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Assessment of Growth Attributes of Himalayan Chirpine Forests - A Randomized Block Study

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Abstract A study to understand and assess the growth attributes of Himalayan Chirpine forests (9/C_{1b}) in Solan Forest Division, Himachal Pradesh (HP), India was carried out during the year 2012-2013. The altitudinal gradient in the present case varied from 900 m to 2100 m amsl. The forests in Solan Forest Division have pure crop of Chirpine and mostly conform to Champion and Seths Group 9-Sub-Tropical pine forests. In all the elevation classes, more trees were of 50–60 and 60–70 cm diameter classes in PB-I and in PB-IN and PB-IV more trees were of 10–20 and 20–40 cm diameter classes of tress. There was higher volume, biomass and carbon in PB-I followed by PB-IN and PB-IV in all the elevation classes and it was more distributed in 50–70 cm, 20–30 cm and 30–40 cm diameter classes of trees, respectively. PB-I had higher incremental growth (MAI) than followed by PB-IN and PB-IV. In all the elevations, MAI was higher in 50–70 cm tree diameter class on PB-I followed by MAI in 30–40 cm tree diameter class of PB-IN and MAI in 20–30 cm tree diameter class of PB-IV. There was an increase in tree volume from the year 1984 to 2002 (18.47%) and 2002 to 2011 (306.03%). However, overall increase in volume of trees from 1984 to 2011 was 381.04%. The maximum volume, biomass and carbon were distributed in diameter classes of 40–60 cm, 30–50 cm and 10–30 cm in PB-I, PB-IN and PB-IV during 1984, 2002 and 2011, respectively. Total biomass was 467.92, 115.25 and 97.27 tonnes/ha and total carbon was 233.96, 57.62 and 48.64 tonnes/ha during 2011, 2002 and 1984, respectively.

Keywords Volume, MAI, Periodic blocks, Elevations.

Introduction

Himalayas are comprised earths most multifaceted and diverse montane ecosystems, characterized by a harsh climate, a strong degree of seasonality and a high diversity of both plant communities and species [1, 2]. Here a wide range of altitude, rainfall, climate, geological condition, river systems and topography have given rise to an immense diversity of ecosystems and ultimately to immense biological diversity [3]. The structure, composition and vegetative functions are most significant ecological attributes of a particular ecosystem, which show variations in response to environmental as well as anthropogenic variables [4—6].

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Himalayas are globally important biodiversity hotspots and are facing rapid loss in floristic diversity and changing pattern of vegetation due to various biotic and abiotic factors. Major threats to ecosystems and biodiversity are habitat loss and fragmentation, overexploitation, pollution, invasions of alien species and global climate change with disruption of community structure [7]. The diversity of climate and environmental conditions prevailing in the Himalayas support diverse habitat and ecosystems with equally diverse life forms. Variations in terms of its size, climate and altitudinal ranges, have created environments those are unique and characteristic to this region only. Himalayas known for its rich and diverse plant wealth had shown a rapid decline in population of many plant species in recent past. Some of them have already been lost whereas many of them are in verge of extinction. The current decline in biodiversity largely through human activities is a serious threat to our ecosystem. If these naturally occurring plant resources are not conserved timely then they may soon become extinct. The assessment of plant wealth in Solan Forest Division may provide a key for its conservation. Keeping these aspects in view, a study was undertaken to know the Chirpine growth attributes in Solan Forest Division in HP.

Materials and Methods

The present study was conducted at elevation ranges from 900 m to 2100 m in year 2012-2013 in Solan Forest Division of Himachal Pradesh, which is located between 30°45′00″ to 31°10′00″ N latitude and 76°55′00″ to 77°15′00″ E longitude covering an area of about 57,158 ha. The forests in Solan Forest Division have pure crop of Chir and mostly conform to Champion and Seths Group 9-Sub-Tropical pine forests. To carry out field investigations, the complete Solan working division elevations were analyzed and it ranged between 900 to 2100 m amsl. In the study area, four sample plots within periodic blocks were identified as per altitudinal ranges, i.e., E_1 (900–1200 m), E_2 (1200–1500 m), E_3 (1500–1800 m) and E_4 (1800–2100 m). Periodic blocks (3) and elevations (4) were considered as treatments that were replicated thrice, thus forming 36 treatment combinations. RBD (factorial) design was used for statistical analysis.

