Biomass loss in village ecosystem due to human-wildlife interaction in Western Himalayan region: A case study

Sushma Rawat (rawatsushma26@gmail.com)
Forest Research Institute, India
Bhuvnesh Nagar
College of horticulture and Forestry, Jhalawar
Bhupendra Singh Adhikari
WII, Dehradun
Rajiv Pandey
ICFRE, Dehradun
Juha M Alatalo
Qatar University

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Abstract

Conservation faces the challenge of reconciling human activities with the simultaneous presence of wildlife in cultivated landscapes. In attempt to estimate biomass and associated carbon loss due to the removal of agroforestry trees species the present study was carried out in two villages of Pauri Garhwal. The results revealed that due to human-animal interaction caused substantial biomass loss (7.4 and 2.46 t ha^{-1}) and carbon loss (3.4 and 15.2 t ha^{-1}) in the two studied villages Manjgaon and Mald Bada, respectively. The estimates of the present study demands protecting existing forests and planting trees through reforestation and afforestation as a measure to enhance carbon sequestration capacity. The success of these management practices will depend on the potential to minimise human-animal interactions especially in the fringes of the village community and agricultural landscapes.

Introduction

Human-wildlife interactions due to competition for food and resources, are widespread and have imposed severe costs on both wildlife and people and even extinction of many species (Artelle et al. 2016; Larson et al. 2016; Nyhus 2016; Redpath et al. 2015). However, local perceptions can vary from positive to negative depending on the species involved in the interaction (Bencin et al. 2016; Alexander et al. 2015). The growing human population and associated expansion of human habitat commonly results in such interactions with wild animals in nearby forest areas (Daniel 2009; Shukla and Kumar 2002) and thus there is a necessity to resolve interactions between conservation and rural people (Ratnayeke et al. 2014; Galvin et al. 2006). 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 (Salerno et al. 2015; Li et al. 2013; Hartter et al. 2011; Inskip and Zimmermann 2009). Such incidences may lead to a situation of risk for people living in the vicinity of protected areas (Silwal et al. 2016; Dunham et al. 2010) and directly affects the overall food supply availability to a family or a community (Ogra 2008). Among various risks faced by the rural communities crop damage due to wild animals is the most prevalent in African and Asian sub-continent (Rohini et al. 2016, Wong et al. 2015; Hill and Wallace 2012; Marchal and Hill 2009; Parker et al. 2007). Due to crop raiding by wild animals affects. The other major consequences of human-animal interactions are loss of life, livestock damage by the wild animals which significantly affect people's livelihood, their food and agricultural security too (Barua et al. 2013).

Human-wildlife interactions are generally more intense in those areas, where agricultural practices along with livestock rearing are the main components of rural people's livelihood and income (Mojo et al. 2014; Li et al. 2013; Treves et al. 2006). Rural inhabitants, especially agricultural producers 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 to minimize this impact. The extent of farmers' tolerance to crop losses due to wildlife is influenced by their dependence on farming for income, size of land holding, length of residence in an area and presence/absence of effective compensation schemes (Hill 2004).

Sometimes the negative impacts of human-wildlife conflicts on the environment and wildlife conservation activities include the clearing of vegetation on private land to reduce the habitat of nuisance wildlife, resulting in lower wildlife numbers (Treves et al. 2006). Possible conflict management measures range from relocation of wild animals to the destruction of their habitat, including felling of trees providing shelter to the wild animals causing problems (Madhurima and Banerjee 2013). Further research is urgently needed to determine the scale and extent of these environmental problems and identify whether they are specific to areas with human-wildlife conflicts.

At present, the co-existence of monkeys with humans is a topic of 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 agricultural lands (Sabic 2011; Cawthon 2005). Similarly to humans, they have a non-specialised and very flexible diet and can survive even in degraded habitats or urban areas, where they feed on whatever humans eat (Campbell et al. 2011). During food scarcity, monkeys are adapted 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). Monkeys in search of their food can create problems for humans, such as damage to crops, fruiting trees and snatching goods and food. With the expansion of human settlements and associated shrinking of natural habitats(Fuentes 2006)many monkeys have become ecological refugees (Mitra 2000). In India, compensation of Rs 0.2 million is paid by the Uttarakhand state to victims of monkey bites (GoUK 2014).

In the mountain villages of Western Himalayan region of India, the conflict between monkeys and humans have accelerated in recent decades. Monkeys are creating problems for the villagers such as destroying crops and fruits, and sometimes injuring 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 as also discussed in a study by Mojo et al. (2014).This practice has resulted in biomass extraction and associated carbon losses, i.e. environmental degradation. 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 and more efforts are needed to be made 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. Thus there is a need of policies for proactive and reactive responses (Athreya and Belsare 2007).

