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Biomass loss in village ecosystems in Western Himalaya due to wild monkey interactions: A case study

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ABSTRACT

Conservation faces the challenge of reconciling human activities with the simultaneous presence of wildlife in cultivated landscapes. In a study carried out in two villages of Pauri Garhwal, Western Himalaya, an attempt was made to estimate biomass and associated carbon loss due to removal of agroforestry tree species to reduce human-animal interactions. The results revealed that tree removal caused substantial biomass loss (7.370–2.444 t ha^{-1}) and carbon loss (3.444–15.137 t ha^{-1}) in the village of Manjgaon and Mald Bada, respectively. This indicates a need for protection of existing forests and for tree planting through reforestation and afforestation, as a measure to support food stock for monkeys in their natural habitats and to enhance carbon sequestration capacity. The success of these management practices will depend on the potential to minimise human-animal interactions, especially at the fringes of village communities and agricultural landscapes.

1. Introduction

Human-wildlife interactions due to competition for food and resources are widespread and have already imposed severe losses of wildlife and of some people, and even extinction of many species (Artelle et al., 2016; Nyhus, 2016). However, local perceptions can vary from positive to negative depending on the species involved in the interaction (Alexander et al., 2015; Bencin et al., 2016). The growing human population and associated expansion of human habitat commonly results in interactions with wild animals in nearby forest areas (Daniel, 2009; Shukla and Kumar, 2002). Thus, there is a need to resolve interactions between conservation and rural people (Galvin et al., 2006; Ratnayeke et al., 2014). In many parts of the developing world, wild animals inhabit landscapes beyond reserves, leading to conflict with local communities and encroaching on many jurisdictional areas (Hartter et al., 2011; Inskip and Zimmermann, 2009). Such incidents may pose a risk to life of people living in the vicinity of protected areas (Dunham et al., 2010; Silwal et al., 2017). They can also directly affect the overall availability of food for families or communities (Ogra, 2008). Among various risks faced by rural communities, crop damage due to wild animals is the most prevalent in Africa and the Asian sub-continent (Rohini et al., 2016; Wong et al., 2015). Crop raiding by wild animals affects yields. Crop raiding is defined as an event when one or more number of animal species interacts with one or more farm crops and then left the farm (Wallace and Hill, 2012). Other major consequences of human-animal interactions are loss of life and livestock damage by wild animals, which significantly affects people's livelihood and their food and farm security (Barua et al., 2013).

Human-wildlife interactions are generally more intense in areas where agricultural practices and livestock rearing are the main components of rural people's livelihood and income (Li et al., 2013; Mojo et al., 2014). Rural inhabitants, especially smallholder farmers and forest landowners, typically bear the brunt of wildlife damage (Conover, 1997). Losses from human-wildlife interactions can be relatively small at the group, village or district level, although individual farmers can lose a considerable proportion of their potential harvest in a season or year (Hill, 2000). Crop raiding by wildlife thus has a significant impact on rural people's livelihood, forcing them to adopt illegal practices such as felling of trees at farm (Mekonen, 2020) and use of poison to kill animals (Mateo-Tomás et al., 2012) to minimise this impact. The tolerance of farmers to crop losses due to wildlife is influenced by their dependence on farming for income, the size of their land holding, their length of residence in an area and presence/absence of effective compensation schemes (Hill, 2000).

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The negative impacts of human-wildlife conflicts on the environment and wildlife conservation activities sometimes result in clearing of vegetation on private land to reduce the habitat of nuisance wildlife, resulting in lower wildlife numbers (Treves et al., 2006). Nuisance wildlife is defined as the nature of animal is destructive or menacing and may be destroying property such as buildings, crops, pets and livestock (ICWDM, 2021). Possible conflict management measures range from relocation of wild animals to destruction of their habitat, including felling trees providing shelter for the wild animals causing the problems (Madhurima and Banerjee, 2013). Further research is urgently needed to determine the scale and extent of human-wildlife conflict with reference to monkey menace problem and associated biomass loss in village ecosystems.

