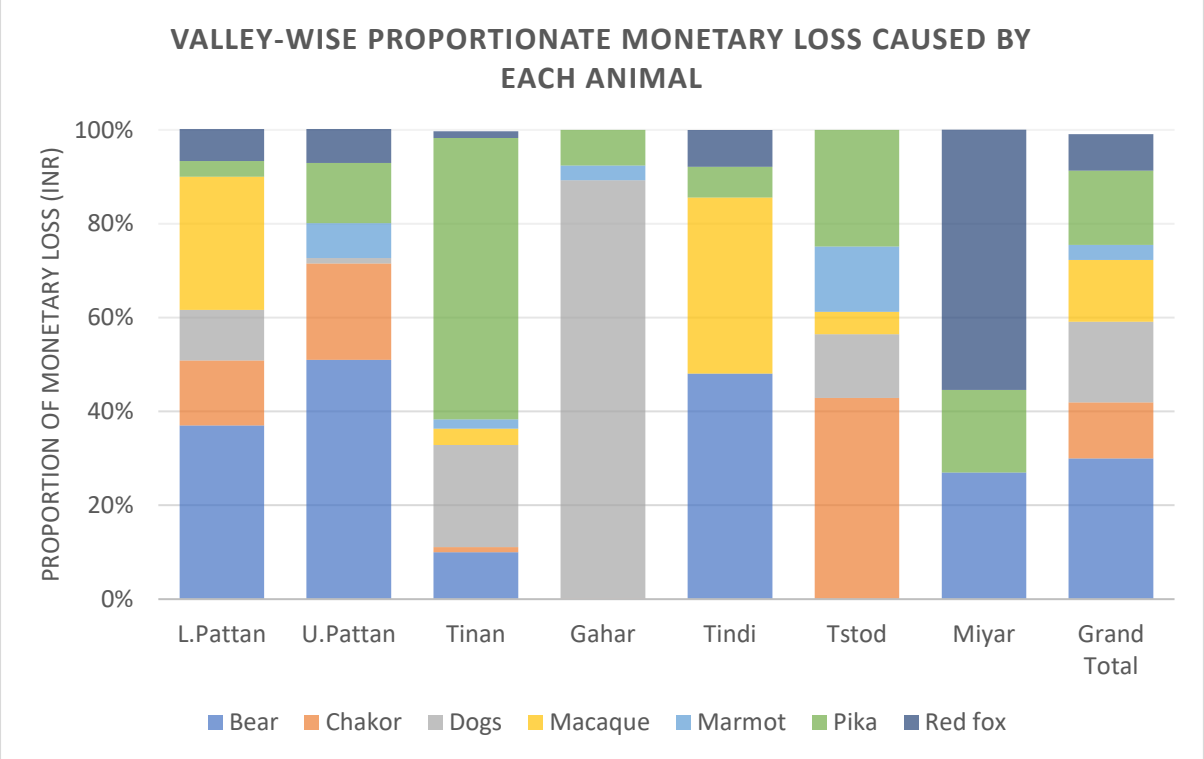


Figure 3.6 Valley-wise proportionate monetary loss caused by each animal

Table 3.4 Valley-wise proportionate monetary loss caused by each animal

Valleys	Bear	Chakor	Dogs	Macaque	Marmot	Pika	Red fox
L.Pattan	37%	14%	11%	28%	0%	3%	7%
U.Pattan	51%	21%	1%	0%	7%	13%	7%
Tinan	10%	1%	22%	4%	2%	60%	1%
Gahar	0%	0%	89%	0%	3%	8%	0%
Tindi	48%	0%	0%	38%	0%	7%	8%
Tstod	0%	43%	14%	5%	14%	25%	0%
Miyar	27%	0%	0%	0%	0%	18%	55%
Grand Total	30%	12%	17%	13%	3%	16%	8%

