# Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya

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**This paper reports regeneration status of trees in two watersheds namely Phakot and Pathri Rao in Uttarakhand. Seedling, sapling and tree density were greater in Phakot watershed forest than those in Pathri Rao watershed forest. In general, both forests were regenerating, although seedling and sapling population was higher in Phakot watershed forest. As far as the regeneration status is concerned, maximum tree species was found with fair regeneration in the forests of both the watersheds. In Phakot watershed, three species (*Accacia nilotica*, *Engelhardtia spicata* and *Olea glandulifera*) and in Pathri Rao watershed seven species (*Acacia nilotica, Anogeissus latifolius, Casearia elliptica, Cassia fistula, Holarrhena pubescens, Mallotus phillippensis* and *Ougeinia oojeinensis*) were found not regenerating. In Phakot watershed, general densities–diameters class distribution showed decline in density from small diameter class to higher diameter class whereas in Pathri Rao watershed no trend was evident.**

**Keywords:** Forest species, Pathri Rao, Phakot, regeneration.

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[1]. The population structure of a species in a forest can convey its regeneration behaviour[2]. The population structure, characterized by the presence of sufficient population of seedlings, saplings and adults, indicates successful regeneration of forest species[2], and the presence of saplings under the canopies of adult trees also indicates the future composition of a community[3]. Regeneration status of trees can be predicted by the age structure of their populations[4–6]. Regeneration of a particular species is poor if seedlings and saplings are much less than the mature trees. The study of regeneration of forest trees has important implications for the management of natural forests, and is one of the thrust areas of forestry. Regeneration is the process of silvigenesis by which trees and forests survive over time[7]. Research in this field contributes to planning, conservation and decision making in forest resources management programmes. This study is an attempt to understand the regeneration status at the watershed level.

The study was carried out in sub-tropical forests of the two watersheds in Uttarakhand namely, Phakot and Pathri Rao watersheds. Phakot is situated between lat. 30°13′04″–30°15′48″N and long. 78°19′42″–78°23′17″E, and Pathri Rao is situated between lat. 29°51′7″N–30°15′50″N and long. 77°57′7″–78°23′36″E. Phakot watershed represents Central Himalayan mountains and covers an area of 1466 ha with elevation ranging from 600 to 2013 m above sea level (asl). In Phakot watershed *Anogeissus latifolius* mixed forest is found from 600 to 1100 m asl. This is a non-protected forest. Pathri Rao watershed represents lower Shiwalik hills and covers an area of 4391 ha with elevation ranging from 300 to 700 m asl. It is a protected forest and a part of Rajaji National Park. Both the watersheds contain *Anogeissus latifolius* mixed forest as a common component for study. This article presents the comparative account of tree regeneration status between *Anogeissus latifolius* forests of Phakot and Pathri Rao watersheds.

Regeneration status of tree species of both the watersheds was studied during 2005–2006. Phytosociological studies were carried out using quadrat method. The quadrats were laid down along the pathways and streams in stratified random manner. To study the regeneration pattern, $10 \times 10$ m square quadrats were laid down on forest floor. For tree, sapling and seedling species, a total of 88 quadrats and 156 quadrats were laid down in Phakot and Pathri Rao watersheds respectively. Species area curve was used to determine minimal sample area which is based on quantitative variation of the vegetation terms of species number[8]. The adequacy of sample size was estimated by stopping sampling at the point at which additional quadrats did not significantly affect the mean of species. In each $10 \times 10$ m quadrat, individuals as having >30 cm CBH (circumference at breast height, i.e. 1.37 m above the ground) were considered trees and were measured species-wise. Individuals having <10 cm circumference were considered as seedlings, and those having the intermediate position with respect to these circumferences were considered as saplings[9]. The density of seedlings and saplings is considered as an indicator of the

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regeneration potential. From the field data, phytosociological parameters of sapling and seedling were calculated as given by Mishra[8,10].

The status of regeneration of species was determined based on population size of seedlings and saplings[11]. Good regeneration, i.e. if particular species is present in seedling > sapling > tree; fair regeneration, i.e. if species present in seedling > sapling < tree; poor regeneration, i.e. if a species survives only in sapling stage, but not as seedling; if a species is present only in adult form it is considered as not regenerating. A species is considered as not abundant if the species has no tree representatives, but only saplings and/or seedlings[11].