The co-existence of monkeys with humans is posing an increasing threat due to growth in both the human and monkey populations (Das and Mandal, 2015). Monkeys are well-adapted to co-exist with humans and thrive near urban and agricultural human settlements, due to the plentiful supply of food from farmland (Cawthon Lang, 2012; Sabic, 2011). Similarly to humans, monkeys have a non-specialised and very flexible diet, and can survive even in degraded habitats or in urban areas, where they feed on whatever humans eat (Campbell et al., 2010). During food scarcity, monkeys adapt to a wide variety of foods, including bark and cones of conifers (Sabic, 2011). Co-operative behaviour, an opportunistic lifestyle and a non-specialised, omnivorous diet have helped primates to become highly adaptable and live alongside humans in rural, urban and semi-urban areas (Hill, 2000; Pirta et al., 1997). However, monkeys in search of food can create problems for humans, such as damage to crops and fruit trees and snatching goods and food. With the expansion of human settlements and associated retreat of natural habitats (Fuentes, 2006), many monkeys have become ecological refugees (Mitra, 2000). In India, annual compensation of Rs 0.2 million is paid by Uttarakhand state to victims of Monkey (*Rhesus macaque*) bites (Raj, 2014).

In the mountain villages of Western Himalaya, India, the conflict between monkeys and humans has accelerated in recent decades. Monkeys are creating problems for the villagers, such as destroying crops and fruits and sometimes injure children. In response, the villagers have attempted to manage the conflict by destroying the monkeys' habitat. One of the management options available is felling/pruning of trees that the monkeys use as shelter on farms (Mojo et al., 2014). This practice has resulted in biomass extraction and associated carbon losses, i.e. environmental degradation. In addition, tree felling on agricultural lands has been shown to have a negative impact on bird diversity (Fischer et al., 2010). The loss of carbon from the field has a bearing on global efforts to mitigate climate change, including the United Nations programmes on the reduction of emissions from deforestation and forest degradation (REDD+). Human-wildlife conflicts are a potential barrier to effective, natural resource management and livelihood improvement. Thus more efforts are needed by local government and development organisations to investigate the problem and mitigate the effects (Hill, 2004). However, there is currently a lack of information and research on plant biomass losses due to human-wildlife conflicts, creating a need for policies on proactive and reactive responses (Athreya and Belsare, 2007).

The objective of the present study was to estimate the loss of standing biomass and associated carbon losses due to felling/pruning of the 10 most common local tree species in Western Himalaya in response to human-wildlife interactions. The overall aim was to improve understanding of carbon storage and forest management practices adopted by rural communities, and hence the REDD+ programme.

2. Materials and methods

2.1. Study area

Pauri Garhwal, a district in the state of Uttarakhand, Western Himalaya, India, encompasses an area of 5230 km^2 and is situated between 29°45′–30°15′N and 78°24′–79°23′ E, with a sub-tropical to temperate climate. The monthly minimum and maximum temperature range in the region is 6–21 °C and 18–35 °C, respectively, with mean annual rainfall of 1500 mm. The soil in the region is derived from weathering of slate down to 30–80 cm deep. The main occupation of the local inhabitants is farming, while other major sources of employment for young people are the armed forces and teaching. Due to lack of infrastructure and challenging geography, there are no major industries in the hilly part of the district (MSME, 2016).

The present study was carried out in two villages, Manjgaon (29°54′54.2″N, 78°52′27.8″E; 1500 m above mean sea level (m.a.s.l.) and Mald Bada (29°55′04.8″N, 078°52′43.7″E; 1534 m.a.s.l.) in Pauri Garhwal district (Fig. 1). In each village, two sites (one on agricultural land (site A) and one on fallow land (site B)) were studied.