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

Materials And Methods

Study Area

Pauri Garhwal, a district in the state of Uttarakhand, in Western Himalayan region encompasses an area of 5230 km^2 and is situated between 29°45’ and 30°15’ N, 78°24’ to 79°23’ E with sub-tropical to temperate climate. Monthly minimum and maximum temperature in the study area ranged between 6–21°C and 18–35°C, respectively, with mean annual rainfall of 1500 mm, while the soil 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 armed forces and teaching. Due to the lack of infrastructure and geography of the area, there are no major industries in the hilly part of the district (MSME 2016).

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

The inhabitants of both villages depend on forest and agricultural resources, such as fuel wood for cooking and fodder for livestock to fulfil their basic needs. Common trees growing along the edges of agricultural fields were *Bauhinia variegata, Celtis australis, Ficus roxburghii, Ficus palmata, Grewia optiva, Prunus cerasoides, Pistacia integerrima, Quercus leucotrichophora, Sapium insigne* and *Toona ciliata.* The fallow land around the village was earlier agricultural land, left due to inadequate irrigation facility and monkey problem. Fallow land consist of various multi-purpose trees such as *Quercus leucotrichophora (*Banj oak), *Celtis australis* (khadik), *Pinus roxburghii (*chir), *Prunus cerasoides (*padam/payya), *Ficus roxburghii (*timla), *Ficus palmate (*bedu), *Bauhinia variegata (*kweral), *Sapium insigne (*khinnu) and *Pistacia integerrima (*kakhad), of which *Celis australis, Prunus cerasoides, Pinus roxburghii* and *Quercus leucotrichophora* are the most common species, while *Berberis asiatica (*kingora), *Rhus parviflora (*tung), *Woodfordia fruticosa (*dhaula) and *Rubus ellipticus (*hisalu) are the most common shrub species in the forested area.

Data collection

Collection of primary data was carried out using a pre-tested semi-structured questionnaire was framed based on the reviewed literature, previous knowledge, a pilot survey and peer discussions during 2011–

2012. The questionnaire included a mix of questions pertaining on the issue under investigation, with the majority being closed-ended questions. 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 as well as in local dialect (Garhwali).

Biomass estimation

The aboveground biomass was calculated using existing volume regression equations for *Toona ciliata, Quercus leucotrichophora* and *Bauhinia variegate (*Table 1) (FSI 1996; FSI 2015). 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 at breast height was measured with a measuring tape and tree height through Ravi multimeter.

Calculation of aboveground biomass for remaining species was as follows:

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

$$A_b = (\pi d^2/4)$$

Where,π = 3.14 and *d* is the diameter of the tree at breast height.

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

$$V = A_b \times H \times BEF$$

Where, H is tree height and BEF is biomass expansion factor used in an Indian context (value 1.575; Kishwan et al. 2009).

Using mean wood density (MWD)of each species, total biomass was calculated in metric tonnes (Rajput et al. 1996). The 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 with wood density (WD) for the corresponding tree species following Brown (1997):

Biomass = V×WD×1000

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 mortar. The powder samples were sieved and oven-dried to constant weight and then a 2g sub-sample of each was transferred to an uncovered crucible, which was placed in a muffle furnace and heated at 575 ± 25°C for 3 hrs 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 have attained room temperature and carbon content (%) of the original sample was calculated following Negi et al. (2003):

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

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

$$\text{Carbon Sequestration} = \text{Carbon} \times 3.666$$

Results And Discussion

Due to long prevailing problem with monkeys, tree felling was conducted in Manjgaon and Mald Bada villages. The decision on tree felling was made by the villagers in a village *panchayat.* 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 productive land for agriculture and to get rid of monkeys. The major tree felling was concentrated to the agricultural fields rather than forested or fallow land around the villages. The intensity of felling was greater in Manjgaon including parts of the nearby forest, 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 ₹ 22,000, 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). According to the villagers, management practices such as lopping and cutting of branches was done for fuelwood and timber as well as to obtain green flush from fodder trees.

