

EFFECT OF ENVIRONMENTAL GRADIENTS ON THE NATURAL REGENERATION OF MIXED CONIFEROUS FOREST, SWAT, PAKISTAN

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Abstract

Forests are the natural resources which produce timber, fuel wood, habitats for wildlife, conserve water and reduce soil erosion. The natural forests of Pakistan are declining at an alarming rate due to anthropogenic pressure and mismanagement. In order to check the status of natural regeneration, this study was conducted in district Swat of Khyber Pakhtunkhwa. A total number of 100 plots, measuring 20X20 meter quadrat were undertaken at different ecological zones in mixed coniferous forest of Swat, Khyber Pakhtunkhwa, Pakistan during 2016-2018. In each plot, the number of seedlings was counted and each seedling was tagged. Seedling percentage was calculated along the altitudinal gradient. The regeneration percentage of *Pinus roxburghii*, *Cedrus deodara* and *Picea smithiana* decreased with the increase of elevation. Among the environmental factors, aspect was positively correlated to the natural regeneration. The increase in slopes resulted in slight increase in the natural regeneration percentage of *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow*. Overall, the percentage of natural regeneration of all the species was higher on the northern aspect. Regeneration assessment is a key to the forest health. This study shall contribute to planning, conserving and decision making in natural forest management and development programs.

Key words: Natural regeneration, Environmental factors, Coniferous forest, Frequency, Density.

Introduction

Forests cover 40% of the earth's surface and habitat to more than 70% for plants and animals. Forest resources provide a wide range of ecological, economic and social benefits (Sandalow, 2000). The survival of the species in an area depends upon the extent to its ability to regenerate under varying ecological conditions. The potential for regeneration is the capability of a species to complete their life phase in a particular atmosphere indicating the suitability of species to that environment. The natural regeneration requires sufficient production of seed, flourishing germination of seedlings subject to weather conditions, site status and competition among species and predation. The prospective regeneration of plant species is seldom the future configuration of forests in a stand, gap and time (Henle *et al.*, 2004; Khan *et al.*, 2018).

A natural regeneration refers to the natural progression that plant species replace or restore usually from the plentiful production of seeds that grow to ensure the improvement of new forests (Malcolm, 1999). The seedlings signify the final phase in the process of seed regeneration. The period between germination of the seed and the establishment of a self-determining juvenile plant are most susceptible stages in the life cycle of a plant (Kitajima & Fenner, 2000).

The dynamics of seedlings are influenced by many factors, such as soil moisture, humidity, temperature, small disturbances, canopy coverage and deep layers of the leaves (Yoshikawa *et al.*, 2002; Maciel-Nájera *et al.*, 2020). It was also reported that biotic factor such as herbivory, infections due to fungi and interspecies competition influence seedlings demography (Satake & Iwasa, 2002; Shen & Nelson, 2018).

Globally, assessment of plant diversity pattern is correlated with the environmental gradients in the tropical and temperate forest ecosystems. Similarly, some of the

vegetation studies targeted to seek the influence of soil properties (Xu *et al.*, 2020), topography (Khan *et al.*, 2019a; 2019b), and climate and anthropogenic activities (Rahman *et al.*, 2021). The effect of environmental factors on plant communities have been the focus of many ecological studies in current years (Kord *et al.*, 2010). Efficient and proper management of natural resources cannot be provided without full scientific appreciation. Therefore the natural study of existing resources as well as the environment can lead to an adequate balance among forest production and logging (Mataji *et al.*, 2009).

Material and Methods

Study area: Swat is the district of Khyber Pakhtunkhwa province of Pakistan and located between 34° 49' 19" North latitude and 72° 29' 20" East longitude having an area of 5337 Km² with the population of 2,137,000 according to 2016 data (Anon., 2016). Swat is a mountain area with different heights range from 600 meters up to 6,000 meters above sea level from south to north to the foothills of the Hindu Kush mountain range.

Sampling: The vegetation surveys were carried out during the spring and fall during 2015 to 2017. Stratified random sampling method was used to choose the plots. Stratification was done on the base of density, elevation, slope and aspect measuring 20x20 meter (400m²) quadrat.

Environmental factors: Elevation, slope and aspect were considered the main environmental factors because of the considerable variation in temperature, rainfall, and humidity which in turn affect plant species distribution. Growth is mostly associated with respect of aspect and slope because they influence solar radiation, air and soil temperature and rate of evapo-transpiration. Elevation influences length of growing season and annual precipitation.