The inhabitants of both villages depend on forest and agricultural resources, such as fuelwood for cooking and fodder for livestock, to fulfil their basic needs. Common trees growing along the edges of agricultural fields are *Bauhinia variegata* (Kachnar), *Celtis australis* (Khadik), *Ficus roxburghii* (Timla), *Ficus palmata* (Bedu), *Grewia optiva* (Bhimal), *Prunus cerasoides* (Padam/Payya), *Pistacia integerrima* (Kakhhad), *Quercus leucotrichophora* (Banj oak), *Sapium insigne* (Khinnu) and *Toona ciliata* (Toon). The fallow land around the village was formerly agricultural land, but was abandoned due to inadequate irrigation facilities and monkey problems. The vegetation on this fallow land consists of various multi-purpose trees such as *Quercus leucotrichophora, Celtis australis, Pinus roxburghii* (Chir), *Prunus cerasoides, Ficus roxburghii, Ficus palmata, Bauhinia variegata, Sapium insigne* and *Pistacia integerrima* of which *Celtis australis, Prunus cerasoides, Pinus roxburghii* and *Quercus leucotrichophora* are the most common species. *Berberis asiatica* (Kingora), *Rhus parviflora* (Tung), *Woodfordia fruticosa* (Dhaula) and *Rubus ellipticus* (Hisalu) are the most common shrub species in the forested area. The most common species used for roosting by monkeys (*Rhesus macaque)* were *Toona ciliata, Celtis australis, Quercus leucotricophora, Pinus roxburghii* and *Ficus roxburghii*.

2.2. Data collection

Collection of primary data was carried out using a pre-tested semi-structured questionnaire framed which was based on the relevant literature such as research papers, news articles and previous knowledge about the monkey menace problem. A semi structured questionnaire is a type of interview in which the interviewer asks only few predefined questions while the rest are not planned in advance (Morse and Field, 1995). For the purpose of study initially a pilot survey was carried out to gather information on the existing problem and changes in the questionnaire were made accordingly based on the discussions with peer during 2011–2012. The questionnaire included a mix of questions pertaining to the issue under investigation, with the majority being closed-ended questions (Table 3). The information was collected by personal visits to the study area and discussion with respondents (local inhabitants), with their prior oral consent. The responses to the questionnaire provided data on household attributes, crops grown and factors responsible for biomass extraction. The interviews and discussions with peers and locals (mainly elderly people and women) lasted for one hour and were conducted in Hindi and in the local dialect (Garhwali).

2.3. Biomass estimation

Aboveground biomass was calculated using existing volume regression equations for *Toona ciliata, Quercus leucotrichophora* and *Bauhinia variegata* (FSI, 2015, 1996) (Table 1). The aboveground biomass values for remaining tree species such as *Celtis australis, Ficus palmata, Ficus roxburghii, Grewia optiva, Sapium insigne, Pistacia integerrima* and *Prunus cerasoides* were estimated using the formula for standing trees, with the results expressed in m^3 (Chaturvedi and Khanna, 1982). The diameter

