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REPORT

Capturing forest dependency in the central Himalayan region: Variations between Oak (*Quercus* spp.) and Pine (*Pinus* spp.) dominated forest landscapes

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Abstract Our study explores the nexus between forests and local communities through participatory assessments and household surveys in the central Himalayan region. Forest dependency was compared among villages surrounded by oak-dominated forests (n = 8) and pine-dominated forests (n = 9). Both quantitative and qualitative analyses indicate variations in the degree of dependency based on proximity to nearest forest type. Households near oak-dominated forests were more dependent on forests (83.8%) compared to households near pine-dominated forests (69.1%). Forest dependency is mainly subsistence-oriented for meeting basic household requirements. Livestock population, cultivated land per household, and non-usage of alternative fuels are the major explanatory drivers of forest dependency. Our findings can help decision and policy makers to establish nested governance mechanisms encouraging prioritized site-specific conservation options among forest-adjacent households. Additionally, income diversification with respect to alternate livelihood sources, institutional reforms, and infrastructure facilities can reduce forest dependency, thereby, allowing sustainable forest management.

Keywords Central Himalaya · Forests resources · Fuelwood and fodder · India · Local livelihood · Oak forests and pine forests

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INTRODUCTION

The Himalayan region is an ecologically important mountainous terrain as it provides a wide range of forest ecosystem services for many mountain communities (Rasul 2014; Badola et al. 2015; Chakraborty et al. 2016a). In addition to this, the Himalayan region is often associated with social and economic benefits for most rural households in this region (Sandhu and Sandhu 2014; Charlery et al. 2016; Hoy et al. 2016). The local communities are directly and/or indirectly dependent on natural resources for sustaining their livelihoods (Tiwari and Joshi 2015). For instance, about 80% of rural communities are dependent on agriculture and related activities in the Indian Himalayan region (GoI 2010). Forests, as a result, become very critical for their agricultural purposes, by its indirect contribution to their livelihoods (Sharma and Vetaas 2015), and in some cases, direct contribution to their livelihoods (Kunwar et al. 2015). Across the entire Himalayan mountain range, many people are highly dependent on forests and forest-based resources (Birch et al. 2014; Khan et al. 2014; Malik et al. 2014; Jadin et al. 2016). This dependence is primarily connected to fulfilling their needs for fuelwood, fodder, medicinal uses, fruits, and other food-related products (Måren et al. 2014; Dhyani and Dhyani 2016). Given the importance of forests and their significance in the life-support system of local communities, several studies have evaluated the forest products and other forest-related goods and services provided across the Himalayan region (Table 1). However, there is less knowledge in terms of variations in forest dependency among local communities with respect to the on-going changes in climate and forests in the Himalayan region (Birch et al. 2014; Xu and Grumbine 2014; Bhatta et al. 2015; Singh and Thadani 2015). Therefore, understanding

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Table 1 Some of the selected documented cases showing various categories of forest ecosystem services provided by the Himalayan forests

Forest ecosystem services		References
Category	Sub-category	
Provisioning services	Fuelwood, fodder, and leaf litter	Awasthi et al. (2003), Cochard and Dar (2014), Dhyani and Dhyani (2016), Joshi and Negi (2011), Malik et al. (2014), Måren et al. (2014), Sharma et al. (2009), and Singh et al. (2010)
	Timber	Ali and Benjaminsen (2004), Dangwal (2005), Rao and Saxena (1996), Sen et al. (2002), and Wangda and Ohsawa (2006)
	Non-timber products	Negi et al. (2011), Rasul et al. (2008), Rijal et al. (2011), Saha and Sundriyal (2012), and Singh (1999)
	Medicinal products	Kala (2000), Olsen (2005), Phondani et al. (2016), and Silori and Badola (2000)
	Biomass fuel and carbon pool	Dar and Sundarapandian (2015), Semwal et al. (2013), Sharma et al. (2008), Sheikh et al. (2009), Singh (1994), Upadhyay et al. (2005), Verma et al. (2012), and Wani et al. (2014)
Regulating and supporting services	Biodiversity	Arya and Ram (2011), Bhardwaj et al. (2012), Bhatt and Joshi (2011), Bhuyan et al. (2003), Nautiyal and Kaechele (2007), and Silori (2007)
	Soil erosion regulation	Hamilton (1987), Jain et al. (2001), Pandey et al. (1983), Sen et al. (1997), Singh et al. (1983), and Singh and Singh (1992)
	Hydrology	Rai et al. (2015), Tiwari and Joshi (2012), and Zobel et al. (2001)
Cultural	Recreation and tourism	Badola (1998), Geneletti and Dawa (2009), Madan and Rawat (2000), and Maharana et al. (2000)

of the drivers of the variation in forest dependency over time and space is very crucial for interventions regarding forest governance and forest use policies that aim to enhance local livelihoods and strengthen community resilience strategies.

The Himalayan mountain range are considered to be particularly threatened by the on-going effects of climate change (Singh and Hietala 2014), with anticipated and observed impacts on glaciers (Bolch et al. 2012; Kumar et al. 2015), water resources (Palazzoli et al. 2015; Li et al. 2016), forests (Wani et al. 2013; Mainali et al. 2015; Manish et al. 2016), agricultural systems (Deb et al. 2015; Jethi et al. 2016), and socio-economic structures (Hoy et al. 2016; Hussain et al. 2016). It faces a number of serious environmental challenges, such as disastrous events in the form of landslides, earthquakes, and flash floods (Kala 2014), or even climate change-related impacts disturbing the socio-ecological systems in the region (Aryal et al. 2014; Xu and Grumbine 2014). In addition to these challenges, due to inadequate infrastructure (Doppler and Bahadur 2013) and meagre income-generating opportunities (Childs et al. 2014), many people in this region are multi-dimensionally deprived in terms of economic growth and development (Tiwari and Joshi 2016). Even with recent construction of roads increasing the relative accessibility in the rural mountainous areas (Charlery et al. 2016) and reasonably high literacy rate (up to 80%) in the Himalayan region (Yadav et al. 2016), most of the population continue to indulge in traditional forest-centred livelihood practices. In several cases, this forest dependence of local communities is often associated to poverty, unemployment, and lack of alternate livelihood sources (Sandhu and Sandhu 2015). However, centuries-old customs and traditional practices, as well as flexible and innovative coping skills, have helped local communities to adapt to a highly variable and dynamic mountain system (Wu et al. 2014; Macchi et al. 2015; Negi et al. 2017). But nevertheless, high forest dependency could also indicate relatively higher levels of poverty (Gerlitz et al. 2015; Uddin et al. 2015), thereby warranting the need for sustainable forest management in the Himalayan region.

Forests across the entire mountainous landscape of the Himalayan region have shown much variation over thousands of years, ever since the existence of human settlements in the landscape (Måren and Vetaas 2007). However, it is only in the last few hundred years, where the influence of human activities has been extremely drastic, especially in the middle altitudinal zones (Pandey et al. 2014). With the increasing population and subsequent high dependence on forest products (Singh et al. 2015), it has resulted in lower diversity in forests (Sharma and Vetaas 2015), forest loss (Grumbine and Pandit 2013; Bruggeman et al. 2016), and forest degradation in many areas in the Himalayan region (Mishra and Chaudhuri 2015). Current resource extraction practices decreases the productivity of forests, and it will eventually lead to the depletion of forest resources in future (Meilby et al. 2014; Pandey et al. 2014; Behera et al. 2016; Charlery et al. 2016). In addition to these disturbances causing changes in the Himalayan forests (Malik et al. 2016), significant impacts due to climate change have been observed at multiple scales ranging from within-species to ecosystem-level changes (Shrestha et al.