The tree density in both the watersheds varied greatly and it was higher in Phakot (10.59 plants/100 sq. m) than Pathri Rao (6.85 plants/100 sq. m). The average sapling density of Phakot was also higher (7.01 individuals/100 sq. m) than Pathri Rao (3.70 individuals/100 sq. m). Seedling density too was higher in Phakot (33.20 individuals/100 sq. m) than Pathri Rao (23.29 individuals/100 sq. m; Figure 1).

The highest tree density in Phakot was recorded for *Mallotus philippensis* (2.06 plants/100 sq. m) followed by *Anogeissus latifolius* (1.92 plants/100 sq. m). Whereas for Pathri Rao, the highest tree density was recorded for *Anogeissus latifolius* (1.17 plants/100 sq. m) followed by *Holarrhnea pubescens* (0.63 plants/100 sq. m; Table 1).

A total of 33 tree species, 21 saplings and 27 seedlings were found in Pathri Rao watershed. The highest density for seedling was recorded for *H. pubescens* (5.35 plants/100 sq. m) followed by *M. philippensis* (3.39 plants/100 sq. m). The lowest seedling density (0.03 plants/100 sq. m) was recorded for *Butea monosperma* and *Dalbergia sissoo*. The highest sapling density (0.77 plants/100 sq. m) was again recorded for *H. pubescens* followed by *Cassia fistula* (0.68 plants/100 sq. m). The lowest sapling density was represented by *Bauhinia malabarica*, *Albizia lebbeck*, *Holoptelea integrifolia* and *Terminalia alata* (0.01 saplings/100 sq. m; Table 1).

A total of 25 species of trees, 27 of seedlings and 28 of saplings were found in Phakot watershed. The maximum seedling density (12.53 plants/100 sq. m) was recorded for *M. philippensis* followed by *Litsea monopetala* (4.10 plants/100 sq. m). The lowest seedling density (0.02 plants/100 sq. m) was recorded for *Terminalia chebula*. The highest sapling density (3.22 plants/100 sq. m) was recorded for *M. phillippensis* followed by *Shorea robusta* (0.82 plants/100 sq. m). The lowest sapling density (0.01 saplings/100 sq. m) was represented by *Helicteres isora* (Table 1).

The three life stages (seedlings, saplings and trees) for different species suggested their possible future status in the forest. The density diameter curve of the tree, sapling and seedling species of Phakot and Pathri Rao watersheds show consistent decrease from seedling to sapling stage (from <10 cm to 20–30 cm), while from sapling to trees density increased. It might be possible that more saplings are removed for cutting, fuel wood and fodder. Thus, in general both the forests were regenerating, although regeneration was higher in Phakot watershed (Figure 1).

The diameter distribution of trees has often been used to represent the population structure of forests[2,4]. In Phakot watershed, population structure showed a reverse J-shaped curve for different diameter classes. The individuals of small diameter classes were higher and decreased with increasing diameter. The proportion of small diameter individuals was greater than large diameter individuals in the tree population of Mawphlang sacred grove in Meghalaya[4]. The population structure of selected West African rain forest canopy tree species was studied by Poorter[12] to evaluate the regeneration status. The population decreased with size, indicating sufficient regeneration[12].

The diameter distribution of Pathri Rao watershed showed individuals with small diameter class (<10 cm) were high but those with diameter class (10–30 cm) were less in number. Further, individual with medium girth class (30–60 cm) increased (Figure 2). In a study

