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Regeneration potential and distribution pattern of tree species along altitudinal gradient in Central Himalaya

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Abstract- The present paper reports the regeneration potential and distribution pattern of natural forest in Taknaur Reserve Forest of Uttarkashi forest division of Garhwal Himalaya, Uttarakhand. A total of 29 tree species were recorded from the area. Density and distribution of seedlings, saplings and trees were assessed along the gradient of altitude using the quadrat size 1x1m (for seedlings) 5x5m (for saplings) and 10x10m (for trees). The numbers of individuals, frequency were recorded and height of the species in the quadrat at 100m drops in altitude. Seedling densities varied markedly among the species and altitude. Lower elevation was dominated with *Pinus roxburghii* and *Quercus leucotrichophora* was found co-dominant species whereas, *Buxus wallichiana* and *Quercus floribunda* was dominant and *Taxus baccata* was co-dominant species in site two (1900-2500m asl). While upper elevations were dominated by *Buxus wallichiana, Quercus floribunda* and *Abies pindrow*, *Cedrus deodara*, respectively, for site 3rd and 4th . However, the highest (10000 ha^{-1}) seedling density , was reported for *Pinus roxburghii* at site 1 followed by *Cedrus deodara* (9000 individuals ha^{-1}) at site 2, *Buxus wallichiana, Taxus buccata, Quercus floribunda Abies pindrow and Cedrus deodara* (4000 individual ha^{-1} of each species) at site 3 and 4, respectively. It is remarkable that economically and ecologically valued species Acer *accuminatum, Ulmus wallichiana, Betula utilis Acer oblongum* which are already in vulnerable in their status were found absent in seedling stage. These species were also reported as regularly distributed in tree and sapling stratum, which is very alarming for the conservation point of view. In tree layer the most of the species (65.16%) were distributed contagiously and remaing (34.84%) were distributed randomly.

Index Terms- Himalaya, Taknaur forest, regeneration potential, *Acer accuminatum, Acer oblongum, Ulmus wallichiana, Taxus buccata.*

I. Introduction

Regeneration is the key feature of the forest dynamics, progress and restoration of degraded forest lands. It depends on number of seedlings, saplings and their distribution pattern in the region. If seedlings and saplings are less than the mature trees, it indicates declining trends in forest and regeneration will be poor. Forest reveals variation in pattern of regeneration both through differences in their constituent species and the environmental variables in which they grow (Demel, 1997a; Denslow, 1987; Whitmore, 1996). Regeneration of any species is confined to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution (Grubb 1977). Trees regenerate one or more pathways: seed rain (recently dispersed seeds), the soil seed bank (dormant seeds in the soil), and the seedling bank (established, suppressed seedlings in the understory) and coppice (root/shoot sprouts of damaged individuals (Demel, 1997b; Demel and Granstrom, 1995; Garwood, 1989; Getachew *et al.* 2002; Whitemore 1996). Sustainable forest utilization is only possible if adequate information on the regeneration dynamics and factors influencing important canopy tree species are available. Thus, study of regeneration of forest trees has important implications for the management of natural forests, and is one of the thrust areas of forestry.

The population structure, characterized by the presence of sufficient population of seedlings, saplings and adults, indicates successful regeneration of forest species (Saxena and Singh, 1984), and the presence of saplings under the canopies of adult trees also indicates the future composition of a community (Austin, 1977). Regeneration status of trees can be predicted by the age structure of their populations (Khan *et al*., 1987; Vablen *et al.*, 1979 and Tripathi and Khan 2007).

Studies on population structure and density of major canopy tree species can help to understand the status of the regeneration of species and thereof, management history and ecology of the forest (Alvarez-Buyalla *et al*,. 1996; Foster 1980; Harper 1977; Hubble and Foster 1986; Lykke, 1993; Saxena *et al*, 1984). Plant population structure shows whether or not the population has a stable distribution that allows continuous regeneration to take place (Enright and Watson, 1991; Rao *et al.*, 1990). Regeneration is the process of silvigenesis by which trees and forests survive over time (Bhuyan *et al*., 2003). If regeneration takes place continuously, then, the distribution of the species cohorts would show reverse J shape curve which is an indicator of healthy regeneration (Demel, 1997a; Silvertown, 1982). Such population structure are common in natural forests where external disturbances are limited (Getachew *et al.* 2002; Feyera, 2006).