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2012; Aryal et al. 2013; Wani et al. 2013). Studies have also reported significant forest cover changes in the central Himalayan region (Gairola et al. 2013; Mishra and Chaudhuri 2015). Such changes in forests have often been attributed to either anthropogenic pressures, such as increasing population causing forest loss in the past (Singh et al. 2014; Chakraborty et al. 2016b; Batar et al. 2017; Chakraborty et al. 2017), or natural causes such as climate change that are likely to alter potential distribution of forests in the future (Rashid et al. 2015; Upgupta et al. 2015; Bhatta and Vetaas 2016; Chakraborty et al. 2016c).

Based on this understanding, it therefore, becomes crucial to fathom the current degree of dependency among local communities utilizing forests and its resources. Our study explores the forest resource usage patterns between 1500 and 2000 m elevation range, which primarily comprises broadleaf oak (*Quercus* spp.) forests and coniferous pine (*Pinus* spp.) forests, which are the two major forest ecosystems in the lower mid-montane central Himalayan region (Joshi and Negi 2011). The primary aim of the study is to examine variations in forest dependency among local communities in the villages of the Kumaon division of Uttarakhand state, India. To achieve this purpose, the study was carried out by grouping villages into distinctive categories based on their proximity to the abundant forest type: (i) villages near oak-dominated forests, and (ii) villages near pine-dominated forests. We address the following research questions based on four major comprehensive themes: (i) degree of forest dependency, (ii) major factors contributing to forest dependency, (iii) usage of forest products, and (iv) causes of forest loss in surrounding areas.

MATERIALS AND METHODS

Study area

The villages selected for sampling were located in two districts in the Kumaon division of Uttarakhand state, India: (i) Bageshwar district, and (ii) Pithoragarh district (Fig. 1). Geographically, the Kumaon division falls within the central Himalayan region, between 28°42′ and 30°48′ north latitude, and 78°43′ and 81°2′ east longitude. This region experiences three major seasons, summer (April–June), monsoon (July–September), and winter (December–February), along with a brief spring season preceding summer and an autumn season just prior to the beginning of winter.

In this study, the main criterion for selection of villages was their proximity to the dominant forest type. Therefore, since the objective was to obtain information on differences in the forest dependency between oak (*Quercus* spp.) and pine (*Pinus* spp.) forests, we categorized sampled villages in two groups: (i) villages near oak-dominated forests (V_{Oak}), and (ii) villages near pine-dominated forests (V_{Pine}).

According to the latest Forest Survey of India (FSI) report (2015), 45.3% of the total geographical area of Uttarakhand state is forested, out of which 69.9% constitutes "reserve" forests, 26% constitutes "protected" forests, and 4.1% constitutes "unclassed" forest category. The surrounding forests near the selected villages were mostly "reserve" forests, except in a few cases. Essentially, forest councils, i.e. *van panchayats*, comprising elected local communities are responsible for forest conservation and management in these areas, with clearly defined rules for access and use of local forests. The Himalayan region is also endowed with rich faunal diversity, as the forests provide natural habitat for a vast array of mammalian and avian species (Paudel and Heinen 2015; Sundriyal and Sharma 2016).

According to the classification of forests in Himalaya (Singh and Singh 1992), vegetation in the central Himalayan region include sub-montane broadleaf deciduous forests, low montane subtropical pine forests, low- to mid-montane hemi-sclerophyllous broadleaved forests, mid-montane needle-leaf evergreen forests, high-montane mixed stunted forests, and very high-montane scrubs, varying along the altitudinal gradient from low to high elevation range. From the spatial distribution viewpoint of the dominant forest types, forests in the study area can be categorized as broadleaf oak forests (*Quercus* spp.) around hill tops (>1900 m), coniferous pine forests (*Pinus* spp.) at lower elevations (900–1800 m), and oak–pine mixed forests at middle elevation range (1600–1900 m). While *Quercus leucotrichophora* occurs extensively between 1500 and 2000 m elevations, and *Q. lanuginosa* is found in pockets between 1800 and 2200 m; other *Quercus* species such as *Q. floribunda* and *Q. semecarpifolia* are distributed between 2000–2300 m and 2400–3000 m elevation range, respectively (Singh and Singh 1992). Historically, since the early 1900s, pine trees (*Pinus* spp.) were planted extensively to commercially extract timber for a continued period in the central Himalayan region (Schreier et al. 1994). *Pinus roxburghii* is the most common *Pinus* spp. found between the 600–900 m elevation range, and in the higher altitudes, the most common *Pinus* spp. include *Pinus wallichiana* (1800–2400 m) and *Pinus gerardiana* (1800–3000 m).

The sampled villages reported here were identified from the results of a larger study on ecological niche-based modelling of dominant forest tree species in the Himalayan region: (i) oak (*Quercus* spp.) forests, and (ii) pine (*Pinus* spp.) forests (Chakraborty et al. 2016c). The site selection of the two locations, V_{Oak} and V_{Pine}, was based on

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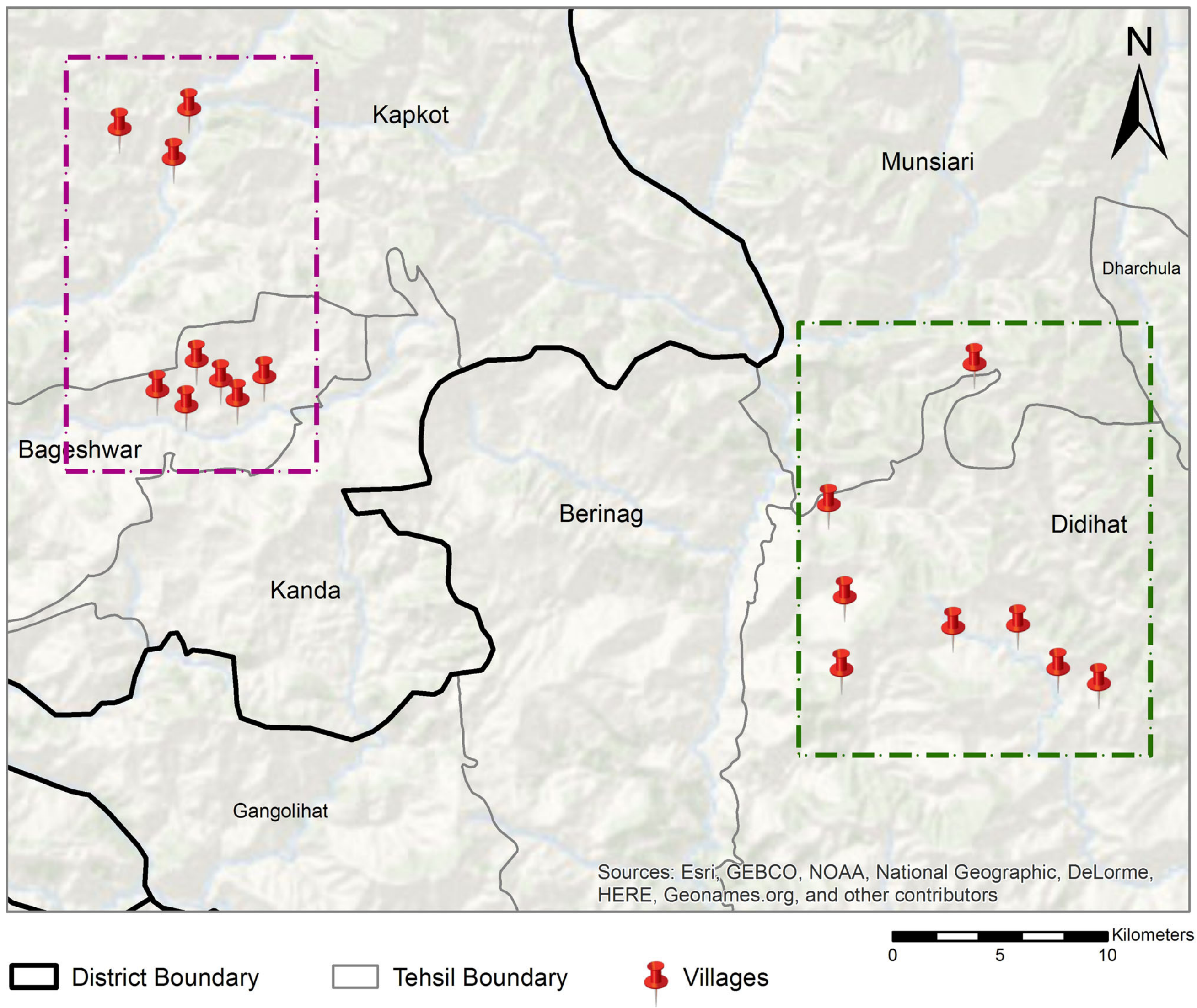

