TREE REGENERATION STATUS AND POPULATION STRUCTURE ALONG THE DISTURBANCE GRADIENT (A CASE STUDY FROM WESTERN HIMALAYA)

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ABSTRACT

The existence of forest community largely depends on its ability to regenerate under varied environmental conditions. In the present study we studied tree regeneration status and population structure along the disturbance gradient in Western Himalaya, India. On the basis of disturbance index and canopy cover, three forests, categorized into highly disturbed (HD), moderately disturbed (MD) and least disturbed (LD) forests were selected. A total of 34 tree species were reported along the disturbance gradient. Regeneration status was determined based on population size of seedlings and saplings. Seedling and sapling density (individual/ha) varied between 1670-7485 and 1850-5690 respectively. Maximum tree species (52.38%) showing good regeneration were reported from the MD forest. Some tree species in the study area showed discontinuous regeneration because of absence of some of their diameter classes and these are feared to be in trouble in future. The overall regeneration status was fairly high in the study area and these communities may be sustained in future unless there is any major environmental stress or interference exerted by human activities. The study concludes that the mild disturbance does not adversely affect the plant diversity of the area; instead it enhances regeneration of species due to creation of additional microsites.

Keywords: Regeneration, Population structure, Seedlings, Saplings, Himalaya.

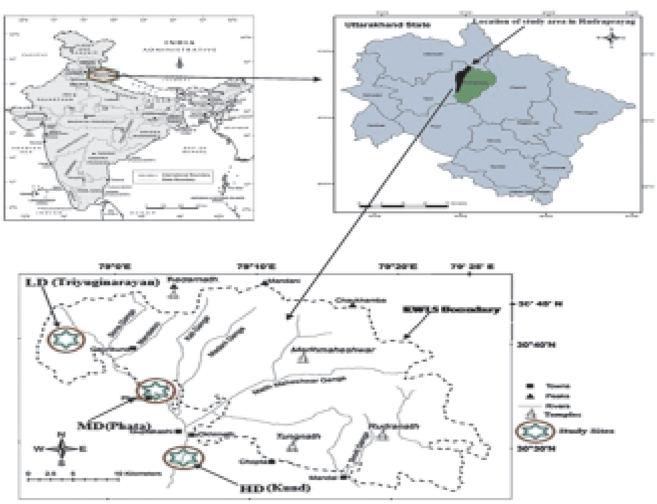
INTRODUCTION

Forests are renewable only because they regenerate (Tripathi *et al.,* 2007). Forests are dynamic entities. These are able to change and adapt. Seeds germinate; seedlings grow and compete with each other and with larger trees. Some survive for hundreds of years while others perish during development because of many reasons (Malik 2014). Regeneration potential is the ability of a species to complete the life cycle and it is a vital process for the existence of species in a community under altered environmental conditions. It has also immense importance in forest management as it maintains the desired species composition after various disturbances (Khumbongmayum *et al.,* 2005). The examination of population structure and regeneration status of tree species in a forest reflects an idea about the feasible alterations in its species makeup in future (Henle *et al.,* 2004). Uninterrupted regeneration and suitable growth of all species in the presence of older and matured plants is mandatory for the establishment and expansion of any plant community (Taylor *et al.,* 1988). Regeneration of any species is bound to a specific range of habitat conditions which figure out its geographic distribution (Grubb 1977). Survival and growth of seedlings/saplings determines the successful regeneration (Good *et al.,* 1972). Rewarding regeneration is possibly the lone important step towards achieving long term sustainability of forests (Malik *et al.,* 2014). The ratio of seedlings and saplings in a population figure out the reproductive status of the population and betokens the future course (Odum 1971). The population structure characterized by the presence of sufficient number of seedlings, saplings and young trees depicts sufficient regeneration; inadequate number of seedlings and saplings of tree species in a forest indicates poor regeneration, while complete absence of seedlings and saplings of tree species in a forest indicates no regeneration (Saxena *et al.,* 1984). The process of regeneration is influenced by different disturbances including both anthropogenic factors Sukumar *et al.*, 1998 and natural calamities (Welden *et al.*, 1991). Forest ecosystems, with time, change in their species composition and organization; but many dramatic changes are witnessed especially when they are exposed to anthropogenic interferences and other factors affecting the natural regeneration process of the species (Malik 2014). Excessive grazing by livestock hinders regeneration of the tree cover to some extent (Maren *et al.*, 2007). Different anthropogenic activities like construction of hydroelectric power projects and hill roads, forest fires, over grazing, lopping of trees for fodder and fuel-wood, removal of leaf and wood litter from the forest floor affect plant diversity and regeneration (Ballabha *et al.*, 2013; Malik *et al.*, 2016). Some species may endure these disturbances while others may give-up to them (Sagar *et al.*, 2003). Insufficient regeneration is a major problem of mountain forests Krauchii *et al.*, 2000 and the same is true for the Himalayan forests. Himalayan moist temperate forests represent centre of high species diversity. Reliable data on regeneration trends is required for the successful management and conservation of natural forests (Eilu *et al.*, 2005). An understanding of the processes that affect regeneration of forest species is of crucial importance to both ecologists and forest managers (Slik *et al.*, 2003). The examination of regeneration status of forest trees has significant consequences for the management of natural forests, and is one of the primary goals of forestry. Research in this domain bestows to planning, conservation and decision making in forest resources management programs and hence the dynamics of regeneration forms a major area in the study of management of natural forests (Dekker *et al.*, 2003). Keeping in view the aforesaid facts, the present study was carried out with the objective: to understand the regeneration status of tree species in relation to disturbance in a part of Western Himalaya.