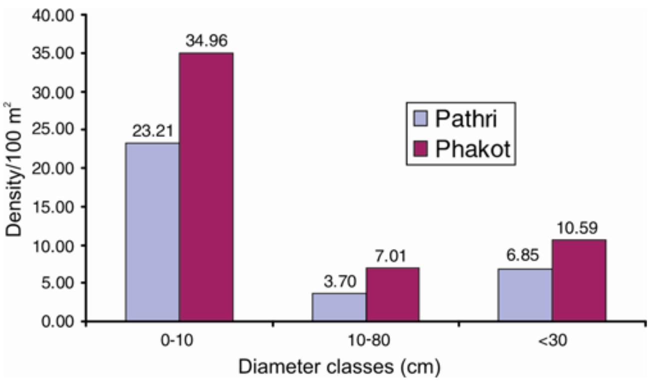


**Figure 1.** Density of seedlings, saplings and trees in Pathri Rao and Phakot watersheds.

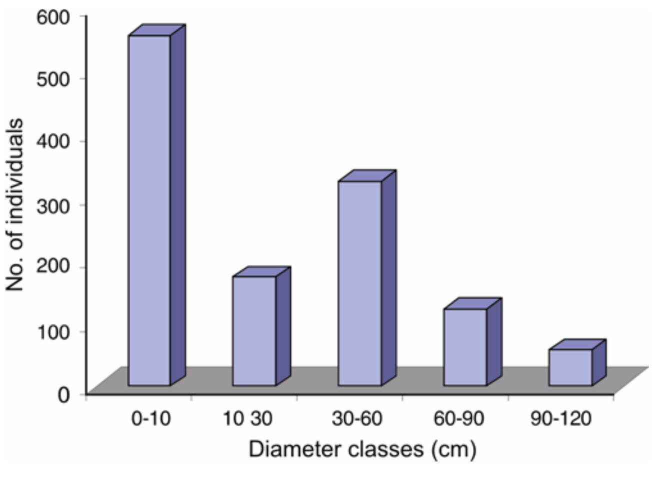


**Figure 2.** Population structure of tree species in Pathri Rao watershed.

**Table 1.** Floristic composition and regeneration status (density/100 m$^2$) in Pakhot and Pathri Rao watersheds

| Species | Phakot watershed | | | | Pathari Rao watershed | | | |
|---|---|---|---|---|---|---|---|---|
| | Tree | Sapling | Seedling | Status | Tree | Sapling | Seedling | Status |
| *Acacia catechu* (L.) Wild | 0.26 | 0.02 | 0.18 | Fair | 0.81 | 0.03 | 2.70 | Fair |
| *Acacia nilotica* (L.) Wild | 0.01 | 0.00 | 0.00 | No regeneration | 0.01 | 0.09 | 0.25 | Good |
| *Adina cordifolia* (Roxb.) Hook | 0.28 | 0.03 | 0.43 | Fair | 0.04 | | | No regeneration |
| *Aegle marmelos* (L.) Correa | | | | | 0.20 | 0.12 | 0.46 | Fair |
| *Ailanthus excelsa* (Roxb.) | | | | | 0.10 | 0.00 | 0.04 | Poor |
| *Albizia lebbeck* (L.) Benth | | | | | 0.03 | 0.01 | 0.12 | Good |
| *Anogeissus latifolius* (D.C.) Richards | 1.92 | 0.13 | 0.34 | Poor | 1.75 | 0.08 | 1.26 | Fair |
| *Bahunia variegata* Roxb. | | | | | 0.09 | 0.15 | 0.05 | Fair |
| *Bauhinia malabarica* Roxb. | | | | | 0.05 | 0.01 | 0.11 | Fair |
| *Bauhinia semla* Wunderlin. | 0.15 | 0.05 | 1.97 | Poor | | | | |
| *Bombax ceiba* L. | | | | | 0.06 | 0.08 | 0.05 | Fair |
| *Butea monosperma* (Lam.) Kuntze. | 0.00 | 0.02 | 0.00 | Not abundant | 0.08 | | 0.03 | Poor |
| *Careya arborea* Roxb. | | | | | 0.02 | 0.00 | 0.00 | No regeneration |
| *Casearia elliptica* Wild. | | | | | 0.01 | 0.06 | 0.58 | Good |
| *Cassia fistula* L. | 0.58 | 0.42 | 2.84 | Good | 0.48 | 0.68 | 2.48 | Good |
| *Cassine glauca* (Rottboel) Kuntze | | | | | 0.02 | 0.00 | 0.00 | No regeneration |
| *Cordia dichotoma* Foster f. | | | | | 0.06 | 0.00 | 0.12 | Poor |
| *Dalbergia sisoo* Roxb. | | | | | | 0.07 | 0.03 | Not Abundant |
| *Diospyros montana* Roxb. | 0.10 | 0.02 | 0.89 | Poor | | | | |
| *Ehretia acuminata* Roxb. | 0.00 | 0.16 | 0.36 | Not abundant | 0.01 | | | No regeneration |
| *Ehretia laevis* Roxb. | | | | | 0.18 | 0.07 | 1.74 | Fair |
| *Engelhardtia spicata* Leschenault ex Blume | 0.07 | 0.10 | 0.00 | No regeneration | | | | |
| *Erythrina variegata* L. | 0.08 | 0.06 | 0.22 | Fair | | | | |