Statistical analysis

A general linear regression model was used to test the differences in seedlings regeneration amongst the different plots. In addition, statistical package for social sciences (SPSS) was used to study the correlation between the variables.

Results

Effect of altitude on natural regeneration: The elevation was divided into three ranges viz., 1800-2300 m, 2301-2800 m and 2801-3300 m that covered the transition zone of all species found in the study area. The mean percentage of the regeneration seedlings was calculated and shown in Fig. 1. The data on natural regeneration percentages of all dominant conifer species recorded along the altitudinal gradient that revealed that there was significant effect of elevation on natural regeneration in mixed coniferous forest of Swat. The natural growth for *Pinus roxburghii* was noted between 1500 to 2500 m elevations and after the transitional zone, other associated species dominated. The percentage of natural regeneration decreases with increasing elevation. According to Fig. 1, maximum natural regeneration percentage of *Pinus roxburghii* was observed as 40.89% at elevational ranges of 1800-2300m, followed by 34.81% at 2301-2800 m and 22.41% at 2801-3300 m elevation ranges. The percentage of natural regeneration of *Pinus wallichiana* was recorded as 18.11% at 1800-2300m and 32.94% at 2801-3300m elevations. The natural regeneration percentage was increased with increased in elevation gradient because of the considerable variation in temperature, rainfall, humidity, solar radiation and nutrients availability which affect regeneration percentage. So, the natural elevation zone of *Pinus wallichiana* is 1500-3700m. There was opposite trend of natural regeneration in *Cedrus deodara* in which the natural regeneration percentage was decreased with increase in altitude (Fig. 1). The maximum regeneration of *Cedrus deodara* was recorded as 21.76% at 1800-2300m elevations, followed by 16.68% at 2301-2800 m elevation and 13.67% at 2801-3300m elevations (Fig. 1). The decrease was due to the palatability of this species by rodents since they cut the stem and leave on the ground. Vertebrate pests such as porcupines also cause damage to plants at the seedling stage.

Since there is an association exists in *Picea smithiana* and *Cedrus deodara* and therefore, there was same trend in natural regeneration percentage of *Picea smithiana*. At 1800-2300 m elevation, maximum regeneration (19.62%) was observed at elevation range, followed by 16.68% at elevation 2301-2800m and 11.54% at 2801-3300m elevations. The natural regeneration percentage decreased with increase in elevation due to the variation in temperature, rainfall and humidity coupled with damage by rodents, porcupine and squirrels. The natural regeneration percentage of *Abies pindrow* was 12% at 1800-2300 m elevation, 16.68% at elevation 2301-2800m and 23.41% at elevation range 2801-3300m (Fig. 1).

Comparing with elevational ranges, *Pinus roxburghii* responded well in terms of highest regeneration percentage (40.89%) at low elevations i.e. 1800-2300m and the lowest was that of *Abies pindrow* (12%) on the

same elevation. Contrary, maximum regeneration percentage (32.94%) was observed at 2801-3300m elevation for *Pinus wallichiana* and the lowest one was that of *Picea smithiana* (11.55%). The variation in natural regeneration between different species in the study area was recorded due to the variation of temperature, rain fall, humidity, nutrients availability and effect of persistent snow. The Similar results were also reported by Ali *et al.*, (2018) who indicated that elevation affects the natural regeneration percentage.

Effect of the slope on natural regeneration: There was significant effect of slope on the natural regeneration percentage as shown in Figure 2. Slope also affects vegetation regeneration due to runoff, temperature, moisture and depth of soil surface. The area was marked with four different slope classes such as 26-30°, 30.1-34°, 34.1-38° and 38.1-42°. According to the give data in Figure 2, the percentage of *Pinus roxburghii* was 34.69% at 26-30° slope gradient, 31.06% at 30.1-34°, 28.21% at 34.1-38° and 29.73% at 38.1-42° slope gradient. A little variation in natural regeneration percentage was found with slope because slope affects the runoff and modifies the intensity of insulation of solar radiation, temperature and moisture content.

The natural regeneration percentage of *Pinus wallichiana* was 20.42% at slope 26-30°, 23.21% at 30.1-34°, 26.94% at 34.1-38° and 29.73% at 38.1-42° slope gradient. Similarly, the percentage of *Picea smithiana* was 11.44%, 14.22%, 17.83% and 21.23%, respectively on the same slope gradients; while, the percentage of *Abies pindrow* was 10%, 12.31%, 14.35% and 14.49%, respectively (Fig. 2). The natural regeneration percentage of *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow* increased along the slope gradients because these species prefer steep slopes and high elevations due to low anthropogenic activities, low trampling affect and less herbivory affect.

