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Natural regeneration dynamics of tree species along the altitudinal gradient in a subtropical moist deciduous forest of northern India

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The present study was conducted to examine the regeneration pattern in 72 random plots of six tropical forest sites of Rajaji Tiger Reserve, Uttarakhand, India. The population structure of the forest was determined through density of seedlings, saplings and trees from the sampling quadrat. Based on individual density of seedling, sapling and adult, the regeneration potential of the species was determined. A total of 58 tree species under 50 genera belonging to 30 families were recorded in the forest. The overall density ranged from 1525 to 6600 ind/ha and the total basal area ranged from 0.577 to 46.81 m²/ha in case of trees and saplings, whereas for seedlings, the value ranged from 511.96 to 1221 cm²/ha. The good regeneration pattern of tree species varied from 12.12% to 31.575%, fair regeneration pattern from 12.12% to 31.57%, new regeneration from 5.26% to 39.13%, poor regeneration from 0% to 10.52%, and no regeneration of trees from 15.78% to 42.42%. Inadequate regeneration status and population structure of tree species like *Shorea robusta*, *Careya arborea*, *Ficus auriculata* were observed which could be due to looping, scraping, grazing and trampling. Anthropogenic disturbances have resulted in the population decline of tree species which may lead to many species becoming endangered, rare and threatened. Therefore, proper management and conservation initiatives with active involvement of the locals must be taken to protect the tropical forest sites of the Reserve.

Keywords: Population structure, natural regeneration, saplings, seedlings, Tiger reserve, trees, tropical forest.

THE tropical forest biomes cover about 6 million km² of the earth’s surface with the tropical rainforest, dry deciduous and savannah. About 50% of the total plant species grow in these tropical forests¹. The tropical moist deciduous forests are found throughout India, except in the northwestern and western regions of the country. These forests are more pronounced in regions which receive rainfall in the range 100–200 cm. They are found in the North East states of the country and in the foothills of the Himalaya, and are succeeded by wet temperate forests between altitudes 1000 and 2000 m. In NE India and the hilly areas of Uttarakhand and West Bengal, these forest mainly comprise of *Tectona grandis*, *Shorea robusta*,

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Table 1. Phytosociological attributes of different sites

Parameter	LS	KR	KB	SF	GS	KS
Shannon–Weaver index						
Tree	1.59	2.16	1.35	2.51	1.46	2.06
Sapling	2.08	1.26	1.77	2.40	1.72	1.86
Seedling	2.78	2.33	1.68	2.40	2.34	2.19
Simpson index						
Tree	0.39	0.24	0.45	0.09	0.44	0.20
Sapling	0.14	0.50	0.21	0.11	0.26	0.27
Seedling	0.15	0.12	0.32	0.09	0.11	0.16
Margalef richness index						
Tree	3.51	4.90	2.58	3.73	3.62	3.49
Sapling	2.53	2.47	2.19	3.17	1.87	2.65
Seedling	2.36	2.55	2.51	2.56	3.09	2.68
Jaccard index (evenness)						
Tree	0.55	0.69	0.51	0.689	0.51	0.85
Sapling	0.84	0.48	0.77	0.86	0.75	0.73
Seedling	1.08	0.86	0.62	0.91	0.80	0.81
Total basal cover						
Tree (m ² /ha)	20.05	3.61	46.81	8.59	18.90	5.36
Sapling (m ² /ha)	0.92	1.20	39.24	0.59	0.59	0.58
Seedling (cm ² /ha)	511.96	1091.30	543.14	1221.82	533.32	589.0

LS, Lalsroth; KR, Kodiya ridge; KB, Kodiya belt 6–8; SF, Sofuti; GS, Ghasiramsroth; KS, Kharastroth.

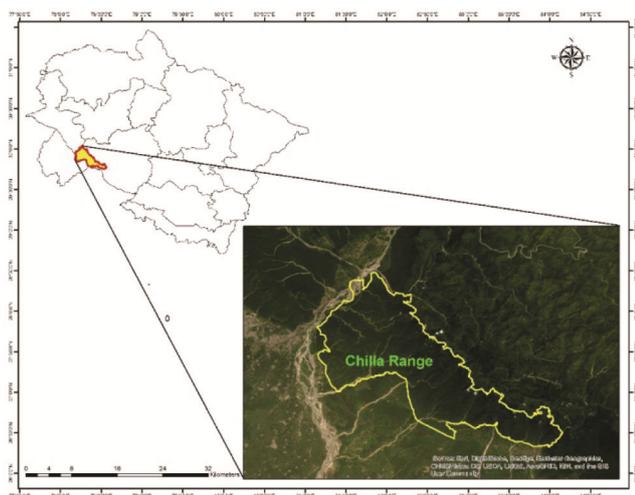


Figure 1. Map of Uttarakhand, India, showing the Chilla Forest Range of Rajaji Tiger Reserve.