| *Eucalyptus tereticornis* Smith | | | | | 0.04 | 0.00 | 0.00 | No regeneration |
| *Flacourtia indica* (Burm. f.) Merrill | 0.19 | 0.41 | 3.26 | Good | | | | |
| *Grewia asiatica* L. | 0.08 | 0.02 | 0.08 | Fair | | | | |
| *Grewia serrulata* DC. | | | | | 0.01 | 0.12 | 0.00 | Poor |
| *Helicteres isora* L. | 0.03 | 0.01 | 0.08 | Fair | | | | |
| *Holarrhena pubescens* (Buch-Ham.) Wallich ex G. Don. | | | | | 0.63 | 0.77 | 5.35 | Good |
| *Holoptelea integrifolia* (Roxb.) Panchon | 0.00 | 0.04 | 0.13 | Not abundant | 0.21 | 0.01 | 0.42 | Fair |
| *Lannea coromandelica* (Houttuyn) Merrill | 1.58 | 0.11 | 0.75 | Fair | 0.16 | 0.00 | 0.04 | Poor |
| *Litsea monopetala* (Roxb) Persoon | 0.22 | 0.25 | 4.10 | Good | | | | |
| *Macaranga pustulata* King ex Hook. f. | 0.38 | 0.08 | 0.59 | Fair | | | | |
| *Madhuca longifolia* (Koeing) Mac Bride | 0.00 | 0.21 | 0.15 | Not abundant | | | | |
| *Mallotus philipensis* (Lam) Muell | 2.06 | 3.22 | 12.53 | Good | 0.41 | 0.65 | 3.39 | Good |
| *Moringa oleifera* Lam. | 0.08 | 0.07 | 0.15 | Fair | | | | |
| *Olea glandulifera* Wallich ex G. Don. | 0.11 | 0.03 | 0.00 | No regeneration | | | | |
| *Ougeinia oojeinensis* (Roxb.) | 0.06 | 0.07 | 0.68 | Fair | 0.13 | 0.35 | 0.36 | Good |
| *Pinus roxburghii* Sargent. | | | | | 0.07 | 0.00 | 0.22 | |
| *Pueraria tuberosa* (Roxb. ex Willd.) | 0.00 | 0.00 | 0.03 | Not abundant | | | | |
| *Rhamnus triqueter* (Wallich) Lawson. | 0.00 | 0.19 | 0.03 | Not abundant | | | | |
| *Sapium insignae* (Royle) Benth. ex Trimen | 0.07 | 0.28 | 0.33 | Fair | | | | |
| *Schleichera oleosa* Wild. | | | | | 0.06 | 0.00 | 0.17 | Poor |
| *Shorea robusta* Roxb. ex Gaertner f. | 1.64 | 0.82 | 3.97 | Good | 0.18 | 0.02 | 0.33 | Fair |
| *Syzygium cumini* (L.) Skeels. | 0.01 | 0.04 | 0.15 | Good | 0.08 | 0.05 | 2.37 | Fair |
| *Terminalia alata* Heyne ex Roth | 0.50 | 0.13 | 0.67 | Fair | 0.17 | 0.01 | 0.15 | Fair |
| *Terminalia bellirica* (Gaertner f.) | 0.03 | 0.02 | 0.03 | Fair | 0.10 | 0.00 | 0.10 | Poor |
| *Terminalia chebula* Retz. | 0.10 | 0.00 | 0.02 | Poor | | | | |
| *Ziziphus mauritiana* Lam. | | | | | 0.55 | 0.27 | 0.31 | Fair |
| *Ziziphus oenoplia* (L.) Miller. | | | | | 0.05 | | | No regeneration |
| Total | 10.59 | 7.01 | 34.96 | | 6.85 | 3.70 | 23.21 | |

