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Decentralized Forest Governance and Resource Management: Assessing Community Dependence and Conservation Effectiveness in Broad-Leaved and Coniferous Forest Stands

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ABSTRACT

Globally decentralized forest governance is being promoted to conserve and sustainably manage forest resources along with meeting local livelihoods. In the Central Himalayan region of India, it came into existence in 1931, long before the time when the concept of decentralized forest governance became popular globally, and the aim was to accomplish the subsistence needs of the smallholders in the region. This article discusses whether the species types (broadleaved and coniferous) affect biophysical conditions, species richness, and conservation effectiveness of community-owned forests (locally called *Van Panchayat* forests), and what could be done to improve their management in the near future. The findings are based on a household survey covering 16 villages as well as a biophysical assessment of 18 community forest stands (9 per forest type) covering an area of 1778 ha and 341 ha in both forest categories. It was found that farmers across the villages are intricately dependent on forest resources to support their livelihoods that are governed by a village institution (*Van Panchayat*) to maintain equity of benefit-sharing among all stakeholders. Both forest categories exhibited high dependence, however, there was a considerable difference in resource quality, viz. quality of fodder, fuel, and litter in broadleaved forests, therefore the community has more preference for such stands. The broadleaved Banj-oak stands revealed better biophysical status in terms of species diversity, tree density, total basal area, and regeneration than the coniferous Chir-pine stands. Although the local government has taken up selective policy initiatives to encourage decentralized forest governance, more needs to be done to strengthen it on the ground level, particularly in Chir-pine stands. It is suggested that the community management of forests needs to be improved in relation to leadership development, rationale use of bio-resources, and adopting site-specific management strategies. In areas with Chir-pine forests community need to be educated to reduce forest fire and promote the plantation of broad-leaved species. Also, the scope of community forests needs to be broadened by adopting and involving smallholders in various forest enterprise development and climate action programs. For this, developing proper alliances of village institutions with civil society groups and other partner institutions along with virtuous support from local government can lead to enhance social and environmental resilience of communities.

Key words: Decentralized governance, stand density, diversity, forest quality, livelihoods, conservation

INTRODUCTION

The past 3-4 decades have witnessed considerable interest in decentralized forest governance by transferring ownership and management responsibilities to local forest user organizations (Agrawal and Ostrom 2008, Dahal and Capistrano 2006, Samii et al. 2015). The major rationale for such preference lies in the assumption that local communities have higher stakes than the state in their resources and have better knowledge of local resources and, therefore, can manage forests more efficiently (Brosius et al. 1998, Gupta et al. 2020). Today, more than 62 countries across all regions claim to have transferred use and management rights to over >700 million hectares of forests to local users and communities (Gilmour 2016). Though not a panacea and although outcomes vary, many decentralized forest governance programs implemented across the globe have been found effective in improving forest management, with better environmental and socioeconomic outcomes compared to centralized management regimes (Klooster and Masera 2000, Gautam 2007, Bowler et al. 2012, Shahabuddin and Rao 2010, Vijge and Gupta 2014).

At the local level, where these decentralized forest governance policies actually operate, outcomes generally depend on the characteristics of the resource system, the user group, the institutional arrangement, and the external environment (Anonymous 2007, Lund et al. 2018). Since the users' choice to engage in collective action or not is largely dependent on the resource system, the variables relating to resource characteristics i.e. size of the forest, its boundaries, species composition, and goods and services being provided by the forests have received substantial attention (Duncker et al. 2012). Moreover, among these variables relating to resource characteristics, the rate and nature of goods and services provided by forests are considered to be the most significant variable under community governance of the forest resources (Gibson et al. 2007).

All over the Himalayan region, the forests are central to local livelihoods and used extensively by the villagers to fulfill a diverse range of their household needs (Sundriyal and Sharma 1996, Chakraborty et al. 2018, Negi 2022). The Central Himalayan state of Uttarakhand is no exception to that. As such the state comprised over 60% of land under the forest that is managed under three different kinds of governance viz. Reserve, Civil & Soyam, and Van Panchayat forests (VP). The Reserve forests are managed exclusively by the Forest Department and villager's rights in these forests are limited just to the collection of dry and fallen leaves and wood. The Civil & Soyam forests are under the legal control of the Revenue Department. Villagers have unlimited rights to these forests therefore these forests are in a highly degraded state. The VP forests are managed by legally recognized village-level institutions (known as Van Panchayats) in participation with State Forest and Revenue departments. Amongst the various contemporary examples of decentralized forest governance approaches, the management of village forests by legally recognized village-level institutions in the Uttarakhand state holds a unique place mainly due to two particular reasons. First, this system of community forest management came into existence in 1931, long before the time when the concept of decentralized forest governance became popular globally (Agrawal and Goyal, 2001, Agrawal and Ostrom, 2008). Second, unlike contemporary government-led decentralized forest governance programs, this system is a product of the villagers' movement that took place in the region during the early 1900s, agitating against the British policy of forest reservation (Guha 1989 and 2001, Pant 1922). Under this community forestry system, villagers (that mainly comprised smallholders) are entitled to form a village-level institution i.e. Van Panchayat (VP) with a task to manage a defined area of forest (known as VP forest) within the village boundary in a manner that does not lead to resource degradation while providing much-needed forest produce e.g. firewood, fodder, leaf litter, timber, etc. to the villagers (Germain et al. 2018). It is important to note here that the VPs fulfill the basic requirements of villagers with the least commercial angle. Only selected NTFPs (lichens, mosses, forest litter, medicinal plants, etc.) are collected on a circular basis however no such records are maintained at the village level. Each VP has a maximum of 9 members (including 2 persons from weaker sections, 2 women, and one head known as *Sarpanch* of the VP committee) elected democratically from the village community through a village-level election held every 5 years. These VPs, with the general consent of village members, can craft specific rules to regulate forest produce harvest from the VP forests and can create monitoring, sanctioning, and arbitration devices to resolve disputes within the local space (Agrawal and Ostrom 2008, Negi et al. 2012). The powers and duties of VPs are, however, regulated by the government departments through VP Rules which were first enacted in 1931 and subsequently amended in 1976, 2001, 2005, and 2012. For example, without prior approval of the concerned government officers, VPs cannot levy a fine (on the offenders) that exceeds the amount specified in the VP rules. Presently, out of nearly 16000 villages in Uttarakhand state, 12089 have VPs, which formally manage nearly 16% (544964 hectares) of the forest area of the state. The forest area available with each VP varies from 5 hectares to over 1000 hectares and is mostly dominated by either Banj-oak (broadleaved) or Chir-pine (coniferous) species. The state Forest department and Revenue department provide technical and administrative support to these VPs.

Most VP forests are situated at mid-hill and dominated by either Banj-oak (*Quercus leucotrichophora*) or Chir-pine (*Pinus roxburghii*) species. Banj-oak and Chir-pine are, in fact, two dominant forest types in the region and differ from each other structurally, functionally, and supporting diverse ecosystem services (Singh and Singh 1992, Negi 2022). Banj-oak is an evergreen, broad-leaved climax species that generally grow in moist aspects, whereas Chir-pine is an evergreen conifer species mostly found in the dry aspects. Both these forest types are used extensively by the villagers to fulfill their daily requirements of firewood, fodder, leaf litter, timber, and a range of other non-timber forest products (Sinha 2002). However, the Banj-oak forests are socially valued since these forests produce qualitatively superior benefits as compared to Chir-pine forests (Joshi and Negi 2011). They produce quality firewood for cooking, year-round green fodder for livestock, litter for animal bedding and manuring, and serve most effectively in terms of soil fertility and water retention. These forests are also known for a good diversity of non-timber forest products e.g. wild fruits, medicinal plants, etc. hence providing income and employment to the local communities through forest-based activities (Bhatt et al. 2000). In contrast, the Chir-pine forests comprised a low humus layer in the soil and so tend to be of less use in water conservation. Chir-pine needles are less preferred than Banj-oak leaves for use as bedding for cattle and manure. Also, Chir-pine needles are not used as fodder. The main benefits of Chir-pine forests are firewood for cooking and heating, timber for house construction, and resin for sale. It is clear from the preceding discussion that broadleaved and coniferous forests are important suppliers of a variety of commodities. Therefore, a comprehensive analysis might lead to the development of efficient management strategies for them.

Users' management practices may be affected significantly by the use of tree species, even when the forest stands are generally managed under similar governance regimes (Agrawal and Ostrom 2008, Somanathan et al. 2009). Tree species preferences are more influenced in view of various provisioning services that bring a significant impact on local livelihoods (Armitage 2002, Hohbein and Abrams 2022). However, the impact of community preference of species on tree structure and regeneration of the forests managed under decentralized governance is the least investigated (Chakraborty et al. 2018). Does the type of species impact the biophysical condition of forests? And how does the biophysical condition of forest impact species richness (biodiversity) and forest conservation? The present paper attempts to unearth these questions by examining resource use patterns and biophysical conditions of the two most common and contrasting forest types (broadleaved and coniferous) under community governance (Van Panchayats) in the Indian Himalayan region. An attempt has also been made to suggest strategies that could lead to the successful and sustainable management of these forest types under decentralized governance in the Indian Himalayan region.