Fig. 1 Geographic locations of the villages are shown with district and tehsil (sub-district) boundaries in Uttarakhand state, India. The dotted green line includes villages near oak-dominated forests (Pithoragarh district), and dotted purple line includes villages near pine-dominated forests (Bageshwar district)

identified forest patches likely to undergo changes in their geographical distribution under uncertain future climate scenarios (Fig. 1).

Selection of villages

The study was executed in two phases. In the *first phase*, local site description through villagers and key informants interviews with available heads of local self-government organizations, viz. *gram panchayat pradhans* (GPPs) and village forest councils, viz. *van panchayats*, and forest guards and/or officers were conducted. This basic information was then used to develop and refine questionnaires that were used in the second phase to gather data on forest dependency through social research methods in the two different locations.

A three-stage criterion method was used to select the villages in the study area. First, largest forest patches of oak and pine forests, likely to undergo changes in future climate scenarios, were identified from Chakraborty et al. (2016c). As per this study, the information through such modelling exercises generates data about the potential changes in climatic niche of the species in concern, which can be further used to implement conservation initiatives, especially in ecologically sensitive regions. Second, within 1 km radius of the identified forest patches, villages were selected based on secondary socio-economic data according to the highlights of the latest available Census statistics

(Census 2011). Highest value of the following variables, namely geographical size of villages, total population, number of households, and total number of livestock, were the major deciding criteria for selecting villages. Third, since practice of agriculture near forests often leads to direct and indirect dependence on forest resources (FAO 1998), we noted the presence of agriculture fields through available Google Earth® images and classified land use land cover (LULC) maps (Chakraborty et al. 2016b). However, these were subject to modification based on irregularity with census data, willingness of villagers to participate in social surveys, and other site-specific problems such as accessibility to the villages. In the end, a total of seventeen (17) villages were selected, where eight (8) villages were sampled near oak-dominated forests and nine (9) villages were sampled near the pine-dominated forests (Table S1). The villages selected in this region are classified 'rural' villages, as they have population less than 5000, with density of population less than 400 per sq. km, and have mostly an agrarian economy (Census 2011). Although we covered most villages surrounding the identified forest patches, it should be noted that despite this effort, one of the limitation of the study was inaccessibility of certain villages selected at the initial stage of the preliminary study. In addition to this, only representative sample from the total number of households in each village (i.e. 30%) were selected for further analysis on forest dependency.

Survey methods

We collected both qualitative and quantitative data, which included participatory assessments and household questionnaire surveys (Fig. 2). The participatory methods include focus group discussions (FGDs) for qualitative information, and household surveys were conducted for quantitative information, to complement the qualitative information collected from the participatory assessment source.

Villages were surveyed during the pre-monsoon seasons in two years: June 2015 and April 2016. The details of data collection in both locations are provided in the supplementary material (Table S2). The participants for this study include the local communities and local self-government organizations [i.e. *gram panchayat pradhans* (GPPs)] and village forest councils (i.e. *van panchayats*) in every village, and forest guards and/or officers in the forest department in the nearest vicinity. They were made fully aware of the purpose of study, and all those who agreed to participate gave their Free, Prior, and Informed Consent (FPIC). While conducting our research, we adhered to the Code of Ethics provided by the International Sociological Association (ISA) for conducting social research (ISA 2001). It should be noted that, in this case, the local communities in the selected villages do not represent the indigenous and tribal communities in the central Himalayan region.

Focus group discussions (FGDs)

Informal and formal discussions with focus groups help in maximizing interactions among researchers and respondents, by creating a more comprehensive dialogue between them (Krueger and Casey 2015). We conducted this exercise in each village, organized within groups of five to eight volunteering participants. The FGDs included a semi-structured questioning route with list of both open-ended and close-ended questions that guided the discussions. The FGDs provided the baseline information by covering topics such as local forest management, perceptions of the drivers of forest cover change, ownership of forests, forest resource usage and dependency patterns among communities, and forest conservation efforts among local communities (Supplementary information S1). While conducting FGDs, we ensured that both men and women actively participated in the group discussions. We specially focussed on the presence of women in the FGDs, as they are usually more involved in the collection of forest products from surrounding forested areas.

Household surveys

Individually conducted household survey was the other selected social research method conducted in this study (Deaton 1997). Stratified sampling procedure was used to select the houses that were interviewed, surveying every possible alternate house, starting from each dispersed hamlet of every village. Each house structure usually consisted of more than one 'household'. A number of criteria can be used to define 'households'. Often, the term 'household' is defined as a group of people who share the goods and services collectively, mainly housing and food resources (UN 2007). Going by this definition, a given house structure in our study site had several households (4–5). Therefore, we interviewed at most two households in a single house. In the end, each household was selected using a non-probability purposive sampling technique, where non-probability samples (in this case, the households) were selected on the basis of availability of local communities and prior knowledge about the sampled villages. From the selected villages, 30% of the total household number was sampled in each village. A total of 285 households were surveyed, where 204 households were sampled near the oak-dominated forests and 81 households were sampled near the pine-dominated forests (Table S3). Although we ensured sampling 30% of the total number of households in each village, due to the smaller size of

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Fig. 2 Field photographs taken during FGDs and household surveys conducted in the study

villages near pine-dominated forests, the total households surveyed near is smaller ($n = 81$) compared to total households surveyed near oak-dominated forests ($n = 204$). Household surveys allowed systematic data collection at the village level on households and land status, dependency on forest products, types of forest products used and their importance, and disturbances (natural and anthropogenic) affecting forests in the studied region (Supplementary information S2). For household surveys, we tried interviewing the head of the targeted household (either male or female). In case of unavailability of household head, age-order procedure was conducted, where older members of the household were interviewed. Other than this, while collecting data, we made sure that the village respondent in a household (i) is more than 18 years old, and (ii) has been living in the village for more than 5 years.