In order to identify the reasons behind the large-scale tree felling, villagers in three different age groups (<25 years, 25–60 years and >60 years) were surveyed. All age groups had the same view regarding the tree felling operations. The main reason was the problem with increasing number 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 reach to the agricultural fields, they raid any crop available and left nothing. Regardless of the crop grown, or sown, in the agricultural fields or in gardens near villagers' houses, it was often destroyed by the monkeys. The monkeys frequently roam around the agricultural fields in the mornings /evenings and at night they roost in nearby trees. As the problem persisted over time, the villagers resorted to fell the sheltering trees. According to the villagers, two groups of monkeys with approximately 25–30 individuals in each group resided in the area and tend to visit the agricultural fields at different times. The villagers reported an increase in the monkey population over the past few decades. The destruction caused by monkeys in farmers' fields is a common phenomenon in many areas of the world (Das and Mandal 2015; Fuentes 2006; Chalise et al. 2001). Incidences of scaring people by aggressive behaviour such as snarls and occasional bites have also been reported by Imam and Ahmad (2013). The monkeys in the study villages had been present since long time, but previously restricted to the forested area and visited the agricultural fields occasionally. The main crops raided by monkeys were reported to be rice, wheat, pulses, maize, and millet. Incidences of eating fruits grown near houses and occasional food stealing from houses has been reported for chimpanzees in Uganda (McLennan and Hill 2012). Damaging of houses by jumping on the roofs of houses and some incidents of monkeys biting humans were also revealed by the rural inhabitants. 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 consequent decline in habitats, as well as degradation of local forests, many monkeys have become ecological refugees (Mitra 2000).

Biomass extraction

Total biomass extraction due to human-wildlife conflict in the study area was estimated to be 5.64 t ha^{-1} fallow land and 1.73 t ha^{-1} agricultural land in Manjgaon village, and 1.61 t ha^{-1} fallow land and 0.85 t ha^{-1}agricultural land in Mald Bada village (Table 3). Maximum carbon stock loss was calculated to be 9.99 t ha^{-1} fallow land and 5.2 tha^{-1}agricultural land in Mald Bada and 2.59 t ha^{-1} fallow land and 0.79 t ha^{-1} agricultural land in Manjgaon (Table 3).

At species level, maximum biomass extraction from farmland was 0.59, 0.55, 0.19, 0.17 t ha^{-1} for *C. australis, T. ciliata, Q. leucotrichophora* and *P.Cerasoides,* respectively in Manjgaon, with the lowest biomass extraction rate of 0.010 t ha^{-1} for *S. insigne.* Maximum 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* and lowest (0.06 t ha^{-1}) for *F. roxburghii (*Figure 2).

Maximum mass extraction of different tree species was lower in Mald Bada. The rate of removal from agricultural land was 0.59, 0.17, 0.10 and 0.03 t ha^{-1} for *C. australis, G. optiva* and *P. cerasoides* and was lowest for *P. integerrima* (0.004 t ha^{-1}) (Figure 2). For fallow land, maximum biomass extraction rate 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,* 0.16 t ha^{-1} for *P. integerrima* and 0.071 t ha^{-1} for *F. roxburghii,* in Mald Bada.

The maximum 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 the fallow land. In Mald Bada, *C. australis* removal represented the maximum carbon loss from both types of land, followed by *G. optiva* and *P. cerasoides (*Table 3). Tree felling was carried out in both villages, but the felling in Manjgaon included part of the nearby forest near the agricultural fields where the monkeys roost at night. This explains the large scale of tree felling in Manjgaon and associated greater loss of carbon.

Conclusion

The presence of tree species in and around agricultural areas plays an important role in carbon sequestration (Mojo et al. 2014). However, tree felling by local villagers to combat the problem of raiding monkeys can cause substantial carbon losses, as demonstrated in this study. To overcome such hidden impacts of human-wildlife conflicts, inhabitants in the region experiencing such conflicts could plant fruit trees inside or near the boundaries of forests, to provide sufficient food stock for wild animals and minimise their raids on agricultural fields.

Protecting existing forests and planting new forests through reforestation and afforestation are important measures to enhance carbon sequestration capacity. To reconcile forest conservation and livelihood improvement under emerging global strategies such as REDD+ and Climate Compatible Development (CCD), it is necessary to acknowledge the socio-economic complexities of forest resource management and design effective management interventions (Entenmann et al. 2014). Specifically, the importance of the success of REDD+ initiatives of specific management measures to minimize human-wildlife conflicts has been stressed (Entenmann et al. 2014) and was also demonstrated in the present study. However, the success of such management practices will depend on the possibility to minimize wildlife conflicts with rural inhabitants.

Declarations

Compliance with Ethical Standards

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Conflict of interest statement

The authors declare that they have no conflict of interest.

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. Final draft of manuscript was read and approved by all the authors.