MATERIALS AND METHODS

Study area and site selection

The study area falls in Uttarakhand (28º43' N-31º27' N latitude and 77º34' E-81º02' E longitude) in the Central Himalayan region of India. The state is composed of 13 districts and administratively divided into two divisions i.e. Kumaun and Garhwal division. Of its total geographical area (53483 km^2), around 92% is covered by mountains and only 8% is Terai plains. The bulk of the state is made up of valleys and mountains that range from 1200 to 3000 meters in height and form a landscape of steep hillsides, forests, and fast-running rivers in the valleys. For the present study, sixteen VPs located in the Almora, Bageshwar, and Nainital districts of the Kumaun division of the state were selected (Fig. 1). These were selected randomly with the help of the Forest Department, with eight stands each dominated by Banj-oak and Chir-pine. Two of the selected VPs (namely Bhaktura in Almora district and Patharkote in Nainital district) mentioned as having a Banj-oak dominated VP forest in the government records were found actually having two distantly located small forest patches, one dominated by Banj-oak species while the other by Chir-pine species. These two distantly located VP forest patches of different vegetation types in both of these VPs were considered as two individual forests purposively to capture intra-village variations in villagers' management practices. The selected villages, while varying considerably with respect to altitude, human, and livestock

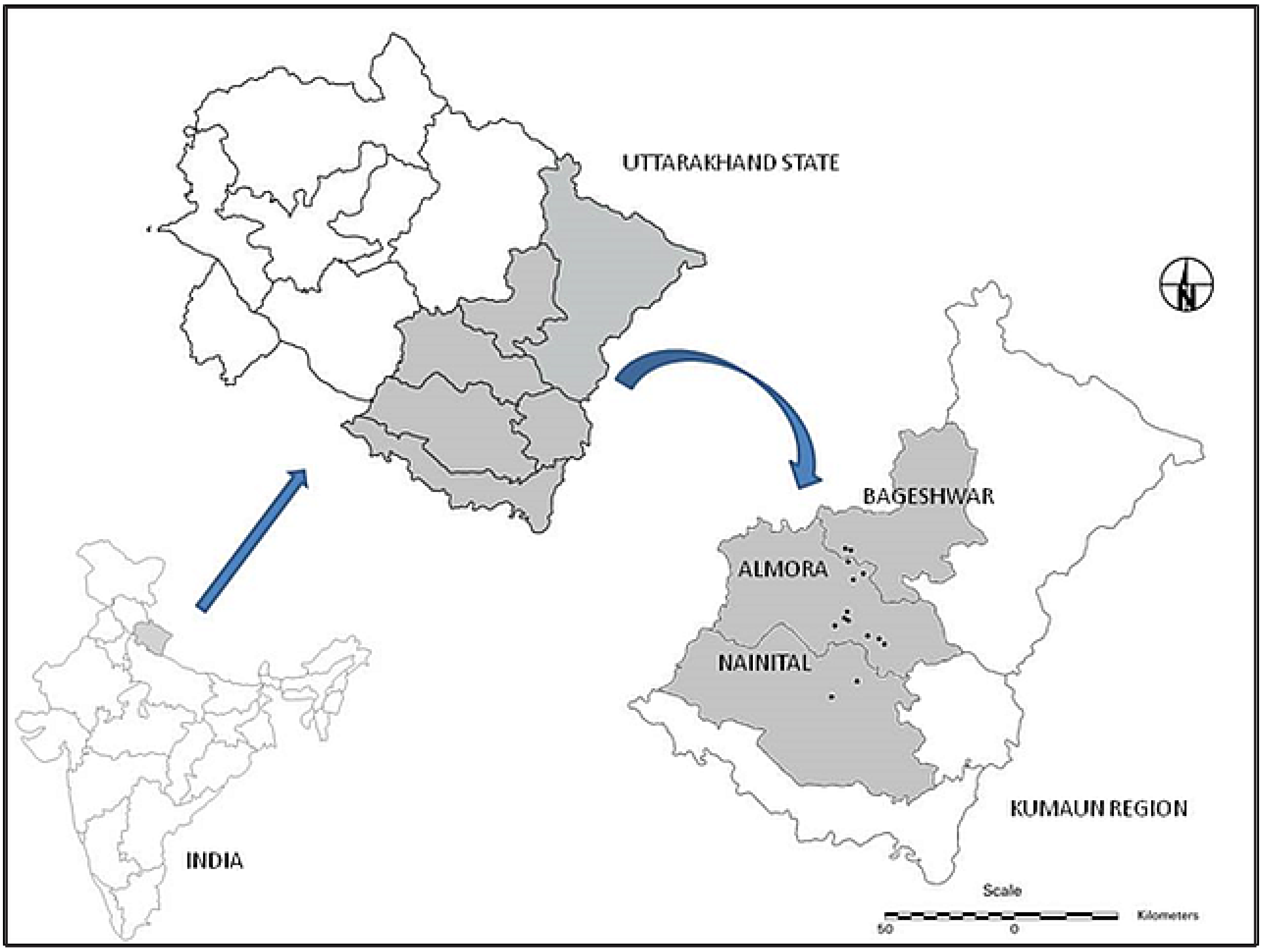

Figure 1. Map showing location of selected Van Panchayat villages in three districts of the Uttarakhand

population, represent the typical environmental setup of the Himalayan region. All the selected forest stands were located between 1150 and 2060 m asl (Table 1). Of the total 12089 VPs of the state, around 70% are located within this altitudinal zone.

Village survey

Open-ended interviews were conducted in each of the selected villages to gather information on general details, functioning, and management strategies taken up by the VPs to protect their forests from overharvesting. Gathering at a suitable place, the VP and Gram Sabha (village council) members were interviewed first and asked to provide information about the methods that they have developed to regulate forest produce harvest, enforce management rules, and resolve resource use conflicts within the village. The number of participants in these discussions ranged between 10 and 25 across the study villages. Since the participants holding positions in village institutions (i.e. Gram Sabha and VPs) may be predisposed to view the functioning of their VP in a favorable light, the information provided by them was crosschecked by interviewing 15 randomly selected households at each of the study villages. If there was a variation in the views between Gram sabha/VP committee members and the village community, the villagers' views collected through household surveys were considered final. The reliability of the information on VPs functioning collected through group discussion and household surveys were further strengthened by observing villagers' activities of forest produce harvest from the VP forests during random field visits.

Forest resource utilization

In order to assess forest produce (i.e. firewood, fodder, and leaf litter) collection from the VP forests in the selected villages, the forest produce collected from these forests by villagers was quantified using a structured

Table 1. Details of selected villages in Uttarakhand state in Central Himalayan region, India

Village	District	Altitude (m)	Total HHs	Human population			Livestock population
				Total	Male	Female	
Patharkote	Almora	1400	63	269	130	139	238
Khadkuna	Almora	1225	24	129	62	67	72
Kaneli	Almora	1450	57	254	125	129	228
Champa	Almora	1600	53	263	125	138	318
Dolpokhra	Almora	1540	17	103	43	60	102
Dhaili	Almora	1800	129	755	402	353	456
Palna	Almora	1800	104	535	261	274	510
Dol	Almora	1150	411	2134	1098	1036	1232
Chaniluesal	Almora	1690	378	1669	780	889	756
Falyanti	Almora	1540	48	252	110	142	310
Tana-Sajoli	Almora	1450	98	520	233	287	585
Laubanj	Bageshwar	1300	132	696	327	369	465
Ghaurara	Bageshwar	1400	64	356	189	167	380
Shama	Bageshwar	2060	193	887	406	481	816
Parbara	Nainital	1420	181	1065	540	525	610
Bhaktura	Nainital	1255	14	74	39	35	62

questionnaire. A total of 15 randomly selected households in each of the sampled villages were interviewed and information was gathered on (1) the number of days (collection days) that they spend in VP forest to collect firewood, fodder, and leaf-litter during rainy, winter, and summer season; and (2) the number of head loads of firewood, fodder, and leaf-litter that they collect in a day from VP forests during the rainy, winter, and summer seasons. To get an annual estimate, seasonal data on the number of collection days for each forest produce was pooled and the average number of collection days per household per year was calculated. Data on the number of head loads of different forest products that a household collects in a day in each season was averaged and an average number of head loads collected per day by a household was determined. The average weight (kg) of a head load of each forest produce i.e. firewood, fodder, and leaf litter was then determined by weighing at least 5 head loads of these forest products directly in the field. With the help of this field-level data, the average number of head loads collected per day by a household was converted to weight (kg). Per household annual collection (in kg) of firewood, fodder, and leaf litter was then determined by multiplying the quantity of forest produce collected in a day by the average number of days spent annually to collect this particular forest produce. Considering that some of the households (particularly those who are either comparatively well off and/or distantly located from the VP forest) are not harvesting forest produce from VP forests in the selected villages, per household annual collection of firewood, fodder, and leaf-litter was multiplied by 80 percent of the total households living in the sampled villages. This gave an approximation of the total annual extraction of firewood, fodder, and leaf litter from VP forests in the sampled villages. Similar quantification methods have been followed by earlier researchers (e.g. Joshi and Negi 2011, Samant et al. 2000, Singh et al. 2010).