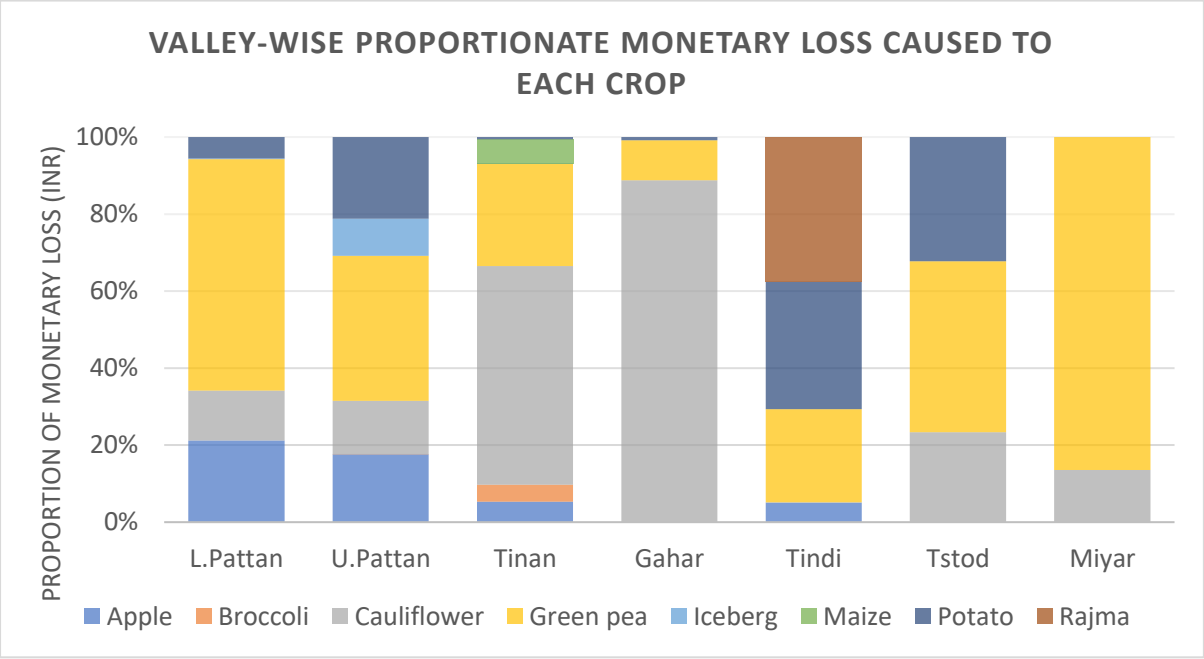


Figure 3.7 Valley-wise proportionate monetary loss caused to each crop

Table 3.5 Valley-wise proportionate monetary loss caused to each crop

Valley	Apple	Broccoli	Cauliflower	Green pea	Iceberg	Maize	Potato	Rajma
L.Pattan	21%	0%	13%	60%	0%	0%	6%	0%
U.Pattan	18%	0%	14%	38%	10%	0%	21%	0%
Tinan	5%	4%	57%	27%	0%	6%	1%	0%
Gahar	0%	0%	89%	10%	0%	0%	1%	0%
Tindi	5%	0%	0%	24%	0%	0%	33%	38%
Tstod	0%	0%	23%	44%	0%	0%	32%	0%
Miyar	0%	0%	14%	86%	0%	0%	0%	0%
Grand Total	**12%**	**1%**	**27%**	**42%**	**2%**	**1%**	**13%**	**4%**

Table 3.6 Description and a priori prediction of socio-ecological and topographical predictor variables used for modelling bear conflict in Lahaul

VARIABLES	*A PRIORI* PREDICTION	SOURCES
a) SOCIO-ECOLOGICAL VARIABLES		
Total cultivated land in 2020 (in Ha)	The extent of agricultural land of a village may act as an attractant to bears as readily available food source.	Triangulated from FGDs, DCHB, 2011 + spatially derived with QGIS 3.22.2.
Village size	Number of households reported in a village. A bigger village may serve as an anthropogenic disturbance to bears.	Census DCHB, 2011
Village population size	Number of inhabitants of a village. A bigger village population may serve as an anthropogenic disturbance to bears	Census DCHB, 2011
Livestock density	Livestock also serve as prey for bears, and therefore a larger availability of livestock in an area may act as an attractant.	Livestock census, 2019 + DCHB, 2011
Apple orchard acreage	This is a highly preferred crop, and therefore a larger apple orchard area may serve as an attractant.	Spatially digitized using QGIS 3.22.2
Green pea acreage in 2020	This is a highly preferred crop, and therefore a larger green pea area may serve as an attractant.	Primary data from FGDs
Iceberg lettuce acreage in 2020	This is a highly preferred crop, and therefore a larger iceberg lettuce area may serve as an attractant.	Primary data from FGDs
Maize acreage in 2020	This is a highly preferred crop, and therefore a larger maize area may serve as an attractant.	Primary data from FGDs
Rajmah acreage in 2020	This is a highly preferred crop, and therefore a larger rajmah area may serve as an attractant.	Primary data from FGDs
Cauliflower acreage in 2020	This is a not a preferred or palatable crop, and therefore a larger cauliflower area may discourage bears to enter a village.	Primary data from FGDs
Potato acreage in 2020	This is a not a preferred or palatable crop, and therefore a larger potato area may discourage bears to enter a village for food.	Primary data from FGDs
Total palatable crop acreage in 2020	Includes all palatable crops. A larger area of palatable or bear preferred crops may serve as an attractant	Primary data from FGDs
Total unpalatable crop acreage in 2020	Includes all unpalatable crops. A larger area of unpalatable crops may serve to discourage bears to enter a village for food.	Primary data from FGDs
Proportion of palatable to unpalatable crops in 2020	A higher proportion of palatable or bear-preferred crops may serve as an attractant.	Primary data from FGDs
b) PHYSICAL VARIABLES		
Valley name	The seven sub-valleys have their distinct topographical characteristics that may have an effect on bear movement in different areas.	Primary data from FGDs
Bank name	The left and right bank of river Chandrabhaga have distinct habitat types that may influence bear movement.	Primary data from FGDs

Pasture area	A larger pasture land or grazing land around a village may serve as a preferred habitat for bear movement for food.	Census DCHB, 2011
Barren land	A larger barren area around a village may serve as less preferred habitat for bear movement and shelter.	Census DCHB, 2011
Forest area	A higher area of conifer or mixed conifer forest may serve as preferred habitat for food and shelter for bears.	QGIS 3.22.2
Forest perimeter	A larger boundary or stretch of forest around a village may increase chances of bear movement between forest and village	QGIS 3.22.2
No. of forest patches	Number of fragments of forest patches around a village may influence bear movement for food and shelter	QGIS 3.22.2
C) TOPOGRAPHICAL VARIABLES		
Slope	Terrain around village may influence bear movement	QGIS 3.22.2
Ruggedness	Higher rugged area around village may serve as shelter for bear during the day in the form of caves and crevices.	QGIS 3.22.2
Elevation	Elevation is a known factor influencing bear presence and movement	QGIS 3.22.2
Aspect	Aspect effects the variation in habitat and micro-habitats which may influence bear movement for food and shelter.	QGIS 3.22.2
D) BIOCLIMATIC VARIABLES		
Bioclimatic factor-temperature	Optimal brown bear habitats have relatively cold and wet climatic conditions.	QGIS 3.22.2
Bioclimatic factor-precipitation	Optimal brown bear habitats have relatively cold and wet climatic conditions.	QGIS 3.22.2

Annexure 4

4.1 Minutes of Meetings (with conflict affected villages)

Villages covered:	Nalda, Jasrath, Rashil, Muling, Gushal
Team members present:	Yash Veer Bhatnagar, Kartik Chugh, Rashmi Singh Rana, Vikram Katoch
Objective:	To share findings of the research with the community and to discuss potential mitigation strategies to reduce bear related conflict with agriculture.

Meetings were conducted with five of the conflict affected villages, wherein results of the research project were shared and strategies to mitigate bear related damage in agriculture were discussed with the concerned communities. A total of 34 participants attended these meetings and engaged ardently with the research team.

A) Key messages and suggestions:

1) While conducting interviews, a common suggestion we got was to relocate bears to a different place. An attempt was made to make the community aware of why removing bears from the landscape was not a viable or a long-term solution.