The natural regeneration percentage of *Cedrus deodara* was 23.4% at 26-30° slope gradient, 19.59% at 30.1-34°, 15% at 34.1-38° and 12.79% at 38.1-42° slope. The natural regeneration percentage of *Cedrus deodara* was decreased because of heavy damage caused by rodent's infestation as they cut down the collar of the young plants in seedling stage (Fig. 2).

Overall, the regeneration percentage of seedling was affected by the slope. The higher percentage of natural regeneration was that of *Pinus roxburghii* (34.69%) at slope gradient (i.e. 26-30°) and the lowest was that of *Picea smithiana* (10%). *Pinus roxburghii* was the dominant species of the study area. At 34.1-38° slope the highest regeneration percentage was recorded as 29.73% for *Pinus wallichiana* which is the second dominant species of the study area; whereas, the lowest was that of *Cedrus deodara* (12.79%) at the same slope. Our results are comparable with the study of Hasegawa (2002) and Cui *et al.*, (2011).

The current study shows that the elevation and slope had significant effects on the natural regeneration in mixed coniferous forest of Swat. These finding are supported by other studies (Haseen, 2003; Ciejark *et al.*, 2008; Cui *et al.*, 2011). These results confirm our hypothesis that

environmental factors affect the abundance, richness and distribution of natural regeneration of vegetation.

The elevation and slope play important roles in natural regeneration of a forest. They affect solar radiation, air temperature, humidity and moisture content in the soil (Kang *et al.*, 2017; Muhlenberg *et al.*, 2012). Altitude has a significant effect on natural regeneration percentage because it is directly linked with ecological factors (e.g. temperature, rainfall, humidity and soil fertility) which directly affect the plant growth (Cierjacks *et al.*, 2008; Shen & Nelson, 2018). On the other, the Swat is located in Himalayan foothills occupied by hardy nature dwarf vegetation adapted to harsh winter season. The short vegetation period is also considered to be a key factor which affects vegetation or seedling growth (Kang *et al.*, 2017).

The seedling regeneration percentage was significantly affected by the slope. The percentage of

natural regeneration of some species was slightly increased with the increase of slope. The results strongly suggest that the variation in the species composition and natural regeneration may be attributed due to different slopes (Hasegawa, 2002; Cui *et al.*, 2011).

In the present study, elevation and slope had important impacts on natural regeneration in mixed coniferous forest of Swat, Pakistan. These factors directly affect solar radiation air temperature, humidity and rainfall which directly affect the percentage of natural regeneration of seedlings. The altitude affects growth period with respect to persistent snow (Muhlenberg *et al.*, 2012; Maciel-Nájera *et al.*, 2020). Besides, there is a significant correlation between the local environmental variables and vegetation and various physical and environmental characteristics, including biotic and abiotic stresses affect the distribution of plant species and communities (Manghwar *et al.*, 2022).