Biophysical condition of the forest stands

We sampled VP forests for vegetation analyses using the line transect method (Muller-Dombois and Ellenberg 1974). Ten, 50×20 m sampling plots were laid randomly at each forest site. The diameter at breast height (DBH) of all the trees (>10 cm DBH) falling within each 50×20 m sample plots at each forest site was measured and recorded. Saplings (3.3-10.0 cm DBH) and seedlings (<30 cm height and 3.3 cm DBH) at each forest site were assessed by ten randomly placed (separate from tree plots) 10×10 and 5×5 m sampling plots, respectively. The field data were quantitatively analyzed for tree density, frequency, and basal area (Curtis and McIntosh 1950). Species richness and diversity index were also computed (Shannon and Wiener 1963, Whittaker et al. 1979, Pielou 1969).

An assessment of tree girth class distribution patterns of various forest stands was also undertaken as an indicator of forest stand quality (Chandrashekara 2013). Such information elucidates recruitment status as well as the disturbance history of each forest stand. All the tree individuals recorded in different quadrates were categorized in different girth classes, such as <10 cm, 10-20, 20-30, 30-40, 40-50, and >50 cm DBH. The data were plotted on a logarithmic scale. Besides, an investigation on cluster analysis was also undertaken to provide valuable clues for species distribution patterns amongst heterogeneous forest stands (i.e. Banj-oak and Chir-pine). Information on the clustering of species helps in a better understanding of landscape and ecological processes operating at different forest sites (Churchill et al. 2013). Accordingly, the cluster analysis for all 18 forest stands was undertaken using PC-ORD with Euclidean distance and Ward's group linkage method considering two vegetation parameters, i.e. density and species richness. Presence/absence data were used and the method proceeded from the individual samples and gradually combined them into groups, in terms of their similarity. The cluster analysis was diagrammatically represented using the dendrogram.

RESULTS

Forest dependence and resource utilization

Details of selected villages, mean altitude, the total number of households, and human and livestock population are provided in Table 1. The selected sites are located between 1150 and 2060 m asl. Further, the details of VP forest, year of formation, forest stand size, and average forest area per household are provided in Table 2. There was a significant

Table 2. General details of studied Van Panchayat (VP) forests and regulations imposed for forest produce utilization

	Year of establishment	Forest area (ha)	VP forest/ HH (ha)	Grazing	Fodder collection	Litter and fuel wood collection	Tree felling and lopping
Broadleaved Banj-oak forests:							
Patharkote 1	1974	33	0.32	NP	RL	RL	PB
Dhaili	1999	58	0.45	NP	RL	RL	PB
Dol	1957	361.5	0.88	NP	RL	NP	PB
Chaniluesal	1974	77.8	0.21	NP*	RL	NP*	PB
Falyanti	1967	55.2	1.15	NP	RL	NP	PB
Tana-Sajoli	1953	71.6	0.73	NP	RL	NP	PB
Shama	1954	823.52	4.27	NP	RL	NP	PB
Parbara	1932	285	1.57	NP*	RL	NP*	PB
Bhaktura 1	1999	12	0.43	NP	RL	RL	PB
Coniferous Chir-pine forests:							
Bhaktura 2	1999	22	0.36	NP	-	NP	PB
Patharkote 2	1974	5	0.08	NP	-	NP	PB
Khadkuna	2004	4.62	0.19	NP	-	NP	PB
Kaneli	2004	12.93	0.23	NP	-	NP	PB
Champa	1957	143	2.7	NP*	-	NP*	PB
Dolpokhra	1958	86	5.06	NP	-	NP	PB
Palna	1932	38	0.37	NP	-	NP	PB
Laubanj	1978	22.76	0.17	NP	-	NP	PB
Ghaurara	1978	6.48	0.23	NP	-	NP	PB

BO = Banj-oak forest; CP = Chir-pine forest; NP = not prohibited; NP = not prohibited except in some small areas of plantation; RL = regulated for tree fodder; PB = totally prohibited difference in forest areas in different villages. The oldest VPs were formed in the year 1932 (Palna and Parbara), which means such villages are having the experience of managing forests for nearly nine decades. Contrarily, the latest VPs were formed in 2004 (Khadkuna and Kaneli). Per household forest area was estimated as 0.17 to 5.06 ha per household in different VPs. Primarily, the communities extract firewood, fodder, and leaf litter from VP forests. NTFPs (such as wild fruits, medicinal plants, lichens, and mosses) were also harvested but these harvestings are small and no records are maintained for such harvesting at the village level. There is no commercial extraction of timber from VP forests. Generally, tree felling and lopping are totally prohibited from VP forests until required for some exceptional circumstances. Except for some small areas of plantations in the Banj-oak forests of Chaniluesal and Parbara VPs and in the Chir-pine forest of Champa VP, grazing was not prohibited in most of the sampled VP forests. However, during field surveys grazing was found rare in the Banj-oak VP forests. Banj-oak forests generally have poor growth of ground fodder; therefore, villagers prefer to graze their cattle in Chir-pine forests available near the villages and/or in harvested crop fields. All VPs perform as winter (January to March) forage banks, which is a lean period of fodder availability. For this, Banj-oak forests offer green tree fodder that is collected during the winter months that is regulated by the VP committee. Villagers in these VPs were permitted to harvest tree fodder for a period that ranges from 10 to 30 days (depending on the size of the forest and availability of the fodder). During the rest of the time, tree fodder collection in these VP forests was completely banned. A nominal fee that varies from Rs. 25 to 50 per household across villages was charged for tree fodder harvest from VP forests. Moreover, during the collection period, only a single person from a household was allowed to carry a bundle of fodder per day. The time for the collection was also fixed in most of the cases.

Leaf litter and firewood collection were regulated in the Patharkote, Dhaili, and Bhaktura Banj-oak VP forests. The main reason behind this regulation was to strengthen natural regeneration in VP forests. In the above-mentioned villages, the forests were opened occasionally for litter and firewood collection. A large share of leaf-litter and firewood requirements of the local residents of these villages was met from surrounding reserve forests. To some extent, firewood and fodder requirements were also met from the trees protected in the margins of agricultural fields. Leaf litter and firewood collection in the rest of the Banj-oak VP forests and in all the Chir-pine VP forests was not regulated. Tree felling and lopping of branches were prohibited in all sampled Banj-oak as well as Chir-pine VP forests. However, during field visits cut and severely lopped trees were frequently found in most of the Chir-pine VP forests. In the case of Banj-oak VP forests, the occurrence of cut and lopped trees was comparatively lesser. Villagers' activities of forest produce harvest from the VP forests in the study villages were monitored either by a forest guard hired from the village community or by the VP committee members. The quantity of three major forest products, i.e. firewood, fodder, and leaf litter extracted by the villagers from Van Panchayat (VP) forests are given in Table 3. Annual firewood collection in the Banj-oak VP forests (range 276.0±56.1 to 4907.0±2232.6 kg/HH) was higher than the Chir-pine VP forests (range 106.1±68.0 to 3891.0±736.9 kg/HH), although it was not significantly different. Annual fodder collection in the Banj-oak VP forests ranged from 221.2±40.9 to 948.0±175.2 kg/HH. Fodder trees were not available in the Chir-pine forests. Annual leaf-litter collection in Banj-oak VP forests (range 240.3±214.8 to 2997.3±1401.4 kg/HH) was higher than the Chir-pine VP forests (range 108.0±68.9 to 2773.3±741.4 kg/HH).