2) Technological interventions to prevent bears from entering the agricultural fields were discussed. A combination of solar/composite fencing, fox lights, and alarm systems to work in tandem was proposed.

3) The possibility of limiting the crops palatable to bears spatially by forming a few enclaves protected by technological measures was discussed.

4) A possibility of forming, training, and employing a "Rapid Response Team" at the village level to guard vulnerable fields was discussed.

5) A phased reduction of palatable crops such as green pea and iceberg lettuce was proposed. The possibility of replacing these crops with traditional and more resilient crops such as Buckwheat, Black peas, and Barley was discussed. It was demonstrated how these traditional crops can be made equally or even more remunerative by 'organic' value addition, and by creating adequate market linkages.

6) A suggestion was made to not increase apple orchard area, and to replace the older apple varieties which take 8-10 years to bear fruit with newer varieties which start yielding fruits as early as in two years.

7) The potential of Heeng (*Ferula assa-foetida*) as an emerging crop in Lahaul that can not only be remunerative but deterring for bears was discussed.

8) Bears have a great affinity towards organic waste. To prevent unwanted encounters in the near future, the importance of active waste management was discussed with the community.

B) Key takeaways from stakeholder consultation in the following villages:

1) *Nalda*

The community engaged enthusiastically in discussions and largely took the suggestions positively. Many participants agreed to experiment with traditional crops in the next cropping season. However, there was a visible apprehension towards market linkages and access to inputs. Another important concern was the sustenance of market linkages after our team exits the landscape. Against our suggestion to form enclaves of palatable crops, many participants noted that crops must be rotated in different fields to preserve productivity. Therefore, it was not practical to limit certain crops to a few fields every year.

2) *Rashil*

In Rashil, the community seemed keen to try the suggested technological interventions. Many believed that the formation of a rapid response team would be an ideal solution as it would not only provide some form of employment to youth but also help minimise bear losses during the harvest season. Moreover, it would relieve them from the labour-intensive task of guarding their fields all night. While many complained how fencing and lighting was ineffective after a while, they were hopeful about the alarm systems. The participants were extremely vocal about bear removal as the only solution to prevent crop-damage. Some even requested for issuing gun licenses or capturing and relocating bears. The team discussed this issue a few times and emphasised on the short-sightedness and temporary nature of this approach. They reluctantly agreed that removal of a bear(s) would allow for others bear(s) to occupy the territory, and thus, would not be a permanent resolution. They informed us about the failed results of solar fencing as well as hanging torches as attempts to dissuade bears from entering crop fields and orchards. One respondent particularly narrated his personal experience with a bear damaging an apple tree that had the torch lights hanging from it. The same respondent had also tried using strong-smelling chemicals as a measure to repel the bears from entering his field only to find it unsuccessful.

Although they agreed to reducing green pea, none of them seemed willing to replace their crops with barley or buckwheat owing to its significantly lower production per acreage even if a market was created. All the respondents were, however, hopeful about the effectiveness of a rapid response team in preventing crop loss. Some of the respondents were very eager and forthcoming about the potential of producing, processing and marketing kuth-based products like oils at the village or panchayat level.

3) *Muling*

The participants in Muling felt a little uneasy about changing their cropping patterns by incorporating traditional crops. Interestingly, people here have already reduced green peas to a modest amount. The idea of incorporating traditional crops, however, made them uneasy because of various reasons. While many expressed the volatile nature of markets as a concern, others expressed their apprehension towards the sustenance of market linkages. In doing so, the participants invoked their past experiences with Hops, and Sea buckthorns. Both these crops were promoted by various stakeholders but ended up failing shortly after. A participant noted that traditional crops could only be cultivated if they have a market like cauliflower – accessible, profitable, local, and national.

While discussing technological interventions, the participants noted the curious nature of bears. While bears are initially cautious towards fox lights, camera traps, fencing, etc., they gradually become

accustomed to them, rendering these deterrents ineffective. Despite that, many believed that a combination of alarm systems and a rapid response team could work, and they were open to experiment.

4) *Jasrath*

The participants from Jasrath admitted that people were steadily getting disinterested in green pea as a cash crop owing to its declining productivity and yield, and consequently, green pea acreage had also reduced. However, they did not see buckwheat as a promising alternative to green pea as a measure to reduce bear-related crop damage. In fact, they informed us that bears used to forage on buckwheat in the past when buckwheat was a dominant crop. They further emphasised that buckwheat can safely be grown only in peak summer months, starting July to September, to ensure that the high temperatures prevent frost-related damage in younger stages of the crop. They were also not hopeful for black peas as an alternative, stating its lower productivity as a limiting factor. On the other hand, they seemed to view barley as a potentially successful crop if market linkages could be established. Moreover, barley is cultivated from April and harvested in September and is not susceptible to frost.

Discussing the potential of technological interventions for preventing crop damage by bears, they believed alarm systems or ANIDERS to be potentially effective, followed by the Rapid Response Team shooing the bear away from the fields. Fencing did not seem to be a viable option since bears can easily break and overcome such obstacles. Also, due to the easy habituation of bears to lights, fox lights were not considered to be a useful mitigation tool. Although a majority of them believed that bear removal was the easiest solution, upon further discussions they did agree that removal of a bear(s) would allow for others bear(s) to occupy the territory, and thus, would not be a permanent resolution. The participants also emphasised that the Forest department does not have the means or resources to manage the problem with bears.

5) *Gushal*

The meeting with respondents from this village was short and inconclusive due to multiple distractions. Like in other villages, the respondents recalled that buckwheat could be a palatable crop for bears. They mentioned that changing cropping patterns and decisions can be difficult to change but might happen in a slow phased-out manner. Deploying a rapid response team could be helpful but might be challenging owing to the vast spread of agricultural land in Gushal. One participant was particularly keen on the bear-related tourism-potential in the village. There were discussions on the potential of declaring certain areas as community reserves or Biodiversity Heritage Sites used for trekking and wildlife-tourism related activities. This can help boost the economy of villagers and offset losses caused by bears.

