

## Ecological Regeneration Trends of Multiple Trees Size and Structure in Central Himalaya, India

Nidhi Bhakuni, Neelu Lodhiyal

Received 3 February 2018; Accepted 23 February 2018; Published on 14 March 2018

**Abstract** Vedic period to present day the conservation and management of forest is a big concern. To focus the forest management and to assess regeneration status of forests, present study was carried out at Van-Panchayat (community managed) and reserve forest located in Central Himalaya. The quadrats were placed randomly for the collection of data and for the estimation of regeneration tree species were distributed in different girth classes. The study reveals that the community managed forests were reported having more young girth class of trees than the older girthclass's tree species. Reserve forest showed slightly better regeneration trends (0–36% species

showed good regeneration, 35–56% species showed fair regeneration, 14–19% species showed poor regeneration) than community forest (22–29% species showed good regeneration, 5–56% species showed fair regeneration, 0–57% species showed poor regeneration). Community people have lesser alternative sources of energy as fuel and fodder so they used oak species from VP forests, to fulfill their basic needs so there is a moderate pressure on oak species. Thus including all the attribute of results it can be concluded that forests needs to be a participatory approach to be conserved and managed for sustainability.

**Keywords** Regeneration, Seedlings, Saplings, Community, Central Himalaya.

### Introduction

Ecologist often uses size distribution to indicate the strength of a population. If there is large number of juveniles relative to adult trees, this is taken to indicate that a population is stable, perhaps growing, but few juveniles can be seen as a warning that the population is in decline. The dearth of direct estimate of population size through time, this appears a reasonable shortcut. It is often very easy to get estimates of size distribution from a population but much harder to record end using population trends (Condit et al. 1998). One main goal of forest ecology is to infer past changes and predict future changes in species composition, and examining the diameter distributions of canopy species is often used toward this end (Lorimer

---

Nidhi Bhakuni\*, Neelu Lodhiyal  
Department of Botany,  
DSB Campus, Kumaun University,  
Nainital 263002, Uttarakhand, India  
e-mail : nidhikunainital@gmail.com  
\*Corresponding author

**Table 1.** Regeneration pattern showing forest and species status.

Curve	Pattern	Regeneration pattern
Reverse J	Seedling>sapling>tree	Good regeneration
J	Seedling<sapling<tree	Poor regeneration
Bell shaped (∩)	Seedling<sapling≥tree	Poor regeneration
Reverse bell shaped (∪)	Seedling>sapling<tree	Fair regeneration
Parallel (  )	Seedling=sapling=tree	Fair regeneration
Irregular ( )	Only seedlings	New species
Irregular ( )	Only mature tree	No regeneration

1980, Knowles and Grant 1983, Ogden 1985, Hart et al. 1989, Franklin et al. 1993, Read et al. 1995). Population size distribution carries a wealth of demographic information and is frequently the most unequivocal and accessible attribute available for a population. The size distribution of a population is a synthesis of the demographic events of recruitment, mortality and individual growth rates over time (Kelly et al. 2001). Theoretical population models predict that the shape of population size distributions results from the interaction between size-specific survival, growth and fecundity (Case 2000, Caswell 2001). If two populations differed in fecundity only, having equal growth and survival rates across size classes, then a larger population growth rate would produce a steeper negative size distribution (Condit et al. 1998). The future composition of the forests depends on the potential regenerative status of tree species within a forest stand in space and time (Henle et al. 2004). Presence of sufficient number of seedlings, saplings, and young trees in a given population indicate a successful regeneration (Saxena and Singh 1984). The aim of the present study is to generate regeneration status in temperate mountain forest zones of part of Central Himalaya. The principle objective of this study is to compute environmental regeneration of studied forest stands so that it can be beneficial for the foresters and the villagers to make them aware of the present condition under the effect of climate change.

(Financial assistance from University Grant Com-

mission, New Delhi under UGC-SAP (BSR) research fellowship is gratefully acknowledged).

## Materials and Methods

### Study area

The present study was conducted forest regeneration affairs in Himalaya region managed through community and forest department in hilly region. The sites were located in Nainital district of Uttarakhand (India) 29° 19' to 29° 34' N and 79°40' to 79°-58' E latitude and longitude, respectively in 1600 to 2500 m elevation from sea level. Six study forest sites were selected i.e. 03 community managed (forest site-1, site-2 and site-3) that are managed by the local community peoples and 03 reserve forest (forest site-4, site-5 and site-6) managed by the forest department and the reserve forest was located near community and community forest. The major forest vegetation of the study forest sites were: *Quercus floribunda*, *Rhododendron arboretum*, *Pinus roxburghii* *Myrica esculenta* and *Quercus leucotrichophora* some tree species were planted in the reserve and community forest. Reserve forest site have some exotic species, they are planted with the native species by forest department.