Biophysical status of forest stands

Efforts were also made to assess the impact of decentralized governance on the biophysical status of various broadleaved (Banj-oak) and coniferous forest stands. The data comprised the density of tree individuals, saplings, seedlings, total basal area, species richness, diversity, and collection of firewood, fodder, and litter (Table 4, Supplementary tables 1 to 4). The Banj-oak VP forests had an average tree density of 797±181 individuals ha^{-1}, which was significantly higher than the average tree density value of 285±154 individuals ha^{-1} of the Chir-pine VP forests. The average total basal area of the Banj-oak VP forest was 34.13±10.88 $m^2 ha^{-1}$, which was

Table 3. Collection of forest produces (i.e. fuel wood, fodder and litter) in studied Van Panchayat forests

VP forests	Fuel wood (n=15)			Fodder (n=15)			Litter (n=15)		
	Collection period (days/HH/ annum)	Collection (kg/HH/ day)	Annual collection (kg/HH)	Collection period (days/HH/ annum)	Collection (kg/HH/ day)	Annual collection (kg/HH)	Collection period (days/HH/ annum)	Collection (kg/HH/ day)	Annual collection (kg/HH)
Banj-oak forests:									
Patharkote 1	15.2±11.5	12.7±9.2	276.0±56.1	10.0±0.0	27.0±6.2	270.0±62.1	12.8±9.6	14.7±9.9	240.3±214.8
Dhaili	10.0±0.0	36.7±8.7	367.3±87.1	10.0±0.0	36.0±6.0	360.0±60.3	10.0±0.0	39.7±6.3	397.3±67.1
Chaniluesal	82.0±26.5	32.0±7.0	2580.0±837.7	10.0±0.0	31.3±5.2	313.3±51.6	83.0±19.1	32.3±6.2	2691.7±833.0
Tana Sajoli	60.0±0.0	24.0±0.0	1440.0±396.1	20.0±0.0	31.3±5.8	626.7±116.3	60.0±0.0	27.7±6.2	1660.0±373.8
Shama	90.7±18.0	31.7±8.8	2885.0±1040.7	30.0±0.0	31.6±5.8	948.0±175.2	89.3±27.3	27.7±5.6	2441.7±835.6
Parbara	187.0±79.5	26.4±7.4	4907.0±2232.6	-	-	-	181.7±45.4	16.7±6.7	2997.3±1401.4
Bhaktura 1	30.86±11.3	31.8±7.2	951.4±352.9	10.0±0.0	31.3±5.8	313.3±58.2	30.0±0.0	32.3±8.2	970.0±186.9
Dol	89.7±23.3	28.7±6.7	2551.7±837.9	7.0±0.0	31.6±5.8	221.2±40.9	89.3±37.3	27.7±5.6	2441.7±835.6
Falyanti	76.0±21.9	30.5±5.2	2331.7±830.8	20.0±0.0	34.0±5.5	680.0±109.3	84.0±20.7	30.0±5.7	2476.7±587.6
Chir-pine forests:									
Patharkote 2	6.4±6.2	18.0±4.5	124.0±54.1	-	-	-	4.0±3.7	9.0±3.2	108.0±68.9
Bhaktura 2	4.0±3.1	8.8±5.7	106.1±68.0	-	-	-	6.2±5.6	13.8±13.7	166.3±144.0
Khadkuna	82.6±21.5	20.3±3.9	1680.0±513.7	-	-	-	64.0±18.8	22.7±6.2	1443.0±576.6
Kaneli	14.0±9.84	28.7±6.9	445±297.1	-	-	-	4.7±1.1	30.7±5.6	141.7±83.6
Champa	109.7±16.8	35.7±5.3	3891.0±736.9	-	-	-	95.3±27.8	27.3±7.0	2575.0±942.2
Dolpokhra	107.1±12.8	31.8±5.9	3440.0±598.9	-	-	-	90.0±16.4	35.7±5.6	2773.3±741.4
Palna	60.7±18.7	28.0±4.5	1696.7±574.9	-	-	-	91.3±22.0	26.3±6.1	2430.0±865.6
Laubanj	82.7±21.7	30.6±3.2	2410.0±741.9	-	-	-	83.7±19.9	32.7±4.6	2528.3±634.4
Ghaurara	85.3±20.3	28.8±6.9	2320.0±620.4	-	-	-	83.7±19.9	33.7±5.6	2528.3±634.4

Note: Tree fodder collection in the Parbara VP forest was banned from last five years; Tree fodder was not available in the Pine VP forests

Table 4. Biophysical status and resource use in the studied VP forests (n=18)

Parameters	Unit	Banj-oak forests (Range)	Chir-pine forests (Range)	t test* (p<)
Tree density	Individuals/ha	587-1200	74-499	0.05
Sapling density	Individuals/ha	90-1320	59-1325	NS
Seedling density	Individuals/ha	1875-10000	0-3750	0.005
Total basal area	m^2/ha	24.16-59.75	2.54-36.08	0.05
Species richness (tree)	No. of Species	3-13	1-7	NS
Species richness (sapling)	No. of Species	4-11	1-10	0.05
Species richness (seedling)	No. of Species	2-8	0-5	0.01
Species diversity	$\bar{H}$	0.69-2.25	0-1.35	0.05
Firewood harvest	kg/HH/Year	276-4907	106-3891	NS
Tree fodder harvest	kg/HH/Year	221-948	-	-
Leaf litter harvest	kg/HH/Year	240-2997	108-2773	NS

HH = household; *t test comparing mean values of forest condition parameters of Banj-oak and Chir-pine forests; NS= Not significant

significantly higher than the 18.17±12.57 $m^2 ha^{-1}$ of Chir-pine VP forests. In the Banj-oak VP forests average sapling density was 618±144 individuals ha^{-1} while it was much lower 359±130 individuals ha^{-1} in Chir-pine VP forests. The average seedling density of Banj-oak VP forests was 6224±856 individuals ha^{-1}, which was significantly higher than the average seedling density (i.e. 1492±506 individuals ha^{-1}) of Chir-pine dominated VP forests. The Banj-oak VP forests exhibited higher tree layer species richness (9.89±2.35) than the Chir-pine forests (3.67±2.41). At the sapling layer, the average species richness in Banj-oak VP forests was 7.44±2.12, which was significantly higher than the average sapling species richness i.e. 3.33±2.65 of the Chir-pine VP forests. The Banj-oak stands also exhibited significantly higher seedling species richness (5.67±2.18) than the Chir-pine stands (2.33±1.87). The Shannon diversity index value of Banj-oak VP forests (1.40±0.16) was also significantly higher than the Chir-pine stands (0.65±0.17) (Table 4, Supplementary table 5).

An assessment of tree girth class distribution patterns of various forests was also undertaken as an indicator of forest stand quality. The data are presented on a logarithmic scale for all investigated Banj-oak and Chir-pine stands (Figs. 2, 3). The results revealed a reverse J-shaped distribution with a preponderance of individuals of lower girth classes than higher ones. The girth size decrease from low to higher classes was more systematic in Banj-oak stands. Although it was slightly distorted in Chir-pine stands showing that later stands are under more biotic pressure.

Clustering of vegetation data

The 18 forest stands were analyzed for their similarity or heterogeneity using density as a vegetational parameter and showed two major groups (i.e. i and ii) for all three vegetation categories (i.e. tree, sapling, and seedling). In the case of the tree layer, group one, as expected, mostly represents Chir-pine stands (Fig. 4a1). The second group exclusively represents Banj-oak stands. However, in the sapling layer, group one represents both Chir-pine and Banj-oak stands, whereas group second represents only Banj-oak stands (Fig. 4a2). While considering the seedling layer, group second represents only one Banj-oak stand (Fig. 4a3) indicating that the distribution of seedlings in that stand is substantially different from the distribution in the remaining stands. The group first, in the case of the seedling layer, can further be divided into two subgroups. Based on species richness at the tree (Fig. 4b1), sapling (Fig. 4b2), and seedling (Fig. 4b3) layers also exhibited 3, 3, and 2 broad clusters showing clear differences in species at both Banj-oak and Chir-pine stands.