4.2 Minutes of meeting (with various government departments)

A landscape-level meeting was held on 30 May 2022 in Keylong, Lahaul to discuss about the key messages emanating from our project and suggestions for planning and action following a landscape approach. The meeting was organised with the help from UNDP-India SECURE Himalaya team working closely with the Forest Department in the landscape.

Date: 30 May 2022
Time: 11:00 AM
Venue: DC Office building, Keylong
Facilitator: Mr. Abhishek Kumar, UNDP-India

The meeting was held for the purpose of inter-departmental convergence to develop and adopt a landscape conservation approach for Lahaul. All line departments were invited for participate in the meeting. The meeting was attended by representatives from Forest department, Police department, Animal Husbandry department, Agriculture department, Krishi Vigyan Kendra, Kukumseri, Horticulture department, Panchayat Samiti, Zila Parishad, Rural Development Office, Himachal Road Transport Corporation.

We presented the key findings from our study and presented our key messages to manage human-wildlife conflict pertaining to crop damage caused by brown bears and black bears in the landscape:

i. *Technological interventions* to prevent and dissuade bears from entering the agricultural fields were discussed. A combination of solar and *composite fencing* (emphasis on its functionality of being easily removable before winters to prevent damage by snow), *fox lights*, and *alarm systems* or *ANIDERS* to work in tandem was proposed. Some of these interventions are being tested by NCF-India and UNDP-India SECURE project.
ii. Creating a *Rapid Response Team/Squad*, trained and hired by the Forest Department on a daily wage-basis, at the village level to guard vulnerable fields during peak crop damage months. This will provide a dual advantage of creating a service of crop field-guarding as well as additional opportunity for temporary employment, similar to the daily-wage employment opportunity provided under NREGA.
iii. A *phased reduction of bear-preferred or palatable crops such* as green pea and iceberg lettuce was proposed. The possibility of replacing these crops with traditional and more resilient crops such as buckwheat, black peas, and barley was discussed. These crops are not preferred by bears, however, our village meetings revealed that buckwheat was foraged by bears in the past. It was demonstrated how these traditional crops can be made equally or even more remunerative by 'organic' value addition, and by creating adequate market linkages.
iv. The possibility of limiting the crops palatable to bears spatially by forming a few *enclaves* protected by technological measures was discussed.
v. A suggestion was made to *not increase apple orchard area*, and to replace the older apple varieties which take ten years to bear fruit with newer varieties which start yielding fruits as early as in five years.
vi. The potential of Heeng (*Ferula asafoetida*) as an emerging cash crop in Lahaul that can not only be remunerative but deterring for bears was discussed.
vii. Bears have a great affinity towards organic waste. To prevent unwanted encounters with bears in the near future, the urgent importance of developing an *efficient garbage disposal and management* was discussed. In light of the growing tourism and consequent increasing waste generation, this intervention is a pressing need that needs active participation from the administration, tourist operators, hoteliers as well as local communities.

Following our proposed recommendations, all participants engaged in a lively discussion, and we received a number suggestions, comments and opinions.

Dr. Chaudhary Ram recommended creating ponds at higher elevations to aid in the existing irrigation system that faced strong challenges this year. To address the growing concerns of water shortage for irrigation, Dr. Bhatnagar highlighted the success of the Spring Recharge Plan initiated in Sikkim by the Rural Development department to meet the irrigation demands. He further suggested a potential for an exposure visit in Sikkim.

Dr. Ram and Ms. Radhika Negi also highlighted that green pea is an important fodder crop in villages have higher livestock holding. However, fodder oats, red clover and white clover are additional sources of fodder for supporting livestock. They also mentioned that cauliflower- an unpalatable crop- is a preferred crop for intercropping with apple in orchards.

Dr. Ganesh brought attention to acquiring tranquiliser guns and darts for bears that were scheduled to arrive in the following month. He suggested radio-collaring for bears to track bears. Dr. Bhatnagar cautioned that any such exercise of dealing with wild animals requires proper training with requisite equipment. Dr. Ganesh agreed that at present, the Animal Husbandry and Livestock Health department has no exposure to or expert training for handling large, wild animals.

With regard to human-wildlife conflict in the form of livestock depredation, Mr. Shiv Kumar informed that the Forest department is in the process of simplifying the tedious procedure of availing compensation for livestock loss by wild animals.

Queries about the compensation schemes for crop loss caused by wild animals were also addressed. Although the Pradhan Mantri Fasal Bima Yojana did release a notification for including an add-on for crop insurance against damage by wild animals, the state government is yet to approve this add-on coverage. Dr. Ram suggested that assessment of crop loss can be done by calculating the amount of loss from the affected farmer directly, vetting through the patwari or Agriculture department, and compensation be paid to the farmer directly.

On discussions about the potential effectiveness of technological interventions, it was noted that fox lights and camera traps were broken by bears in Gushal- the village where these interventions were piloted last year by NCF-India and Forest department. It was also brought to notice that alarm systems proved to be ineffective in deterring bears from approaching it or changing its path. Failure of the solar fences in Gushal were also discussed. Dr. Ram suggested that fencing that have nets up to the height of 4 feet can potentially control snow-related damages. From these pertinent observations and remarks, we gathered that these suggested technological interventions need to be more rigorously tested, monitored and evaluated for expected outcomes. This will be done in near future with collaborative efforts with the Forest department and UNDP-India.

Additionally, another issue that attracted curious attention and active discussion was that of pertaining to growing populations of free-ranging dogs and resultant issues of livestock depredation and crop damage. The lack of infrastructure available to the Animal Husbandry department was put forward by Dr. Ganesh as being the main cause to address and control the numbers of free-ranging dogs.

Annexure 5 (Baselines)

Table: Baseline table for all 78 sampled villages. Baseline on reported agricultural crop-related information.