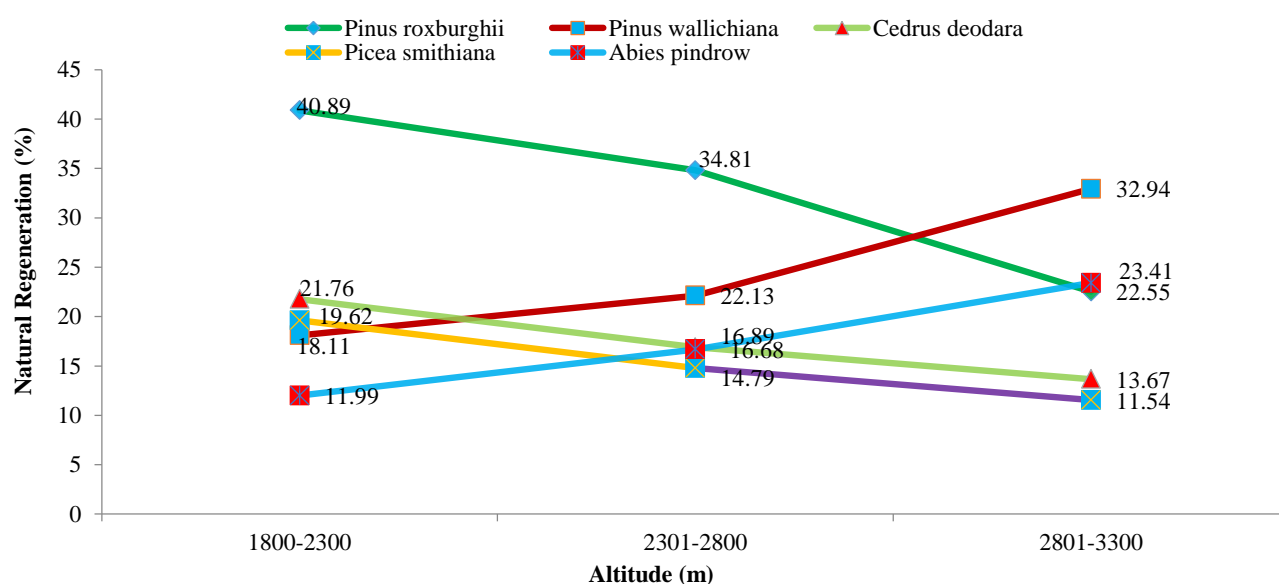


Fig. 1. Effect of elevation on natural regeneration of conifer forest of Swat.

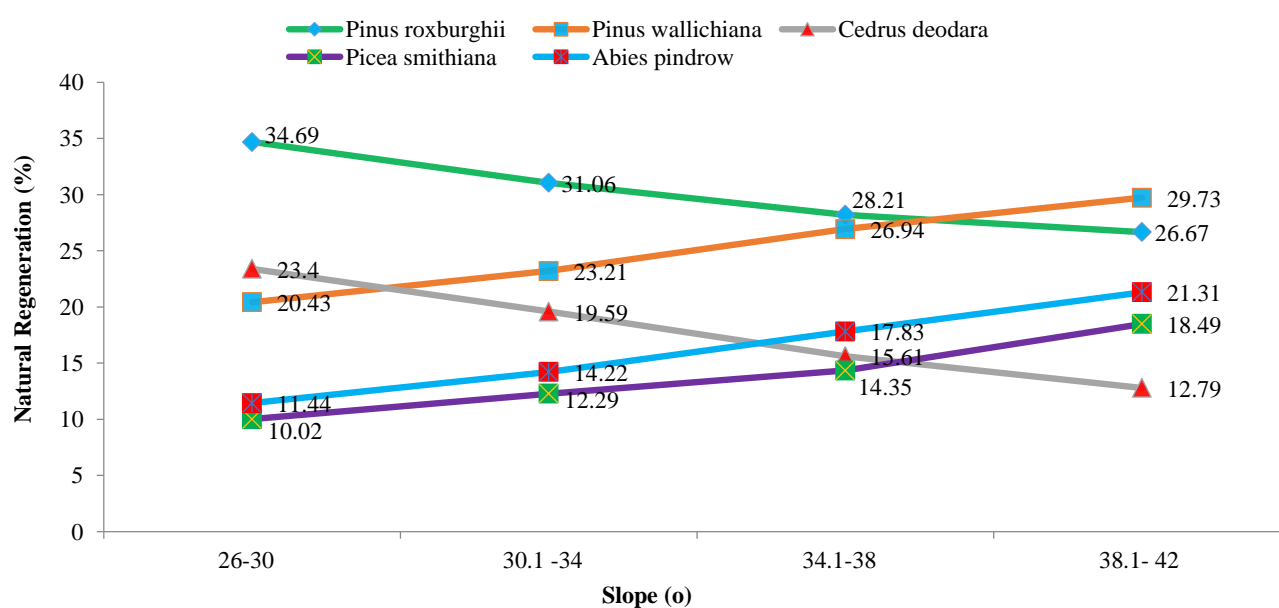


Fig. 2. Effect of slope on natural regeneration of the conifer forest of Swat.

