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Research article

Natural regeneration dynamics of dominant tree species along an altitudinal gradient in three different forest covers of Darhal watershed in north western Himalaya (Kashmir), India

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Abstract: Regeneration is a cost effective natural process by which plants re-establish themselves and this strategy help the plants to maintain their diversity and genetic identity. This study was undertaken in three different forest cover types which were dominated by *Quercus incana*, *Persea duthiei and Abies pindrow*, respectively. The aim of the present study was to investigate the regeneration pattern of dominant tree species along the altitudinal gradient in Darhal watershed, situated in the Pir Panjal mountain region of Jammu and Kashmir State. A total of 14 tree species were recorded. The tree density varied between 492 to 1325 individuals/ ha, whereas the total basal area ranged between 25.88 to 188.90 m^2 ha^{-1}. In general the density of seedlings, saplings and trees increased with increase in elevation. All the three forest types have poor regeneration. The recruitment of *Q. incana* seedlings and the rate of conversion of *A. pindrow* seedlings to saplings and then saplings to young trees were very low. Proper care needed to prevent excessive exploitation of these forests and livestock grazing should be controlled in all these forest types to conserve these forests. Our study results could help for better management plans for sustainable management and conservation of Himalayan mountain forests, especially in Pir Panjal mountain region.

Keywords: Darhal watershed - Density - Elevation gradient - Regeneration status.

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INTRODUCTION

The Himalayas are one of the richest and vast mountain ecosystems on earth covering India, Pakistan, Afghanistan, Nepal, Bhutan, Bangladesh, China and Myanmar (Semwal *et al*. 2004). Himalayas are diverse with a variety of forest covers due to elevation and climatic gradients as the vegetation community had a direct relationship with altitude (Mani 1978). The Himalayan forest cover plays a significant role in providing many ecological services to the human population and their livestock; however management of these forest types have not been addressed properly due to inadequate reliable information on watershed and forest distinctiveness. A majority of watersheds in the Himalayan region are experiencing a decline in different forest covers and agricultural land use type has happened to be the main constituent of the current landscape (Sundriyal *et al.* 1994). Studies of demographic structure and population dynamics are important for understanding coexistence mechanism of the tree species and long-term ecological status of forests (Miura *et al*. 2001). Population structure determines the dominant status of tree species and development within the forest community (Gairola *et al*. 2014). The species existence and recruitment process in a forest mostly depends on its regeneration potential under varied climatic factors, competition between species, predation and anthropogenic disturbances. Based on the demographic structure, the regeneration processes of tree species may reveal the seral stage of the community and understand the prospective climax vegetation of a particular region (Mishra *et al.* 2013, Gariola *et al*. 2014). The presence of the sufficient number of young trees, saplings and seedlings in a specific forest population indicates that the tree species are able to regenerate successfully (Khan *et al.* 1987). Jammu & Kashmir (J&K) State is a part of the north western Himalaya and has rich phytodiversity like rest of western

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Himalaya. These forest types are susceptible to variations in climatic conditions. Moreover, the impacts of different types of anthropogenic disturbances such as over grazing, lopping, tree extraction, fodder and fuel wood extraction, road building, defense and other development activities are severe and damaged the tree diversity in the region (Barik *et al.* 1996, Gupta 2004, Kumar & Sharma 2014). These forest covers are considered valuable as they are rich in biodiversity and a sensitive indicator towards climate alterations and anthropogenic influences (Rawal & Dhar 1997). Inadequate regeneration is the main problem of forests in mountain regions (Krauchii *et al.* 2000). Sustainable conservation of forests involves proper planning and management of seedlings, saplings and young trees that ensure maintenance of forest community structure and ecological stability (Moravie *et al.* 1997). Successful management of forest covers needed reliable research data on aspects such as structural attributes and demographic profile of tree species. Therefore, it is important to study the population structure and regeneration potentials of different natural forest trees in Kashmir Himalaya to determine the probable trends of vegetation in the future. Several studies were conducted in western Himalaya on phytodiversity and phytosociology aspects by various workers (Saxena & Singh 1982, Bankoti 1990, Rawal & Pangtey 1994, Singh *et al*. 1994, Baduni 1996, Dhar *et al*. 1997, Baduni & Sharma 1999, Ghildiyal *et al*. 1998, Kumar & Ram 2005, Gairola *et al*. 2008, Gairola *et al*. 2012; Pala *et al.* 2012, Gairola *et al*. 2014, Kumar & Sharma 2014, Dar & Sundarapandian 2015). However, information related to the regeneration dynamics of different forest covers in this area is still lacking. Taking into consideration this gap, we explored the population structure of tree species along the elevation gradients in subtropical, temperate and subalpine forests of Pir Panjal mountain region of western (Kashmir) Himalaya and to suggest some strategies for successful regeneration of dominant tree species in this sensitive ecological mountain region.