Comparison with other Banj-oak and Chir-pine forest stands

The data clearly showed that various investigated

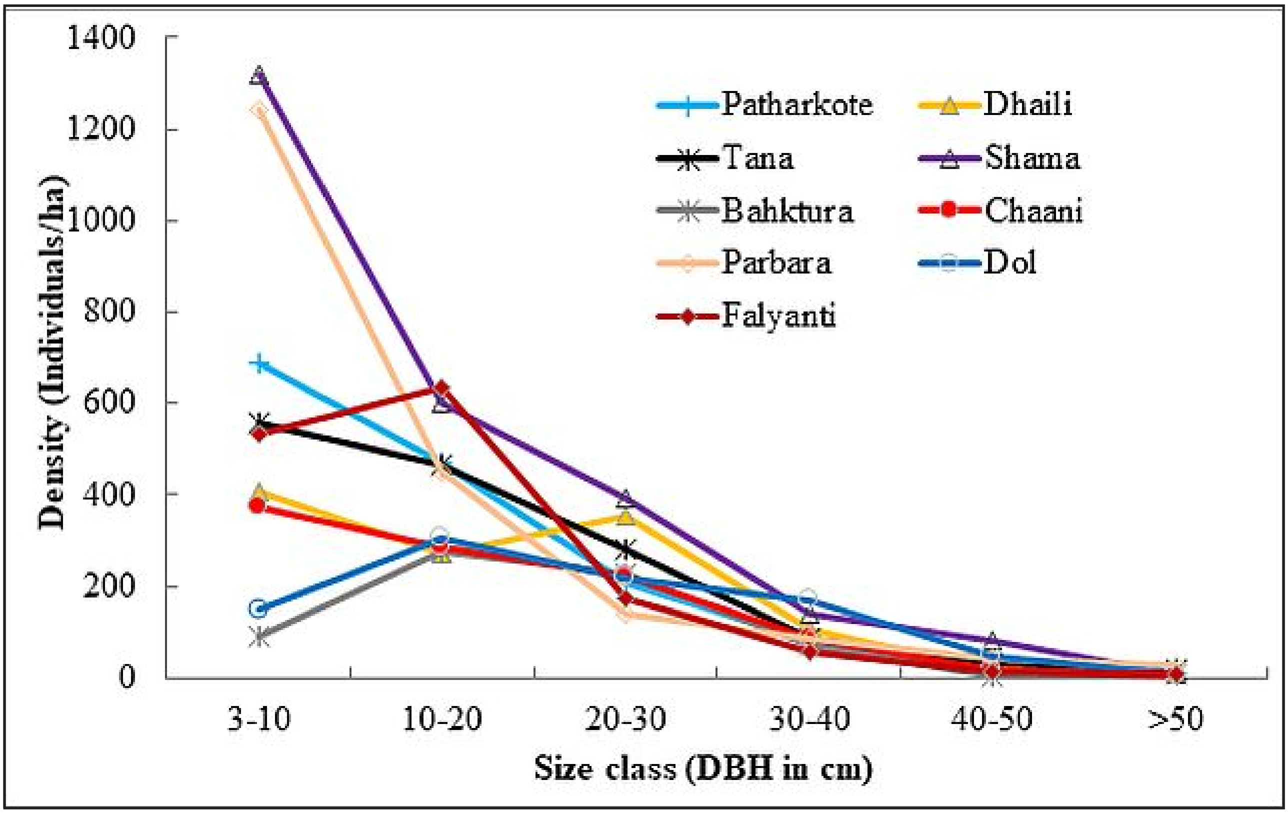

Figure 2. Girth class structure of Banj-oak dominated VP forests

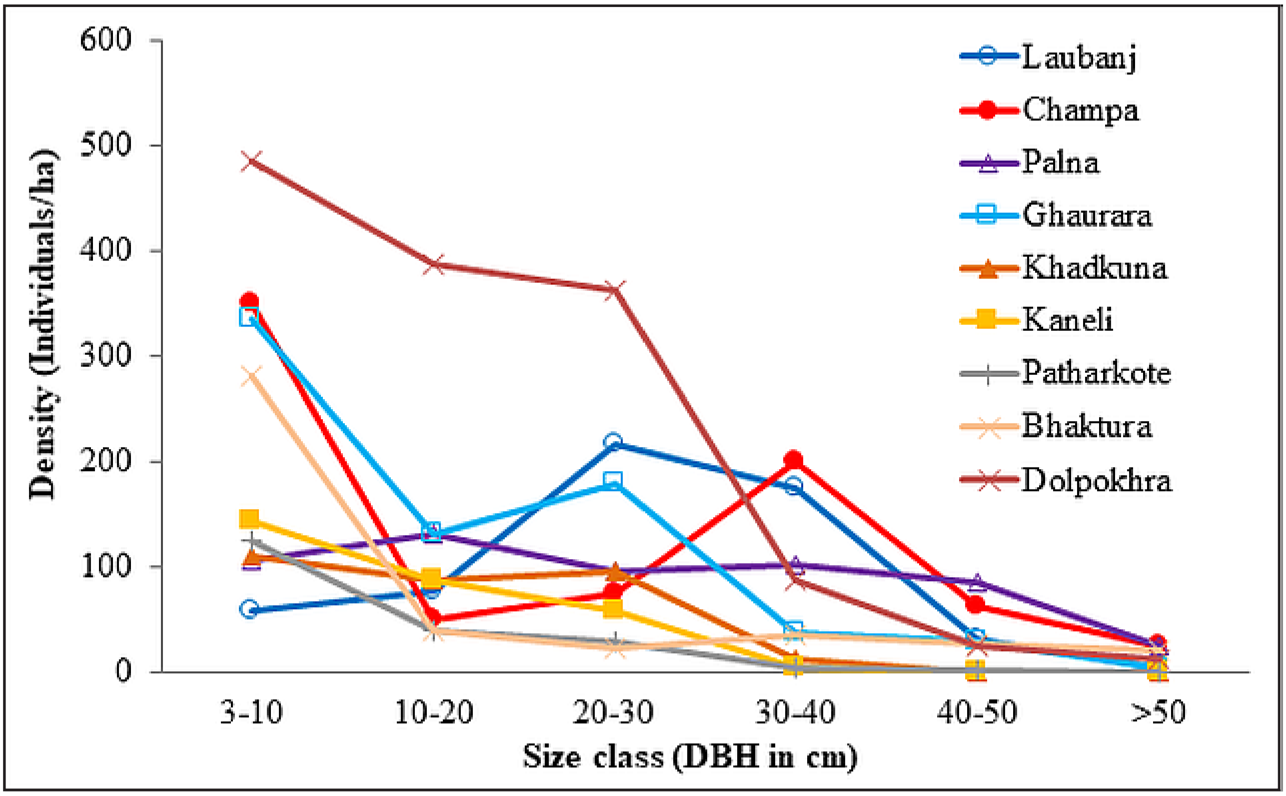

Figure 3. Girth class structure of Chir-pine dominated VP forests

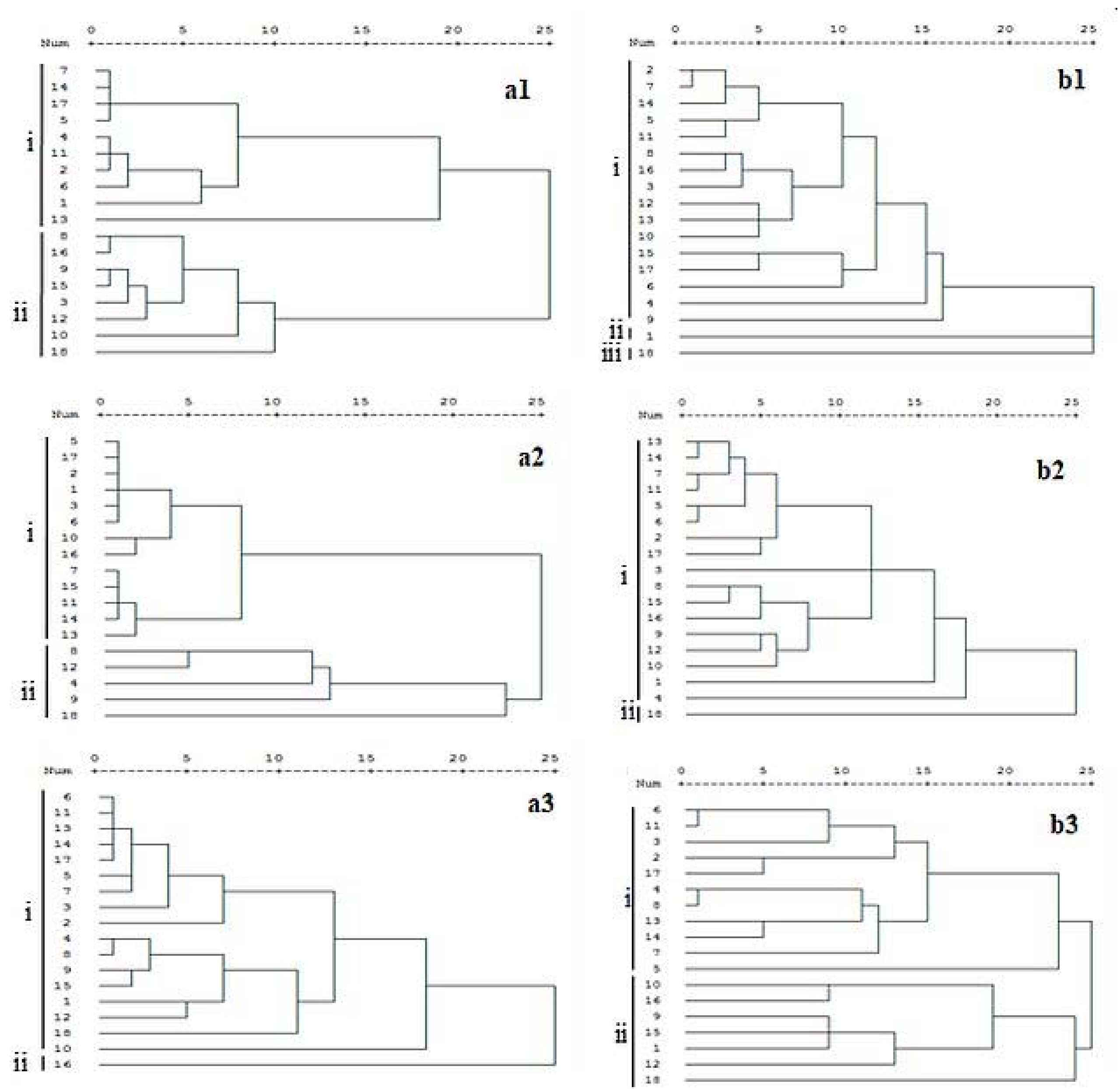

Figure 4. Clustering of all forest stands with respect to tree density (a1), sapling density (a2) and seedling density (a3); and tree species richness (b1), sapling species richness (b2) and seedling species richness (b3). 1 Dol Oak, 2 Kadkuna Pine, 3 Bhaktura Oak, 4 Bhaktura Pine, 5 Laubanj Pine, 6 Patharkote Pine, 7 Ghaurara Pine, 8 Patharkote Oak, 9 Parbara Oak, 10 Tana-Sajoli Oak, 11 Kaneli Pine, 12 Falyanti Oak, 13 Dolpokhra Pine, 14 Champa Pine, 15 Chaniluesal Oak, 16 Dhaili Oak, 17 Palna Pine, and 18 Shama Oak