Table 1. Characteristics of the study area

Site	Forest	Altitude (m)	Geographic Coordinates	Aspect	Slope	*DI TBC (%)	Canopy Cover (%)
Kund	Highly Disturbed (HD)	1000-1150	^{0}30'00.30N, 079^{0}05'25.73E	SE	23^{0}±8^{0}	39.83	30
Phata	Moderately Disturbed (MD)	1850-1950	30^{0} 34' 18.87N, 079^{0} 02'10.84E	S	16^{0}± 9^{0}	8.42	50
Triyuginarayan	Least Disturbed (LD)	2250-2400	30^{0}38'47.11N, 078^{0}58'4.75E	WWS	30^{0}±5^{0}	4.26	70

***DI TBC**= Disturbance index on the basis of total basal cover of cut stumps



$$\text{DI TBC} = \frac{\text{TBC of cut stumps in the forest per hectare}}{\text{Total TBC of all the standing stems in the forest per hectare}} \quad 100$$

Fig. 1. Location of the study sites in KWLS and its adjoining areas

MATERIAL AND METHODS

STUDY AREA

The study was carried out in a protected area (Kedarnath Wildlife Sanctuary, KWLS) and its adjoining areas in Western Himalaya. The KWLS is one of the largest protected areas extending to 975 km^2 of districts Chamoli and Rudraprayag of Uttarakhand between the coordinates 30°25'- 30°41' N, 78°55'-79°22' E in the Garhwal region of Greater Himalaya and falls under the IUCN management category IV (Managed Nature Reserve). The sanctuary lies in the upper catchment of the Alaknanda and Mandakini Rivers, two major tributaries of the Ganges. The present study was carried out in three differently disturbed, mixed broad-leaved forests in Rudraprayag district (Fig. 1). After reconnaissance survey, these three forests were selected on the basis of varying disturbance index (%) and canopy cover (%) and categorized into highly disturbed (HD), moderately disturbed (MD) and least disturbed (LD) categories (Table 1). LD forest in Triyuginarayan area forms the core zone of KWLS; MD forest in Phata marks the fringe area of KWLS while the HD forest in Kund comes under its adjoining areas. The climate in the study areas is divisible into four distinct seasons, *viz.*, summer (May–July), rainy (mid July–September), winter (October–January) and spring (February-April). The rainfall pattern in the region is largely governed by the monsoon rains (July–September), which account for about 60–80% of the total annual rainfall. However, at higher altitudes, precipitation is almost a daily routine. The soil types found in the region are podozolic soils. Soil texture of the study area is predominantly sandy loam and sandy clay loam whereas soil colour varies from dark brown to black. Soils are generally gravelly and large boulders are common in the area (Malik 2014).

METHODOLOGY

Disturbance factors

On the basis of canopy cover (%) and disturbance index (%), the forests were categorized into HD, MD and LD forests. Disturbance index was calculated (Murali *et al.*, 1996). Where DI TBC is the disturbance index on the basis of total basal cover of cut stumps. Lopping percentage and grazing intensities were calculated (Bhat *et al.*, 2012; Saxena *et al.*, 1984).

Regeneration status

Regeneration status of the selected forests was studied to predict some possible compositional changes in future. For this purpose, twenty 10 m × 10 m quadrats were laid down on the forest floor at each site.

Species were identified and density of all the individuals of seedlings (< 20 cm height), saplings (<30 cm collar circumference at the base and >20 cm in height) and trees (> 30cm dbh) were determined. Regeneration status of species was determined based on population size of seedlings and saplings (Khan *et al.*, 1987, 2013; Uma Shankar 2001) as:

(i) Good regeneration, if seedlings > saplings > adults;
(ii) Fair regeneration, if seedlings > or =saplings =adults;
(iii) Poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults);
(iv) No regeneration, if a species is present only in adult;
(v) New regeneration, if the species has no adults but only seedlings or saplings.