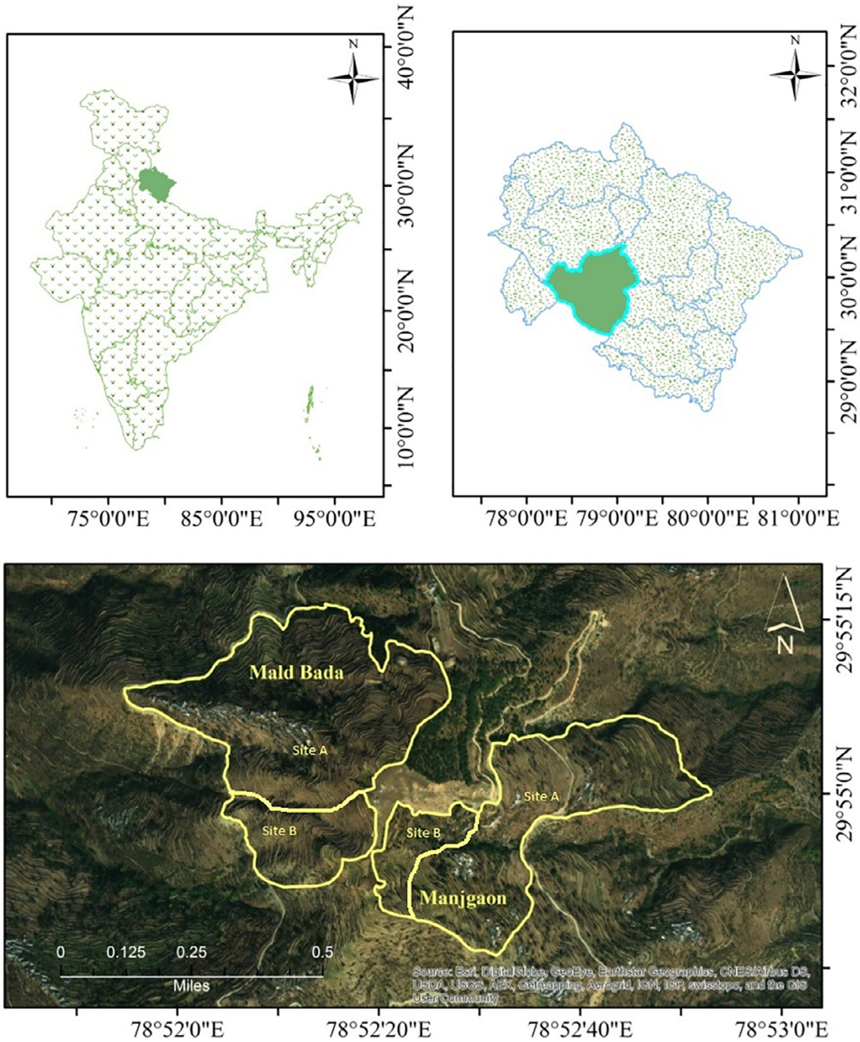

Fig. 1. Map showing the location of the study area, Pauri Garhwal, Western Himalaya, India. *A* = agricultural land, *B* = fallow land.

Table 1
Equations used for calculating the volume of different tree species.

Species	Volume Equation	Reference
Toona ciliata	$V = 0.21869 - 2.04074 \times D + 10.41713 \times D^2 + 1.85232 \times D^3$	FSI 1996
Quercus leucotrichophora	$\sqrt{V} = 0.240157 + 3.820069 \times D - 1.394520 \times \sqrt{D}$	FSI 2015
Bauhinia variegata	$V = -0.0236 + 0.3078 + 1.2361 \times D^2$	FSI 2015

V is tree volume, D is tree diameter.

at breast height (DBH) was measured with a measuring tape and tree height with a Ravi multimeter.

2.4. Calculation of aboveground biomass for remaining species was as follows

The basal area(A_b) of merchantable bole was estimated as:

$$A_b = \left(\pi d^2/4\right) \quad (1)$$

where $\pi = 3.14$ and d is the diameter of the tree at breast height.

The merchantable bole is the biomass of sound wood from a 1.0 feet stump height to a minimum of 4.0 inches top diameter (Domke et al., 2013).

The volume (V) in m^3 was calculated as:

$$V = A_b \times H \times BEF \quad (2)$$

where H is tree height and BEF is biomass expansion factor (1.575 the value of BEF was used for the species) (Kishwan et al., 2009).

Using mean wood density (MWD) of each species, total biomass was calculated in metric tonnes (Rajput et al., 1996). A MWD value of 0.72 was used for species for which the exact MWD was not known (Kaul et al., 2009). The calculated volume of the trunk was used to estimate total trunk biomass (kg) by multiplying by wood density (WD) for the corresponding tree species, following (Brown, 1997):

$$\text{Biomass} = V \times WD \times 1000 \quad (3)$$

2.4.1. Assessment of carbon stocks

To estimate the carbon content of trees in the study area and total biomass extraction, samples of wood were taken from felled trees of the different species. The ash content method was used to estimate carbon content, following Negi et al. (2003), due to its simplicity and the availability of resources such as equipment and research expertise. Twenty samples were taken from each tree species and ground into powder using an electric pestle and mortar. The powder samples were sieved and oven-dried to constant weight and then a 2 g sub-sample of each was