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Tables

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

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

V is tree volume, D is tree diameter

Table 2. Major tree species with their silvicultural characteristics and uses in the study area

Species name	Habitat	Local use (%)		
		Energy (cooking/heating)	Fodder	Fibre
Celtis australis (khadik)	Deciduous	97.12	83.7	-
Quercus leucotrichophora (Banj Oak)	Evergreen	63.31	85	-
Toona ciliata (toon)	Evergreen	76.54	-	-
Bauhinia variegata (kachnar)	Deciduous	49.26	67.5	-
Sapium insigne (khinnu)	Deciduous	33.81	-	-
Pistacia integerrima (kakhhad)	Deciduous	57.29	-	-
Ficus palmata (bedu)	Evergreen	-	73.4	-
Ficus roxburghii (timla)	Evergreen	36.2	81.21	-
Grewia optiva (bhimal)	Deciduous	97.14	91.37	93.51
Prunus cerasoides (padam)	Deciduous	59.3	71.56	-

Table 3. Total biomass extraction (t ha^{-1}) due to tree felling on agricultural land (Site A) and fallow land (Sites B) in study villages

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 (0.79)**	**5.64 (2.59)**	**0.85 (5.22)**	**1.61 (9.99)**

*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

Figures

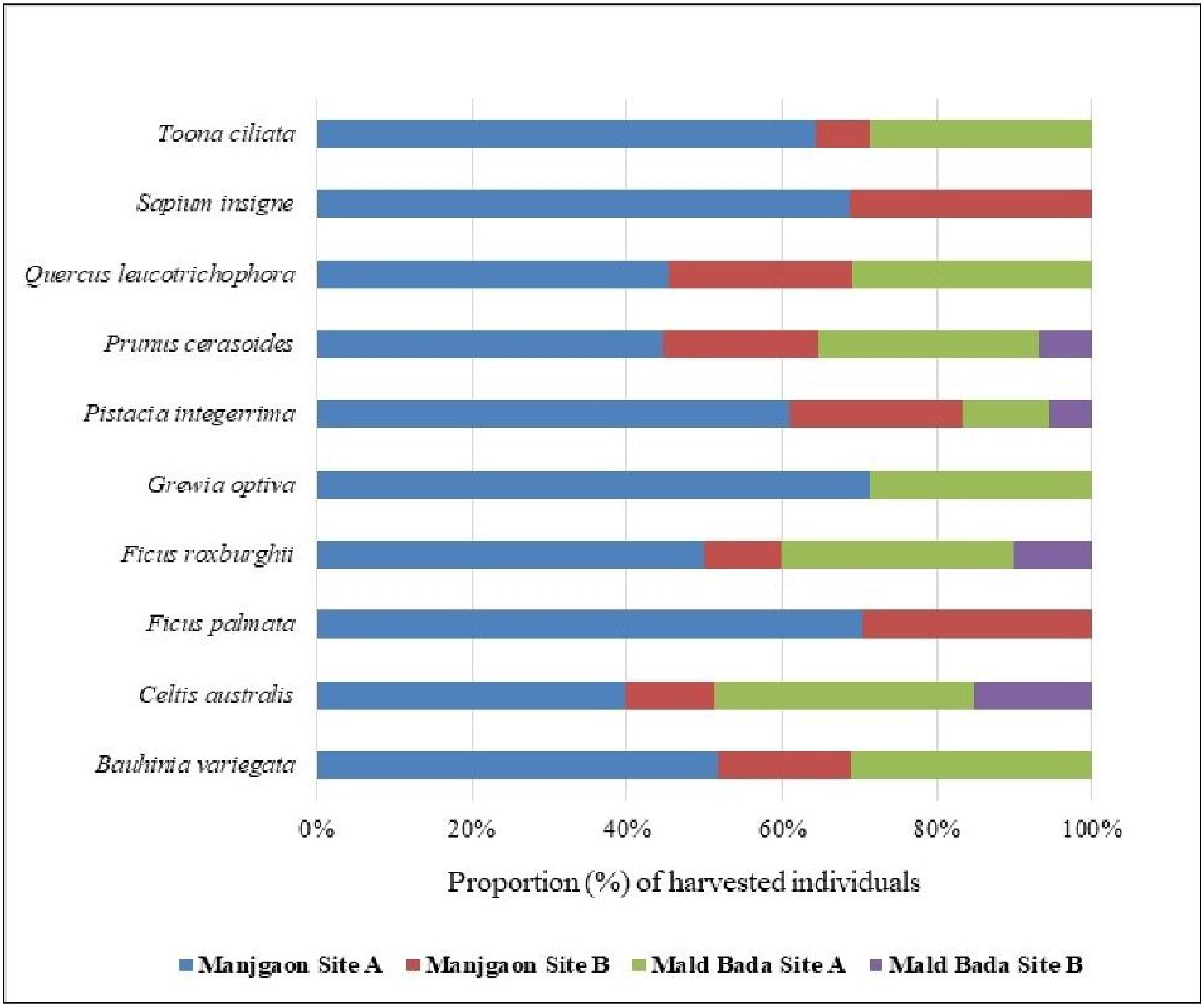

Figure 2. Proportion (%) of harvested individuals of different tree species.