### Vegetation and diversity analysis

The study period, the trees in the vegetation type were classified into three growth phase girth was measured at breast height from ground level (Circumference at breast height i.e. 1.37 m) i.e. <10 cm seedling, 10.1–30 cm and sapling, >30 cm adult trees. The sampling was carried out in 10 × 10 m for tree, sapling and seedling and the sampling size was one fourth (2500 m<sup>2</sup>) of one hectare forest for the assessment (Saxena and Singh 1984, Misra 1968). Species richness was computed through the number of individual taken from collection in forest sites. Species diversity of tree species in each studied forest site was calculated by using Shannon-Weiner information index (Shannon and Weaver 1963).

$$H' = - \sum_{i=1}^s \left( \frac{N_i}{N} \right) \log_2 \left( \frac{N_i}{N} \right)$$

**Table 2.** Density (plant/ha) of different life stage of plants according to their girth (cm).

Sites/ Girth (cm)	Area (ha)	Seedling 0–10	Sapling 10.1–30	Density (ind/ha)					Density (ind/ha) Average	Species diversity H'	Species richness
				30.1–60	60.1–90	90.1–120	120.1–150	>150			
Site-1	206	1620	2990	1150	267	60	20	40	878±424	2.73	20
Site-2	314	2757	1123	947	427	113	63	47	782±368	3.05	18
Site-3	118	2263	83	177	277	157	27	3	427±308	2.25	09
Site-4	216.8	770	443	103	320	197	80	20	276±99	2.80	14
Site-5	308	1160	790	313	150	123	97	67	386±160	2.84	20
Site-6	90	817	53	160	137	120	70	33	199±104	3.04	16

Where,  $N_i$  is total number of individual species;  $N$  is total number of individuals of all species (Shannon and Weaver 1963).

#### Regeneration

The regeneration status of a tree species was estimated to categorized on the basis of the girth classes of the tree that are <10 cm seedling, 10.1–30 sapling, >30 adult trees (30.1–60, 60.1–90, 90.1–120, 120.1–150, >150). The regeneration pattern was estimated through different graph curve developed through MS excel, as the pattern of curve shown in Table 1 we determine the regeneration status of species and forest sites (Condit et al. 1998, Sukumar et al. 1992).

Sorenson index of similarity (Magurran 1988) was used:  $S = 2c/(a + b)$ , where  $S$  is Sorenson index of similarity,  $c$  is number of species shared between growth phases (here mature tree phase and regenerating phase, i.e. saplings + seedlings),  $a$  is total number of species in growth phase a (regenerating phase), and  $b$  is total number of species in growth phase b (mature phase).

## Results and Discussion

#### Density and diversity

The species dominance in the forest sites were based

on density of individuals (sapling+mature tree), seedlings were excluded because they were not shared in canopy cover. The *Q. floribunda* was the dominant tree species in forest site-1 and site-2 on the basis of density (sapling + mature tree) but *P. roxburghii* was the dominant tree species in forest site-3 in community managed forest (Table 2). In reserve forest site-4, dominant tree species was *P. roxburghii* and *Q. leucotrichophora* was dominant in forest site-4 and 5 (Table 2). Total species richness in the studied forest sites were ranged 09–20 in western Himalaya region. In community managed forest site-1, site-2 and site-3 saplings and seedling density were higher than mature trees, in reserve forest site-4, site-5 and site-6 mature tree density was higher than seedlings density than sapling (Table 3). The mean density of all phase (seedling, sapling and mature tree) represents higher density reported in community forests than reserve forests. Species diversity of the forests was ranged 2.25 to 3.05 which is approximately equal in community and reserve forests sites (Table 3).