To estimate the dominance of Chirpine, quadrate size was increased to 30 m × 40 m, were laid and basal area of Chirpine mature trees were measured with the help of tree caliper at breast height and height of all the individuals was calculated with the help of Ravi Multimeter.

Tree diameter : The diameter of stem over bark (ob) was measured at 1.37 m above ground level with the help of calliper (taking mean of two right angle measurements) and expressed in centimeters.

Tree height: The height of the tree was measured with the help of Spiegel Relaskop and expressed in meters.

Volume of standing trees: Volume of standing trees was calculated by the formula proposed by Pressler [8] and expressed in cubic meters.

Volume per hectare: The volume per hectare was calculated by multiplying the mean volume with number of trees in respective diameter classes per hectare.

Temporal growth trend in Himalayan Chirpine forests: For getting the temporal growth trend, compartment history files and forest inventory records maintained by forest department for various dates (year 1984 and 2002) was used as data source.

Results and Discussion

The average number of trees present per hectare at various diameter classes of Chirpine crop in various periodic blocks and elevations depicts that among all the elevations under study, E_2 (1200–1500 m) was having maximum number of trees followed by E_1 (900–1200 m), E_3 (1500–1800 m) and then E_4 (1800–2100 m).

Regarding the various periodic blocks, PB-I showed the maximum followed by PB-IN and then the minimum number of trees per hectare for PB-IV in all the four elevations.

The data of growth attributes pertaining to spatial distribution on diameter basis depicted that at all the elevations and in different periodic blocks, i.e., PB-I, PB-IN, and PB-IV, Class V (10–20 cm) trees ranged between 153 in E_4 to 400 in E_2; in class IV (20–30 cm) it varied between 133 in E_4 to 325 in E_1; Class III (30–40 cm) trees were found to range between 58 in E_4 to 117 in E_3; in class IIA the range was between 33 E_1 to 47 E_2, in class IIB the range was between 47 E_1 to 128 E_2; in class IA (60–70 cm), the number varied between 31 E_4 to 86 E_2. In IB (70–80 cm), the range was between 14 E_4 to 42 E_1, in IC (80–90 cm), the range was found to vary between 3 (E_3 and E_4) to 8 in E_1. While, in case if ID (>90 cm), they were totally absent in E_1 and E_4 class while E_2 and E_3 possessed 3 in each. On overall basis, the number of trees of all classes (V to ID) depicted that lowest value (336) was recorded in E_4 followed by E_3 (420), E_1 (570) and E_2 (712). The data also dopicts that in PB-I, PB-IN and PB-IV, the total number of trees ranged between 256 to 570, 350 to 712, 203 to 420, 183 to 336 in elevation E_1, E_2, E_3 and E_4, respectively. Overall, it can be stated that the tree numbers kept on decreasing as we moved upwards from a low E_1 to upper E_4 but the second elevation was having maximum value with respect to first elevation class (900–1200 m). The results of phytosociological studies revealed that the total number of tree species decreased with the increase in elevation. The decrease in number from lower elevation to higher elevation might probably be due to variation in edaphic and climatic conditions of lower temperature and short growing period at upper elevation. The results are also in accordance with the findings of number of researchers like [9—12] who worked on different forest species/tree stands. The total number of trees per hectare was found to decrease with increase in elevation class, i.e., at 1493/ha and 1229/ha for lower elevations to 962/ha for middle elevation and 839/ha for upper elevation. The reason for the number of trees to be more at lower elevation may be that since the microclimate as conditioned by climate, edaphic and topographic conditions is more favorable for growth and development at lower elevation [13]. The results are also in conformity with that of Rawat et al. [14], while he was working on *Cedrus deodara* in western Himalayas.

The age distribution pattern depicts that at different elevations, PB-I trees age was found to vary between 77.10 years in E_3 to 83.09 in E_1; in PB-IN it varied between 66.62 in E_2 to 76.93 in E_1; while in PB-IV the tree age was found to vary between 52.54 in E_2 to 57.20 in E_3. Among all the elevations, PB-I was having old and mature trees, while the young trees were present in PB-IV.