Table 2. Details of vegetation and resource use pattern in the study area

Forest Type (Geo-Coordinates)	Main Vegetation [(b)]	Anthropogenic disturbances (Resource use pattern)[(c)]
HD ($30^0$30'00.30N $079^0$05'25.73E)	*Neolitsea cuipala , Toona hexandra, Engelhardtia spicata, Cinnamomum tamala, Mallotus philippensis, Albizia chinensis, Quercus leucotrichophora*	HTL, HSC, HG
MD ($30^0$34'18.87N $079^0$02'10.84E)	*Daphniphyllum himalense , Betula alnoides, Lyonia ovalifolia, Quercus floribunda. Q. leucotrichophora, Rhododendron arboreum*	HG, LSC, HTL, CNTFP
LD ($30^0$38'47.11N $078^0$58'4.75E)	*Rhododendron arboreum, Lyonia ovalifolia, Quercus spp., Ilex dipyrena, Symplocos ramosissima, Taxus baccata, Buxus wallichiana, Juglans regia, Aesculus indica*	LG, LSC, LTL, CNTFP

RESULTS

A total of 34 tree species (belonging to 30 genera and 21 families) were reported along the disturbance gradient. The details of dominant and associated tree species in the studied forests along with their resource use pattern (Table 2). Maximum number of tree species (20) was reported from the LD forest, lowest (11) from HD while MD occupied an intermediate position (18) with respect to species richness. Also, as far their seedling and/or sapling stage is concerned, the number of species varied along the disturbance gradient (Fig. 2).

(a) Courtesy: (Malik *et al.*, 2014),
(b) Species in bold are dominant tree species,
(c) LTL= Low tree lopping, LG= low grazing, HTL=heavy tree lopping, HG=Heavy grazing, LSC=low stem cutting, HST=heavy stem cutting, CNTFP=collection of non-timber forest products.

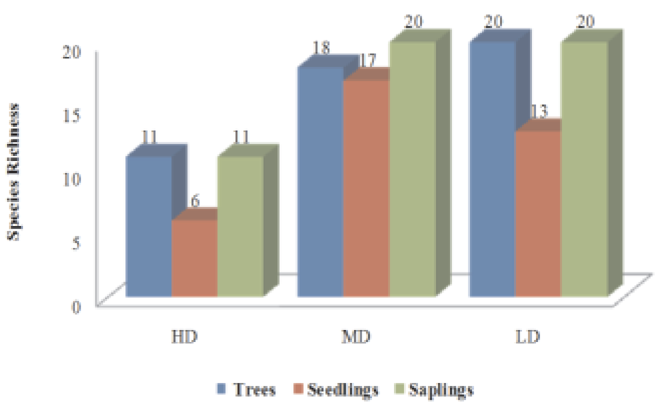


Fig. 2. Species richness of tree, sapling and seedling layers in different forests

i). Regeneration status along the disturbance gradient

Although, all the forests are regenerating, the regeneration status of individual tree species varied along the disturbance gradient as described below: Highly Disturbed (HD) forest: In this forest, sapling density (number of saplings/ha) was highest (1850), followed by seedlings (1670) and trees (235). Out of 11 tree species reported, only 6 were found in seedling stage. Highest seedling density (960/ha) was recorded for *Neolitsea cuipala,* while the lowest seedling density (55/ha) was recorded for *Albizia chinensis*. Tree species whose seedling stage was absent include *Engelhardtia spicata*, *Ficus auriculata*, *Lyonia ovalifoilia*, *Mallotus philippensis* and *Pinus roxburghii* (Table 3). All the 11 species reported, were found in the sapling stage. The highest density of saplings (850/ha) was recorded for *Neolitsea cuipala*, while its lowest value was observed for *Ficus auriculata* and *Mallotus philippensis* (35 saplings/ha each). As far as the regeneration status of this forest is concerned, maximum (46%) species displayed poor, 27% good and 27% fair regeneration (Fig. 3). Also, the individual tree species depicted varied regeneration status.

Moderately disturbed forest

In this forest, seedling density was highest (7485 ind/ha), followed by that of saplings (5690) and trees (465). Out of the 18 tree species reported, only 17 were found in seedling stage. Highest seedling density (2150/ha) was recorded for *Litsea elongata* while the lowest seedling density (60/ha) was recorded for *Quercus leucotrichophora*. The highest density of saplings (1850/ha) was recorded for *Daphniphyllum himalense,* while its lowest value was observed for *Prunus venosa* (10/ha). As far as the regeneration status of this forest is concerned, maximum species (53%) exhibited good regeneration, 14% fair, 19% poor and 14% new regeneration (Fig. 3). Four species that showed poor regeneration include *Juglanus regia*, *Lyonia ovalifolia, Prunus venosa* and *Swida macrophylla* (Table 4). Three species *viz., Euonymous pendulus, Ficus glaberima* and *Symplocos racemosa* showed 'New Regeneration' because these were present in seedling and/or sapling stages only and hence new to this forest.

Least disturbed forest

In this forest, seedling density was highest (2100 Ind/ha), followed by that of saplings (1965) and trees (505). Out of 20 tree species reported, only 13 were found in seedling stage. Highest seedling density (500/ha) was recorded for *Litsea elongata* while its lowest value (40/ha) was recorded for *Quercus semecarpifolia*. The highest density of saplings (300/ha) was recorded for *Litsea elongata,* while it's lowest value (20/ha) was observed for *Persea odoratissama.* As far as the regeneration status of this forest is concerned, 35% species showed good regeneration, 30% fair and 35% poor regeneration (Fig. 3). Overall seedling density ranged between a maximum of 7485 Ind/ ha in MD and a minimum of 1670 Ind/ha in HD, whereas sapling density varied between a maximum of 5690 Ind/ha in MD and a minimum of 1850 Ind/ha in HD. Maximum percentage of seedlings (55%) was recorded in MD forest and minimum (45%) in HD forest (Fig. 4). Highest percentage of saplings (49%)