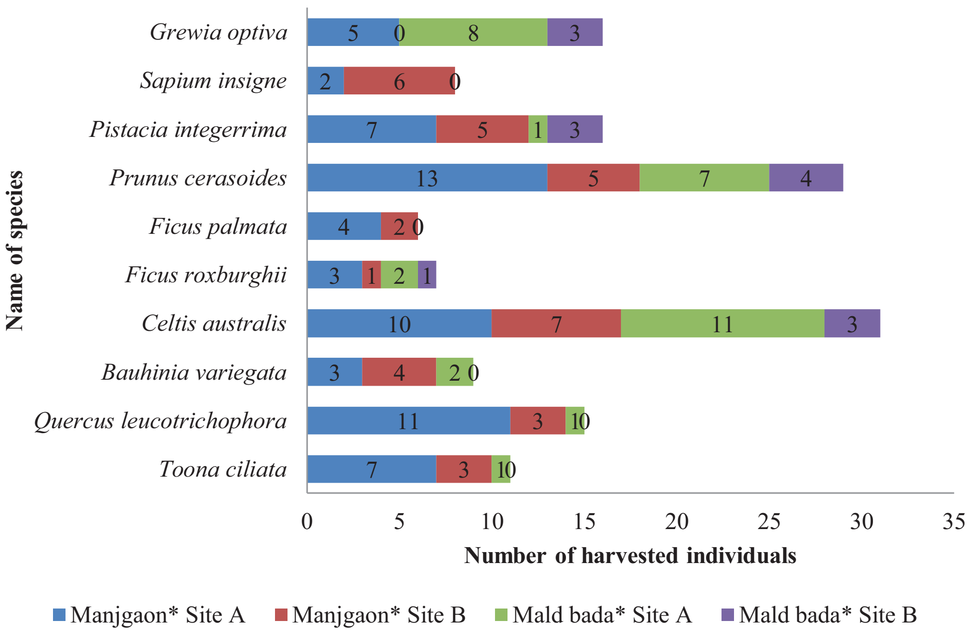

Fig. 2. Number of individuals of different tree species harvested from agricultural land (site A) and fallow land (site B) in the two study villages (Manjgaon and Mald Bada), Pauri Garhwal, Western Himalaya.

transferred to an uncovered crucible, which was placed in a muffle furnace and heated at 575 ± 25 °C for 3 h to eliminate the carbon. The crucibles were then placed in desiccators for cooling, to avoid moisture absorption (Ehrman, 1994). Finally, the weight of ash was measured after the crucibles had attained room temperature and carbon content (%) of the original sample was calculated following (Negi et al., 2003) as:

$$\text{Carbon \%} = 100 - \left[\text{Ash Weight} + \text{Molecular Weight of } O_2(53.3) \text{ in } C_6H_{12}O_6\right]$$

$$\text{Carbon(C)} = \text{Biomass} \times \text{Carbon \%}$$

$$\text{Carbon Sequestration} = \text{Carbon} \times 3.666 \quad (4)$$

3. Results and discussion

Due to long-standing problems with monkeys, tree felling has been carried out around both Manjgaon and Mald Bada villages. The decision on tree felling in the study area was made by the villagers, in a village *panchayat*. According to the perception of villagers felling/pruning of trees around agricultural fields and nearby areas was expected to yield a new flush of green tree foliage that could be used as fodder and fuelwood, which in turn could increase the productivity land for agriculture, and also would help to get rid of monkeys. The major tree felling was concentrated to the agricultural fields rather than fallow land around the villages. The intensity of felling was greater in Manjgaon and included parts of the nearby forest (Fig. 2), as the monkey problem was perceived to be more severe in Manjgaon, because the agricultural fields were closer to the forest where monkeys sheltered at night. The felling was carried out by contractors and the total expenditure on the task was around Rs 22,000 (approx. 300 USD), with some other expenses such as cutting and logging. Most of the logs were used by the villagers for making furniture, as sleepers and as fuelwood (Table 2).

In order to identify the reasons behind the large-scale tree felling, villagers in three different age groups (<25 years, 25–60 years, >60 years) were surveyed (Table 3). All age groups had the same view regarding the tree felling operations somehow the answers provided by age group <25 years had less knowledge about the situation. The main reason was the problem with increasing numbers of monkeys in the past few decades. People older than 60 years were particularly unhappy with monkeys, reporting that they had destroyed crops in their agricultural fields over the past two decades. Once the monkeys reached the agricultural fields, they raided all available crops and left nothing. Regardless of the crop grown, or sown, in the agricultural fields or in gardens near villagers' houses, it was reported to be often destroyed by the monkeys. The monkeys frequently roamed around the agricultural fields in the mornings/evenings, while at night they roosted in nearby trees. As the problem persisted over the time, the villagers resorted to cut down the sheltering trees. According to the villagers (>60 years age group), two groups of monkeys, with approximately 25–30 individuals in each group, resided in the area and tended to visit the agricultural fields at different times. The villagers reported an increase in the monkey population over recent decades. However, after felling of trees in the study cites the villagers reported that the number of monkey visit had decreased. Thus, they felt that the felling of trees had a positive effect on decreasing the damage made by the monkeys (Table 3).