Seedling densities in forest understories are dynamic and rates may vary among species and in gap and shade environments (Bazzaz, 1991). The rates also vary due to mortality, which could include abiotic stresses such as light, drought and biotic factors that includes herbivores, diseases and competition (Augspurger, 1984). Information on tree seedling story can provide option for forest development through improvement in recruitment, establishment and growth of the desired species (Swaine 1996). Thus regeneration studies have significant applications on the management, conservation and restoration of degraded natural forest.

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II. Material and Methods

Study Area

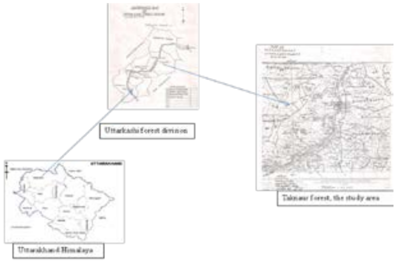

Fig.1. Location map of study area

The study has been carried out in Taknaur reserve forest of Uttarkashi forest division of Central Himalaya. Geographically the forest division extends from 30° 24′ 30″ to 31° 27′ 30″ N latitude and 78° 09′ 40″ to 79° 25′ 05″ E longitude and occupies an area of about 224370.60 ha while the study area stretches between 30° 49′ 41″ to 30° 54′ 06″ N latitude and 78° 35′ 08″ to 78° 40′ 33.7″ E longitude and covers an area of about 66755.90 ha, which is 29.75% of the division, while altitudinally, the area ranges from 1280 m asl to 3500 m asl.

Geologically, the study area falls in the middle and greater Himalayan zone, which is mainly comprised of unfossiliferous sedimentary rocks of various ages from Precambrian to Paleozoic (Valdia, 1976). Climatic conditions are generally dry with low annual precipitation, but there is heavy rainfall during the monsoon from late June to early September. Prevailing mist and low cloud during the monsoon keeps the soil moist, hence the vegetation is lush than is usual in the inner areas. The area is usually snow-bound for six to seven months between late October and late March.

For understanding the study area, it was divided in four sites along gradients of altitudes as **Site 1 (1280-1900m asl**), **Site 2 (1900-2500m asl**), **Site 3 (2500-3000m asl**) and **Site 4 (3000-3500m asl**) as per its geographical condition and vegetation type **Fig. 1**.

Methodology

Tree, sapling and seedling survey work were conducted during October 2008 to July 2010 and data were collected from the different forest types based on stratified random sampling method. For the purpose of this study, the terms seedling, sapling and tree were defined as plants with heights up to 150cm, between 150 and 300cm and above the 300cm respectively as per Getachew *et al.* 2002. The vegetation data were quantitatively analyzed by laying the quadrats at different sites, 10x10m for trees, 5 × 5 m for sapling and 1 × 1 m size quadrates were laid down for seedlings randomly at each site separately for abundance, density, frequency following the methods discussed by Curtis and Cottom (1956).

III. Results

Through the exhaustive phyto-sociological surveys of different sites of Taknaur forest the comprehensive data were collected and results were summarized in table 2, which describes species diversity story of the forest. A total of 29 tree species were recorded among them *Pinus roxburghii, Quercus leucotrichophora* (at Site 1), *Buxus wallichiana, Cedrud deodara, Quercus floribunda, Taxus baccata* (at site 2), *Buxus, wallichiana, Cedrus deodara, Pinus wallichiana, Acer accuminatum* (at site 3) and *Abies pindrow, Cedrus deodara, Quercus semicarpifolia, Picea smithiana* (at site 4) were found dominant species. Which clearly categories the forest in four forest types along the altitudinal gradients. The general features of the area can understood from the table no 1. Thus, study area, the Taknaur reserve forest can be categorized in four forest types viz (1) Pine-oak forest, (2) Oak-mixed forest (3) Oak-conifer forest and (4) Conifer forest. The forest represents generally conifer-oak mixed type forest.

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Table: 1 General characteristics of the study area of Taknaur forest.

Sites	Altitude	Aspect	Dominant species	Forest types
Site 1	1280-1900	South-west	*Pinus roxburghii*, *Quercus leucotrichophora* and *Rhododendron arboreum*	Pine–oak forest
Site 2	1900-2500	North	*Buxus wallichiana*, *Cedrus deodara Quercus floribunda*, *Lyonia ovalifolia*, and *Pinus wallichiana*	Mixed oak- conifer forest
Site 3	2500-3000	West	*Quercus floribunda*, *Swida microphylla Lyonia ovalifolia*,*Cedrus deodara*, *Pinus wallichiana* and *Picea smithiana*	Mixed broad leaved conifer forest
Site 4	3000-3500	East	*Abies pindrow*, *Picea smithiana*, and *Cedrus deodara*	Conifer forest

Table: 2. Regeneration potential and distribution pattern along gradient of altitudes and aspects of Taknaur forest of Uttarakashi forest division in Garhwal Himalaya.