The calculated volume of Chirpine trees of different diameter classes and periodic blocks between all the four elevations showed that in all the periodic blocks, the average volume ranged between 0.42 m^3/ha in E_2 and E_4 to 22.18 m^3/ha in E_2 PB-IV; in class IV it ranged between 2.08 in PB-I at E_3 to 59.05 in PB-IV at E_2; in class III it was found to vary between 5.71 in PB-I at E_1 to 79.93 in PB-I at E_3. In IIA the range was found to vary between 15.06 in PB-IV at E_3 and E_4 to 60.24 in PB-I at E_2. In class IIB the values ranged between 12.56 in PB-IV at E_1 and E_3 to 288.92 in PB-I at E_2. In IA the values were between 0 to 292.96 PB-I at E_2. While in ID, the volume range was found absent in PB-IV E_1, E_2, E_3 and E_4 and the maximum value of 53.25 was recorded in PB-I at E_1; in case of ID, it was observed that they were found only in E_2 and E_3 with value of 22.88. Regarding the various periodic blocks, PB-I showed the maximum followed by PB-IN and then the minimum number of trees per heatare was least for PB-IV in all the four elevations. The trend is similar with that of tree numbers. Perusal of data showed that the second elevation class, i.e., 1200–1500 m showed the maximum volume of Chirpine trees followed by E_1, E_3 and E_4 as in case of number of trees. On overall altitudinal and periodic block basis, it can be said that the tree volume kept on decreasing as we move upwards from a low elevation to upper elevation. This may be due to the reason that tree numbers kept on decreasing to the same fashion and the tree volume depends on the number of trees also. Other reason was obvious due to higher photosynthetic activity, stomatal conductance and water use efficiency that result in higher growth rate as a result of increase in temperature in lower elevation as compared to higher elevation. Such differences in tree volume with elevation has also been reported earlier [15—18]. Similar results have also been reported by Luo et al. [19] in *Pinus tabulaeformis* and *Rabinia pseudoacacia* and Poso and Kujala in *Pinus sylvestris* and *Betula pubescens* Poso and Kujala [20] but, the second elevation (1200—1500 m) was having maximum value of volume as well as number with respect to first elevation class (900–1200 m). This is due to the distributional range of the Chirpine species which grows best in this altitudinal range. Data pertaining to the pattern of volume distribution in different elevations and periodic blocks revealed that different elevations and periodic blocks has significantly effect over average spatial distribution of volume in Chirpine. During our study, among different elevations, maximum average volume (440.74 m^3/ha) was recorded under E_2 and minimum average volume (244.30 m^3/ha) was recorded under E_4. However, from different periodic blocks, PB-I recorded a higher value (621.25 m^3/ha). Whereas, minimum value for volume of Chirpine (141.70 m^3/ha) was recorded in PB-IV. However, the interaction (PB × E) between periodic block and elevation showed the maximum value of volume of Chirpine in PB-I E_2 (885.78 m^3/ha). Whereas, the minimum value was recorded under PB-IV E_4 (126.73 m^3/ha), which was statistically at par with PB-IV E_1 (147.00 m^3/ha), PB-IV E_2 (162.47 m^3/ha), PB-IN E_3 (230.82 m^3/ha), PB-IV E_3 (130.60 m^3/ha) and PB-IN E_4 (206.24 m^3/ha).

Regarding the different periodic blocks, PB-I showed the maximum followed by PB-IN and then the minimum MAI values of trees was least for PB-IV in all the elevations. The trend is similar with that of tree numbers, volume, biomass and carbon. Perusal of data showed that the second elevation class, i.e., 1200–1500 m showed the maximum MAI values of chir pine trees followed by E_1, E_3 and E_4 as in case of number and volume/biomass/carbon of trees. To summarize all, it can be said that the tree MAI kept on decreasing as we move upwards from a low elevation to upper elevation but the second elevation was having maximum value with respect to first elevation class (900–1200 m).