Figure 1

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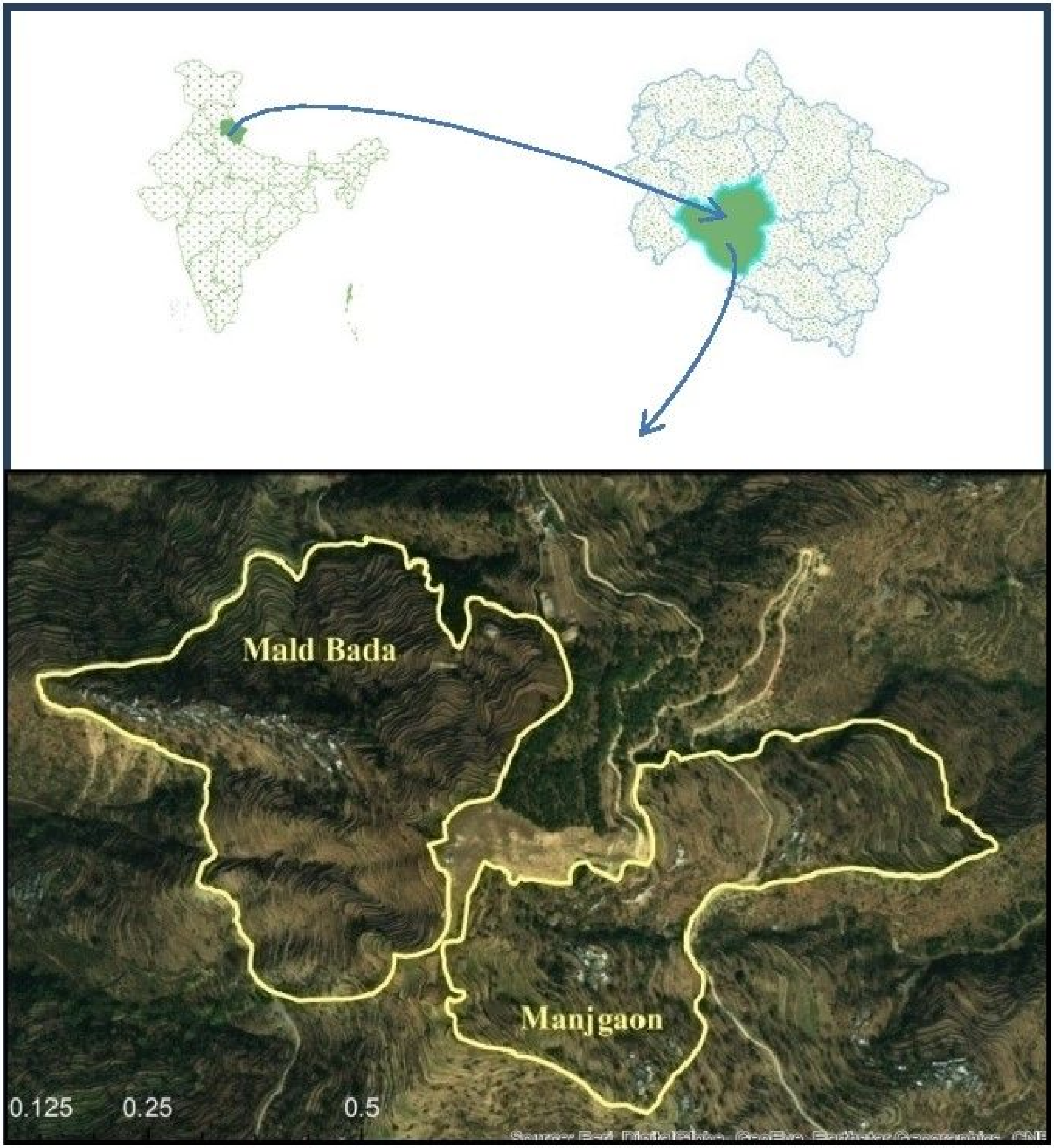

Figure 1. Location map of study area.

Figure 2

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