Table 3. Density/ha of Seedlings, saplings and trees along the disturbance gradient

Tree Species	Density/ha along the Disturbance Gradient								
	Highly Disturbed			Moderately Disturbed			Least Disturbed		
	SD*	SP*	TR*	SD	SP	TR	SD	SP	TR
Acer caesium	-	-	-	-	-	-	60	40	15
Acer cappadocicum	-	-	-	-	-	-	0	20	10
Aesculus indica	-	-	-	170	55	15	140	100	20
Albizia chinensis	55	90	15	-	-	-	-	-	-
Alnus nepalensis	-	-	-	370	190	20	-	-	-
Betula alnoides	-	-	-	460	315	35	-	-	-
Buxus wallichiana	-	-	-	-	-	-	-	50	20
Cinnamomum tamala	110	115	25	-	-	-	-	-	-
Daphniphyllum himalense	-	-	-	1700	1850	70	-	-	-
Engelhardtia spicata	-	135	15	-	-	-	-	-	-
Euonymous pendulus	-	-	-	255	550	-	340	285	15
Ficus auriculata	-	35	20	-	-	-	-	-	-
Ficus glaberima	-	-	-	360	150	-	-	-	-
Fraxinus micrantha	-	-	-	210	165	20	-	40	10
Ilex dipyrena	-	-	-	270	150	25	90	100	30
Juglans regia	-	-	-	-	35	20	-	60	15
Lindera pulcherrima	-	-	-	360	95	25	60	70	25
Litsea elongata	-	-	-	2150	1200	50	500	300	20
Lyonia ovalifolia	-	60	15	-	25	40	175	130	45
Mallotus philippensis	-	35	20	-	-	-	-	-	-
Neolitsea cuipala	960	850	45	-	-	-	-	-	-
Persea odoratissima	-	-	-	135	55	10	-	20	10
Pinus roxburghii	-	60	20	-	-	-	-	-	-
Prunus venosa	-	-	-	-	10	5	-	-	-
Pyrus pashia	-	-	-	210	180	25	-	40	15
Quercus floribunda	-	-	-	410	285	15	50	75	35
Quercus glauca	-	-	-	-	-	-	-	60	10
Quercus leucotrichophora	170	110	20	60	220	40	185	210	50
Quercus semecarpifolia	-	-	-	-	-	-	40	30	30
Rhamnus virgatus	-	-	-	125	45	10	-	-	-
Rhododendron arboreum	140	150	15	125	35	35	215	235	100
Swida macrophylla	-	-	-	-	35	5	-	-	-
Symplocos racemosa	-	-	-	115	45	-	-	-	-
Symplocos ramosissima	-	-	-	-	-	-	85	30	15
Taxus baccata	-	-	-	-	-	-	160	70	15
Toona hexandra	235	210	25	-		-	-	-	-
Total	**1670**	**1850**	**235**	**7485**	**5690**	**465**	**2100**	**1965**	**505**

Note: SD =Seedlings, SP= Saplings, TR=Tree, '-' =Absence of species

was recorded in HD forest and lowest (42%) in MD forest, whereas maximum percentage (11%) of trees was recorded in LD forest and minimum (3%) in MD forest.

Population structure

All the forests (whether it is HD, MD or LD) showed inverse-J (i-J) curve based on the overall density-diameter

Table 4. Regeneration status of individual tree species along the disturbance gradient

	Regeneration status along the disturbance gradient		
Tree Species	**Highly Disturbed**	**Moderately Disturbed**	**Least Disturbed**
Acer caesium	-	-	Good
Acer cappadocicum	-	-	Poor
Aesculus indica	-	Good	Good
Albizia chinensis	Fair	-	-
Alnus nepalensis	-	Good	-
Betula alnoides	-	Good	-
Buxus wallichiana	-	-	Poor
Cinnamomum tamala	Fair	-	-
Daphniphyllum himalense	-	Fair	-
Engelhardtia spicata	Poor	-	-
Euonymous pendulus	-	New	Good
Ficus auriculata	Poor	-	-
Ficus glaberima	-	New	-
Fraxinus micrantha	-	Good	Poor
Ilex dipyrena	-	Good	Fair
Juglans regia	-	Poor	Poor
Lindera pulcherrima	-	Good	Fair
Litsea elongata	-	Good	Good
Lyonia ovalifolia	Poor	Poor	Good
Mallotus philippensis	Poor	-	-
Neolitsea cuipala	Good	-	-
Persea odoratissima	-	Good	Poor
Pinus roxburghii	Poor	-	-
Prunus venosa	-	Poor	-
Pyrus pashia	-	Good	Poor
Quercus floribunda	-	Good	Fair
Quercus glauca	-	-	Poor
Quercus leucotrichophora	Good	Fair	Fair
Quercus semecarpifolia	-	-	Fair
Rhamnus virgatus	-	Good	-
Rhododendron arboreum	Fair	Fair	Fair
Swida macrophylla	-	Poor	-
Symplocos racemosa	-	New	-
Symplocos ramosissima	-	-	Good
Taxus baccata	-	-	Good
Toona hexandra	Good	-	-

class distribution (Fig. 5). The inverse-J type population structure is formed when lower diameter classes have the highest frequency with a gradual decrease in the number of individuals in the higher classes which are due to high mortality of juvenile trees in the initial stage of their life because of various reasons including high anthropogenic disturbances. The number of individuals reduced sharply with the increase of diameter. The highest percentage (about 88-96%) of individuals were recorded in 0-30 cm girth class that included seedlings and saplings, and it gradually decreased with increasing diameter class. It indicates continuous regeneration (Fig. 5).