Banj-oak and Chir-pine forests support varied ecosystem services and exhibited distinct biophysical conditions and species richness (biodiversity) and forest conservation status. An effort was made to compare the stand density and total basal area of all investigated forests with less disturbed forest stands in the region (Table 5). Our values of tree density in Banj-oak stands falls within the range of the values reported for similar less disturbed stands. In the Shama VP stand, the tree density was higher than other Banj-oak stands in the region. In the case of Chir-pine stands, the tree density value of only two forest stands lies within the range of the values reported for less disturbed Chir-pine forest stands of

Table 5. Structural characteristics of some less disturbed Banj-oak and Chir-Pine forests of the western Himalayan region

Forest types	Altitude (m)	Density (trees ha^{-1})	Total basal area ($m^2 ha^{-1}$)	Reference
Banj-oak	2065	1042	48.40	Stephenson and Saxena (1994)
	1950-2025	940	53.02	Saxena and Singh (1984)
	1950	570	36.83	Rawat and Singh (1988)
	2194-2240	760	35.84	Rawat and Singh (1988)
	-	-	-	Upreti et al. (1985)
	-	-	35.57	Tewari (1992)
	1800-2200	600	36	Thadani and Ashton (1995)
	1710-2045	891.72	-	Ilyas and Khan (2006)
	2060-2200	841.67	-	Ilyas and Khan (2006)
	1880-1980	787.68	-	Ilyas and Khan (2006)
	1200-2300	741	40.90	Singh and Singh (1987)
	1600	580	43.7	Rawat and Pangtey (1994)
Chir-pine	1280-1320	420	30.24	Saxena and Singh (1982)
	1700	-	35.92	Rana et al. (1988)
	1300	700	45.40	Chaturvedi and Singh (1987)
	-	-	37.24	Tewari and Singh (1985)
	-	900	-	Kala (2004)
	-	800	-	Kala (2004)
	1750	657	36.30	Ralhan et al. (1982)
	1300	700	45.4	Singh and Singh (1987)
	1300	580	37.1	Rawal and Pangtey (1994)

the region. The tree density value of other studied Chir-pine VP forests was too low than the values reported for less disturbed similar forests showing that they are under higher biotic pressure. The total basal area (TBA) value of investigated Banj-oak VP forests was lesser than other similar undisturbed forest stands showing that these forests are evolving. With a higher number of individuals in younger size classes (Figs. 2, 3) most of the sampled Banj-oak VP forests were young growth, therefore, exhibited low basal area values as compared to less disturbed mature stands of the same forest type of the region. In the case of Chir-pine-dominated VP forests, the TBA of most of the forest stands does not fall within the range of the values reported for undisturbed stands of the same forest type of the region.

DISCUSSION

Forests are important suppliers of diverse household needs in rural communities. While uncontrolled harvesting often leads to resource degradation, the forest produce regulation by the users themselves in the forests under community control can significantly halt this degradation (Bowler et al. 2012, Gupta et al. 2020). In the present study, we evaluated decentralized forest governance, equitable distribution of forest produces, and status in 18 randomly selected VP forest stands in the Central Himalayan region. The community forests in the region are governed by certain regulations (Negi et al. 2012, Germain et al. 2018). These forest types comprised broad-leaved Banj-oak and coniferous Chir-pine stands. Both the forest types supported substantial livelihood benefits in the form of firewood, fodder, and leaf litter to the local residents. In the Central Himalayan region, the local communities fulfill their daily requirements. It was found that the better quality and quantity of goods supplied by Banj-oak stands in terms of firewood, green tree fodder, and litter for animal bedding and manuring, thus helping in managing soil fertility and water retention. Contrarily, Chir-pine forests support poor fodder (herbage), firewood, and other services (Negi 2022). Besides, such forests do not have a good humus layer with highly acidic soil and play a minimal role in water conservation (Sinha 2002). Chir-pine needles although used for animal bedding, however, allow low-grade manure than Banj-oak litter. Although there is some extraction of timber and resin from the VP forests, however, it is largely regulated by the government. Moreover, the accumulation of Chir-pine needles often leads to fire hazards in such forests. Because of this, Chir-pine forests are less socially valued than Banj-oak forests (Joshi and Negi 2011). It is argued that the quality and quantity of forest goods and services largely depend on available species types, and villagers pay greater attention to such forests that provide higher livelihood support to them (Somanathan 1991, Gibson et al. 2007, Samii et al. 2015).

A comparison of tree density and basal area values of presently studied VP forests with less disturbed forest stands of the same forest types of the region clearly indicated that the Banj-oak VP forests are better managed than the Chir-pine VP forests. The quality of forests also depends on the potential regenerative status of species composing the forest stand, in space and time (Sundriyal and Bisht 1988, Barker and Kirkpatrich 1994). The regeneration status of a forest is generally determined by assessing the number of seedlings and saplings per unit area (density) and by constructing girth class structures. Seedling and sapling density in undisturbed government-reserved Banj-oak forests of the region generally range between 4165-5899 and 879-1380 individuals ha^{-1}, respectively (Saxena and Singh 1984, Rawat and Singh 1988).

The seedling density of all presently studied Banj-oak VP forests is well within the range of the values reported for less disturbed government reserve Banj-oak forests of the region. The sapling density of most of the studied Banj-oak VP forests is also within the range of the values reported for less disturbed government-reserved Banj-oak forests of the region. In the case of Chir-pine VP forests, the seedling and sapling density ranged between 0-3750 and 59-1325 individuals ha^{-1}, respectively. Saxena and Singh (1984) have reported a seedling density value of 5432 individuals ha^{-1} for a less disturbed government-reserved Chir-pine forest of the region. Despite having a frequent reproducing nature (Singh and Singh 1992), none of the studied Chir-pine VP forests showed a seedling density value close to the value reported by Sexena and Singh (1984) showing that such forests are under more pressure in recent times. Sapling density in most of the Chir-pine VP forests is too low and does not fall within the range of the values reported for undisturbed stands of the same forest type of the region.

A careful analysis of the girth class structure further confirms disturbance history in Banj-oak and Chir-pine stands that exhibited a more exponential girth class distribution in former stands with a clear preponderance to lower girth classes in Banj-oak stands while it was more distorted in Reverse J shaped girth class structures have often been reported for well regenerating less disturbed forest stands (Deb and Sundriyal 2008). In the present study, the reverse J-shaped girth class structures of most of the Banj-oak VP forests clearly indicate that these forests are in a good regenerating state. The slight bulge in the middle region of these graphs may indicate comparatively less mortality and/or good growth of trees of the intermediate girth classes. In contrast, the irregular girth class structures of most of the Chir-pine VP forests imply the poor regeneration condition of these forests. The present enumeration and analysis of ecological information of contrasting forest types under community control clearly indicate that the broadleaved Banj-oak VP forests are in far better condition than the Chir-pine VP forests that are under more pressure. Furthermore, the clustering of vegetation data based on density and species richness at tree, sapling, and seedling layers describes different species habitat preferences of Banj-oak and Chir-pine forest stands. The information characterizes to differentiate species into various groups as per the similarity between species (Lookingbill et al. 2010, Zhang et al. 2017).

The variation in the biophysical condition of Banj-oak and Chir-pine-dominated VP forests can be correlated to a large number of factors such as forest size, rule enforcement, leadership quality, and use value (Agrawal and Goyal 2001). Among these factors, enforcement of locally devised rules is an essential condition for effective governance of the resources (Gibson et al. 2005, Coleman 2009). Many empirical studies have found that the probability of effective governance increases with increasing levels of local rule enforcement (Chhatre and Agrawal 2009, Nagendra 2007, Cadman et al. 2023). To protect the forest from over-harvesting, management rules have been crafted in both Banj-oak and Chir-pine-dominated VPs. The poor regeneration status (low seedling density and irregular distribution of individuals across different girth classes) and occurrence of severely lopped and cut trees in the Chir-pine VP forests, however, indicates a level of pressure on individual stands. In contrast, the better regeneration and girth class status, and the absence of stumps in Banj-oak VP forests indicate that the management rules and sustainable harvesting of forest produce are strictly followed by the villagers. Since the Banj-oak forests provide qualitatively superior benefits to the villagers as compared to Chir-pine forests, the higher utility of Banj-oak forests generates enough incentive among the rural communities to use these forests in a sustainable manner (Joshi and Negi 2011). In this study, there were two villages i.e. Patharkote and Bhaktura which have both Banj-oak and Chir-pine forest stands. A comparatively better condition of Banj-oak forests than the Chir-pine forests in these two villages further clarifies the above justification.