	Gradients of elevation							
	1280-1900 m		1900-2500 m		2500-3000 m		3000-3500 m	
Name of species	Density (ha^{-1}) Tree/Sap /Seedlings	A/F Ratio Tree/Sap /Seedlings	Density (ha^{-1}) Tree/Sap /Seedlings	A/F Ratio Tree/Sap /Seedlings	Density (ha^{-1}) Tree/Sap /Seedlings	A/F Ratio Tree/Sap /Seedlings	Density (ha^{-1}) Tree/Sap /Seedlings	A/F Ratio Tree/Sap /Seedlings
Pinus roxburghii	490/640/10000	0.30/0.20/0.62						
Quercus leucotrichophora	190/180/4000	0.47/0.23/0.10						
Lyonia ovalifolia	130/260/3000	0.14/0.33/0.03	140/180/3000	.028/.01/----	70/50/2000	.028/.024/.05	90/120/3000	.04/.024/.075
Rhododendron arboreum	90/120/----	0.22/0.15/----	60/60/----	.06/.07/.075				
Buxus wallichiana	80/80/2000	0.80/0.50/0.20	460/560/8000	.28/.17/.09	210/180/4000	.084/.036/.04		
Taxus baccata	90/140/3000	0.90/0.70/0.30	260/480/8000	.07/.04/.021	140/260/4000	.056/.02/.025	150/160/3000	.025/.02/.03
Abies pindrow			180/240/5000	.11/.03/.053	100/120/----	0.25/0.15/----	180/180/4000	.05/.04/.025
Acer acuminatum			70/80/----	.07/0.10/----	40/60/----	.10/.30/----	20/40/----	.20/.20/----
Pinus wallichiana			180/220/6000	.03/.022/.03	160/180/4000	.03/.036/.25		
Quercus semecarpifolia			230/200/6000	.04/.015/.024	130/220/3000	.035/.02/.075	130/140/3000	.028/.014/.07
Swida macrophylla			60/40/----	.15/.20/----	30/40/----	.075/.20/----		
Quercus floribunda			280/420/5000	.07/.058/.02	150/260/4000	.04/.03/.025	110/140/3000	.13/.076/.075
Cedrus deodara			290/360/9000	.03/.02/.018	180/260/3000	.027/.02/.03	180/160/4000	.037/.015/.04
Aesculus indica			30/20/----	.03/.10/----	110/20/----	.02/.10/----	40/60/1000	.10/.075/.10
Salix babylonica			50/80/----	.50/.10/----	20/----/----	.20/.025/----		
Juglans regia					20/40/----	.20/.20/----	30/40/1000	.075/.20/.10
Fraxinus micrantha					30/20/1000	.30/.10/.10	4/40/----	.10/.20/----
Alnus nepalensis			50/80/1000	.12/.10/.10	20/20/----	.20/.10/----		
Ilex dipyrena					40/40/1000	.10/.20/.10	40/60/1000	.10/.30/.10
Acer oblongum			30/30/2000	.30/.04/.20	20/20/----	.05/.10/----		
Betula anoides			120/100/3000	.03/.02/.075	30/40/----	.03/.05/----		
Populus ciliata					10/20/----	.10/.10/----	30/20/----	.075/.10/----
Toona serrata			20/40/----	.05/.20/----	20/20/-----	.20/.10/----		
Cupressus torulosa					30/40/----	.30/.20/----	50/60/1000	.13/.075/.10
Picea smithiana					20/20/----	.20/.10/----	70/60/1000	.05/.075/.10
Carpinus viminea					10/20/----	.10/.10/----		
Symplocos chinensis					30/20/----	.075/.10/----		
Ulmus wallichiana					30/40/----	.75/.05/----		
Betula utilis							50/60/----	.05/.075/----

The seedlings of *Pinus roxburghii* showed the concentration at lower elevation (1280m - 1900m asl) only and does not occurs throughout the elevations in the study area. Seedling densities varied considerably with altitude ranging between 530 individuals ha^{-1} at 1900m and 10000 individuals ha^{-1} at 1280m asl. Of the total seedlings 57% were less then 50cm. in height.