While FGDs provided baseline information on broad themes such as forest conservation and management, and drivers of forest cover change, specific detailed data were gathered describing community profiles using household survey and their dependency on forest resources. The following variables were appraised: (i) age and gender of the household's respondent, (ii) education status and size of the households, (iii) major income of households (farmer, labourer, shopkeeper, driver, retired/pensioner and other services), (iv) total land holdings (area including agriculture land and forest land), (v) livestock possessions (number of cows, bulls, buffaloes, goats, sheep, hens, donkeys, and horses), and (vi) usage of alternative fuels, such as kerosene or liquefied petroleum gas (LPG).

In addition to this information, data were gathered to assess the usage of forest products and perceptions on change in forest resource availability. Specifically, the following variables were appraised: (i) forest-based livelihood dependency (with binomial categories, either yes or no) and forest-based livelihood dependency in terms of both basic household requirements (such as fuelwood and fodder) and contributions to household income (such as non-timber forest products (NTFPs) (on a Likert scale with

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five levels: 'very high', 'high', 'medium', 'low', and 'very low'), (ii) livestock feeding sources from either forests, agriculture, or other market sources (on a Likert scale with ten levels with 1 as the lowest and 10 as the highest value), (iii) collection and use of forest products (with nominal categories, either yes or no) and importance of forest products used (on a Likert scale with three levels: 'high', 'medium', and 'low'), and (iv) natural and/or anthropogenic disturbances causing changes in forests (on a Likert scale with five levels: 'very high', 'high', 'medium', 'low', and 'very low').

Data analysis

The qualitative data were assessed through the narratives of the FGDs conducted in the sampled villages in two different locations. The transcription of the discussions explored the research questions of the study, thereby developing a detailed and contextually grounded theme of the research. We extracted information on the following particular themes: (i) forest conservation, (ii) forest management, and (iii) drivers of forest cover change. It was then summarized based closely on the evidences from the narratives. To further illustrate the general patterns and consistent themes of the FGDs, specific quotes that deemed fit were pulled from the transcripts. For quantitative data analysis, the information collected from household surveys was coded, re-arranged, and analysed in the Statistical Package for Social Science (SPSS) (Bryman and Cramer 2002). SPSS was further used to establish significant variable interrelationships using appropriate statistical methods. Descriptive statistics and non-parametric binomial tests were used to analyse the variations in the households' dependency on forest resources for their livelihoods. This was followed by descriptive statistics and non-parametric Mann–Whitney U tests for understanding the changes in forest dependency based on both need and income. For analysing livestock feed in two locations, we compared both importance and availability from three sources. We used non-parametric Friedman tests and post hoc Wilcoxon signed-rank tests to check statistically significant differences between values of low to high preferences. Binomial logistic regression was used to analyse the influence of social factors influencing forest dependency among local communities. In addition, the discrete variables for frequency of forests products used or not and their importance were summarized for villages in two groups based on nearest forest type. In the end, mean scores of factors causing disturbances was compared between the sampled villages in the two different locations.

RESULTS

Socio-demographic profile of local communities

The respondent's socio-demographic information served as an introduction to the background of local communities in the sampled villages. Major income status show many people relying of agricultural activities in both the locations. However, the presence of agriculture as one of the major sources of income was significantly higher in V_{Oak} (24.5%) than V_{Pine} (19.8%). Local communities near pine-dominated forests preferred working as labours in non-agricultural activities as it provided a better source of income (23.5%). However, this was not the case for local communities near oak-dominated forests as the frequencies were comparatively low (15.2%), with major share of income through agriculture and other related activities. Another important source of income was engagement in different sectors which are not linked to utilization of natural resources, such as banking, government institutions, and private-sector companies (26% in V_{Oak} and 37% in V_{Pine}). These income sources include working as shopkeepers in nearby towns, local drivers, or relying on retirement income sources such as pension. Male members were often quoted to be working elsewhere in towns and cities. As a result, the difference in numbers between females (57.8%) with respect to males (42.2%) present in V_{Oak} was relatively high. Similarly, the difference in numbers between females (61.7%) with respect to males (38.3%) in V_{Pine} was also very high. Almost all age groups above 18 years old were covered while conducting the surveys. Household size was mostly up to five members in each village in both locations. The sampled villages, despite being classified as 'rural' villages (Census 2011), had very high literacy rates (82.8% in V_{Oak} and 90.1% in V_{Pine}).

Apart from some households in V_{Oak}, within all the rural households, the marginal land owners practised agriculture, primarily subsistence in nature. Since local communities typically engaged in agriculture, most households had total livestock population of up to five or more. This includes cows, bulls, buffaloes, and goats, in general. In some cases, it also includes sheep, hen, and donkeys, and in very few cases, horses as well. The majority of local communities' relying on forests was due to their requirements of fuelwood. This also compliments with very low values of alternative usage of fuels, such as kerosene or liquefied petroleum gas (LPG) observed in most sampled villages. The comparative accounts of the frequencies of different categories describing the socio-demographic conditions of the sampled households are provided in the supplementary material (Table S4).

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Forest dependency of local communities

Forest-based livelihood dependency

General livelihood dependency was assessed by framing dependency as a binary-choice model, which assumed that respondents were either dependent (yes) or not dependent (no) on forest resources. In this case, forest-based livelihood dependency is mainly with respect to local communities residing near forests. Local communities are usually involved in agricultural practices outside the forests, and therefore regularly use forest products, partly for their own subsistence purposes and partly for income generation. Of the total 285 interviewed households, 227 households (79.6%) said they were dependent and 58 households (20.4%) said they were not dependent on forests and forest-based resources. However, this distribution of forest dependence varied between V_{Oak} and V_{Pine}. The forest dependency was much higher in V_{Oak} (83.8%), as compared to V_{Pine} (69.1%) (Table S5). The binomial tests indicate that there is no statistically significant difference in the responses in V_{Oak} ($p > 0.05$). Contrastingly, binomial tests indicate that there is statistically significant difference in the responses in V_{Pine} ($p < 0.05$).

Dependency based on households' requirements and income

To identify what constitutes forest dependency, we categorized forest-based livelihood dependency by comparing two groups of villages based on nearest abundant forest type. We assessed forest-based livelihood dependency of the local communities for two scenarios: (i) households' requirement for basic needs, and (ii) households' requirement as a source of income.

We compared the degree of forest dependency with rank scores from very low (1) to very high (5) values (Fig. 3). Forest-based livelihood dependency was mostly for basic household requirements, such as fuelwood, fodder, natural fertilizers (such as leaf litter and stall litter), and housing/roofing materials, rather than as a source of household income through non-timber forest products (NTFPs), in both the locations. For example, 36.3% respondents in V_{Oak} and 29.6% respondents in V_{Pine} agreed to very high forest dependency with respect to basic household needs. On the contrary, income generation from forests was almost negligible in many villages, other than few households in mostly V_{Oak}. Comparative account indicates higher degree of dependency for oak-dominated forests than pine-dominated forests. The Mann–Whitney U test indicated that dependency based on need was significantly greater for V_{Oak} (mean = 4.1) than V_{Pine} (mean = 3.8), leaning towards 'high' dependency, with $U = 7082$ ($p < 0.05$). It also indicated that dependency based on income was significantly greater for V_{Oak} (mean = 1.5) than V_{Pine} (mean = 11), leaning towards 'very low' and 'low' dependency, with $U = 6475$ ($p < 0.05$).