Destruction caused by monkeys in farmers' fields is a common phenomenon in many areas of the world (Das and Mandal, 2015; Fuentes, 2006; Siljander et al., 2020). Cases of monkeys scaring people by aggressive behaviour such as snarls and occasional bites have also been reported, e.g. by Imam and Ahmad (2013). The monkeys in the study villages had been present for a long time, but had previously restricted themselves to the forested area and only visited the agricultural fields occasionally. The main crops raided by the monkeys at that time were reported to be rice, wheat, pulses, maize and millet. Cases of chimpanzees eating fruits grown near houses and occasional food stealing from houses have been reported in Uganda (McLennan and Hill, 2012). Damage to houses by monkeys jumping on the roof and some incidents of monkeys biting humans were also reported by the villagers in the study area. Such threatening behaviour by primates towards humans, especially children, has also been identified as a major problem in Africa (McLennan and Hill, 2012). With the expansion of human settlements and associated decline in habitats, as well as degradation of local forests, many monkeys have become ecological refugees as they are forced to move out of their natural habits in search of food (Mitra, 2000).

3.1. Biomass extraction

Total biomass extraction due to human-wildlife conflicts in the study area was estimated to be 5.64 t ha^{-1} fallow land and 1.73 t ha^{-1} agricultural land (7.370 t ha^{-1} combined) in Manjgaon village, and 1.61 t ha^{-1} fallow land and 0.834 t ha^{-1} agricultural land (2.444 t ha^{-1} combined) in Mald Bada village (Table 4). Maximum carbon stock loss was calculated to be 9.92 t ha^{-1} fallow land and 5.217 t ha^{-1} agricultural land (15.137 t ha^{-1} combined) in Mald Bada, and 2.62 t ha^{-1} fallow land

Table 2
Major tree species and their silvicultural characteristics and uses in the study area, Pauri Garhwal, Western Himalaya.

Species name	Habitat	Local use (%)				
		Fuelwood	Fodder	Fibre	Furniture	Sleeper
Celtis australis (Khadik)	Deciduous	97.12	83.7	0.00	62.79	40.70
Quercus leucotrichophora (Banj oak)	Evergreen	63.31	85.00	0.00	47.67	31.40
Toona ciliata (Toon)	Evergreen	76.54	0.00	0.00	59.30	37.21
Bauhinia variegata (Kachnar)	Deciduous	49.26	67.50	0.00	0.00	0.00
Sapium insigne (Khinnu)	Deciduous	33.81	0.00	0.00	0.00	0.00
Pistacia integerrima (Kakhhad)	Deciduous	57.29	0.00	0.00	50.00	41.86
Ficus palmata (Bedu)	Evergreen	0.00	73.40	0.00	0.00	0.00
Ficus roxburghii (Timla)	Evergreen	36.20	81.21	0.00	0.00	0.00
Grewia optiva (Bhimal)	Deciduous	97.12	91.37	93.02	0.00	0.00
Prunus cerasoides (Padam)	Deciduous	59.3	71.56	0.00	0.00	0.00

Table 3
Villager's responses to the questions.