MATERIALS AND METHODS

Study area

The present study was carried out in Darhal watershed which is situated (latitude 33°23′32″–33°24′18″ N and longitude 74°18′38″–74°30′20″ E) in Rajouri district of the Jammu and Kashmir state, in the north western Himalayan biogeographic zone. The watershed lies entirely in the Pir Panjal mountain range (lesser Himalaya) and is characterized by undulating topography with moderate to very steep slopes towards south and southwest directions. The area of watershed is about 116.27 km^2 and with an elevation ranging from 900–3700 m above mean sea level (m asl). The climate of watershed varies from subtropical to alpine agro climatic zones. The main drainage in the area flows from the north east to south west discharging into Munawwar Tawi River and is a part of the Chenab sub basin. The watershed area is inhabited by 11 revenue villages with a population of about 36227 people.

The age of rocks in the Pir Panjal Mountain region ranges from precambrian to the quaternary period. The Rajouri district is a part of Autochthonous Folded Belt, one of the three geological structural units in poonch area of Jammu and Kashmir Himalaya (Wadia 1931). On the northern side, it is bounded by the Panjal thrust and on the southern side by Murree Thrust (Wadia 1928). Approximately 80% of the area is comprised of Murree rocks of late Eocene to early Miocene, and are unconformably underlined by Subathu rock Formation. Murree rock group mainly consists of pink sandstone and clay. Northern part of the Rajouri district consists of metamorphic and older crystalline rocks, and southern side is composed of a medium to coarse sandstone, light grey and clay stones. The soils in the study area are generally classified into three types such as Red yellow and Brown Soils (Utisols), Bhabar Soil (Entisols) and Sub-Mountainous Soil (Alfisols) (Anonymous 2013).

Vegetation survey and data analysis

After the reconnaissance survey, the study area was found to be dominated by three dominant forest types *viz.* oak forest (OF), mixed broadleaf forest (MF) and fir forest (FF). Three sites of about 1 ha size were selected along the altitudinal gradient for each forest type (Table 1). Levels of disturbance in selected sites was assessed by the degree of anthropogenic pressure in terms of ground grazing, extraction of timber, fuel and fodder, lopping of trees, frequency of fire incidence and ease of accessibility. Based on a normal scale, the level of disturbance were grouped into three classes, *i.e.*, very high, moderate and low. For assessing the population structure of dominant tree vegetation at each site, ten 10 × 10 m quadrats were randomly laid down, thus a total of 90 plots were established. In each quadrat, trees with >30 cm CBH (circumference at breast height *i.e.*, 1.37 m above the ground) were enumerated and their circumference was measured individually. Each 10 × 10 m Quadrat was divided into four 5 × 5 m sub quadrats for enumeration of the saplings and seedlings. Individuals having circumference between 10–30 cm were considered as saplings and those having circumference <10 cm were considered as seedlings (Knight 1963). The rate of progression of density of seedlings, saplings and adult trees is considered as the indicator of regeneration potential. The regeneration status of dominant trees in a given forest type was categorized as:

(i) Good regeneration *i.e.* if number of seedlings > saplings >adults.