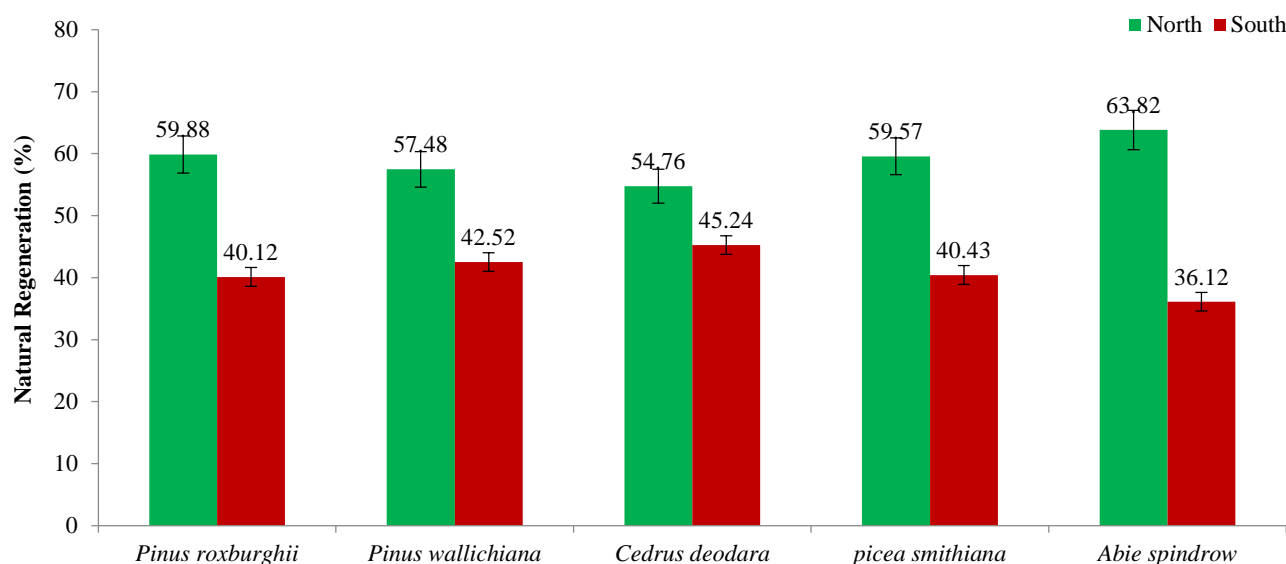


Fig. 3. Effect of aspect on the natural regeneration of forest of Swat.

Effect of aspect on the natural regeneration: The natural regeneration percentage was recorded on both northern and southern aspect. It was high on the northern aspect due to the availability of optimum temperature, moisture retention; high rainfall and essential nutrients for plant growths such as organic matter, nitrogen, phosphorus, potassium, etc. According to Figure 3, the natural regeneration in the forest of Swat was highly affected by the aspect. Seedlings are more stable in forest ecosystems following natural regeneration. However, the regeneration in most plantations is difficult due to artificial intervention and over-exploitation (Gao *et al.*, 2020).

The natural regeneration percentage of seedlings of *Pinus roxburghii* was higher (59.88%) on the northern aspect; while on the southern aspect, the same was lower (40.12%). In the same way, the regeneration of *Pinus wallichiana* was high (57.48%) on northern aspect and lower (42.52%) on the southern aspect. Similarly, the natural regeneration percentage of *Cedrus deodara* was higher (54.76%) on northern aspect and lower (45.24%) on the southern aspect. *Picea smithiana* had higher regeneration (59.57%) on the northern aspect and lower (40.43%) on the southern aspect. There was maximum natural regeneration percentage of *Abies pindrow* (63.82%) on the northern aspect and the lowest (36.12%) on southern aspect. Such variations in the natural regeneration percentage may be attributed due to the considerable variation in temperature, rainfall, humidity and solar radiation. The highest percentage among all the dominant species on the southern aspect was that of *Cedrus deodara* (45.24%).

The natural regeneration percentage was considerably affected by the aspect. The natural regeneration decline gradually in the south west; while, it increased with the slope on the north east. The natural regeneration seedling percentage increased from the south towards north. These results study were comparable with the study of Ali *et al.*, (2018). The natural regeneration percentage was high on the northern aspect; while, it was low on southern aspect.

The solar radiation and intensity of light is gradually affected by the slope direction from sunny to shady slope which also affect the distribution of species and seedling regeneration (Muhlenberg *et al.*, 2012). The natural regeneration found high on northern aspect because of the optimum temperature, moisture retention, low transpiration rate and high humidity which directly affect the growth of seedlings and their distribution.

Competition with ground vegetation is another factor which also affects the growth of seedling (Hanssen, 2003). Some researchers also reported that canopy closure and competition for nutrients and light are the key factors which affect regeneration in pine forest (Kuuluvainen & Rouvinen, 2000; Maciel-Nájera *et al.*, 2020).

Conclusion

For analyzing the status of forests, regeneration assessment is utmost important. Such studies contribute to planning, conserving and decision making in natural forest management and development programs. This information can be used for research, education, training, etc. The regeneration percentage of *Pinus roxburghii*, *Cedrus deodara* and *Picea smithiana* decreased with increase of elevation. The increase in slopes resulted in slight increase in the natural regeneration percentage of *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow*. Among the environmental factors, aspect was positively correlated to natural regeneration. Overall, the percentage of natural regeneration of all the species was higher on the northern aspect.

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