The perusal of data reveals that stem biomass (tonnes/ha) in all the three periodic blocks and four elevations ranged between 0.21 in PB-I at E_2 and E_4 to 9.91 in PB-IV at E_2 in class V trees; in class IV the range was found to vary between 1.02 PB-I E_3 to 28.99 PB-IV E_2; in class III it was from 2.80 PB-I E_1 to 39.25 PB-IN E_3; in class IA 7.39 PB-IV E_3 and E_4 to 29.58 PB-IN at E_2 and E_3, 6.17 in PB-IV at E_1 and E_3 to 141.86 in PB-I at E_2 in IIB; in IA 4.64 PB-IV E_2 to 143.84 PB-I E_2; in IB 6.52 in PB-IN E_3 and E_4, PB-IV at E_3 to 97.76 PB-I E_1. While in IC it was found to range between 8.72 PB-IN E_1, E_2 and PB-I E_3 to 26.15 PB-I E_1. While class ID were found totally absent in E_1 and E_4 and biomass of 11.23 was recorded in PB-I at E_2 and E_3. Overall basis in various periodic blocks, PB-I showed the maximum values followed by PB-IN and then the minimum biomass of trees per hectare was in PB-IV at all the four elevations. The trend is similar to that of tree numbers and volume as discussed previously. Perusal of data showed thus the second elevation (E_2) class, i.e., 1200–1500 m possessed the maximum biomass values of Chirpine trees followed by E_1, E_2 and E_4 as in case of number and volume of trees. To summarize all, it can be said that the tree biomass kept on decreasing as we move upwards from a low elevation to upper elevation but the second elevation was having maximum value with respect to first elevation class (900–1200 m). RBD factorial analysis are pertaining to the effect of elevation and periodic block on the average spatial distribution of stem biomass (tonnes/ha) in Chirpine. Perusal of data revealed that at different elevations and in different periodic blocks predicted significant control over average spatial distribution of stem biomass.

During our study, among different elevations, maximum average stem biomass (216.41 tonnes/ha) was recorded under E_2 and minimum (119.95 tonnes/ha) was recorded under E_4. However, from different periodic blocks, PB-I recorded a higher value (305.04 tonnes/ha). Whereas, minimum value for stem biomass of Chirpine (69.58 tonnes/ha) was recorded in PB-IV. The interaction (PB × E) between periodic block and elevation showed the maximum value of average stem biomass of Chirpine in PB-I E_2 (434.92 tonnes/ha), and the minimum value was recorded under PB-IV E_4 (62.23 tonnes/ha) which was statistically at par with PB-IV E_1 (72.18 tonnes/ha), PB-IV E_2 (79.77 tonnes/ha), PB-IN E_3 (113.33 tonnes/ha), PB-IV E_3 (64.13 tonnes/ha) and PB-IN E_4 (101.27 tonnes/ha).

The calculated average stem carbon (tonnes/ha) depicted that in three periodic blocks at different elevations ranged between 0.10 at PB-I E_4 to 4.95 PB-IV E_2 in class V; in class IV between 0.51 PB-I E_3 to 14.50 PB-IV E_2; in class III from 1.40 PB-I E_1 to 19.62 PB-IN E_3; in IIA between 3.70 PB-IV at E_3 and E_4 to 15.71 PB-I E_2; in IIB 3.08 PB-IV E_1 and E_3 to 70.93 PB-I E_2; in IA 2.32 PB-IV E_2 to 71.92 PB-I E_2; in IB it depicted a range from 3.26 in PB-IV E_3 and E_4 to 48.88 PB-I E_1 and in IC the maximum value of 13.07 was recorded in PB-I E_1 while in ID class, no trees were found growing in elevation E_1 and E_4 and only carbon of 5.62 was recorded in PB-I at E_2 and E_3. In different periodic blocks, PB-I showed the maximum stem carbon value followed by PB-IN and then the minimum stem carbon of trees was least for PB-IV in all the four elevations. The trend is similar with that of tree numbers and volume and biomass. Perusal of data showed that the second elevation class, i.e., 1200–1500 m showed the maximum carbon values of Chirpine trees followed by elevation 1, elevation 3 and elevation 4 as in case of number and volume of trees. To summarize all, it can be said that the tree carbon kept on decreasing as we move upwards from a low elevation to upper elevation but the second elevation was having maximum value with respect to first elevation class (900–1200 m). The stem carbon distribution pattern revealed that different elevations and periodic blocks has significantly control over average spatial distribution of stem carbon. During our study, among different elevations, maximum average stem carbon (108.20 tonnes/ha) was recorded under E_2 and minimum (59.98 tonnes/ha) was recorded under E_4. However, from different periodic blocks, PB-I recorded a higher value (152.52 tonnes/ha). Whereas, minimum value for stem biomass of Chirpine (34.79 tonnes/ha) was recorded in PB-IV. The interaction (PB × E) between periodic block and elevation showed the maximum value of average stem biomass of Chirpine in PB-I E_2 (217.46 tonnes/ha). Whereas, the minimum value was recorded under PB-IV E_4 (31.11 tonnes/ha) which was statistically at par with PB-IV E_1 (36.09 tonnes/ha), PB-IV E_2 (39.88 tonnes/ha), PB-IN E_3 (56.67 tonnes/ha), PB-IV E_3 (32.06 tonnes/ha) and PB-IN E_4 (50.63 tonnes/ha).