(ii) Fair regeneration *i.e.* if number of seedlings > or < saplings < adults.

(iii) Poor regeneration *i.e.* if the species was found as sapling, but no seedlings (Number of saplings maybe more, less or equal that of adults).

(iv) No regeneration *i.e.* if individuals of species are present only as adults.

(v) New regeneration *i.e.* if individuals of species have no adults but present as seedlings or saplings.

Table 1. General details of selected sites of three forests cover types in Darhal watershed.

Forest sites	Forest cover type (Dominant)	Altitude (m a.s.l.)	Disturbance level
OF1	Mainly *Quercus incana*	1650	High
OF2	Mainly *Quercus incana*	1800	Moderate
OF3	Mainly *Quercus incana*	2100	Low
MF1	Mixed broad leaved	1900	High
MF2	Mixed broad leaved	2000	Moderate
MF3	Mixed broad leaved	2150	Low
FF1	Mainly *A. pindrow*	2250	High
FF2	Mainly *A. pindrow*	2470	Moderate
FF3	Mainly *A. pindrow*	2630	Low

Note: OF – oak forest, MF – mixed broad leaf forest, FF – fir forest.

The dominance of a plant species was determined using the Importance Value Index (IVI) of these species. Vegetation composition was evaluated by analysing the frequency, density, abundance and IVI, using the standard methods suggested (Mishra 1968, Curtis & McIntosh 1950). The basal area of each tree was calculated by dividing the square of CBH (circumference at breast height) with 4π. The mean basal area was multiplied with the density of each species to obtain total basal area (TBA) (m^2 ha^{-1}). The ratio of abundance to frequency (*A*/*F*) for different species was derived to elicit the distribution pattern. The distribution pattern is considered regular if the A/F ratio is (< 0.025), random (0.025–0.050) and contiguous (> 0.050) (Whitford 1949).The importance value index (IVI) was calculated with the following formulae: IVI = $R_F + R_D + R_{Do}$, where R_F is the relative frequency, R_D relative density and R_{Do} relative dominance (Phillips 1959).

RESULTS

Phytosociological analysis of tree species

A total of 14 tree species were recorded in tree stratum in three different forest types in the study area. *Q. incana*, *P. duthiei* and *A. pindrow* were the dominant tree species at all the sites of oak forest (OF), mixed broadleaf forest (MF) and fir forest (FF) in terms of their Importance Value Index (IVI), respectively. In OF1, the highest importance and tree density was recorded for *Q. incana* (IVI = 147.06, D = 529 individuals ha^{-1}, TBA = 30.60 m^2 ha^{-1}) followed by *Pinus roxburghii*, *Pyrus pashia*, *Ficus palmata* and *Acacia nilotica* (Table 2). Likewise *Q. incana* also showed the highest importance and density in OF2 (IVI = 191.56, D = 608 individuals ha^{-1}, TBA = 24.40 m^2 ha^{-1}) and OF3 (IVI = 234.58, D = 780 individuals ha^{-1}, TBA = 28.23 m^2 ha^{-1}) followed by *Olea cuspidata* and other tree species (Table 2). Maximum value of frequency was observed for *Q. incana* (100 %) at all the three oak forest stands while the lowest Frequency was observed for *F. palmata* (40%), *Punica granatum* (40 %) and *O. cuspidate* (30 %) in OF1, OF2 and OF3, respectively. The abundance to frequency (A/F) ratio of different tree species ranged from 0.02 to 0.05, 0.01 to 0.06 and 0.03 to 0.11 for OF1, OF2 and OF3, respectively. Among three sites of oak forest, the maximum total tree density and total basal area was observed for OF1 (988 individuals ha^{-1} and 49.14 m^2 ha^{-1}) followed by OF3 (934 individuals ha^{-1} and 30.61 m^2 ha^{-1}) and OF2 (817 individuals ha^{-1} and 28.78 m^2 ha^{-1}) (Table 2).