Seedlings of *Taxus baccata* showed distinct altitudinal concentration between 1500m to 3000m asl. Seedling densities increased (8000 individuals ha^{-1}) at the elevation of 2500m while it was decreased progressively (3000 individuals ha^{-1}) at 3200m asl. The highest seedling density was recorded at 2500m asl. It was found throughout the altitudinal gradients in contagious distribution in the study area.

Cedrus deodara was found in tremendous occurrence (9000 individuals ha^{-1}) in seedlings stratum at the site 2 (1900m-2500m) but lower at higher elevations (Site 3 & 4). *Buxus wallichiana* (8000 individuals ha^{-1}) was found co-dominant, whereas, *Rhododendron arboreum* (3000 individuals ha^{-1}) was showed very poor performance in new generation at site 2.

Seedlings of *Lyonia ovalifolia* were not concentrated at any elevation and occurred across the altitudinal ranges of study area. Of all the seedlings, 45% were less than 50 cm in height.

The seedling densities of different species at site 1 showed that it was young new growing Pine-oak forest. The highest seedling density (10000 individuals' ha^{-1}) was recorded for *Pinus roxbughii* followed by *Quercus leucotrichophora* and *Taxus buccata* (4000 and 3000 individuals $ha^{-1,}$ respectively), while, *Buxus wallichiana* showed lowest (2000 individuals ha^{-1}) of seedlings.

Sapling densities and distribution pattern of different species at different altitude was recorded different from their mature plants. *Pinus roxburghii* (640 individuals ha^{-1}) was found dominant with contagious distribution followed by *Rhododendron arboreum* (260 individuals ha^{-1}) whereas least sapling density was observed for *Buxus wallichiana* (100 individuals ha^{-1}) at site first (1280-1900m asl). At second site (1900-2500m asl) sapling density was highest for *Buxus wallichiana* (560 individuals ha^{-1}) followed by *Taxus baccata* (480 individuals ha^{-1}) as co-dominant species. Site third had different story in compared to their mature trees that is *Quercus floribunda, Taxus buccata* and *Cedrus deodara* (260 individuals ha^{-1} of each species) were the dominant species and showed same sapling densities whereas their tree stratum was little varying. *Lyonia ovalifolia* and *Aesculus indica* (20 individuals ha^{-1}) was least occurred plant species at this site. However, the site fourth was giving good regeneration potential in their second generation as *Abies pindrow* (180 individuals ha^{-1}) was dominating along with *Cedrus deodara* and *Taxus buccata* (160 individuals ha^{-1} of each species) co-dominating species. *Populus ciliata* was found with very poor performance (20 individuals ha^{-1}) at this site.

Densities of different trees at different altitude was also varied as *Pinus roxburghii* 490, *Quercus leucotrichophora* 190 individuals ha^{-1} at site 1, while, *Buxus wallichiana* showed least (80 individuals ha^{-1}) density at this site. Increasing with altitude that is site second (1900-2500m) the reverse trends were shown as *Buxus wallichiana* expressed highest density (460 individuals ha^{-1}) followed by *Cedrus deodara* (290 individuals ha^{-1}) whereas least was shown by *Aesculus indica* (30 individuals ha^{-1}). At higher elevational range (2500-3000m) *Buxus wallichiana* also maintained its dominancy with 210 individuals ha^{-1} which is again followed by *Cedrus deodara* (180 individuals ha^{-1}) and poorly occurring species was *Populus ciliata* (10 individuals ha^{-1}). The site fourth (3000-3500m asl) had a different tree composition with dominant elements of *Abies Pindrow, Cedrus deodara* (180 individuals ha^{-1}) and *Taxus buccata* (150 individuals ha^{-1}) as a co-dominant species. Here *Acer accuminatum* was least occurred (20 individuals ha^{-1}) plant species.

IV. Discussion

Seedling densities varied significantly among species. Seedling densities were highest for *Pinus roxburghii, Cedrus deodara, Abies pindrow*, *Taxus buccata* and *Quercus floribunda* at different sites due to their optimum requirements of climatic, geographic and edaphic conditions and high reproductive potential of mother trees. However, 42-61% of the seedling populations of several species in Ethopian forest were lost annually due to drought, disturbances and herbivory damage (Getachew 2008). *Ilex dipyrena, Populus ciliata, Picea smithiana, Juglans regia* and *Aesculus indica* had the lowest seedling density which could be attributed due to unfavorable climatic conditions, anthropogenic disturbances, other biotic interferences and low reproductive performance of the mother trees. The pioneering species *Alnus nepalensis*, *Pinus roxburghii* and *Quercus leucotrichophora* were concentrated only at lower elevation whereas *Betula utilis* was concentrated only at higher elevation. This is very clear indications of topographic, geographic and climatic restrictions of the species.