Census village name	Agricultural land (in Ha)	Total unpalatable crop acreage (in Ha)	Total palatable crop acreage excluding apple (in Ha)	Total palatable crop acreage including apple orchards (in Ha)	Kuth acreage (in Ha)	Manu acreage (in Ha)	Barley acreage (in Ha)	Wheat acreage (in Ha)	Buckwheat acreage (in Ha)	Potato acreage (in Ha)	Pea production (in kg)	Pea acreage (in Ha)	Cauliflower production (in kg)	Cauliflower acreage (in Ha)	Broccoli acreage (in Ha)	Iceberg acreage (in Ha)	Carrot acreage (in Ha)	Apple acreage (in Ha)	Rajma acreage (in Ha)	Maize acreage (in Ha)	Exotic crop acreage (in Ha)	Other garden vegetables acreage (in Ha)
Kuang	3.2	2.4	0.8	1.2	0.16	0.16	0	0	0	1.6	22500	0.8	22500	0.32	0	0	0	0.36	0	0	0	0.16
Rashil	16.8	10.92	5.88	10.1	0	0	0	0	0	0.5	120875	5.88	312500	10.08	0	0	0	4.25	0	0	0	0.34
Jasrath	18.1	11.58	6.52	8.8	0.09	0.27	0	0	0	4.53	22227.5	5.43	100000	5.43	0.91	0.91	0	2.32	0.18	0	0	0.36
Bhujund	24	13.2	10.8	10.8	0	0	0	0	0	13.2	10447.5	7.2	NA	0	0	0	0	0	1.2	2.4	0	0
Jholing	15.2	9.88	5.32	5.4	0.3	0	0	0.46	0	1.52	42324	4.56	106250	7.6	0	0.76	0	0.12	0	0	0	0
Rape	22	13.2	8.8	12.8	1.1	1.1	0	0	0	2.2	90000	8.8	96000	8.8	0	0	0	3.98	0	0	0	0
Nalda	31.7	28.53	3.17	5.0	0	0	3.17	0	3.17	19.02	145800	3.17	198000	3.17	0	0	0	1.81	0	0	0	0
Lingar	10.1	9.09	1.01	1.5	0	0	0	0	0	1.01	8000	1.01	125000	7.07	0	0	0	0.44	0	0	0	1.01
Gushal	96	86.4	9.6	35.1	0	0	0	0	0	14.4		9.6	3750000	62.4	0	0	0	25.52	0	0	0	9.6
Karpat	16	10.88	4.96	5.0	0.48	0.32	0.16	0.16	0.16	1.6	16040	4.8	175000	8	0	0	0	0	0.16	0	0	0
Khawagling	16	14.4	1.6	1.6	0	0	0	0	0	8.64	6125	1.6	200000	5.76	0	0	0	0	0	0	0	0
Purd	18.4	18.2	0.18	0.2	0	0	0	0	0	2.58	22950	0.18	220000	14.72	0	0	0	0	0	0	0.92	0
Margaraon	64	32	32	40.3	0	0	0	0	0	9.6	182247	32	601680	19.2	0	0	0	8.34	0	0	0	3.2
Chhokar	2.8	1.87	0.93	0.9	0	0	0	0	0	0.93	4462.5	0.93	6413	0.93	0	0	0	0	0	0	0	0
Gondhla	52	48	4	4.8	0	0	0	0	0	4	2315	4	319000	43.99	0	0	0	0.81	0	0	0	0
Nain Gahar	14.8	10.88	2.72	2.7	0	0	0	0	0	4.08	10140	2.72	50000	6.8	0	0	0	0	0	0	0	0
Sindwari	18	5.94	12.06	13.8	0.36	0	0	0	0	1.8	80000	11.7	75000	3.6	0	0	0	1.75	0.36	0	0	0.18

Census village name	Agricultural land (in Ha)	Total unpalatable crop acreage (in Ha)	Total palatable crop acreage excluding apple (in Ha)	Total palatable crop acreage including apple orchards (in Ha)	Kuth acreage (in Ha)	Manu acreage (in Ha)	Barley acreage (in Ha)	Wheat acreage (in Ha)	Buckwheat acreage (in Ha)	Potato acreage (in Ha)	Pea production (in kg)	Pea acreage (in Ha)	Cauliflower production (in kg)	Cauliflower acreage (in Ha)	Broccoli acreage (in Ha)	Iceberg acreage (in Ha)	Carrot acreage (in Ha)	Apple acreage (in Ha)	Rajma acreage (in Ha)	Maize acreage (in Ha)	Exotic crop acreage (in Ha)	Other garden vegetables acreage (in Ha)
Khangsar 12/8	33.6	26.2	7.39	7.5	1.34	0	0	0	0	1.34	24750	0.67	253000	13.44	6.72	6.72	0	0.12	0	0	0	3.36
D.P.F.Bhiyari	4	3	1	1.2	0	0	0	0	0	0.4	12475	0.8	56875	2.4	0	0	0	0.19	0.2	0	0	0.2
Khanjar	12	10	2	2.0	0	0	2.4	0	2.4	2	52852.5	2	67250	2	0	0	0	0	0	0	0	1.2
Muling	23.7	22.75	0.95	4.5	0	0	0	0	0	0.24	4500	0.24	66000	22.52	0	0.47	0	3.57	0.24	0	0	0
Bargul	24	21.29	2.09	2.6	0	0	0	0	0	1.61	9000	1.61	14400	19.2	0	0	0.48	0.46	0	0	0	0.48
Chokhang	14.8	11.84	2.96	3.0	0	0	0	0	0	4.44	5625	2.96	54450	7.4	0	0	0	0	0	0	0	0
Kewak	6.2	5.43	0.78	0.8	0	0	0	0	0	4.65	10628	0.78	37125	0.78	0	0	0	0	0	0	0	0
Arat	4.8	3.84	0.96	1.5	0	0	0	0	0	0.48	185	0.48	23000	3.36	0	0	0	0.55	0.24	0.24	0	0
Bha Baring	4	3.2	0.8	0.9	0	0	0	0	0	2.8	18000	0.8	7500	0.4	0	0	0	0.05	0	0	0	0
Bha Chewar	4.8	3.84	0.96	1.0	0	0	0	0	0	3.36	24340	0.96	50000	0.48	0	0	0	0	0	0	0	0
Bha-Sumnam	8.8	7.6	1.2	2.0	0	0	0	0	0	1.6	248100	0.8	80000	4.4	1.6	0.4	0	0.78	0	0	0	0
Biling	23.2	13.46	6.96	12.2	0	0	0	0	0	8.82	1000	6.96	3000	4.64	0	0	0	5.23	0	0	0	0
Bok	7.4	5.55	1.85	2.0	0	0	0	0	0	2.59	22500	1.48	230000	2.22	0.52	0.22	0	0.14	0.15	0	0	0.22
Chaling	20	18	2	2.0	0	0	4	0	0	6	46050	2	88250	8	0	0	0	0	0	0	0	0
Chamrat	20	17.6	2.4	3.0	0.6	0.4	0	0.4	0	4.2	14000	2	175000	12	0	0	0	0.62	0.4	0	0	0
Cheling	8	7.34	0.66	1.2	0	0	0	0	0	1.34	14625	0.66	2500	5.34	0.66	0	0	0.54	0	0	0	0
D.P.F.Lobar	10.8	9.18	1.62	4.1	0	0	0	0	0	1.62	9000	1.62	70000	7.56	0	0	0	2.47	0	0	0	0
D.P.F.Lohni	4.8	3.36	1.44	1.7	0	0	0	0	0	1.68	5400	0.96	NA	1.68	0	0	0	0.29	0	0.48	0	0
Dimphuk	17.8	17.8	0	0.0	0	0	0	0	0	16.02	5000	0	64000	0	0	0	0	0	0	0	0	1.78
Duansha	14.4	10.08	4.32	6.4	0	0	3.6	0	0	3.6	67500	3.6	125000	2.88	0	0.72	0	2.05	0	0	0	0
Girmus	4.8	3.36	1.44	1.4	0	0	0	0	0	1.92	19656	1.44	52535	1.44	0	0	0	0	0	0	0	0
Gopa Thang	10.4	9.88	0.52	0.5	0	0	0	0	0	1.04	2440	0.52	687500	8.84	0	0	0	0	0	0	0	0