In mixed broadleaf forest type stands studied, a total of 6 tree species were encountered during study period. In MF1, the highest importance and tree density was observed for *P. duthiei* (IVI = 182.50, D = 784 individuals ha^{-1}, TBA = 20.40 m^2 ha^{-1}) followed by *Q. incana*, *P. pashia* and *E. umbellate* (Table 3). In MF2 and MF3, the highest values of importance and tree density were also recorded for *P. duthieii* (IVI = 224.57, D = 739 individuals ha^{-1}, TBA = 23.00 m^2 ha^{-1} and IVI = 169.42, D = 910 individuals ha^{-1}, TBA = 30.50 m^2 ha^{-1})

followed by *Buxus wallichiana* (IVI = 44.35, D = 70 individuals ha^{-1}, TBA = 0.69 m^2 ha^{-1} and IVI = 84.8, D = 319 individuals ha^{-1}, TBA = 14.67 m^2 ha^{-1}), respectively. The least values of importance and density were recorded for *Persea odoratissima* both in MF2 and MF3. *P. duthiei* showed the maximum frequency of 90% in MF1 and 100% each in MF2 and MF3, respectively. In MF1, the A/F ratios for different tree species ranged from 0.02 to 0.10 whereas in MF2 and MF3 it ranged from 0.02 to 0.08 and 0.02 to 0.09 respectively (Table 3). The highest tree density and total basal area among three stands of mixed broadleaf forest were observed for MF3 (1325 individuals ha^{-1} and 48.97 m^2 ha^{-1}) followed by MF1 (1129 individuals ha^{-1} and 27.00 m^2 ha^{-1}) and MF2 (839 individuals ha^{-1} and 25.88 m^2 ha^{-1}), respectively.

Table 2. Phytosociological analysis of trees at three different sites of Oak forest.

Forest sites	Tree species	Frequency %	Density (individuals ha^{-1})	Ab	A/F	TBA (m^2 ha^{-1})	IVI
OF1	*Q. incana*	100	529	5.29	0.05	30.6	147.06
	P. roxburgii	70	250	3.57	0.05	11.9	71.39
	A. nilotica	50	60	1.20	0.02	1.54	24.83
	P. pashia	60	78	1.30	0.02	1.70	30.10
	F. palmata	40	71	1.78	0.04	3.40	26.61
Total			988			49.14	
OF2	*Q. incana*	100	608	6.08	0.06	24.4	191.56
	O. cuspidata	50	71	1.40	0.03	1.91	31.34
	P. granatum	40	38	0.95	0.02	0.50	19.30
	P. pashia	60	51	0.85	0.01	1.12	29.50
	M. philiphinensis	60	49	0.82	0.01	0.85	28.31
Total			817			28.78	
OF3	*Q. incana*	100	780	7.8	0.08	28.23	234.58
	O. cuspidata	30	99	3.3	0.11	1.66	33.66
	P. pashia	40	55	1.38	0.03	0.72	31.76
Total			934			30.61	

Note: Ab: Abundance, A/F: Abundance/Frequency ratio, IVI: Importance Value Index, TBA: Total Basal Area.

Table 3. Phytosociological analysis of trees at three different sites of Mixed broadleaf forest.

Forest sites	Tree species	Frequency %	Density (individuals ha^{-1})	Ab	A/F	TBA (m^2 ha^{-1})	IVI
MF1	*Q. incana*	50	223	4.46	0.10	4.50	57.25
	P. duthiei	90	784	8.71	0.09	20.40	182.50
	E. umbellata	50	42	0.84	0.02	0.90	27.89
	P. pashia	40	80	2.00	0.05	1.20	28.20
Total			1129			27	
MF2	*P. duthiei*	100	739	7.39	0.07	23.00	224.57
	P. odoratissima	40	30	0.75	0.02	2.19	31.09
	B. wallichiana	30	70	2.33	0.08	0.69	44.35
Total			839			25.88	
MF3	*P. odoratissima*	80	96	1.20	0.02	3.80	45.77
	B. wallichiana	80	319	3.99	0.05	14.67	84.80
	P. duthiei	100	910	9.10	0.09	30.50	169.42
Total			1325			48.97	