Forests contribute to the livestock feed for many households in the villages, as local communities practice lopping leaf fodder from forest trees in many areas of the Himalayan region (Gururani 2002; Semwal et al. 2004). Therefore, we compared the importance and availability of livestock feed from three main sources, namely (i) forests, (ii) agriculture (or crop-feed), and (iii) other market sources. The density plots of preferred livestock feed among the rural households were compared among V_{Oak} and V_{Pine} (Fig. 4). We compared the median values of the scores (1 as the lowest and 10 as the highest value) of the three main sources to account for the current forest dependency of local communities. In V_{Oak}, median values indicate

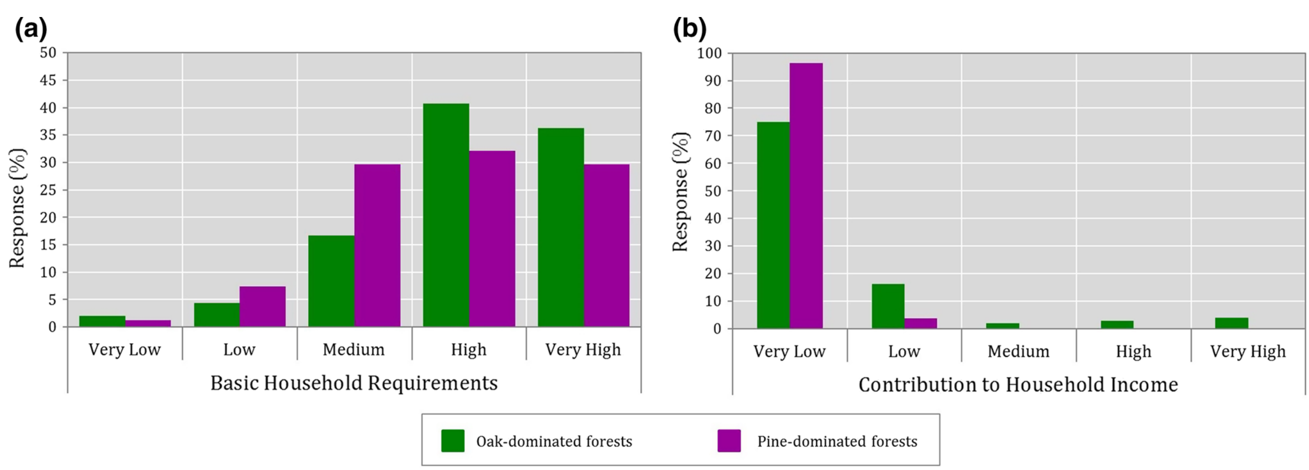

Fig. 3 Forest dependency based on **a** households' requirement for basic needs, and **b** households' requirement as a source of income

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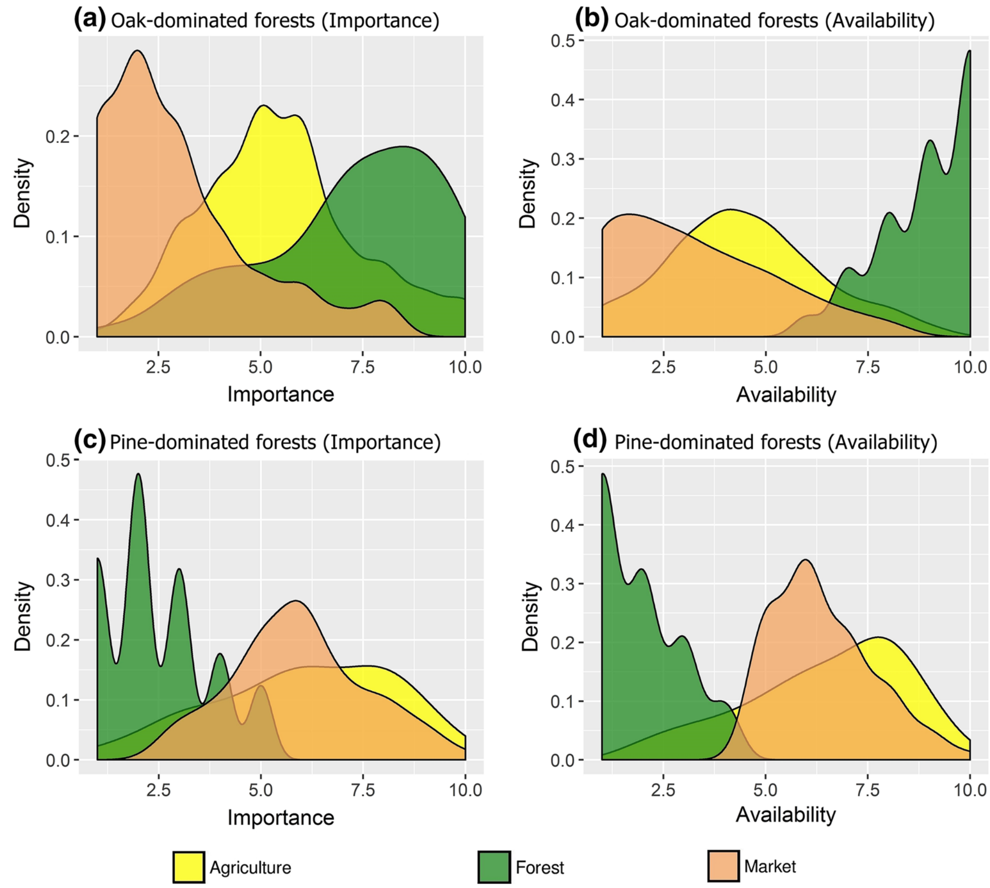

Fig. 4 Density plots showing probability densities of preference of livestock feed from forest, agriculture, and other market sources: **a** importance near oak-dominated forests, **b** availability near oak-dominated forests, **c** importance near pine-dominated deforests, and **d** availability near pine-dominated forests

preference of forests (eight for importance and nine for availability) as the major livestock feed, instead of agriculture (five for importance and four for availability) and market sources (two for importance and three for availability) (Table S6). On the contrary, in V_{Pine}, median values indicate preference of agriculture (six for importance and seven for availability) and market sources (six for importance and six for availability) as the major livestock feed, instead of forests (two for importance and two for availability) (Table S7). There was statistically significant difference in the preference of livestock feed among households in V_{Oak}, depending on the source of acquirement, for importance χ^2 (2) = 393.8 and $p < 0.01$, and for availability χ^2 (2) = 400.5 and $p < 0.01$. Similarly, statistically significant difference was seen in V_{Pine}, for importance χ^2 (2) = 134.4 and $p < 0.01$, and for availability χ^2 (2) = 136.6 and $p < 0.01$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction, resulting in a significance level set at $p < 0.003$, which showed statistically significant differences between the three livestock feed sources. This difference highlights the proximity of nearest forest types determining the stronger association of people with forests in the Himalayan region.