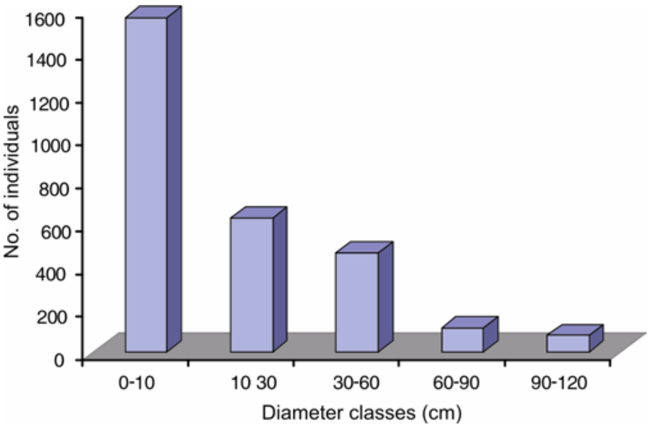


**Figure 3.** Population structure of tree species in Phakot watershed.

conducted elsewhere the proportion of large diameter individuals was greater than small diameter individuals in the tree population in undisturbed stand while in the disturbed stand the proportion of young individuals was more[13].

In Phakot watershed, out of 25 tree species, six species, viz. *C. fistula*, *Flacourtia indica*, *L. monopetala*, *M. phillippensis*, *S. robusta* and *Syzygium cumini* showed good regeneration as all these species having good number of seedlings and saplings, 12 species recorded fair, four species poor regeneration and three were not abundant. Three species, viz. *Adina cordifolia*, *Engelhardtia spicata* and *Olea glandulifera* were not regenerating. It might be due to thick litter accumulation which reduced seed germination of most canopy species[14,15].

In Pathri Rao watershed, out of 33 tree species, 7 showed good regeneration, viz. *Acacia nilotica*, *Anogeissus latifolius*, *Casearia elliptica*, *C. fistula*, *H. pubescens*, *M. phillippensis* and *Ougeinia oojeinensis*, 12 species recorded fair and 7 species recorded poor regeneration while 6 species were not found to be regenerating, viz. *Adina cordifolia*, *Careya arborea*, *Cassine glauca*, *Ehretia acuminata*, *Eucalyptus tereticornis* and *Ziziphus oenoplia* and 1 species was categorized as not abundant (Table 1). The population size of the species that lack either seedlings or saplings may decline in the coming years. The forest stands characterized by the abundance of only adults of the species or absence or very low population of seedlings and saplings are expected to face local extinction[16]. Densities of seedlings are influenced by the densities of large trees[17]. The density diameter class distribution of tree species of Phakot showed decline in density from small diameter class to higher diameter class. It shows that smaller diameter class individuals were high in number and only a small fraction of the seedlings and saplings classes survived to the larger tree classes (Figure 3). A study on density–diameter distribution of woody species in the four sacred groves showed the highest stand density in the lowest girth class (30–60 cm)[18].

In general both forests were regenerating, although regeneration was better in Phakot watershed because of high density of seedlings and saplings in Phakot watershed. Pathri Rao watershed comes under a protected area and lopping is not allowed within the national park, and thus the forest having good canopy cover might have affected the survival of seedlings under good tree canopy due to the absence of light. Further, herbivore wild animals are more in number than in Phakot watershed so grazing pressure was high in Pathri Rao watershed. It has been recorded that regeneration of species is affected by fire[19,20], grazing, light[21], canopy density, soil moisture, soil nutrients and anthropogenic pressure. Regeneration of a species is dependent on internal forest process and exogenic disturbance[22]. In the present study, seven species in Pathri Rao and three species in Phakot were not regenerating so it should be given emphasis in further research.

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