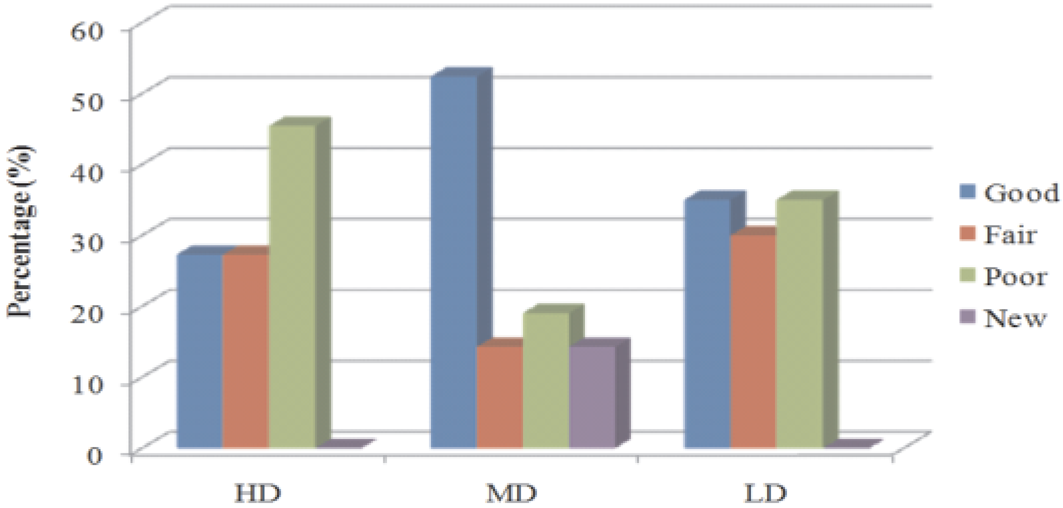


Fig. 3. Graphical representation of regeneration status along the disturbance gradient

Table 5. Tree species showing discontinuous regeneration in the study area

Forest type/ Tree species	
Highly Disturbed Forest	**Absent Diameter Classes (cm)**
Albizia chinensis	31-60, 91-120
Neolitsea cuipala	91-120
Toona hexandra	121-150, 151-180, 181-210
Moderately Disturbed Forest	
Aesculus indica	31-60
Alnus nepalensis	31-60
Juglans regia	31-60, 91-120
Prunus venosa	31-60
Quercus floribunda	31-60, 91-120, 121-150, 151-180, 181-210
Least Disturbed Forest	
Aesculus indica	31-60, 151-180, 181-210
Fraxinus micrantha	31-60
Juglans regia	31-60
Quercus glauca	31-60
Quercus floribunda	121-150, 181-210
Quercus leucotrichophora	121-150
Quercus semecarpifolia	61-90, 151-180

Excluding seedling and sapling (0-30 diameter class), diameter wise stem density (Ind/ha in each diameter class) distribution in different forests has been graphically represented (Fig. 6). Because of the limited employment opportunities, the forests are the important source of income for the rural people in this part of Garhwal Himalaya (Malik *et al.*, 2014). The local people are dependent on these forests for their basic requirements, such as fuel wood, grazing, timber, fodder for cattle, small timber for agricultural implements and other non-timber forest products. Because of these anthropogenic disturbances, there are some tree species in the study area that showed discontinuous regeneration because of absence of some of their diameter classes (Table 5).

Statistical analysis

Carl-Pearson Correlation coefficients were calculated between various parameters of regeneration and disturbance (Table 6). Seedling diversity ($\bar{H}$) showed

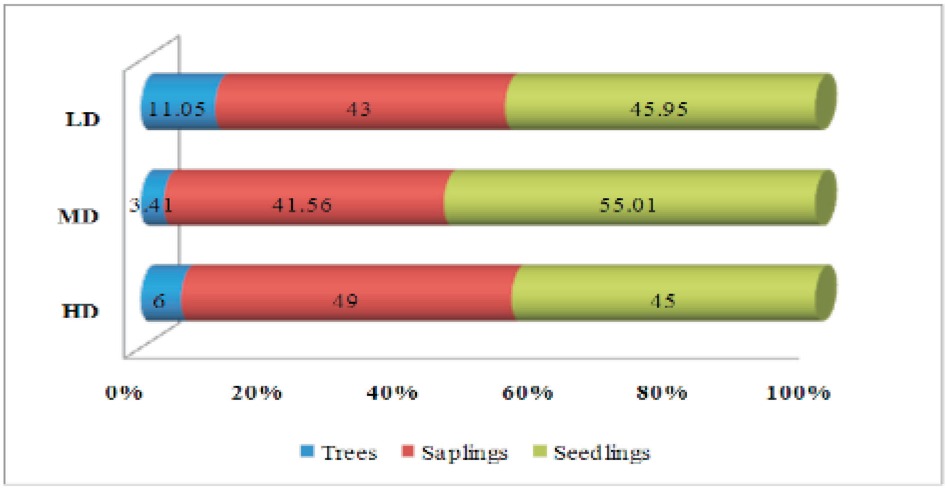


Fig. 4. Percentage of seedlings, saplings and trees along the disturbance gradient