Census village name	Agricultural land (in Ha)	Total unpalatable crop acreage (in Ha)	Total palatable crop acreage excluding apple (in Ha)	Total palatable crop acreage including apple orchards (in Ha)	Kuth acreage (in Ha)	Manu acreage (in Ha)	Barley acreage (in Ha)	Wheat acreage (in Ha)	Buckwheat acreage (in Ha)	Potato acreage (in Ha)	Pea production (in kg)	Pea acreage (in Ha)	Cauliflower production (in kg)	Cauliflower acreage (in Ha)	Broccoli acreage (in Ha)	Iceberg acreage (in Ha)	Carrot acreage (in Ha)	Apple acreage (in Ha)	Rajma acreage (in Ha)	Maize acreage (in Ha)	Exotic crop acreage (in Ha)	Other garden vegetables acreage (in Ha)
Guskyar	4.7	2.82	1.88	2.6	0	0	0	0	0	1.88	20700	1.88	12100	0.94	0	0	0	0.75	0	0	0	0
Gwajang	13.4	10.43	2.48	3.1	0	0	0.38	0	0.12	3.73	11580	2.48	13500	6.2	0	0	0	0.62	0	0	0	0
Haruka	27.2	18.13	9.07	11.3	0	0	0	0	0	9.07	20935.5	9.07	147250	9.07	0	0	0	2.25	0	0	0	0
Jagle	28	22.93	5.07	5.1	0	0	0	0	0	0.2	9000	0.2	144000	16.8	5.6	4.87	0	0	0	0	0	0.34
Jahlma	40	34	6	14.5	0.4	0	0	0	0	3.6	100800	6	475200	24	0	0	0	8.51	0	0	6	0
Jispa	27.7	19.39	8.31	8.6	0	0	0	0	0	8.31	10680	8.31	10000	8.31	0	0	0	0.26	0	0	0	2.77
Kamring	8.5	5.1	3.41	4.1	0	0	0	0	0	2.13	22500	2.98	87500	2.98	0	0.43	0	0.65	0	0	0	0
Karing	5.2	3.64	1.56	2.3	0	0	0	0	0	1.56	14700	1.56	100000	2.08	0	0	0	0.72	0	0	0	0
Kawaring	16.8	14.28	2.52	2.7	0.42	0.42	0.42	0	0.42	6.72	11385	2.52	12100	5.04	0	0	0	0.15	0	0	0	0.84
Khangsar 13/3	3.2	2.24	0.96	1.0	0	0	0	0	0	0.96	1840	0.96	78750	0.96	0	0	0	0	0	0	0	0.32
Khangsar 8/4	34.4	27.52	6.88	6.9	0	0	0	0	0	13.76	1665	6.88	9200	13.76	0	0	0	0	0	0	0	0
Khoksar	30	30	0	0.0	0	0	0	0	0	27	10800	0	50000	0	0	0	0	0	0	0	0	3
Kirting	21.6	18.36	3.24	6.6	0.22	0	0	0	0	1.94	90000	3.24	432000	12.96	0	0	0	3.36	0	0	3.24	0
Kothi	6.4	5.12	1.28	2.4	0	0	0	0	0	3.84	20810	1.28	41250	1.28	0	0	0	1.11	0	0	0	0
Krozing	7.6	6.33	1.27	5.3	0	0	0	0	0	1.27	2250	1.27	261250	1.27	0	0	0	4.03	0	0	0	3.8
Kurched	6.1	3.46	2.65	2.8	0	0	0	0	0	3.05	7543.5	1.83	0	0	0	0	0	0.17	0.41	0.41	0	0.41
Kyor	8.4	5.88	2.52	3.5	0	0	0	0	0	2.52	22000	2.52	20000	2.52	0	0	0	1.01	0	0	0	0.84
Lapshak	13.2	9.11	3.96	6.2	0	0	0.4	0	0.4	3.96	30300	3.96	171500	3.96	0	0	0	2.21	0	0	0	0.4
Leh Baring	4.8	3.84	0.96	1.2	0	0	0	0	0	3.36	27000	0.96	17500	0.48	0	0	0	0.22	0	0	0	0
Lindur	15.7	13.08	2.62	3.2	0	0	0	0	0	10.21	10710	2.62	16875	1.31	0	0	0	0.56	0	0	0	1.57
Lomach	3.3	2.31	0.99	2.0	0	0	0	0	0	0.99	9350	0.99	5625	0.99	0	0	0	0.99	0	0	0	0.33
Lot	38	28.5	9.5	16.2	1.9	1.9	0	0	0	15.2	22500	7.6	5600	7.6	0	0	0	6.66	1.9	0	0	1.9