#### Regeneration

Percent of regenerating species was maximal of seedlings as compared to the sapling and mature trees. The percent of mature phase was lesser than regenerating phase (seedling and sapling). Regenerating species was ranged 43 to 78%, which means seedling transform to sapling and sapling transform to mature tree (Table 3). The similarity percent was 8 to 15%

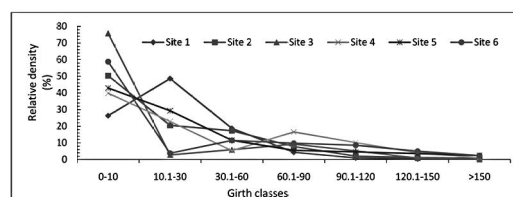
**Table 3.** Distribution pattern of adult trees and seedling + sapling of trees occur in different forests. Regenerating species (seedling + sapling + adults trees i.e. >30 cm girth) share in all phases of trees. Similarity % (using Sorenson index of similarity) of adult trees and saplings + seedlings in different forest site and new species recruited (only seedling present) are also shown. \*A number of species occur in saplings and/or seedlings, and these species may or may not have mature tree stage.

Sites	Tree species (%)	Seedling + sapling only (%)	*Regene- rating species (%)	Sorenson index (%)	New entry species %
Site-1	25	75	55	13	14
Site-2	29	71	67	14	0
Site-3	21	79	78	8	22
Site-4	37	63	43	9	0
Site-5	28	72	60	15	15
Site-6	37	63	69	15	13

which represent the common regenerating phase species that were present in mature phase also (Table 3). New invade species include 0 to 22% in forest sites, that represent number of species march into that place from which newly existed (Table 3).

Forest site-1 showed bell shaped curve which depicted poor regeneration pattern (Fig. 1). The number of saplings was very high in the forest site than seedling and mature trees; discrepancy in the relative proportion of old and medium sized trees was expected to occur depending on forest disturbance regime. The dominant tree species *Q. floribunda* showed bell shaped curve which showed poor regeneration, these saplings was higher in percentage than other species and other sub species *R. arboreum* showed reverse J curve represent good regeneration. The fodder species undergo high pressure than other sub-species (Table 4).

Forest site-2 showed reverse J shaped curve which represent the good regeneration (Fig. 1). In forest site-2 seedlings and adults were higher than saplings. The dominant tree species showed *Q. floribunda* J shaped curve which depicted poor regen-



**Fig. 1.** Regeneration status of the forests.

eration and followed by *R. arboreum* and *L. ovalifolia* showed reverse bell shaped curve which represented fair regeneration in forest site (Table 4). *Q. floribunda* undergoes more anthropogenic pressure (caused by fodder, fuel wood collection and cattle grazing) than other sub species.

Forest site-3 showed reverse J shaped curve which represent the good regeneration (Fig. 1). The dominant tree species *P. roxburghii* showed reverse bell shaped curve which represented fair regeneration, seedling and mature tree much higher than saplings stage. Fodder species *Q. leucotrichophora* species showed reverse J curve which represent good regeneration, the community people planted oak species and managed them (Table 4).

The reserve forest nearby community and village showed better regeneration status. In forest site-4 showed reverse J shaped curve predict good regeneration (Fig. 1). The dominant tree species *P. roxburghii* showed reverse bell shaped predict fair regeneration, followed by *C. torulosa* represent I shaped curve (only mature trees were present) reveals no regeneration and *Q. leucotrichophora* represented reverse J curve which showed good regeneration (Table 4).

Forest site-5 showed reverse J shaped which represent good regeneration pattern, seedlings was greater than sapling than adults (Fig. 1). The dominant species *Q. leucotrichophora* showed reverse J shaped predict good regeneration, *P. roxburghii* reverse bell shaped represented fair regeneration and *C. torulosa* showed J shaped showed poor regeneration (Table 4).