Results showed an increasing trend from the past to the recent years in PB-I and PB-IN and in PB-IV, where there was an increase in tree numbers from the year 1984 to 2002; 2002 to 2011 and 1984 to 2011. The per cent deviation in total numbers per hectare was maximum between the years 1984–2002 (+460.00) and minimum between 2002 to 2011 (+6.11) both in the same periodic block, i.e., PB-IV. The average values of distribution of volume in different periodic blocks of Chirpine forest depicts that the temporal distribution of average volume (m^3/ha) of trees per hectare at various diameter classes in different periodic blocks of Chirpine forest in various years viz., 1984, 2002 and 2011. Results showed that because of ban on green felling since after year 1985, there was an increasing trend from the past to the recent years in PB-IN and PB-IV which is different from the early history, where the forests were cleared indiscriminately for cultivation; from time to time, some forests leased to contractors were exploited uncontrolled; on efforts were made either to regenerate the felled areas or to check the number of felled trees; and there was non scientific management opted for the proper treatment of forest. In PB-I, there was a decrease in tree volume from the year 1984 to 2002. There might be many reasons, viz., frequent fires (ineffective fire protection), overfelling of trees, no control over grazing or untrained staff. The per cent deviation in total volume per hectare was maximum (1151.89) between the years 2002–2011 in PB-I while it was minimum (58.55) in PB-IV. The per cent deviation was found to be negative (-52.41) between the years 1984–2002 in PB-I. The per cent deviation between 2002–2011 was maximum (1151.89) in PB-I followed by PB-IN (134.00) while it was minimum (58.55) in PB-IV.

Comparison of average stem biomass in present study with previous official records depicted that the temporal distribution of biomass in different periodic blocks of Chirpine forest reveals the temporal distribution of average biomass (tonnes/ha) of trees at various diameter classes in different periodic blocks of chir pine forest in various years viz., 1984, 2002 and 2011. Results showed the similar trend as in case of volume. The trend was found to be similar to volume studies.

Conclusion

At the end of this study it may be concluded that In all the elevation classes, more number of trees of 50–70 cm diameter class in PB-I were found, while in PB-IN and PB-IV, trees of 10–20 and 20–40 cm diameter classes dominated the area. Higher volume, biomass and carbon were recorded in PB-I followed by PB-IN and PB-IV in all the elevation classes and it was more distributed in 50–70 cm, 20–30 cm and 30–40 cm diameter classes of trees, respectively. PB-I had higher incremental growth (MAI) followed by PB-IN and PB-

IV. In all the elevations, MAI was higher in 50–70 cm tree diameter class of PB-I followed by MAI in 30–40 cm tree diameter class of PB-IN and MAI in 20–30 cm tree diameter class of PB-IV. There was an increase in tree number from the year 1984 to 2002 (178.84%) and 2002 to 2011 (16.11%). However, overall increase in number of trees from 1984 to 2011 was 223.77%. There was an increase in tree volume from the year 1984 to 2002 (18.47%) and 2002 to 2011 (306.03%). However, overall increase in volume of trees from 1984 to 2011 was 381.04%. In PB-I, 13.41% trees were added during the period 1984 to 2002 as compared to 29.57% between 2002 to 2011. In PB-IN, 230.77% tees were added from 1984 to 2002 and 23.59% from 2002 to 2011. In PB-IV, 427.78% of trees were added from 1984 to 2002 and thereafter 6.11% between 2002 to 2011. In PB-I, (-) 52.41% of volume of trees decreased during the period 1894 to 2002, while during 2002 to 2011, it showed an increase in volume by 1151.89% in PB-I. In PB-IN, 48.66% of volume was added from 1984 to 2002 and 134.63% from 2002 to 2011. In PB-IV, 160.63% of volume was added from 1984 to 2002 and thereafter 58.55% between 2002 to 2011. The maximum volume, biomass and carbon were distributed in diameter classes of 40–60 cm, 30–50 cm and 10–30 cm in PB-I, PB-IN and PB-IV in 1984, 2002 and 2011, respectively. Total biomass of 467.92, 115.25 and 97.27 tonnes/ha and total carbon of 233.96, 57.62 and 48.64 tonnes/ha was recorded for the years 2011, 2002 and 1984, respectively.

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