Questions	Group size (in years)		
	Below 25 (n = 21)	25–60 (n = 48)	Above 60 (n = 17)
Main reason for felling of trees	Monkey menace	Monkey menace	Monkey menace
Problem of monkey menace in existence (years)	Since childhood	Since last 40 years	Since last 60 years
Damage caused by monkeys	Damage roof of houses	Steal food, damage roof of houses and eat as well as destroy fruit from trees	Steal food, damage roof of houses and eat as well as destroy fruit from trees
Usual time of visit by monkeys	Morning	Morning and evening	Daily in the morning and evening
Roosting place of monkeys	Nearby forest	On trees near agricultural fields	On trees near agricultural fields
Number of monkeys in a group	Nearly 20	20–25	Above 30
Number of groups of monkeys	One	Two	Two
Any decrease or increase in the population of monkeys in last few decades	No idea	Yes (increase)	Yes (increase)
Present status of monkey population	Less in numbers after felling	Comparatively less in numbers	Very few are seen after felling
Food available for monkeys	Agricultural crops, domesticated fruits	Vegetables, fruits, crops, pulses, wild fruits	Wild fruits, domesticated fruits, crops, vegetables
Agricultural crops eaten by monkeys	Wheat, rice, maize	Wheat, rice, jhangora, maize, chaulai	Wheat, rice, jhangora, maize, chaulai, pulses
Any other kind of harm done by them	–	Biting people	Biting people
Permission taken for felling	No idea	Yes from village panchayat	Yes decision was taken by village panchayat with the consent of villagers
Approximate expenditure in felling	No idea	Approximately 300 USD	Approximately 300 USD
Tree logs used for the purpose	Fuelwood	Fuelwood, furniture, sleepers	Fuelwood, furniture, sleepers

n is the number of respondents in each age group.

Table 4
Total biomass extraction (t ha^{-1}) due to tree felling on agricultural land (Site A) and fallow land (Sites B) in study villages (Manjgaon and Mald Bada), Pauri Garhwal, Western Himalaya.

Name of species	Total biomass extraction (t ha^{-1})			
	Manjgaon		Mald Bada	
	Site A*	Site B**	Site A*	Site B**
Toona ciliata	0.55 (0.25)	1.30 (0.60)	0.014 (0.087)	0.00 (0.00)
Quercus leucotrichophora	0.19 (0.09)	0.34 (0.16)	0.01 (0.09)	0.00 (0.00)
Bauhinia variegata	0.05 (0.02)	0.42 (0.19)	0.03 (0.16)	0.00 (0.00)
Celtis australis	0.59 (0.27)	2.61 (1.20)	0.50 (3.10)	0.88 (5.44)
Ficus roxburghii	0.02 (0.01)	0.06 (0.03)	0.02 (0.15)	0.07 (0.44)
Ficus palmata	0.03 (0.05)	0.10 (0.06)	0.00 (0.00)	0.00 (0.00)
Prunus cerasoides	0.17 (0.08)	0.37 (0.17)	0.10 (0.61)	0.24 (1.47)
Pistacia integerrima	0.05 (0.02)	0.27 (0.13)	0.004 (0.03)	0.17 (1.01)
Sapium insigne	0.01 (0.004)	0.16 (0.08)	0.00 (0.00)	0.00 (0.00)
Grewia optiva	0.07 (0.03)	0.00 (0.00)	0.16 (0.99)	0.25 (1.56)
Total	**1.73 (0.824)**	**5.64 (2.62)**	**0.834 (5.217)**	**1.61 (9.92)**
	7.37 (3.444)		**2.444 (15.137)**	

* Site A- Farmland.

** Sites B- Fallow land; Values in the parenthesis are the corresponding values for carbon sequestration; Total harvested area is 4.2 and 0.62 ha in site A and site B, respectively of Manjgaon; 3.62 and 0.5 ha in site A and site B, respectively of Mald Bada.

and 0.824 t ha^{-1} agricultural land (3.444 t ha^{-1} combined) in Manjgaon (Table 4).

At species level, the highest biomass extraction from farmland was 0.59, 0.55, 0.19 and 0.17 t ha^{-1} for *C. australis, T. ciliata, Q. leucotrichophora* and *P. cerasoides*, respectively, in Manjgaon, while the lowest biomass extraction rate was 0.01 t ha^{-1} for *S. insigne*. The highest biomass extraction from fallow land in Manjgaon was 2.61, 1.30, 0.42 and 0.37 t ha^{-1} for *C. australis, T. ciliata, B. variegata* and *P. cerasoides*, respectively, and the lowest was 0.06 t ha^{-1} for *F. roxburghii* (Table 4).