Determinants of forest dependency

Forest dependency of the households based on their proximity to nearest forest type can be influenced by different socio-economic factors. In this case, major income source, gender and age group of the respondents, household size, education status, total land holdings, number of livestock, and usage of alternative fuels were used the major factors that were linked to forest dependency. The overall regression model shows that it was statistically significant for V_{Oak}, χ^2 (13) = 27.4, $p < 0.01$, and not statistically significant for V_{Pine}, χ^2 (13) = 25.4, $p > 0.01$. This implies that variations in forest dependency can explained by factors included in the regression model for V_{Oak}; however, the same cannot be concluded for V_{Pine}. In our study, the model shows lower range values of R^2 estimates, indicating that the dependent variable (forest dependency) could be explained by other factors, which have not been included in the current regression model. This could also imply that

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Table 2 Comparative account of the factors determining forest dependency between two different locations (B = Beta Coefficient (β), SE = Standard Error of the Estimate, Wald = Wald's t-test, Sig. = Significance or p values, and superscript (*) shows statistically significant model is at p < .05 level)

Variables	Coefficients											
	V_{Oak}						V_{Pine}					
	B	SE	Wald	*df*	Sig.	Exp(*B*)	*B*	SE	Wald	*df*	Sig.	Exp(*B*)
Constant	4.608	1.302	12.529	1	0.000	100.314	1.740	1.640	1.125	1	0.289	5.697
Income												
Labourer	−0.142	0.808	0.031	1	0.861	0.868	−0.210	0.951	0.049	1	0.825	0.811
Shopkeeper	−0.238	0.932	0.065	1	0.798	0.788	−0.337	1.113	0.092	1	0.762	0.714
Driver	1.212	1.052	1.326	1	0.250	3.359	−2.956	1.854	2.543	1	0.111	0.052
Retired/pensioner	−0.443	0.827	0.287	1	0.592	0.642	−0.914	1.338	0.467	1	0.494	0.401
Others/service (Base = agriculture)	0.117	0.743	0.025	1	0.875	1.124	−0.034	0.847	0.002	1	0.968	0.966
Gender												
Male (Base = female)	−0.117	0.468	0.063	1	0.802	0.889	0.095	0.739	0.016	1	0.898	1.099
Age	−0.035	0.013	6.916	1	0.029*	0.966	−0.019	0.022	0.731	1	0.392	0.981
Household size	−0.032	0.093	0.121	1	0.728	0.968	0.131	0.161	0.658	1	0.417	1.140
Household education (Base = no)	−0.013	0.722	0.000	1	0.985	0.987	0.431	0.983	0.192	1	0.661	1.539
Land holdings	0.008	0.012	0.413	1	0.020*	0.992	0.013	0.022	0.319	1	0.072	1.013
Livestock	0.120	0.076	2.515	1	0.013*	1.128	0.107	0.177	0.365	1	0.046*	1.113
LPG usage												
Often (have)	−1.007	0.823	1.496	1	0.221	0.365	−1.333	0.881	2.290	1	0.130	0.264
Seldom (have and emergency) (Base = never)	−2.540	0.975	6.783	1	0.009*	0.079	−4.157	1.429	8.461	1	0.004*	0.016
	$\chi^2(13) = 27.376$, $p = 0.011$						$\chi^2(13) = 25.407$, $p = 0.20$					
Nagelkerke R^2	21.4%						37.9%					
Hosmer and Lemeshow test	$p = 0.028$						$p = 0.343$					
Classification accuracy	88.7%						79%					

irrespective of their socio-economic conditions, local communities are more or less dependent on forests as seen in the previous section. Nonetheless, considering the factors included in the model, age of the respondents, households' land holdings (mainly cultivated area), livestock possessions, and seldom or negligible usage of alternative fuels largely influence the forest dependency in V_{Oak}, returning p values less than 0.05. Similar results can also be seen in V_{Pine}. The remaining factors did not prove significant in explaining forest dependency. The summarized results of binomial logistic regression analysis ascertain effects of different factors in determining forest dependency within the region (Table 2).

Forest products used and their importance

According to the FGDs and household surveys, majority of the people unanimously agreed that oak-dominated forests were the most important forest types for many villages and most livelihood products were also procured from them.

We compared the importance of forest products used between the sampled villages (V_{Oak} and V_{Pine}), and the results show that unanimously, most of the forest-adjacent households ranked the usage of fuelwood as the highest required forest product in their households. The categorization of major and minor forest products was on binary-choice model of respondents either using (yes) or not using (no) any forest product. The threshold value for major products was set above 70% for respondents using forest products, while the values lower than 70% were categorized as minor products. In V_{Oak}, major forest products include fuelwood, fodder, leaves, dried wood (used for agricultural and other related activities), and stall litter used as animal bedding (also, in later stages, used as manure) (Table 3). Minor forest products in V_{Oak} include products such as fruits, flowers, seeds, and medicinal plants obtained from the forests. In V_{Pine}, major forest products include fuelwood, stall litter, and small timber collected for housing purposes. Small timber was primarily used for making agricultural activities and in some cases in constructing and

Table 3 Percentage profile of the comparative account of usage of forest products in the villages near oak-dominated and pine-dominated forests. Superscript denotes the major (1) and minor (2) forest products used in the sampled villages. The forest products used in V_{Oak} is represented by 'a' and forest products used in V_{Pine} is represented by 'b'

	$V_{Oak}^{(N=204)}$					$V_{Pine}^{(N=81)}$				
	Use		Importance			Use		Importance		
	Yes	No	Low	Medium	High	Yes	No	Low	Medium	High
Fuelwood[a1,b1]	91.7	8.3	10.3	15.7	74.0	85.2	14.8	2.5	12.3	85.2
Fodder[a1,b2]	78.9	21.1	54.4	9.3	36.3	60.5	39.5	34.6	27.2	38.3
Housing/roofing[a2,b1]	46.6	53.4	36.8	45.6	17.6	92.6	7.4	66.7	28.4	4.9
Leaves[a1,b2]	97.1	2.9	12.7	21.6	65.7	63.0	37	17.3	50.6	32.1
Dried wood[a1,b2]	70.1	29.9	22.5	49.5	27.9	64.2	35.8	37	50.6	12.3
Stall litter[a1,b1]	75.5	24.5	19.1	27.0	53.9	72.8	27.2	19.8	35.8	44.4
Fruits[a2,b2]	40.7	59.3	67.6	30.4	2	1.2	98.8	100	0	0
Flowers[a2,b2]	44.6	55.4	61.8	9.8	28.4	2.5	97.5	100	0	0
Vegetables[a2,b2]	0	100	100	0	0	0	100	100	0	0
Seeds[a2,b2]	31.4	68.6	99.5	0.5	0	6.2	93.8	95.1	4.9	0
Medicinal uses[a2,b2]	34.8	65.2	87.7	6.4	5.9	3.7	96.3	98.8	1.2	0

repairing houses. However, according to the respondents, no trees were cut for that purpose and only fallen trees and branches were utilized. Minor forest products in V_{Pine} include fodder and leaves, which were obtained from the nearby forests. Usage of other products such as fruits, flowers, seeds, and medicinal plants were almost negligible. Table 3 shows the distribution of forest products used in V_{Oak} and V_{Pine}.