The distribution of seedlings along elevational gradients also showed marked variations among species. *Taxus buccata*, and *Lyonia ovalifolia* showed wide distributions and occurred along entire elevational range in the forest. On the other hand *Pinus Roxburghii, Quercus leucotrichophora* restricted to lower elevation (1280-1900m); *Betula utilis* was found restricted to higher elevation (3000-3500m) only whereas, *Ulmus wallichiana* was concentrated only at middle evevation (2500-3000m). Maximum species were distributed in contagious pattern across the altitudinal ranges. Odum (1971) have emphasized that contagious distribution is the commonest pattern in nature. Kumar and Bhatt (2006) also reported contagious distribution pattern in foot-hills forests of Garhwal Himalaya. At the upper elevation, relatively humid climatic conditions would restrict the distribution of some species.

The data of densities and distribution of trees, sapling and seedlings (table 2) clearly explains that the site second is naturally healthy conifer-mixed oak forest with high regeneration status of *Cedrus deodara* folloed by *Taxus buccata* and *Buxus wallichiana.* But at the same time it is very negative sign that the valuable species *Acer accuminatum* has no regeneration mark in the area.

Tree densities were varying along the altitude but the trends were very similar to previous studies in the Himalaya. Bargali *et al*. (1987) has described the values of tree density ranging from 490 to 1640 individual ha^{-1} in Kumaun forest. Pangtey *et al*. (1989) reported the density values of trees ranging from 140 to 750 individual ha^{-1} in Pindari catchments forest. Kumar *et al.*

(2001) reported density values of tree ranged 652 to 1028 individual ha^{-1}.

The absence of seedlings of *Acer accuminatum, Acer oblongum, Betula utilis, Ulmus wallichiana*, and *Swida macrophylla* may be partially attributed to the absence of a conductive environment for germination of their seeds such as severe disturbance of the canopy and forest soils. Climatic conditions and biotic interference influence the regeneration of different species in the vegetation. Higher seedling density values reduced to perform as sapling stage due to biotic disturbance and competition for space and nutrients Kumar and Bhatt (2006). In previous study similar results were obtained for several species in Ethopian forest by Getachew and Demel 2005b.

Among all the 29 tree species occurring in the study area, 10 tree species as *Acer accuminatum, Acer oblongum, Ulmus wallichiana, Betula utilis, Carpinus viminea, Symplocos recemosus, Populus cilata, Toona serrata, Salix babylonica* and *Swida macrophylla* were found completely absent in seedling stratum. This clearly says that there is no regeneration in these species. Since, these data were on the basis 2 years observations, therefore straightly it cannot be concluded that in future these species will remain absent in the area but it is essentially alarming sign of vulnerability of these species. Because out of these 10 species *Acer accuminatum, Acer oblongum, Ulmus wallichiana, Betula utilis* are already in vulnerable in IUCN Red data book and their mature tree and saplings are also not well in distribution and densities in the investigated area, they are in regular distribution. Therefore, it is evident that these species requires urgent conservation measures in the area for their restoration. *Acer accuminatum, Acer oblongum, Ulmus wallichiana, Betula utilis* are not important only due to their conservation status but also important due to their economic and ecological values in the ecosystem.

The species that requires high conservation in Uttarkashi forest division were *Betula utilis, Acer oblongum, Acer accuminatum, Ulmus wallichiana*. Regeneration problem was largely attributed to human disturbances, lack suitable habitat for seeds to germinate or problem associated with producing mature and fertile seeds. On the other hand, high seedling densities or adeptive defenses to herbivory were common attribute to healthy regenerating species.

Based on our results, the following recommendations are forwarded as option for sustainable forest management of the forest division. i) Initiate *in-situ* conservation efforts for *Betula utilis, Acer oblongum, Acer accuminatum, Ulmus wallichiana*, including restrict protection of remaining mother trees. ii) Promote sustainable utilization of trees through traditional knowledge based decision system such as population growth models of each species. iii) Study of reproductive ecology of the species including pollination, seed production, dispersal and germination.

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