Note: Ab: Abundance, A/F: Abundance/Frequency ratio, IVI: Importance Value Index, TBA: Total Basal Area

In fir forest, only 2 tree species were encountered and *A. pindrow* has highest values of Importance and density at all the three sites studied *i.e.*, FF1 (IVI = 231.62, D = 392 individuals ha^{-1}, TBA = 156.30 m^2 ha^{-1}), FF2 (IVI = 240.47, D = 463 individuals ha^{-1}, TBA = 159.60 m^2 ha^{-1}) and FF3 (IVI = 238.89, D = 619 individuals ha^{-1}, TBA = 163.50 m^2 ha^{-1}) (Table 4). The least values of frequency, density and TBA were observed for *A. smithiana* at the all three sites studied (Table 4). Maximum total tree density was recorded for FF3 (690 individuals ha^{-1}) followed by FF2 (526 individuals ha^{-1}) and FF1 (492 individuals ha^{-1}), whereas the highest value for total basal area was observed for FF3 (188.90 m^2 ha^{-1}) followed by FF1 (183.20 m^2 ha^{-1}) and FF2 (178.30m^2 ha^{-1}).

Table 4. Phytosociological analysis of trees at three different sites of Fir forest.

Forest sites	Tree species	Frequency %	Density (individuals ha^{-1})	Ab	A/F	TBA (m^2 ha^{-1})	IVI
FF1	*A. pindrow*	100	392	3.91	0.04	156.3	231.62
	A. smithiana	50	100	2.00	0.04	26.9	68.38
Total			492			183.2	
FF2	*A. pindrow*	100	463	4.60	0.05	159.6	240.47
	A. smithiana	60	63	1.00	0.02	18.7	59.53
Total			526			178.3	
FF3	*A. pindrow*	100	619	6.19	0.06	163.5	238.89
	A. smithiana	50	71	1.40	0.03	25.4	61.11
Total			690			188.9	

Note: Ab: Abundance, A/F: Abundance/Frequency ratio, IVI: Importance Value Index, TBA: Total Basal Area

Regeneration status of dominant tree species

All the 14 tree species present in the study area were also recorded as juveniles in the studied plots (Table 5). The density of adult trees, saplings and seedlings varied greatly among dominant tree species along the elevation gradient. In OF1, the highest density for saplings and seedlings were recorded for *P. roxburghii* (143 and 190 individuals ha^{-1}) followed by *Q. incana* (91 and 188 individuals ha^{-1}), whereas the lowest density of saplings and seedlings were observed for *F. palmate* (16 and 33 individuals ha^{-1}) and *A. nilotica* (18 and 32 individuals ha^{-1}). In OF2, the maximum density for saplings and seedlings were recorded for *Q. incana* (287 and 210 individuals/ ha) whereas the lowest density for saplings and seedlings were obtained for *P. granatum* (20 and 9 individuals ha^{-1}) and *P. pashia* (11 and 36 individuals ha^{-1}) and *O. cuspidata* (11 and 33 individuals ha^{-1}). Likewise maximum density for saplings and seedlings in OF3 were observed for *Q. incana* (371 and 312 individuals ha^{-1}). However, the minimum density for saplings and seedlings were recorded for *P. pashia* (30 and 19 individuals ha^{-1}).