Determinants of forest loss

Based on the FGDs conducted in our survey in both the locations, five (5) causes of forest loss and degradation have been identified. The broad causes in this region include collection, grazing, lopping, cutting (including soil erosion/forest clearing activities), and fire (Table 4). According to the respondents in V_{Oak}, forest loss in nearby areas was not substantial. Grazing and cutting were the major causes of forest loss, with mean values of 2.8 (± 1) and 2.5 (± 1), respectively, leaning towards 'low' and 'medium' scores. However, other causes of forest loss included collection, lopping, and fire, with mean values of 2.1 (± 0.9), 2.2 (± 0.8), and 2.2 (± 1.2), respectively. On the contrary, according to the respondents in V_{Pine}, forest loss in nearby areas was much more over the years. Fire and cutting were the major causes of forest loss, with mean values of 4.3 (± 0.8) and 3.5 (± 1.1), respectively, leaning towards 'high' and 'very high' scores. Collection, grazing, and lopping were likely to not cause forest loss, with mean values of 1.2 (± 0.5), 1.6 (± 0.7), and 1.3 (± 0.6), respectively. Table 4 shows the comparison between V_{Oak} and V_{Pine} about the perception on disturbances (both natural and anthropogenic) causing forest loss in the central Himalayan region.

DISCUSSION

Forest-dependent people are often described as human population that derive benefits from forests in some way or the other (Newton et al. 2016). In this study, the dependence on forests is either for basic household requirements such as fuelwood and fodder or for contribution in the household income in rural areas. Similar accounts have been reported in other areas across the Himalayan region (Naidu 2011; Rayamajhi et al. 2012; Måren et al. 2014). Even with the co-management of forests by both government agencies and local communities, disturbances in many forms have degraded forests in the central Himalayan region. Often, anthropogenic activities cause forest fires in this landscape, but mostly in the pine-dominated forested areas (Singh et al. 2016). In case of commercial extraction of timber, tree felling has been banned above an altitude of 1000 m (Singh 2014); however, illegal logging is carried out in some pockets of the hilly terrain (Rana and Chhatre 2016). In addition to these causes of forest loss, human encroachment to primary forest areas (Rawat et al. 2012; Brandt et al. 2013), over-grazing (Malik et al. 2014), deforestation (Kumar and Ram 2005; Pandit et al. 2006), and other land use practices such as agricultural expansion and urban infrastructural development are known to further degrade the forests in the central Himalayan region.

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Table 4 Percentage profile of households' perception on disturbances (both natural and anthropogenic) causing forest loss

	$V_{Oak}^{(N=204)}$							$V_{Pine}^{(N=81)}$						
	Very low	Low	Medium	High	Very high	Mean score	Std. dev.	Very low	Low	Medium	High	Very high	Mean score	Std. dev.
Collection	25.5	47.1	16.2	10.3	1	2.14	0.95	79	17.3	3.7	0	0	1.25	0.51
Grazing	15.2	18.6	32.8	33.3	0	2.84	1.05	55.6	32.1	11.1	1.2	0	1.58	0.74
Lopping	26	34.8	37.3	2	0	2.15	0.83	79	14.8	4.9	1.2	0	1.28	0.62
Cutting	7.8	54.4	19.1	12.7	5.9	2.54	1.01	7.4	9.9	25.9	39.5	17.3	3.49	1.12
Fire	34.8	26.5	23	10.8	4.9	2.25	1.18	0	2.5	13.6	38.3	45.7	4.27	0.79

Forest ecosystem services in the central Himalayan region

Forests are an integral component of the subsistence-based agro-economy in the central Himalayan region (Uniyal et al. 2003; Sood and Mitchell 2009). Our study provides evidences about the dependence of local communities, through direct or indirect contribution of forests to their daily livelihoods. This dependence, however, is based on the availability and accessibility to the nearest forest type, along with the economic and physical status of the local communities. While it is primarily established that dependence of local communities on forests and forest-based resources relates to their individual household usage, it also suggests that this dependency on natural resources, in this case, forests, depicts their social order, which is representative of a more localized economy.

Forests primarily fulfil the basic household requirements for fuelwood, fodder, natural fertilizers (leaf litter and stall litter), timber, medicinal uses, fruits, and other food-related products. In addition to this, agriculture-related dependency is maintained by inputs of biomass and nutrients derived from the forests. Fuelwood is one of the major forest ecosystem services required by the local communities, due to the lack of alternative fuels, such as kerosene, LPG, and improved *chullahs*. In the absence such alternatives, fuelwood remains the only source for cooking and heating purposes for the most households in the villages. Although there is a varied degree of forest dependency among the villages for other forest products, for example, in case of requirements of fodder, or natural fertilizers (leaf litter and stall litter), or housing and roofing materials, nonetheless, most of the households heavily rely on fuelwood for their daily day-to-day activities. In addition to fuelwood, fodder, and leaf litter collection for livestock feed was another major requirement among the rural households. However, this varied between the two locations, as villages near oak-dominated forests preferred green fodder from forests and livestock grazing in the surrounding forested areas, while villages near pine-dominated forests preferred fodder from agriculture lands mixed with green fodder from forests and other market sources. The diversity of the species used for fuelwood, fodder, and leaf and stall litter collection, majorly depended on the accessibility and availability of the forest type surrounding these villages. Other forest-based products such as small timber, fruits, and forest vegetables also contributed to the livelihoods of the local communities to a very small extent. Most of the forest products in the study area are extracted only for household consumption, and in many cases do not add any direct revenue to the household income. The is most likely due to poor economic conditions of the rural households in both locations and, more importantly, the availability of forest resources based on their proximity to the forest types, i.e. oak-dominated forests or pine-dominated forests. In the present study, most local communities unanimously reported preferring oak-dominated forests instead of pine-dominated forests, which results in their higher dependency on the surrounding forests. These results are in accordance with a number of forest-based studies that highlight the importance of oak (*Quercus* spp.) forests in maintaining the forest-based livelihoods of local communities in the Himalayan region (Joshi and Negi 2011; Måren et al. 2014; Dhyani and Dhyani 2016).

One of the main reasons of forest degradation in the present study area is the increase in population and expansion of agriculture over the years (Tiwari and Joshi 2014). This phenomenon, coupled with a notable increase in the livestock sector in the earlier years (1970s–1980s), has accelerated lower diversity in the forests surrounding these villages (Joshi and Negi 2011; Makino 2011; Rawal et al. 2012; Negi and Maikhuri 2017). Nevertheless, over the last 5–10 years, with comparatively limited irrigation facilities, declining soil quality, and accelerated soil erosion due to over-exploitation and improper management of nearby forested lands, it has led to agricultural land abandonment in many of the sampled villages. Apart from these natural and social factors, the extreme level of crop-raiding menace by pests such as monkeys and wild boars is now a widespread concern among the local communities. Therefore, as a consequence to the low agricultural productivity in these villages, it has invariably resulted in reduced direct and indirect dependence on forests and forest-based resources to meet the subsistence needs of rural households.

Forest institutional dynamics in Uttarakhand, India

In the present study, through the narrations of FGDs and discussions with the heads of local self-government organizations, viz. *gram panchayat pradhans* (GPPs), it was observed that local communities through the influence of forest institutions, in this case, village forest councils (i.e. *van panchayats*), were responsible for regulating and monitoring the use of forests.