Nevertheless, it cannot be said that the condition of all the Chir-pine VP forests is poor all over the state. The present study indicated that on a random sample the probability of Banj-oak VP forests being in good condition than the Chir-pine stands. In many places (but not in all), Chir-pine VP forests can also be found in good condition as recorded in this investigation at Laubanj and Palna. It could be attributed to better local leadership that plays an important role in local resource governance (Vedelt 2000) and exhibited effective enforcement of forest conservation measures (Meninzen-Dick 2007). The institution of VP is headed by a *Sarpanch* who acts as a leader and most management works are a result of his/her ability. In fact, in places where Banj-oak forests are not available, the Chir-pine forests are the only source from where the local communities get livelihood benefits. In the Laubanj and Palna villages, most of the forest vegetation was dominated by Chir-pine and these forests were the only source from where villagers acquired firewood and leaf litter for manuring.

CONCLUSIONS

The study clearly revealed that communities extensively use both Banj-oak and Chir-pine stands as per the forest category available to them to meet their subsistence needs, however, the type of species impacts the biophysical condition of forests under community control as there was a greater inclination for the earlier category because of more benefits. VPs play an important role in managing forest resources and ensuring a sustainable supply of diverse produces. The study also revealed that the biophysical condition of forest impact species richness (biodiversity) thus leading to better forest conservation that is evident in the quality of forests. However, the important challenge is how to best manage both types of forest stands. The villager best utilize their capacity in managing resources in both types of stands, there is a need to improve them further. For example, In order to further improve the status of Banj-oak forests, community-led management needs to be improved in relation to leadership development, rationale use of bio-resources, equity of benefit-sharing, and various management strategies. Similarly, to improve the status of Chir-pine forests community needs to be educated to reduce forest fire, and to promote the plantation of multipurpose broadleaved tree species to increase community benefits. Although the local government has taken up various policy initiatives designed to encourage decentralized forest governance, it is yet to achieve the desired results. A proper strategy should be tailored in forest policies to support decentralized governance as it would lead to reducing the burden on a centralized system. Developing an appropriate micro plan for each VP forest, covering short- and long-term livelihood and environmental goals should be developed and implemented. Moreover, smallholders should be engaged in various forest enterprise development and climate action programs to shape better forest outcomes. For this, developing local leadership and building their skill in sustainable forest management are most desired. In recent years there are many networks that support forest producers to strengthen benefits from forest areas and harness their potential to sustainably manage forest resources (Anonymous 2017). It can be done by developing alliances of village institutions with various civil society groups, governments, and other partners. Also, implementing proper policy advocacy is highly desirable to improve the status of many community forests. If properly implemented decentralized governance will not only satisfy community needs but also mitigate climate change and adapt to its impact; ultimately leading to contribute significantly to the social and environmental resilience of the region.

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Supplementary table 1. Vegetation analysis of Banj-oak dominated Van Panchayat forests, Uttarakhand, Central Himalaya

Location	Species composition	Density (ind./ha)	Frequency (%)	Abundance	Basal area (m^2/ha)	A/F	IVI
Patharkote 1	*Q. leucotrichophora*	470	100	47.00	15.87	0.47	158.45
	Myrica esculenta	247	60	24.75	6.83	0.41	91.67
	R. arboreum	20	20	2.67	0.64	0.13	28.38
	P. roxburghii	20	50	4.00	0.84	0.08	21.50
	Total	**757**			**24.16**		**300.00**
Bhaktura 1	*Q. leucotrichophora*	565	100	56.50	28.01	0.57	231.45
	P. roxburghii	12	75	1.67	2.67	0.02	44.12
	Myrica esculenta	10	50	2.00	0.16	0.04	24.44
	Total	**587**			**30.84**		**300.00**
Chaniluesal	*Q. leucotrichophora*	500	100	50.00	23.80	0.50	205.67
	P. roxburghii	98	60	16.33	2.23	0.27	45.57
	R. arboreum	2	20	1.00	0.02	0.05	7.54
	Cedrus deodara	18	60	3.00	0.34	0.05	25.61
	Acacia mearnsii	2	20	1.00	0.15	0.05	8.03
	Cupressus torulosa	2	20	1.00	0.03	0.05	7.57
	Total	**622**			**26.57**		**300.00**
Dhaili	*Q. leucotrichophora*	459	100	33.50	27.24	0.34	180.61
	Myrica esculenta	219	88	10.86	3.21	0.12	58.61
	R. arboreum	38	50	7.75	2.60	0.16	32.64
	P. roxburghii	35	38	9.33	1.21	0.25	23.50
	Pyrus pashia	1	13	1.00	0.01	0.08	4.63
	Total	**753**			**34.27**		**300.00**
Falyanti	*Q. leucotrichophora*	501	100.00	50.00	10.70	0.50	118.11
	P. roxburghii	190	100.00	19.00	12.08	0.19	88.29
	R. arboreum	121	100.00	12.17	1.89	0.12	41.07
	Myrica esculenta	53	100.00	5.33	0.94	0.05	29.69
	Lyonia ovalifolia	13	83.33	1.60	0.19	0.02	18.90
	Castanopsis tribuloides	3	16.67	2.00	0.06	0.12	3.95
	Total	**883**			**25.85**		**300.00**
Tana Sajoli	*Q. leucotrichophora*	348	100	34.88	10.46	0.35	92.61
	Q. glauca	246	88	28.14	8.53	0.32	72.74
	Myrica esculenta	142	88	16.29	4.79	0.19	51.23
	P. roxburghii	126	75	16.83	14.33	0.22	71.02
	R. arboreum	17	25	7.00	0.21	0.28	8.98
	Lyonia ovalifolia	1	12	1.00	0.02	0.08	3.42
	Total	**882**			**38.35**		**300.00**
Parbara	*Q. leucotrichophora*	470	100	47.00	14.32	0.47	111.11
	P. roxburghii	60	40	15.00	3.80	0.38	57.90
	R. arboreum	54	30	18.00	4.29	0.60	35.87
	Myrica esculenta	40	47	8.51	2.12	0.18	26.67
	Lyonia ovalifolia	32	38	8.42	0.32	0.22	25.98
	Cupressus torulosa	25	18	13.89	0.45	0.77	12.65
	Q. semecarpifolia	20	60	3.33	2.28	0.06	14.17
	Cedrus deodara	20	25	8.00	1.55	0.32	10.87
	Pyrus pashia	19	16	11.88	0.35	0.74	4.78
	Total	**740**			**29.48**		**300.00**

Location	Species composition	Density (ind./ha)	Frequency (%)	Abundance	Basal area (m^2/ha)	A/F	IVI
Shama	*Q. leucotrichophora*	530	100	5.30	22.77	0.05	103.11
	R. arboreum	280	100	2.80	12.33	0.03	64.80
	Lyonia ovalifolia	140	80	1.75	4.94	0.02	36.60
	Q. lanuginosa	70	50	2.80	8.69	0.06	30.80
	Q. glauca	20	20	1.00	0.84	0.05	7.24
	Alnus nepalensis	60	50	1.20	5.09	0.02	23.94
	Pyrus pashia	40	30	1.33	2.52	0.04	13.80
	Symplocos chinensis	10	10	1.00	0.41	0.10	3.61
	Neolitsea pallens	30	30	1.00	1.90	0.03	11.92
	Ficus palmata	20	10	2.00	0.26	0.20	4.18
	Total	**1200**			**59.75**		**300.00**
Dol Gajar	*Q. leucotrichophora*	178	80	21.50	8.15	0.27	54.18
	P. roxburghii	160	80	20.00	13.43	0.25	66.50
	R. arboreum	172	80	22.25	7.14	0.28	52.33
	Myrica esculenta	76	100	7.60	3.67	0.08	32.01
	Lyonia ovalifolia	62	80	7.75	1.50	0.10	21.98
	Pyrus pashia	28	100	2.80	0.97	0.03	18.48
	Alnus nepalensis	38	60	6.33	2.14	0.11	18.03
	Q. floribunda	4	20	2.00	0.10	0.10	3.24
	Symplocos racemosa	16	80	2.00	0.36	0.03	12.85
	Cornus capitata	4	40	1.00	0.07	0.03	5.59
	Celtis australis	3	20	2.00	0.20	0.10	3.49
	Cryptolepis buchanani	6	60	1.00	0.15	0.02	8.51
	Betula alnoides	2	20	1.00	0.04	0.05	2.82
	Total	**750**			**37.92**		**300.00**

IVI= Importance value index (sum of relative frequency + relative density + relative dominance)

Supplementary table 2. Vegetation analysis of Chir-pine dominated Van Panchayat forests, Uttarakhand, Central Himalaya