Dalbergia sissoo, *Phyllanthus emblica*, etc. In the present study, we have focused on the regeneration potential among six tropical forest sites of the Chilla Range, Rajaji Tiger Reserve (RTR), Uttarakhand, India.

The present study was carried out in the six forest sites at different altitudes namely Lalsroth (378.6 m), Kodiya ridge (350 m), Kodyabelt 6–8 (458.1 m), Sofuti (482.7 m), Ghasiramsroth (304 m), Kharasroth (318 m) of Chilla Forest Range, RTR (29°15′–30°31′N, 77°52′–78°22′E, altitude 250–1100 m amsl). The Chilla Forest Range lies to the east of River Ganga, and comes under the Garhwal Forest Division. The elevation lies between

302 and 1000 m amsl. The vegetation of RTR is represented with extensive stands of several forest types like mixed forest, pine forest, grassy pasture land and broad-leaf forest. The dominant plant species are *S. robusta*, *D. sissoo*, *Cassia fistula*, *Terminalia bellerica*, *Acacia catechu*, *Mallotus philippensis*, *Listea chinensis*, *Ficus benghalensis*, *Adina cordifolia* at lower elevations of the Reserve, while the high-altitude region is dominated by *Pinus roxburghii*, *Celtis australis* and *M. philippensis*^{2,3}.

The stratified quadrat method was used to study the regeneration potential of tree species occurring in each forest site. In each site, 12 quadrats (total 72 quadrats) of 20 × 20 m² were laid randomly for tree species. In order to determine the population structure of the forest and to observe the regeneration pattern of tree species, the trees were measured for CBH (circumference at breast height, 1.37 m) with a girthing tape. Further, they were classified as seedlings, saplings and trees classes⁴. The regeneration status of the species was determined on the basis of population size of seedlings, saplings and trees⁵. Specimens were collected and herbarium of each species was prepared by following the method of Jain and Rao⁶ and further confirmed by the Botanical Survey of India, Dehradun. Diversity indices were calculated for each forest site^{7–10}. The individual rarefaction curve was constructed using PAST software, version 3.14 on the basis of the number of individual trees, saplings and seedlings in all the sites (Figure 1).

The studied subtropical moist deciduous forest is dominated by many species like *S. robusta*, *Holoptelea integrifolia*, *D. sissoo* and *M. philippensis*. All the sites showed differences in terms of various forest structural attributes such as diversity and total basal cover