In the state of Uttarakhand, due to the conflicts during the British colonial period in the early Twentieth century, village forest councils were established following the settlement and reservation of forests in hilly areas of the mountainous terrain (Agrawal and Chhatre 2006; Baland et al. 2010; Tompsett 2014). The first state-approved forest council was established in the year 1931 during the British colonial period in India (Agrawal 2001). Since then, many forest councils have been created which broadly represents a decentralized form of democratic local governance of forests in the central Himalayan region. They are mainly responsible for conserving and managing the civil forests (i.e. forests situated within villages) (Tiwari and Joshi 2015). They are accountable for maintaining the local communities' dependence on forests and forest-based resources through amount of grazing, collection of fuelwood, fodder and small timber, as well as protection of civil forests within their respective villages. According to the interviews with forest guards and forests officers in the study region (Bageshwar district and Pithoragh district), the village forest councils can also work in close collaboration with the Forest Department for technical assistance for forest conservation and management plans. There are nearly 12 089 village forest councils managing 5449 km^2 of forests, covering approximately 15.32% of total forest cover in the state (Department of Forest 2006). The officials of the Forest Department were of the view that they work closely with local communities in terms of forest management and conservation. But in few instances, they regarded recent degradation of forests to annual ground burning activities causing forest fire events in pine-dominated forests. Often, local communities are involved in burning off the understory of forests to promote the growth of fresh fodder in the region (Supplementary information S3). Such claims can be supported through previous literature in the central Himalayan region (Naudiyal and Schmerbeck 2016).

In the present study, our interviews led to the observation that in many villages, there is lack of coordination between the village forest councils and the State Forest Department. In most cases, the forest councils often criticized the civil administration and the Forest Department for their inappropriate practices and allocation of forest management funds in their districts (Supplementary information S3). Most of the discussions highlighted the need for more democratic power by making these institutions rather self-governing and autonomous in the decision-making process, while incorporating local communities with a larger stake in the village forest councils, and providing incentives to others to actively engage in forest management and conservation. At present, the major stakeholders in the forest councils include the elected local communities, the State Forest Department, the State Revenue Department, and civil society organizations (Tiwari and Joshi 2015).

It should be noted that despite the closely inter-linked association of forests and people, the evidences suggested that illegal tree felling, timber extraction, forest grazing, and other encroachment activities could not be completely regulated, even with such decentralized form of forest governance. Nonetheless, fuelwood and fodder extraction was in control to some extent, in the forests surrounding these villages.

Forest management implications in the central Himalayan region

Based on the present study, we noticed that the association of local communities with forests is directly connected to forest conservation, as their dependency acts as a compelling motivation for both forest management and conservation initiatives. Therefore, forest conservation initiatives should be linked to community-oriented practices, especially looking into the proximity of local communities to degraded or disturbed forested areas. This, along with the type of forests, will play an essential role as the deciding factor in their participation in various forest conservation initiatives. The objective should be involvement of local communities in the planning and decision-making process, only after prioritizing their current need for forest resources, so that successful contribution can be expected in the forest management plans and policies.

Measures to protect forests from fire incidents should be implemented, especially in pine-dominated forests. By identifying reasons for forest fire, alternate options to fulfil the livelihood needs of local communities should be provided. This will prevent loss of forests due to fire incidents, whether caused accidentally, as described by the local communities in the present study, or purposefully by the local communities only to allow good fodder growth in

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pine forests (Rao and Pant 2001). In other instances, utilization of pine needles for energy generation by converting them into energy efficient high-density pine needle briquettes might prove as an incentive to conserve pine forests (Bisht et al. 2014). This can be a promising option for controlling forest fires, as well as it will provide an economically beneficial decentralized source for energy production in the study area. Along with prevention from forest fire incidents, cutting, grazing, and lopping should be curtailed, so as to allow regeneration in the nearby forest stands. Alternatives to fodder collection should be provided with promotion of fodder banks (to fulfil fodder demand during lean seasons), compact feed systems, and growing high biomass yielding fodder varieties (on the edges of village kitchen gardens and agricultural fields as methods), for reducing existing pressure on forest resources (Dhyani and Maikhuri 2012). In addition to this, it is also crucial to meet the sustainable supply of fuel resources in the study area for maintaining local livelihoods. The present dependence on biomass from forests as the primary fuel source stems from the unavailability of alternate fuel sources and poor socio-economic conditions of the rural households (Sandhu and Sandhu 2015). Alternate energy sources including LPG, biogas, solar energy, and electricity could be the potential ways to reduce stress on forests for fuelwood in the study area (Katuwal and Bohara 2009; Aggarwal and Chandel 2010; Surendra et al. 2011; Rasul 2014).

Due to the primary use for fuelwood, fodder, and natural fertilizers in the rural households, oak-dominated forests are the most preferred forest type among local communities. Therefore, forest management options should be implemented in support of development of oak-dominated forests in the study area. In addition to different silvicultural methods to support forest management in the central Himalayan region, it is essential to implement forests resource extraction practices in a responsible and sustainable way. In order to maintain future supply of forest-based resources, it is crucial to explore and employ different social options for sustainable forest management, which require a rather extensive understanding of the current forest dependency of local communities and their subsequent participation in the conservation of forests in the central Himalayan region.

CONCLUSION

Against the backdrop of forest loss in the Himalayan region, more effective approaches to forest management are required. Although the concept of human dependence upon forests is not new, it is the current rate of forest loss, increasing population and over-exploitation of forest resources, which makes it of utmost importance to understand present and future needs of forest-dependent communities. Integration of both government institutions and forest-dependent communities encourages forest management practices which can likely address both adaptation and mitigation roles of forests to deal with issues of climate change (Pandey et al. 2016). This will ultimately help in ensuring availability and supply of forest goods and services in the present, and simultaneously minimizing the impacts of climate change on vulnerable socio-ecological systems in future, thereby fostering resilience with change and uncertain disturbance regimes (Seidl et al. 2016).

Our study attempts to explore the comparative accounts between villages in two different locations based on their proximity to oak-dominated forests and pine-dominated forests. Our findings revealed that the degree of forest dependency is still very high in the surveyed areas. One of the most significant observations from the study was that the nearest forest type was the major deciding factor in the degree of forest dependency, as well as the association of people with forests. There is a distinguishable pattern which indicates higher dependence on forests in villages near oak-dominated forests than pine-dominated forests. Specifically, oak-dominated forests are of greater importance for local communities than pine-dominated forests. Our results suggest that all the villages in the entire study region are not homogeneous entities and the degree of dependence on forests could vary due to socio-economic factors, along with their proximity to the forest type shaping their individual preferences.

We advocate prioritization of community-based forest conservation initiatives, along with self-governing and autonomous village forest councils (i.e. *van pachayats*) in central Himalayan region. By delineating different regions based on their current resource dependency on forests, sustainable forest management can be prioritized based on village cohesiveness and homogeneity, alongside local regulatory institutions. More efforts are required to increase the participation of local communities in the conservation of forests through socio-economic reforms and ecological evaluation of forests, with focus on conserving specific forest types and vulnerable regions. By providing information on resource management alternatives, forest conservation and sustainable forest management can be achieved by mapping the potential utilization patterns. This could entail alternatives for collection of fuelwood, fodder, and natural fertilizers, as well alternative livelihood opportunities for local communities, which will eventually reduce pressure on degraded forests. By providing local population with incentives to conserve forests with potentially viable management choices, it will, therefore, help in warranting continuous availability of

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forests and forest-based products in future for dependent local communities in the central Himalayan region.

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