Location	Species composition	Density (ind./ha)	Frequency (%)	Abundance	Basal area (m^2/ha)	A/F	IVI
Dolpokhra	*P. roxburghii*	125	100	7.25	12.09	0.07	205.84
	Myrica esculenta	75	63	1.20	3.01	0.02	42.46
	Lyonia ovalifolia	25	25	1.00	0.52	0.04	14.70
	Q. leucotrichophora	25	25	1.00	1.69	0.04	17.64
	Alnus nepalensis	13	13	1.00	2.24	0.08	12.34
	R. arboreum	12	13	1.00	0.13	0.08	7.02
	Total	**275**			**19.68**		**300.00**
Bhaktura 2	*P. roxburghii*	112	100	11.25	12.44	0.11	206.12
	Q. leucotrichophora	10	25	4	0.11	0.16	16.82
	Syzygium cumini	5	50	1	0.40	0.02	24.55
	Myrica esculenta	2	25	1	0.03	0.04	11.02
	Bombax ceiba	2	25	1	0.24	0.04	12.56
	Q. serrata	5	25	2	0.09	0.08	13.24
	Lyonia ovalifolia	7	25	3	0.19	0.12	15.69
	Total	**145**			**13.50**		**300.00**

Location	Species composition	Density (ind./ha)	Frequency (%)	Abundance	Basal area (m^2/ha)	A/F	IVI
Palna	*P. roxburghii*	350	100	35.00	29.41	0.35	203.63
	Q. leucotrichophora	36	20	18.00	1.33	0.90	19.30
	Myrica esculenta	14	20	7.00	0.49	0.35	11.79
	R. arboreum	6	20	3.00	0.26	0.15	9.29
	Cedrus deodara	18	40	4.50	1.29	0.11	22.26
	Acacia mearnsii	18	80	2.25	0.36	0.03	33.74
	Total	**442**			**33.15**		**300.00**
Laubanj	*P. roxburghii*	470	100.00	47.11	30.01	0.47	257.60
	Alnus nepalensis	27	33.33	8.33	1.81	0.25	34.31
	Pyrus pashia	1	11.11	1.00	0.06	0.09	8.09
	Total	**499**			**31.87**		**300.00**
Patharkote 2	*P. roxburghii*	15	66.67	2.33	0.83	0.03	96.24
	Alnus nepalensis	42	22.22	19.50	1.10	0.88	114.91
	Q. leucotrichophora	4	22.22	2.00	0.04	0.09	21.70
	Cupressus torulosa	11	33.33	3.33	0.56	0.10	58.02
	Acacia mearnsii	1	11.11	1.00	0.01	0.09	9.13
	Total	**74**			**2.54**		**300.00**
Kaneli	*P. roxburghii*	123	75.00	14.14	5.25	0.19	235.40
	Alnus nepalensis	18	37.50	5.00	1.16	0.13	64.60
	Total	**142**			**6.41**		**300.00**
Khadkuna	*P. roxburghii*	195	100	19.50	6.85	0.20	300.00
	Total	**195**			**6.85**		**300.00**
Ghaurara	*P. roxburghii*	380	100	38.00	18.82	0.38	300.00
	Total	**380**			**18.82**		**300.00**
Champa	*P. roxburghii*	400	100	4.00	35.97	0.04	285.54
	Myrica esculenta	13	13	1.00	0.12	0.08	14.46
	Total	**413**			**36.08**		**300.00**

IVI= Importance value index (sum of relative frequency + relative density + relative dominance)

Supplementary table 3. Sapling and seedling density (individuals ha^{-1}) of Banj-oak dominated Van Panchayat forests

Location	Species	Sapling	Seedling
Patharkot 1	*Q. leucotrichophora*	505	2500
	Myrica esculenta	140	0
	R. arboreum	8	0
	P. roxburghii	20	1250
	Prunus cerasoides	10	0
	Pyrus pashia	5	0
	Total	**688**	**3750**
Bhaktura 1	*Q. leucotrichophora*	67	0
	Prunus cerasoides	10	625
	Grewia optiva	3	0
	Pyrus pashia	10	1250
	Total	**90**	**1875**

Location	Species	Sapling	Seedling
Chaniluesal	*Q. leucotrichophora*	8	2500
	Pinus roxburghii	290	1797
	R. arboreum	34	859
	Cedrus deodara	22	0
	Pyrus pashia	10	859
	Myrica esculenta	10	0
	Lyonia ovalifolia	0	391
	Ficus roxburghii	0	78
	Total	**374**	**6484**
Dhaili	*Q. leucotrichophora*	329	2656
	Myrica esculenta	119	1094
	R. arboreum	83	1484
	P. roxburghii	59	2031
	Ficus palmata	14	0
	Cryptolepis buchanani	1	0
	Pyrus pashia	4	78
	Q. glauca	0	2656
	Total	**608**	**10000**

Location	Species	Sapling	Seedling
Falyanti	*Q. leucotrichophora*	311	1563
	Pinus roxburghii	17	1563
	R. arboreum	75	938
	Myrica esculenta	67	521
	Lyonia ovalifolia	52	1250
	Pyrus pashia	3	729
	Castanopsis tribuloides	2	729
	Elaeagnus parvifolia	7	625
	Total	533	7917
Tana-Sajoli	*Q. leucotrichophora*	101	1875
	Q. glauca	78	2344
	Myrica esculenta	63	938
	Pinus roxburghii	118	1484
	R. arboreum	128	1172
	Lyonia ovalifolia	54	0
	Morus alba	15	625
	Pyrus Pashia	3	469
	Total	558	8906
Parbara	*Q. leucotrichophora*	310	2856
	P. roxburghii	190	1343
	R. arboreum	213	783
	Myrica esculenta	224	514
	Lyonia ovalifolia	198	323
	Q. semecarpifolia	86	34
	Pyrus pashia	21	43
	Total	1242	5896
Shama	*Q leucotrichophora*	320	2500
	R. arboreum	340	859
	Lyonia ovalifolia	340	391
	Neolitsea pallens	110	0
	Q. lanuginosa	120	0
	Alnus nepalensis	10	0
	Q. floribunda	20	0
	Ficus subincisa	20	0
	Symplocos chinensis	20	78
	Pyrus pashia	10	859
	Ficus palmata	10	0
	Ficus roxburghii	0	1797
	Total	**1320**	**6684**
Dol	*Pinus roxburghii*	46	750
	Q. leucotrichophora	12	1000
	R. arboreum	16	1250
	Myrica esculenta	6	500
	Lyonia ovalifolia	6	500
	Purus pashia	6	250
	Symplocos racemosa	40	0
	Viburnum cotinifolium	2	250
	Celtis australis	12	0
	Betula alnoides	2	0
	Total	**148**	**4500**

Supplementary table 4. Sapling and seedling density (individuals ha^{-1}) of Chir-pine VP forests

Location	Species	Sapling	Seedling
Dolpokhra	*Pinus roxburghii*	368	328
	Myrica esculenta	32	45
	Lyonia ovalifolia	86	12
	Total	**486**	**385**
Bhaktura 2	*Q. leucotrichophora*	450	1875
	Lyonia ovalifolia	175	0
	Syzygium Cumini	50	0
	Pinus roxburghii	25	1250
	Albizia stipulata	50	0
	Pyrus pashia	225	0
	Quercus serrata	25	0
	Ficus palmata	25	0
	Ficus roxburghii	25	0
	Myrica esculenta	275	0
	Total	**1325**	**3125**
Palna	*Pinus roxburghii*	70	625
	Acacia mearnsii	22	625
	Myrica esculenta	6	0
	Q. leucotrichophora	8	0
	Total	**106**	**1250**
Laubanj	*P. roxburghii*	53	903
	Alnus nepalensis	6	347
	Ficus palmata	0	417
	R. arboreum	0	69
	Pyrus pashia	0	556
	Total	**59**	**2292**
Patharkote 2	*Pinus roxburghii*	25	0
	Q. leucotrichophora	50	0
	Alnus nepalensis	50	0
	Total	**125**	**0**
Kaneli	*Pinus roxburghii*	283	0
	Pinus wallichiana	50	0
	Total	**333**	**0**
Khadkuna	*P. roxburghii*	103	1875
	Pyrus pashia	3	1250
	Acacia mearnsii	5	625
	Total	**110**	**3750**
Ghaurara	*Pinus roxburghii*	334	1125
	Q. leucotrichophora	0	375
	Q. glauca	0	375
	Myrica esculenta	0	250
	Lyonia ovalifolia	0	250
	Total	**334**	**2375**
Champa	*P. roxburghii*	275	250
	Myrica esculenta	75	0
	Total	**350**	**250**

Supplementary table 5. Species richness and diversity of trees, saplings and seedlings in studied VP forests

VP forests	Species richness			Species diversity (H)
	Trees	Saplings	Seedlings	
Banj-oak forest				
Patharkot	4	6	2	1.11
Bhaktura	3	4	2	0.69
Chaniluesal	6	6	6	1.04
Dhaili	5	7	6	1.13
Falyanti	6	8	8	1.46
Tana-Sajoli	6	8	7	1.51
Parbara	9	7	7	1.56
Shama	10	11	6	1.86
Dol	13	10	7	2.25
Chir-pine forest				
Dolpokhra	6	3	3	1.07
Bhaktura	7	10	2	1.17
Palna	6	4	2	1.11
Laubanj	3	2	5	0.48
Patharkote	5	3	0	1.35
Kaneli	2	2	0	0.52
Khadkuna	1	3	3	0.00
Ghaurara	1	1	5	0.00
Champa	2	2	1	0.19