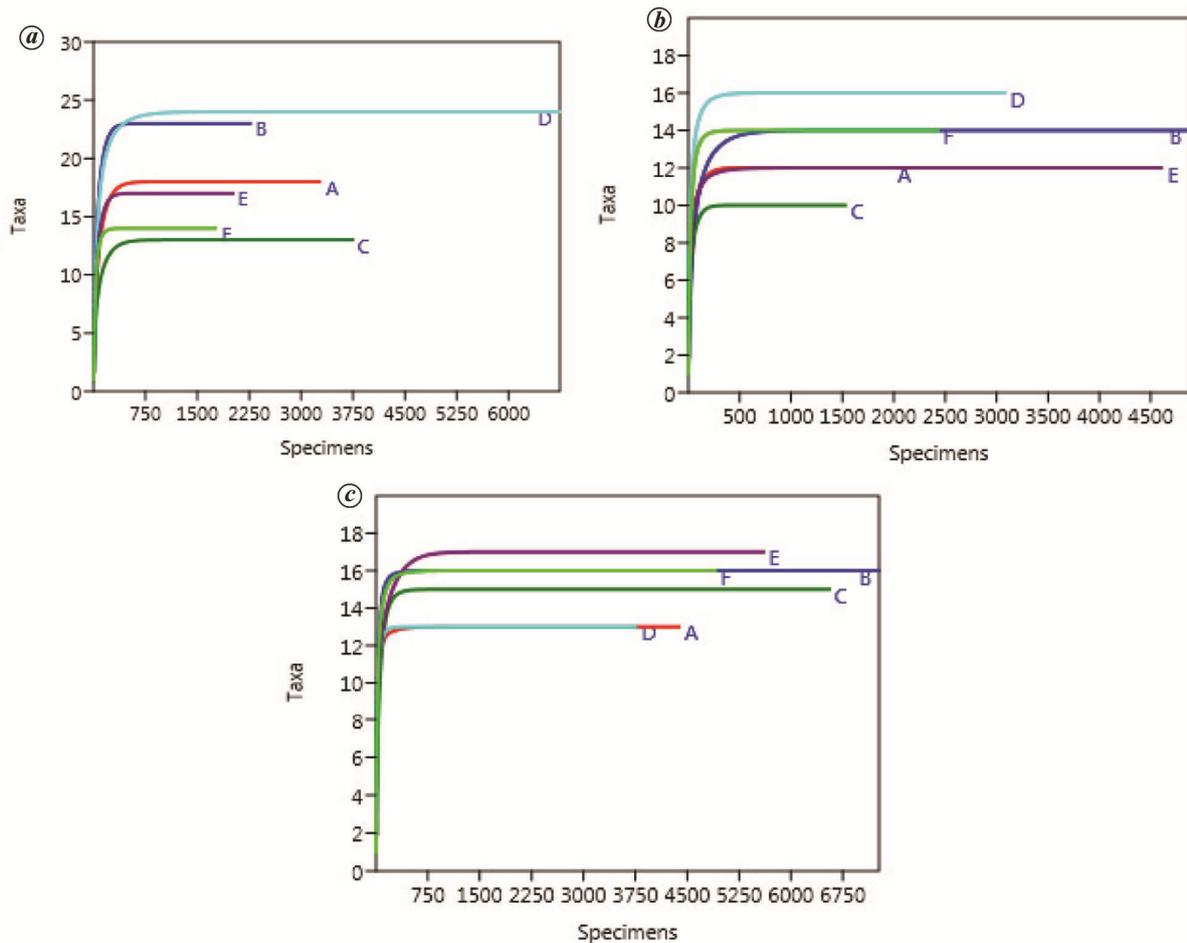


Figure 2 a-c. Individual rarefaction curve of (a) trees, (b) saplings, and (c) seedling species among all the study sites (A, Lalsroth; B, Kodiya ridge; C, Kodiyabelt 6-8; D, Sofuti; E, Ghasiramsroath, F, Kharasroth).

(Table 1). In Lalsroth, the density of seedlings was highest (4375 ind/ha) followed by trees (3275 ind/ha) and sapling (1925 ind/ha). Further, maximum species (31.57%) showed good regeneration, followed by 26.31% fair, 10.52% poor, and 26.31% no while 5.26% showed new regeneration. In Kodiya ridge, the density of seedlings was highest (6100 ind/ha) followed by saplings (4875 ind/ha) and trees (2225 ind/ha). Maximum species (42.42%) showed no regeneration, 33.33% showed new while 12.12% showed both fair and good regeneration. In Kodiyabelt 6-8, the density of seedlings was highest (6600 ind/ha) followed by trees (3825 ind/ha) and saplings (1525 ind/ha). Maximum species showed fair regeneration (31.57%) followed by 26.31% new regeneration, 15.78% each for good and no regeneration, and 10.52% showed poor regeneration. In Sofuti, the density was highest for seedlings (3975 ind/ha) followed by trees (3125 ind/ha) and saplings (2850 ind/ha). The species showed 24% fair, no and new regeneration each, whereas 20% showed good and 8% poor regeneration. In Ghasiramsroth, the density of seedlings was highest (6025 ind/ha) followed by trees (4775 ind/ha) and sap-

lings (3050 ind/ha). While 29.16% species showed both new and no regeneration, 25% showed fair and 16.66% good regeneration. In Kharasroth, the density of seedlings was again highest (4600 ind/ha) followed by saplings (2300 ind/ha) and trees (1825 ind/ha). Maximum species showed new regeneration (39.13%), whereas 21.73% showed fair and no regeneration each, followed by 13.04% good, but only 4.34% species showed poor regeneration. The species richness was negatively correlated with concentration of dominance ($r = -0.19163$) and positively correlated with density ($r = 0.151013$). Diversity was positively correlated with species richness ($r = 0.11637$), but negatively correlated with the density ($r = -0.01428$). On the other hand, density was positively correlated with concentration of dominance ($r = 0.006711$). The longest individual rarefaction curve of tree species in the study area revealed the highest number of individuals in Sofuti (SF) followed by Kodiyabelt 6-8 (KB), Lalsroth (LS), Kodiya ridge (KR), Ghasiramsroth (GS) and Kharasroth (KS), whereas in saplings the longest individuals rarefaction curve was observed in KR followed by GS, SF, KS, LS and KB (Figure 2 a-c). On the other hand for

seedlings, the longest individuals rarefaction curve was observed in KR followed by KB, GS, KS, LS, SF.