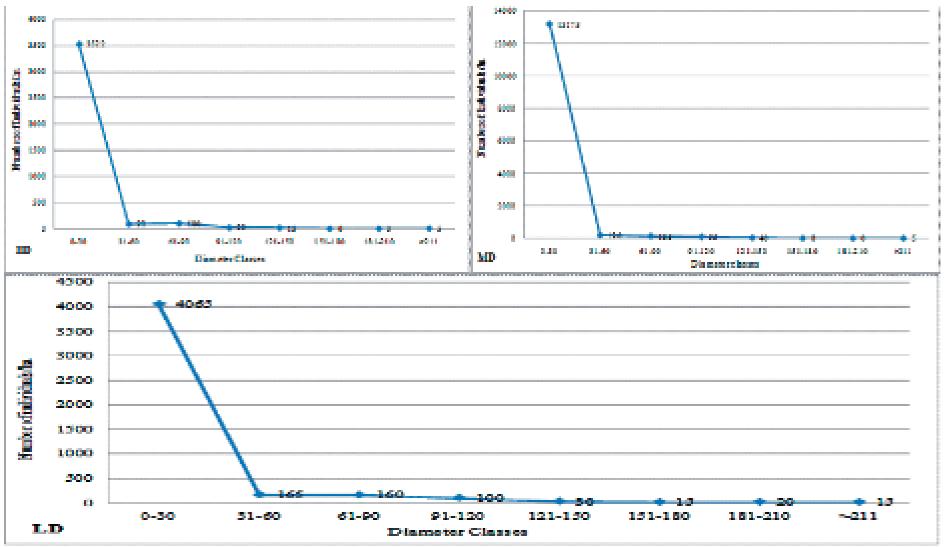


Fig. 5. Population structure based on the diameter at breast height (1.37 m) class distribution of the tree species in different forests along the disturbance gradient

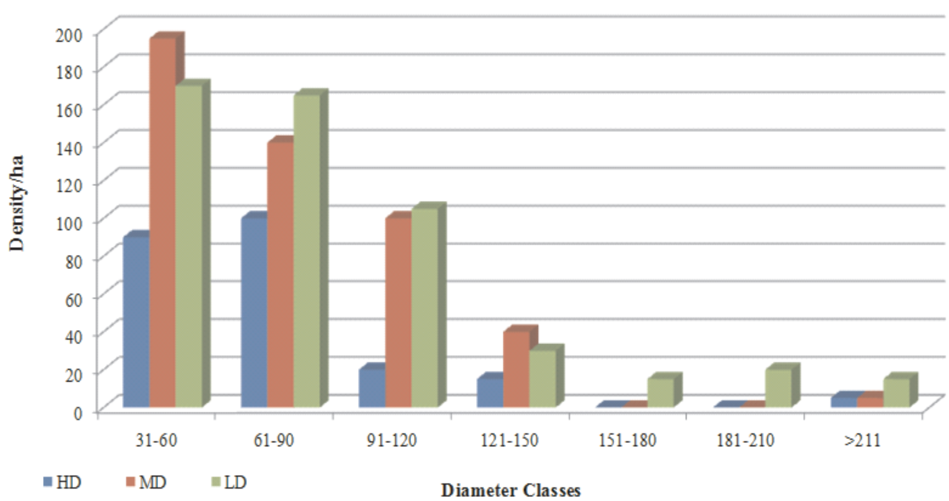


Fig. 6. Diameter wise density distribution of tree species along the disturbance gradient

Table 6. Carl-Pearson's correlation coefficients between regeneration and disturbance parameters

	LP	**DID**	**DITBC**	**AD**	GI	**CC**	**SED**	**SAD**	**TOR**	**SEDH¯**	**SEDH¯**
LP	1										
DID	0.929*	1									
DITBC	0.924*	0.976*	1								
AD	0.940*	0.821**	0.757	1							
GI	-0.241	-0.323	-0.283	-0.125	1						
CC	-0.921*	-0.854**	-0.849	-0.884**	0.111	1					
SED	-0.270	-0.381	-0.402	-0.087	0.549	-0.086	1				
SAD	-0.450	-0.456	-0.438	-0.353	0.699	0.101	0.905**	1			
TOR	-0.348	-0.420	-0.426	-0.196	0.622	-0.012	0.985	0.964*	1		
SEDH¯	-0.852**	-0.863**	-0.937*	-0.629	0.438	0.751	0.492	0.535	0.521	1	
SAPH¯	-0.765	-0.919*	-0.908**	-0.580	0.475	0.770	0.317	0.338	0.333	0.844**	1

significant negative correlation with disturbance parameters like lopping percentage (r = -0.852), DI D (r= -0.863), DI TBC (r = -0.937) and a strong (non-significant) negative correlation with anthropogenic disturbance (r=-0.629). Similar correlation was shown by sapling diversity (H¯) with these disturbance parameters.