Census village name	Agricultural land (in Ha)	Total unpalatable crop acreage (in Ha)	Total palatable crop acreage excluding apple (in Ha)	Total palatable crop acreage including apple orchards (in Ha)	Kuth acreage (in Ha)	Manu acreage (in Ha)	Barley acreage (in Ha)	Wheat acreage (in Ha)	Buckwheat acreage (in Ha)	Potato acreage (in Ha)	Pea production (in kg)	Pea acreage (in Ha)	Cauliflower production (in kg)	Cauliflower acreage (in Ha)	Broccoli acreage (in Ha)	Iceberg acreage (in Ha)	Carrot acreage (in Ha)	Apple acreage (in Ha)	Rajma acreage (in Ha)	Maize acreage (in Ha)	Exotic crop acreage (in Ha)	Other garden vegetables acreage (in Ha)
Meh	12	10.8	1.2	1.2	0	0	0	0	0	2.4	9134	1.2	11990	8.4	0	0	0	0	0	0	0	0
Othang	18	11.97	6.03	6.0	0	0.54	0	0	0	6.03	39397.5	6.03	45382.5	5.4	0	0	0	0	0	0	0	0
Prasprag	4.8	3.36	1.44	1.7	0	0	0	0	0	1.68	13580	1.44	11000	1.68	0	0	0	0.21	0	0	0	0
Rangbe	16	12	4	7.4	0.8	0.8	0	0	0	6.4	27247.5	3.2	224400	3.2	0	0	0	3.38	0.8	0	0	0.8
Ropsang	18.4	12.88	5.52	5.5	0	0	0	0	0	5.52	54045	5.52	250000	5.52	0	0	0	0	0	0	0	1.84
Ruring	10.4	9.67	0.73	4.3	0	0	0	0	0	2.29	9000	0.52	62500	7.28	0	0	0	3.61	0.21	0	0	0.1
Salpat	9.6	6.53	3.07	4.4	0	0	0	0.19	0.1	1.44	18160	2.88	9380	4.8	0	0	0	1.34	0	0.19	0	0
Shansha	61.6	25.87	35.73	55.7	0	0	0	0	0	18.48	607500	30.8	875000	6.16	0	4.93	0	19.94	0	0	1.23	0
Shuiling	40	38	2	2.0	0.2	0	0	0	0	8	49500	2	462000	27.8	2	0	0	0	0	0	0	0
Stingiri	9.6	5.76	3.84	4.4	0	0	0	0	0	2.88	45000	3.84	180000	2.88	0	0	0	0.58	0	0	0	0
Thapak	10.4	7.28	3.12	3.1	0	0	0	0	0	4.16	17200	3.12	47250	1.56	0	0	0	0	0	0	0.31	1.25
Tingrat	48	43.2	4.8	4.8	0	0	0	0	0	9.6	32000	4.8	425000	28.8	0	0	0	0	0	0	0	4.8
Tinno	40	32.8	7.2	7.2	2	2	0	0	0	14.4	40360	7.2	78750	14.4	0	0	0	0	0	0	0	0
Triloknath	64	57.6	6.4	9.2	0	0	0	0	0	32	90850	6.4	1295500	19.2	0	0	0	2.78	0	0	0	6.4
Wari	22	20.9	1.1	6.4	0	0	0	0	0	1.1	1750	1.1	60000	17.6	0	0	0	5.26	0	0	0	2.2
Yang Kirting	6.4	4.48	1.92	2.9	0	0	0	0	0	2.56	21492.5	1.92	60750	0.96	0	0	0	0.96	0	0	0.19	0.77
Yoche	48	33.6	14.4	14.4	0	0	7.2	0	0	24	11857.5	14.4	0	2.4	0	0	0	0	0	0	0	0

Table: Baseline information table for all 78 sampled villages on reported agricultural crop-related income and bear-related crop losses.

Census village name	Agricultural income (in Rs.)	Per capita agriculture income	Total crop loss by bears (in kg)	Total crop monetary loss by bears (in Rs.)
Kuang	2396500	108932	260	7800
Rashil	13662575	164609	15666	665284.5
Jasrath	5931500	47075	10787.5	441343
Bhujund	8813562.5	48964	8822	555605
Jholing	3197025	27093	8456	342383
Rape	10043000	67403	3452	106282
Nalda	12274000	54070	4850	218250
Lingar	3666400	74824	4241	230960.5
Gushal	155250000	398077	3225	172875
Karpat	10367000	46281	1600	131200
Khawagling	9221875	93150	500	37500
Purd	15660000	295472	450	31500
Margaraon	28738287.5	40996	208	10400
Chhokar	779230	31169	212.5	17306.25
Gondhla	18378800	55863	200	9000
Nain Gahar	2355000	45288	140	8400
Sindwari	6465000	25353	130	5200
Khangsar 12/8	18389100	193569	107	3978
D.P.F.Bhiyari	3005312.5	83481	100	4500
Khanjar	9838150	149063	67.5	6075
Muling	3153000	18547	23	621
Bargul	2560200	25602	14	378
Chokhang	3399975	29824	18	18
Kewak	2671250	121420	3	165
Arat	3478325	48310	0	0
Bha Baring	1322000	52880	0	0
Bha Chewar	30370000	632708	0	0
Bha-Sumnam	2595000	117955	0	0
Biling	369000	2306	0	0
Bok	21337000	328262	0	0
Chaling	7715000	54716	0	0
Chamrat	11291800	74288	0	0
Cheling	1846425	61548	0	0
D.P.F.Lobar	1782000	48162	0	0
D.P.F.Lohni	406800	4109	0	0
Dimphuk	8565000	57483	0	0
Duansha	7172500	94375	0	0