Regeneration status of the tree species in a forest is estimated on the basis of saplings and seedlings. A large number of seedlings, saplings and trees in a forest depicts good or satisfactory regeneration, whereas inadequate number of saplings and seedlings depicts poor regeneration and complete absence of saplings and seedlings depicts no regeneration¹¹. In the present study, the density of seedlings ranged from 3975 to 6600 ind/ha and that of saplings from 1525 to 4875 ind/ha. These values are comparable with those of Gairola *et al.*¹², who studied the regeneration pattern of tree species in a moist temperate valley of Garhwal Himalaya, India (the values for seedlings ranged from 600 to 30,000 ind/ha and for saplings from 96 to 9792 ind/ha). Diversity is regulated by the long-term factors such as community stability and evolutionary time as heterogeneity of both macroclimatic and microclimatic factors affects diversification among different plant communities¹³. The diversity (Shannon Wiener index) of tree species in the study area varied from 1.35 (Kodiyabelt 6–8) to 2.51 (Sofuti). These values are more or less similar with those reported by earlier workers like Ghidiyal *et al.*¹⁴ (1.86–2.73) from the Garhwal Forest Division, and Raturi¹⁵ (0.78–3.45) from the Rudraprayag Forest Division, Uttarakhand. The total basal area (m²/ha) of trees in present study ranged from 3.61 to 46.81 m²/ha. These values are more or less similar to those reported by Raturi¹⁵ (3.18–43.62 m²/ha), Lata and Bisht¹⁶ (13.60–71.25) from different parts of northern India. Seedling diversity also favours good regeneration status in an area. The good regeneration status in the study area was due to the well-established seedling, sapling and tree species, which reveals that the future communities may be sustained unless there is any major environmental interference due to anthropogenic activities. However, survival, growth and reproduction ability of the plant species showing ‘poor’ or ‘no’ regeneration

may be at risk in future. The sapling diversity ranged from 1.26 to 2.40 in the study area. These values are similar to those reported by Pant and Samant¹⁷ (0.59–2.57) from Western Himalaya. Although overall regeneration in the study area was fairly high, in Kodiya ridge maximum species showed no regeneration. The maximum plant species which showed poor and no regeneration in Kodiya ridge also showed good and fair regeneration in the other sites of the study area. No and poor regeneration may be due to anthropogenic activities such as lopping, grazing, scraping and trampling. Poor biotic potential of tree species may be another reason for bad regeneration pattern of species which either effects seed germination or fruiting and conversion of seedlings into saplings¹⁸. Therefore, it is necessary to develop conservation strategies and management plans for maintenance of the species in the forest. Further sustainable development as well as awareness among the locals are essential for proper utilization of forest resources.

The present study reveals that overall regeneration pattern is fairly good due to ample number of seedlings, but in some areas of the forest there is poor regeneration pattern of species which could be due to various anthropogenic activities of the past. So it is necessary to give sufficient time to reduce the forest pressure. Further, seedlings and saplings need time to establish and reach the mature stage. Closing the open sites for local residing communities of the RTR would be best strategies to provide vegetation regeneration. Enrichment planting in the closed compartment of the forest with useful species will also favour best regeneration of species in the area. Further, the baseline information obtained from the present study suggests that there is a need to formulate conservation plans and their implementation in all the studied zones of RTR having poor regeneration.

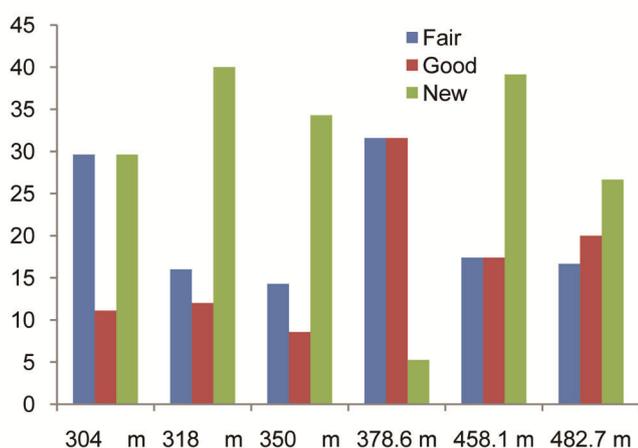


Figure 3. Regeneration (%) shown by all the species along different altitudinal gradients.

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