In MF1, the maximum and minimum density for saplings and seedlings were recorded for *P. duthiei* (503 and 375 individuals ha^{-1}) and *Elaeagnus umbellata* (33 and 40 individuals ha^{-1}). Similar to MF1, in MF2 the maximum density for saplings and seedlings were observed for *P. duthiei* (863 and 453 individuals ha^{-1}) and MF3 (1230 and 534 individuals ha^{-1}). The lowest density for saplings and seedlings were obtained for *P. odoratissima* both in MF2 (23 and 13individuals/ haand MF3 (33 and 20 individuals ha^{-1}).In case of subalpine forest cover, the maximum density of saplings and seedlings was recorded for *A. pindrow* followed by *A. smithiana* at all the three sites of fir forest cover *i.e.*, FF1, FF2 and FF3 (Table 5). The maximum and minimum density of saplings and seedlings for *A. pindrow* was recorded in FF3 (64 and 231 individuals ha^{-1}) and FF1 (20 and 98 individuals ha^{-1}).

Table 5: Regeneration status of tree species in selected sites of three forest cover types.

Tree species		OF1	OF2	OF3	MF1	MF2	MF3	FF1	FF2	FF3
Q. incana	Sed.	188	210	312	121	-	-	-	-	-
	Sap.	91	287	371	160	-	-	-	-	-
	Trees	529	608	780	223	-	-	-	-	-
	Status	F	P	P	P					
P. roxburgii	Sed.	190	-	-	-	-	-	-	-	-
	Sap.	143	-	-	-	-	-	-	-	-
	Trees	250	-	-	-	-	-	-	-	-
	Status	F								
A. nilotica	Sed.	32	-	-	-	-	-	-	-	-
	Sap.	18	-	-	-	-	-	-	-	-
	Trees	60	-	-	-	-	-	-	-	-
	Status	F								
P. pashia	Sed.	41	36	19	49	-	-	-	-	-
	Sap.	22	11	30	40	-	-	-	-	-
	Trees	78	51	55	80	-	-	-	-	-
	Status	F	F	P	P					
F. palmata	Sed.	33	-	-	-	-	-	-	-	-
	Sap.	16	-	-	-	-	-	-	-	-
	Trees	71	-	-	-	-	-	-	-	-
	Status	F								

O. cuspidata	Sed.	-	33	14	-	-	-	-	-	-
	Sap.	-	11	42	-	-	-	-	-	-
	Trees	-	71	99	-	-	-	-	-	-
	Status		F	P						
P. granatum	Sed.	-	9	-	-	-	-	-	-	-
	Sap.	-	20	-	-	-	-	-	-	-
	Trees	-	38	-	-	-	-	-	-	-
	Status		P							
M. philipinensis	Sed.	-	15	-	-	-	-	-	-	-
	Sap.	-	34	-	-	-	-	-	-	-
	Trees	-	49	-	-	-	-	-	-	-
	Status		P							
E. umbellata	Sed.	-	-	-	40	-	-	-	-	-
	Sap.	-	-	-	33	-	-	-	-	-
	Trees	-	-	-	42	-	-	-	-	-
	Status				P					
P. duthiei	Sed.	-	-	-	375	453	534	-	-	-
	Sap.	-	-	-	503	863	1230	-	-	-
	Trees	-	-	-	784	739	910	-	-	-
	Status				P	P	P			
P. odoratissima	Sed.	-	-	-	-	13	20	-	-	-
	Sap.	-	-	-	-	23	33	-	-	-
	Trees	-	-	-	-	30	96	-	-	-
	Status					P	P			
B. wallichiana	Sed.	-	-	-	-	0	11	-	-	-
	Sap.	-	-	-	-	7	95	-	-	-
	Trees	-	-	-	-	70	319	-	-	-
	Status					P	P			
A. pindrow	Sed.							98	154	231
	Sap.	-	-	-	-	-	-	20	32	64
	Trees	-	-	-	-	-	-	391	460	619
	Status							P	P	P
A. smithiana	Sed.	-	-	-	-	-	-	28	29	37
	Sap.	-	-	-	-	-	-	9	7	11
	Trees	-	-	-	-	-	-	100	60	70
	Status							P	P	P

Note: P= poor regeneration and F= fair regeneration.