**Table 4.** Regeneration status of species in forests sites.

Forest site Species	Community managed				Reserve forest	
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
<i>A. indica</i>	–	Poor	–	–	Poor	Poor
<i>A. mearnsii</i>	–	–	–	–	Poor	–
<i>A. nepalensis</i>	–	Poor	–	Poor	Fair	–
<i>A. oblongum</i>	–	Poor	–	–	–	Fair
<i>A. pindrow</i>	Fair	–	–	–	–	–
<i>B. orientalis</i>	–	–	–	–	–	–
<i>B. rugulosa</i>	Good	–	–	–	–	Fair
<i>C. capitata</i>	–	Good	–	–	–	No
<i>C. deodara</i>	Poor	–	–	–	Fair	Poor
<i>C. micrantha</i>	–	–	–	–	–	No
<i>C. torulosa</i>	Poor	–	–	No	Fair	Poor
<i>E. parviflora</i>	Good	Good	–	Fair	Fair	New
<i>E. tereticornis</i>	–	–	–	–	Fair	–
<i>E. micrantha</i>	–	No	–	–	–	–
<i>I. dipyrrena</i>	Good	Good	–	–	–	–
<i>L. ovalifolia</i>	Poor	Fair	Fair	Fair	Good	Fair
<i>L. umbrosa</i>	Poor	–	–	–	–	–
<i>M. esculenta</i>	Poor	Poor	Fair	Fair	Good	Fair
<i>P. cerasoides</i>	Good	Good	New	Poor	New	–
<i>P. communis</i>	Poor	–	–	–	–	–
<i>P. orientalis</i>	–	–	–	Good	New	–
<i>P. pashia</i>	Fair	Fair	Fair	Good	Fair	Fair
<i>P. roxburghii</i>	Poor	Poor	Fair	Fair	Fair	Fair
<i>Q. floribunda</i>	Poor	Poor	–	–	Poor	–
<i>Q. lanuginosa</i>	New	–	–	No	Poor	–
<i>Q. leucotrichophora</i>	Poor	Fair	Good	Good	Good	Fair
<i>R. arboreum</i>	Good	Fair	Fair	Fair	Poor	Fair
<i>S. chinensis</i>	Poor	Fair	Good	Good	Good	New
<i>S. nigra</i>	New	–	–	–	–	–
<i>T. baccata</i>	–	–	–	–	–	–
<i>T. ciliata</i>	–	–	–	Good	No	Fair
<i>F. cotinifolium</i>	Poor	Good	New	–	New	–

Forest site-6 showed reverse bell shaped curve represented fair regeneration (Fig. 1). Approximately all the species showed reverse bell shaped curve represented fair regeneration (Table 4).

The forest site 1, 2 and 3 were community managed forest and forest site 4, 5 and 6 managed by forest department. The community managed forest was reported more young girth class of trees than mature trees. The size distribution alone is a good predictor of future population trends, since size distribution is also affected by other demographic variable that vary between species (Condit et al. 1998).

As the results showed the forest site-1 more percent of species showed poor regeneration (57%) and followed by good regeneration (24%) which predicts that juvenile density was lesser than sapling density and saplings were higher than adult's density (Fig. 1). Non-positive symmetry may characterized the population size distribution of a long-lived pioneer that depends on moderate disturbance events to successfully regenerate, the complete lack of small individuals frequently seen in adult-dominated populations is not a necessary characteristic of the ecological models (Souza 2007). The fodder species in the forest site-1 have relatively moderate pressure. In forest site-2 more number of species showed good regeneration (23%) followed by poor regeneration (21%), the saplings were lesser than the juvenile density and adults density (Fig. 1). In forest site-2 community people participate in forest managed and conservation. In forest site-3 juvenile density and adults density were much higher than the sapling which illustrate fair regeneration, in the forest site local peoples gave more emphasis to the planted the fodder or broad leaf plant species (*Quercus* species) and avoid *Pinus* species plantation because the resin extract decline the soil fertility and soil become acidic. Forest site-3, 56% species showed fair and 22% species showed good regeneration (Fig. 1), the new plantation was held on 2014.

In forest site-4, juvenile and adults density was higher than saplings density represent fair regeneration, the dominated species *Pinus roxburghii* showed more adult density compare to juvenile density and sapling density. Site-4, 33% of species showed good and fair regeneration the forest department play a significant role in management of forest (Fig. 1), the local community interaction was less in reserve forests. In forest site-5 Juvenile density was higher followed by saplings than adult's density, represent good regeneration, dominant species *Quercus leucotrichophora* showed juvenile and adults density was higher than saplings density represent fair regeneration. *Q. leucotrichophora* not showed good regeneration because the percentage of seedling is the lowest and being a multipurpose species with high demand, yields more biotic stresses, and may be replaced by the invading species (Tiwari and Tiwari 2012). Site-5, 35% species showed fair regeneration, 25% species

showed poor regeneration and only 20% species showed good regeneration. In forest site-6, juvenile and adults density was higher than saplings density representing fair regeneration. Site-6, 56% species showed fair regeneration, no single species showed good regeneration and 19% species showed poor regeneration (Fig. 1). The above discussion exemplify that forest managed forest or reserve forest was comparatively well managed. The community forest sites were relatively disturbed through the anthropogenic disturbances and climatic factors (landslide). The anthropogenic disturbance causes disruption of forest structure and change in species composition, which eventually leads to reduction of tree species richness and abundance, which are the major attributes of forests (Jayakumar and Nair 2013). The unsustainable exploitation of the forest by the local communities has critically affected species evenness of the woody plants and population structure of the forest (Alelign et al. 2007).