The highest mass extraction of different tree species was lower in Mald Bada. The highest rate of removal from agricultural land was 0.50, 0.16, 0.10 and 0.03 t ha^{-1} for *C. australis, G. optiva* and *P. cerasoides*, respectively, and the lowest was 0.004 t ha^{-1} for *P. integerrima* (Table 2). For fallow land, the highest biomass extraction rate in Mald Bada was 0.88 t ha^{-1} for *C. australis*, 0.25 t ha^{-1} for *G. optiva*, 0.24 t ha^{-1} for *P. cerasoides* and 0.17 t ha^{-1} for *P. integerrima*, while the lowest was 0.07 t ha^{-1} for *F. roxburghii*.

The greatest carbon loss from harvest of tree species in Manjgaon was for *C. australis*, followed by *T. ciliata* and *Q. leucotrichophora* on agricultural land and for *C. australis* followed by *T. ciliata* and *B. variegata* on fallow land. In Mald Bada, *C. australis* removal represented the greatest carbon loss from both types of land, followed by *G. optiva* and *P. cerasoides* (Table 4). Tree felling was carried out in both villages, but the felling in Manjgaon included part of the nearby forest around the agricultural fields, where the monkeys roosted at night. This explains the large scale of tree felling in Manjgaon and associated greater loss of carbon.

Biomass loss caused by harvest of fuelwood, fodder and other non-wood timber products by local inhabitant is common around the world (Constant et al., 2015; Hill, 2004). The extraction of biomass and accompanying degradation of the environment has led to increased human- animal conflicts, such as increase of raiding of crops by wild animals, making it common in and around many agricultural landscapes (Constant et al., 2015; Hill, 2004; Nyhus, 2016). In addition, the Himalayan region is predicted to vulnerable to climate change (Pandey et al., 2105). Thus, in order to combat the climate change, biomass and carbon loss, as well as monkey raiding, tree felling, and degradation of nearby forests should be minimized. Protecting and restoring existing village forests and planting new forests through reforestation and afforestation programmes can help to protect crops and be an important measure to minimise the human wildlife interaction and contribute to carbon sequestration. Decreasing wild animal visit to the agricultural lands will also encourage tree farming practice. Decreasing wild animal visits could potentially be done by guarding and using fences around agricultural fields to minimising monkey raids on agricultural fields (Nyhus, 2016; Siljander et al., 2020). Another option could be planting of local/native fruit trees inside or near the boundaries of forests which could improve food stock for wild animals and thereby minimise their raids on agricultural fields (Siljander et al., 2020). To reconcile forest conservation and livelihood improvement under emerging global strategies such as REDD+ (Reducing emissions from deforestation and forest degradation, conserving and enhancing forest carbon stocks, and sustainably managing forests) (Corbera and Schroeder, 2011), and Climate Compatible Development (CCD) which is a policy processes that combine local development, climate change adaptation and mitigation (Suckall and Tompkins, 2020; Tanner et al., 2014), it is necessary to acknowledge the socio-economic complexities of forest resource management and design effective management interventions. However, the success of such management practices will depend on the possibility to minimise wildlife conflicts with rural inhabitants.

4. Conclusions

In India, local farmers living near forests frequently report having problems with monkeys raiding their farm, causing substantial negative impact on all crops grown by the villagers. In Western Himalaya, farmers perceive that the problems have increased during later years. In order to decrease negative impact of raiding monkeys, villagers frequently turn to tree felling in the agricultural and fallow lands. The rationale of this is to minimize the resting places for monkeys. However, while tree felling by local villagers help to decrease the problem of raiding monkeys, tree felling caused substantial biomass and carbon losses. Increased monkey raids are frequently caused by human degradation of the monkey's habitats resulting in food shortage in their natural habitats. Tree felling also contribute to climate change. Thus, in order to minimize raiding and to mitigate climate change, local villagers need to protect, and restore local forests and increase the natural food stock for monkeys.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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Author's contribution

SR carried out the field study under the guidance of BSA. SR and BN completed the first draft of the manuscript. BSA, RP and JMA read and revised the manuscript. The final draft of the manuscript was read and approved by all authors.

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