DISCUSSION

Phytosociological analysis of tree species

Forest structure and species composition are determined and regulated by a variety of ecological and anthropogenic factors (Dolezol & Srutek 2002). Regular human interventions like overgrazing, lumbering and encroachments of forest areas are among the key regulatory factor controlling the distribution of species (Muller & Ellenberg 1974). Furthermore altitude is also one of the most important factors which determine the distribution of tree species due to its direct effect on the microclimatic conditions of the habitat (Rawal & Pangtey 1994, Singh *et al*. 2009). In the present study the tree density of the dominant species increased with increase in altitude. Such trends were also reported by Rawat & Singh (2006) in various forest communities in Great Himalayan National Park (GHNP) in north western Himalaya. However, opposite trends were also reported from other parts of north western Himalaya where the density of trees decreased with increase in altitude (Gairola *et al.* 2014, Kumar & Sharma 2014). In the present investigation the total density of dominant tree species in OF, MF and FF types ranged from 529 (OF1) to 780 individuals per ha (OF3), 784 (MF1) to 910 individuals per ha (MF3) and 392 (FF1) to 619 individuals per ha (FF3) in oak, mixed and fir forests, respectively. These values are similar to the tree density values reported by other studies in the north western Himalaya such as for *Quercus* species (Singh *et al*. 1994, Ghildiyal *et al.* 1998, Kumar & Ram 2005, Sharma *et al*. 2001), *A. pindrow* (Baduni *et al*. 1996, Dhar *et al*. 1997, Sharma *et al.* 2010, Gairola *et al.* 2010, Gairola *et al*. 2014) and *P. duthiei* (Pant & Samant 2012). Total basal area of trees did not showed any trend with change in altitude. In the present study total basal area of OF ranged from 28.78 to 49.14 m^2 ha^{-1} which was similar to the values recorded in other oak forests of western Himalaya (Saxena & Singh 1982, Ghildiyal *et al.* 1998, Kumar & Ram 2005). Total basal area of MF ranged from 25.88 to 48.97m^2 ha^{-1} which was lower than the values reported from other temperate broadleaved Himalayan forests (Pant & Samant 2012). We assume that, this may be due to greater number of trees in smaller CBH classes in the study sites. Total basal area of FF ranged from 156.30to 178.3 m^2 ha^{-1} which was comparatively higher than the values reported for similar forest types in western Himalaya (Baduni *et al*. 1996, Dhar *et al*. 1997, Gairola *et al*. 2010, Dar & Sundarapandian 2015). This may be due to the fact that the *A. pindrow* trees were more in larger CBH classes in our study area.

Regeneration status of dominant tree species

The occurrence of a sufficient number of young trees, saplings and seedlings in a given forest population indicates successful regeneration (Saxena & Singh 1984).The above three life stages for various tree species signify the probable forest structure in future. In general all the 14 tree species analysed in this study were found to be more or less regenerating. The overall regeneration status was poor in these forests as survival from saplings to poles was found to be almost non-existing in all the studied sites. Poor regeneration of *Quercus s*pecies in Himalayan mountain forests was also reported by other workers from time to time (Saxena & Singh 1982, Thadani & Ashton 1995) and anthropogenic disturbance was attributed for this. However, good regeneration of *Quercus* species was also observed in similar forests of north western Himalaya (Gairola *et al*. 2012, Pala *et al.* 2012) when the extent of such forests was large or stricter management regimes were in place. In the present study *P. duthiei* in all the studied sites (MF1, MF2 and MF3) shows poor regeneration with low rate of conversion to trees from sapling stage in MF2 and MF3. Inadequate regeneration pattern of *P. duthiei* was also observed by Pant and Samant (2012) in Khokhan Wildlife Sanctuary (KhWLS) in north western Himalaya. *B. wallichiana*, a multipurpose high value tree species was present in MF2 and MF3, but shows very poor to no regeneration. Uses of *B. wallichiana* in wood craft industry, extraction for fodder and fuel are the possible reasons for its very poor conversion from lower CBH to higher CBH classes. Similar results were also reported by Pant (2011) and Ahmed *et al*. (2015) in Rajouri and Poonch districts of J&K State. *A. pindrow*, an important timber yielding species in the study area also showed inadequate representation in young stages. In addition to livestock grazing, there are many other factors which hamper the regeneration of *A. pindrow* such as undecomposed layer of litter (due to low temperature) (Troup 1921), growth of noxious weeds and release of hydrophobic substances from litter decomposition (Jha *et al.* 1984). Moreover, drainage conditions in the *A. pindrow* dominated forests also limit the wetting of soil which hampered its natural regeneration (Troup 1921). Therefore, *A. pindrow* forests in the study area along with those in the region needed proper care from the forest department officials and local people so that the seedlings and saplings could survive and replace adult trees in future. We believe there are possibilities of destruction of this important forest tree species if present state of affairs continues for longer period of time.