Girmus	3701250	68542	0	0
Gopa Thang	21014000	477591	0	0
Guskyar	1651750	36706	0	0
Gwajang	2849406	42528	0	0
Haruka	6356825	27519	0	0
Jagle	25282500	495735	0	0
Jahlma	16397850	48371	0	0
Jispa	2025000	10025	0	0
Kamring	4209500	32134	0	0
Karing	4340000	140000	0	0
Kawaring	3660700	32685	0	0
Khangsar 13/3	2771625	98987	0	0
Khangsar 8/4	1078250	4814	0	0
Khoksar	6100800	78215	0	0
Kirting	33372104	167699	0	0
Kothi	2744689	124759	0	0
Krozing	4917781.25	104634	0	0
Kurched	4.00E+05	5970	0	0
Kyor	3170037.5	83422	0	0
Lapshak	6850000	91333	0	0
Leh Baring	2082000	29324	0	0
Lindur	7308250	101503	0	0
Lomach	831250	29688	0	0
Lot	4385000	22839	0	0
Meh	3670000	50972	0	0
Othang	4316275	123322	0	0
Prasprag	1637500	44257	0	0
Rangbe	6097000	55936	0	0
Ropsang	19127920	277216	0	0
Ruring	3929500	112271	0	0
Salpat	1204650	7257	0	0
Shansha	154062500	481445	0	0
Shuiling	22177000	100348	0	0
Stingiri	9670000	18007	0	0
Thapak	4288150	107204	0	0
Tingrat	25915000	79985	0	0
Tinno	10616250	84930	0	0
Triloknath	59602000	67653	0	0
Wari	1465225	40701	0	0
Yang Kirting	5231500	100606	0	0
Yoche	945000	9947	0	0

Table: Baseline information table for all 78 sampled villages on village demographics and livestock-holding. (Source: District Census Handbook, DSA, Livestock Census report).

Census village name	Village size (no. of households)	Village population	Total no. of cultivators	Livestock density	Total livestock holding	Cattle holding	Small livestock holding
Kuang	5	22	14	16.5	169	13	78
Rashil	14	83	59	20.9	469	85	192
Jasrath	20	126	52	13.1	319	59	130
Bhujund	35	180	100	7.9	898	70	414
Jholing	20	118	51	8.5	627	63	282
Rape	28	149	87	32	988	118	435
Nalda	38	227	105	12.9	681	95	293
Lingar	7	49	29	24.2	482	56	213
Gushal	79	390	237	4.9	489	145	172
Karpat	36	224	123	1.3	179	71	54
Khawagling	30	99	33	6.1	31	31	0
Purd	12	53	24	3	23	23	0
Margaraon	141	701	313	8	3401	235	1583
Chhokar	6	25	17	56.5	194	17	177
Gondhla	73	329	171	4	172	74	49
Nain Gahar	12	52	32	19.9	480	38	221
Sindwari	63	255	96	2.4	905	71	417
Khangsar 12/8	17	95	62	11.7	729	41	344
D.P.F.Bhiyari	6	36	17	0.7	190	12	89
Khanjar	15	66	34	0.3	23	23	0
Muling	29	170	133	5.2	90	50	20
Bargul	18	100	84	5.1	222	48	87
Chokhang	28	114	36	7	205	45	80
Kewak	5	22	12	16.8	30	30	0
Arat	13	72	27	4.6	324	20	152
Bha Baring	5	25	10	20	159	15	72
Bha Chewar	7	48	16	46.1	266	22	122
Bha-Sumnam	5	22	15	4.9	191	11	90
Biling	46	160	107	8.4	254	94	80
Bok	21	65	42	1.5	6	6	0
Chaling	28	141	79	7.2	435	73	181
Chamrat	29	152	87	3.8	626	52	287
Cheling	7	30	21	4.1	54	18	18

D.P.F.Lobar	6	37	11	0.7	500	30	235
D.P.F.Lohni	28	99	30	1.7	572	28	272
Dimphuk	48	149	40	3.6	28	28	0
Duansha	13	76	31	11.3	377	39	169
Girmus	8	54	29	12.4	97	25	36
Gopa Thang	8	44	21	5.8	18	18	0
Guskyar	8	45	22	21.9	184	36	74
Gwajang	18	67	33	7.5	235	23	106
Haruka	54	231	63	2.6	445	61	192
Jagle	9	51	33	3.1	26	26	0
Jahlma	85	339	160	4.9	200	108	46
Jispa	51	202	113	3.8	232	20	106
Kamring	25	131	53	10.1	193	45	74
Karing	5	31	13	6.3	83	17	33
Kawaring	19	112	72	5	236	44	96
Khangsar 13/3	7	28	16	8.5	10	10	0
Khangsar 8/4	45	224	133	8.7	550	104	223
Khoksar	18	78	38	9.5	36	36	0
Kirting	41	199	106	8.2	133	61	36
Kothi	5	22	13	3.1	42	16	13
Krozing	9	47	22	12.2	160	28	66
Kurched	15	67	29	1	485	21	232
Kyor	5	38	18	13.3	257	17	120
Lapshak	13	75	41	10.4	378	40	169
Leh Baring	16	71	30	9.1	99	23	38
Lindur	14	72	34	13.3	736	58	339
Lomach	5	28	17	14	57	17	20
Lot	36	192	92	4.9	84	44	20
Meh	18	72	34	9.1	172	28	72
Othang	8	35	23	4.7	210	24	93
Prasprag	7	37	21	25.8	275	41	117
Rangbe	18	109	55	3	29	25	2
Ropsang	14	69	42	4.2	95	39	28
Ruring	9	35	20	7.7	140	36	52
Salpat	32	166	82	12.8	592	50	271
Shansha	72	320	195	16.1	2545	277	1134
Shuiling	46	221	140	4.8	127	47	40
Stingiri	76	537	27	15	308	24	142
Thapak	7	40	21	6.5	329	25	152
Tingrat	73	324	174	6	1622	128	747
Tinno	29	125	91	6.2	366	48	159
Triloknath	146	881	226	14.8	3295	325	1485
Wari	9	36	24	5.5	235	23	106
Yang Kirting	8	52	32	18.7	446	28	209
Yoche	14	95	59	18.6	509	47	231



Credits: Shiv Yadav, WII