*Correlation is significant at 0.01 significance level; **Correlation is significant at 0.05 significance level.

Abbreviations

LP= Lopping Percentage; DI D= Disturbance Index on the basis of density of cut stumps; AD= Frequency of Anthropogenic Disturbances (%), GI= Grazing Intensity; CC= Canopy Cover; SED= Seedling Density; SEDH¯ = Seedling Shannon-Wiener Diversity Index; SAD= Sapling Density; SAPH¯ = Sapling Shannon-Wiener Diversity Index; TOR= Total Regeneration (Seedlings+Saplings).

DISCUSSION

The regeneration of a forest is a vital process and necessary to its continued existence, in which old trees perish and are replaced by juveniles in perpetuity. Knowing the regeneration status and understanding the various factors including disturbances that affect regeneration of our forests is of crucial importance for their maintenance. In this study an attempt was made to study the tree regeneration status along the disturbance gradient in KWLS and its adjoining areas in the Western Himalaya, India. The ratio of various age groups (seedlings, saplings and trees) in a population determines the reproductive status of the population and indicates the future course. In the present study, seedling density ranged from 1670 Ind/ha (HD) to 7485 Ind/ha (MD) while sapling density varied from a minimum of 1850 Ind/ha (HD) to a maximum of 5690 Ind/ha (MD). These values are more or less similar to those reported by earlier workers. Ballabha *et al.*, 2013 reported seedling density ranging from 520-1240 Ind/ha while sapling density from 400-800 ind/ha from a sub-tropical forest in Alaknanda Valley, Garhwal Himalaya. Pala *et al.*, 2013 reported seedling density ranging from 1136-1874 Ind/ha and sapling density from 884-1520 Ind/ha from different sacred and protected landscapes in Garhwal Himalaya. Sarkar *et al.*, 2014 reported seedling and sapling densities of 6754/ha and 1002/ha respectively from Northeast India. Recently, Singh *et al.*, 2016, while studying the regeneration status of different oak (*Quercus* spp.) dominated forests of Garhwal Himalaya, reported seedling density ranging from 1550-9600/ha while sapling density varied from 167-1296/ha. The regeneration status of tree species varied along the disturbance gradient. In case of highly disturbed (HD) forest, maximum tree species displayed poor regeneration status. About 50% of species had no seedlings stage. Forest areas, characterized by plenteousness of only adults and the absence or low incidence of seedlings and saplings of these species, are expected to face local extinction in due course of time (Dalling *et al.*, 1998). The reason for minimum percentage (27%) of species with good regeneration and maximum percentage (46%) of species exhibiting poor regeneration in the HD forest is the extravagant anthropogenic disturbances that leads to scarce of the tree layer and alters the forest microclimatic conditions which, in turn, conceivably have hindered regeneration process of the tree species (Mishra *et al.*, 2004). Reduced canopy cover (30%) and the consequent large canopy gaps have immediate effect on the seed production. Indirectly, it may also negatively influence the regeneration process through changes in the understorey vegetation and soil properties (Vetaas 2000). Maximum tree species (53%) showing 'Good' regeneration were reported from the MD forest while least (27%) were reported from HD forest. The reason for highest percentage of species with good regeneration status in the moderately disturbed forests may be the formation of additional microsites created due to manmade mild or gentle interference, favouring the germination of maximum of the species of stand and improving their regeneration. Same is the reason for presence of species showing "new" regeneration in MD forest. New regeneration was reported only in the MD forest. Forest ecosystems approached by disturbance allow regeneration of vegetation, thereby usually supporting vegetation composition and successional cycles (Thonicke *et al.*, 2001). MD forest had highest density of both seedlings and saplings among all forests studied. This could be due to encouraging surrounding factors like sufficient solar radiation, soil nutrients, temperature and topography. In least disturbed (LD) forest a good percentage (35%) of tree species showed poor regeneration and the main reason in this case is browsing of herbaceous vegetation including seedlings and saplings by cattle. Extravagant browsing, trampling and crushing seriously hinders the seedling settlement and hence regeneration of arboreous elements (Singh *et al.*, 1992). Grazing and trampling also influence the soil structure by compacting it; the highly compacted soil shows, in general, lower moisture content because of reduced permeability and higher run-off (Saxena *et al.*, 1984). All these things may alter the woning and make it less suitable for the setting up and survival of seedlings. In times of dearth of foliar fodder, cattle depend/feed on the herbaceous vegetation including the seedlings and saplings of dominant tree species like *Quercus sp*., which is considered to be the best fodder in this region (Malik *et al.*, 2014). The exorbitant grazing, browsing and trampling by livestock damage the ground vegetation and impede regeneration of dominant tree species in the area (Malik *et al.*, 2014). In the Himalayan region, the predominant belief is that grazing is detrimental to forests. Forest grazing is often blamed for slow regeneration, poor forest conditions, and, in extreme cases, causing potential ecological disasters (Roder *et al.*, 2002). Exorbitant grazing and overstocking of livestock prevent regeneration of the tree cover (Kumar *et al.