The anthropogenic disturbance in the study area is high and hence inadequate regeneration is expected for *Quercus* species. OF1 and OF2 were situated in the vicinity of villages (Dodaj & Chowkian) and thus anthropogenic disturbances such as ground grazing by cattle, tree lopping, and extraction of fuel wood, fodder and timber were also observed during the present study. According to Singh (1992), the grazing by cattle is the basic cause of poor regeneration of *Quercus* species in the Central Himalayan forest. However, OF3 located at higher elevation (2100 m asl.) and comparatively away from the village settlements and was subjected to lesser human disturbances and shows fair regeneration. Sharma *et al*. (2008) also observed the impacts of human interferences on forest degradation in Birhun watershed, which is situated in district Udhampur of J&K State. Kumar & Sharma (2014) also reported that the impacts like tree felling, looping, grazing by domestic cattle, fire incidents, extraction of fodder and fuel wood are responsible for inadequate regeneration of forest trees in Padder valley area of northwest Himalaya in J&K State. Similar impacts of human interference on forest plant species composition was also reported by Kiran *et al.* (1999) and Kumar & Hamal (2009) from Poonch and Kishtwar district of J&K State. In the present study the effect of fire was found to be low to moderate. Forest litter was used as bedding material in the animal sheds and soil erosion was observed in the forests due to human disturbances and steep slopes in the area. Overall the livestock grazing pressure in the study area was found to be high and transhumant communities such as Gujjar, Bakerwal and some Paharis in the area migrate to alpine pastures during summer for grazing their cattle's, goats and sheep's. The grazing, browsing and trampling by livestock cause a considerable mortality of saplings and seedlings and hence hamper the natural regeneration of forest trees in the study area. Krzic *et al.* (2006) who studied the effects of cattle grazing on composition of plant species in central interior British Columbia also reports similar results.

CONCLUSIONS

The present study revealed that the tree density of dominant tree species showed marginal increase with increase in altitude. Most of the dominant tree species showed poor regeneration which warrants the immediate attention of forest managers and local forest dependent communities. In case of oak forest if current state of recruitment of seedlings and saplings stage does not improve, its tree population composition might change in the long run. In mixed broad leaved forest (MF2 and MF3) comparatively greater number of individuals in saplings stage indicates that the rate of conversion of saplings to tree CBH size classes was not proportional. Moreover, it also suggests that if present state of seedling recruitment continues the tree population may decline in future. The results of this study also revealed that *A. pindrow*, an important timber yielding tree species of the region showed poor regeneration. Therefore, if the current pattern of conversion of saplings to trees in this subalpine forest continues, the fir forest might be replaced in future. Present study also revealed that the studied forest types are under different anthropogenic pressures from growing population of neighboring human settlements for higher demands of timber, fuel, fodder and ground grazing and therefore needs some management and silvicultural intervention. Some of the prescription may include implementation of controlled extraction and grazing, enrichment planting of tree species in protected forest compartments, proper lopping, less use of wood for house construction and fuel by providing alternative options. In addition the formulation and implementation of effective conservation strategies are required for proper regeneration of some of the ecologically and economically important tree species such as *A. Pindrow*, *B. wallichiana*, *P. duthiei* and *Q. incana*.

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