The conclusion of the study was as follow

The broad leaf species have more pressure such as *Q. floribunda*, *Q. leucotrichophora*, *R. arboreum* and *L. ovalifolia* for multiple purposes (Fodder, fuel wood and other uses). The more seedlings and saplings (young tree girth classes) than adults in community forests, needs to be proper management and conservation for the future sustainability. Reserve forests was dominated older girth classes than seedlings and saplings but for the further more sustainability and maintain good regeneration of forest needs to be more plantation in barren and unused areas in forest. During study period we acquainted with that the community people now actively participated in the forest management, in community forests Sarpanch (Head of community forest or Van-Panchayat) and committee members of Van-Panchayat formed small groups of women to manage and protect their forest from various disturbances. Thus, the indigenous women are well aware and play important role in reserves and conserve the degrading forest in their surrounding forests. The species richness was higher in community forest than reserve forest, the anthropogenic pressure slightly enhance the species richness of the forest.

## References

- Alelign A, Teketay D, Yemshaw Y, Edwards S (2007) Diversity and status of regeneration of woody plants on the peninsula of Zegie, Northwestern Ethiopia. *Trop Ecol* 48(1) : 37—49.
- Case TJ (2000) An illustrated guide to theoretical ecology. Oxford University Press, Oxford.
- Caswell H (2001) Matrix population models: Construction, analysis, and interpretation. Sinauer Assoc, Sunderland.
- Condit R, Sukumar R, Hubbell SP, Foster RB (1998) Predicting population trends from size distributions : A direct test in a tropical tree community. *Am Nat* 152 (4) : 495—509.
- Franklin SB, Robertson PA, Fralish JS, Kettler (1993) Overstory vegetation and successional trends of land between the lakes, USA. *J Veg Sci* 4 : 509—520.
- Hart TB, Hart JA, Murphy PG (1989) Mono dominant and species-rich forests of the humid tropics: Causes for their co-occurrence. *Am Nat* 133 : 613—633.
- Henle K, Davies KF, Kleyer M, Margules C, Settele J (2004) Predictors of species sensitivity to fragmentation. *Biodiver Conserv* 13 : 207—251.
- Jayakumar R, Nair KKN (2013) Species diversity and tree regeneration patterns in tropical forests of the Western Ghats, India. *Ecology* doi.org/10.1155/2013/890862
- Kelly CK, Smith HB, Bockley YM et al. (2001) Investigations in commonness and rarity: A comparative analysis of co-occurring, Congeneric Mexican trees. *Ecol Lett* 4 : 618—627.
- Knowles P, Grant MC (1983) Age and size structure analyses of engelmann spruce, ponderosa pine, lodge pole pine, and limber pine in Colorado. *Ecology* 64 : 1—9.
- Lorimer CG (1980) Age structure and disturbance history of a Southern Appalachian Virgin forest. *Ecology* 6(11) : 69—84.
- Magurran AE (1988) Ecological diversity and its measurement, Croom Helm. Ltd, London, UK.
- Misra R (1968) Ecology work book. Oxford and IBH Publ Co. Calcutta, pp 244.
- Ogden J (1985) Past, present and future: Studies on the population dynamics of some long-lived trees. In : White J (eds). Studies on plant demography. Academic Press, London, pp 3—16.
- Read J, Hallam P, Cherrier F (1995) The anomaly of monodominant tropical rainforests: Some preliminary observations in the Nothofagus-dominated rain forests of New Caledonia. *J Trop Ecol* 11 : 359—389.
- Saxena AK, Singh JS (1984) Tree population structure of certain Himalayan forest associations and implications concerning their future composition. *Vegetatio* 58 : 61—69.
- Shannon CE, Weaver W (1963) The mathematical theory of communication. Univ of Illinois Press, Urbana, IL. USA, pp 117.
- Souza AF (2007) Ecological interpretation of multiple population size structures in trees: The case of *Araucaria Angustifolia* in South America. *Aust Ecol* 32 : 524—533.

Sukumar R, Dattaraja HS, Suresh HS et al. (1992) Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, Southern India. *Curr Sci* 62 : 608—616.

Tiwari PK, Tiwari SC (2012) Species diversity and environ-

mental regeneration potential of tree species along an altitudinal gradient in subtropical montane forests of a part Central Himalaya, India. *Int J Basic & Appl Sci* 1(1) : 27—37.