*, 2005). Therefore, appropriate management interventions and amicable solutions for better livestock management need to be initiated without any further delay. The population structures of a species in forest portraits its regeneration behavior and those characterized by the presence of sufficient seedlings, saplings and adults point out a successful regeneration. In the present study, maximum species exhibited highest density of individuals in the lower girth classes and the density decreased progressively as the diameter classes increased. Variations in the number of individuals in different diameter classes along the disturbance gradient may be attributed to the prevailing environmental factors and degree of disturbance. If a species shows "inverse J- shaped" distribution with higher number of individuals in seedling stage and the number gradually decreased in saplings, small trees, old trees categories, such distribution shows that these species are in dominant form in the forest at present. Reverse J type of distribution is considered to be a token of good regeneration status (Vetaas 2000; Tesfaye *et al.*, 2010). Those species which are represented by nearly equal number of seedlings, saplings and trees are anticipated to be prevailing in the near future (Bhuyan *et al.*, 2003). In the present study many tree species showed an "inverse-J" shaped population structure (*i.e.* good regeneration) having a number of small tree individuals, considerable number of medium sized individuals and very few large tree individuals. Some other species revealed poor status, while a few displayed 'new regeneration' because these were represented by seedling and sapling stages only and such species were supposed to be new intruders in the studied stands and in future, they may also form sub-canopy. In the present study, there were a few tree species in each of the studies forests that exhibited interrupted or discontinuous regeneration. These tree species although dominant at present may be in trouble in future. *Albizia chinensis*, *Quercus floribunda*, *Q. leucotrichophora*, *Q. semecarpifolia*, etc. are frequently used as fodder as well as fuel and hence are under tremendous pressure throughout the area. *Aesculus indica*, *Neolitsea cuipala*, *Quercus glauca*, *Toona hexandra*, etc. are cut or lopped for fuel. *Fraxinus micrantha*, *Neolitsea cuipala*, *Quercus glauca*, *Quercus floribunda*, *Q. leucotrichophora*, *Q. semecarpifolia*, *Lyonia ovalifolia*, *Juglans regia*, etc. are regularly exploited for agricultural implements. *Persea odoratissima*, *Q. semecarpifolia*, *Fraxinus micrantha* and *Pinus roxburghii* are exploited as timber for construction purposes. Extracting of fuel-wood and timber has profound effect on the biodiversity of the forest ecosystem (Sayer *et al.*, 1991), usually changing the species composition and vegetation structure (Berkmuller *et al.*, 1990). Sagar *et al.*, 2003 have noticed that some species may put up with these disturbances, while others may surrender to them. Malik *et al.*, 2014 while studying forest resource use pattern in the study area found that 100% of families used wood as a source of energy for cooking and heating purposes. These forests are the main source of fodder and bedding material for livestock in the area. Biomass extraction, in the form of grazing, fuelwood collection and extraction of non-timber forest product (NTFP), is the most prevalent distress on forests in the rural areas, where people rely significantly on these activities for household and livelihood needs (Pattanayak *et al.*, 2003). One of extreme impacts of sequential fuel wood extraction on the structure of the forest is the ruthless diminution of large old trees leading to their complete disappearance (Malik 2014). Once these trees are lost, the size of gaps created either by natural tree falls or logging also increases Ruger *et al.*, 2007, resulting in forest fragmentation and vulnerability to invasion by ephemerals, that inhibit the regeneration of seedlings of tree species (Malik *et al.*, 2014; Malik 2014). Seedling diversity was found to be negatively and significantly correlated with lopping percentage (-0.852). Similar correlation was shown by saplings (-0.765). The sequential lopping of trees for leaf-fodder (and fuel wood) diminishes the potency as well as seed production (Saxena *et al.*, 1984).

CONCLUSION

The present study concludes that the mild disturbance caused to the vegetation of the study area due to collection of fuel-wood, fodder and cattle grazing do not adversely affect its plant diversity. On the contrary it enhances regeneration of species in the area. However, the increased degree of disturbance, beyond a certain limit, caused loss in plant diversity and brought about changes in community characteristics. The overall regeneration status was fairly high in the study area and hence these communities may be sustained in future unless there is any major environmental stress or interference exerted by human activities. Some species showed poor regeneration status, while a few were represented in seedling and sapling stages only and such species seem to be new intruders in the studied stands and may form sub-canopy in future. The regeneration status was very low in HD forest that comes under the adjoining areas and hence unprotected from various anthropogenic disturbances, while in MD and LD forests the regeneration was appreciable. Hence this study also gives the importance of establishment of protected areas for the conservation of biodiversity of Himalaya.

ACKNOWLEDGEMENT

The work has been funded through fellowship granted to the first author by HNB Garhwal University and UGC, New Delhi which is gratefully acknowledged

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