Variation in Tree Layer Composition Across Mid and Higher Elevation Forest Sites in Kumaun Himalayan Region, Uttarakhand

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Abstract
The Himalayan forests are rich in biodiversity and distributed over a large extent from lower to higher elevations. The dependence of the locals for their daily requirements of fuel, fodder and medicinal plants is high on these forests. The study was conducted at altitude varied between 1725 and 3250 masl (above sea level) in Kumaun region. The study deals with the comparison of tree layer vegetation in higher elevation sites (HES) and mid elevation sites (MES) with reference to Diversity, Richness, Basal area (BA), Dominance and Important Value Index. The MES were dominated by mixed Quercus leucotrichophora and Pinus roxburghii forests where as HES sites were dominated by Quercus semecarpifolia and Aesculus indica forests and Rhododendron campanulatum in the understory. Across all the sites the tree species richness ranged between 9 and 15. Tree density was maximum (1400 trees/ha) at MES. Tree diversity and total basal area were maximum at HES. The study will be useful in developing baseline data for carrying out future studies. The data generated will be helpful for the conservation of biodiversity of the region.

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Introduction
The Himalaya among global mountains is most complex, vast and diversified and produce a distinct climate.¹ The Himalayan forests are very diverse ranging from Shorea robusta dominated foothill forests to the alpine meadows above the treeline.² The Himalayan forests are equally important for millions of people residing in the adjoining plain areas due to the various ecosystem services they provide. The regeneration ability of a species is chiefly dependent on biotic pressure and community dynamics.³ Various aspects of biodiversity, its
compilation and structure of these forests have been studied. For socioeconomic development and betterment of soil, livestock and human, the conservation of biodiversity is of special importance for socioeconomic development of local population. Vegetation within forest is greatly affected by differences in the microclimate, aspect and altitude. The chronic disturbance and destruction, both natural and man-made are the major threats to biodiversity. The forest resources of the Himalaya are shrinking in size due to over exploitation. The rich plant diversity of IHR has been utilized by the local communities in various forms such as medicine, fuel, fodder, timber, agricultural implements and small scale enterprises and in religious ceremonies. The recent phenomenon of climate change is also influencing the composition and regeneration of many plant species. Young individuals grow within the most severe micro environment in a forest. Regeneration in the forest is dependent on the capacity of mature trees to produce seeds, seed germination capacity and viability. The focus of present study was to compare the forest composition and tree diversity of selected forest areas of Uttarakhand region located at mid altitude sites (MES) and high altitude sites (HES). The baseline data generated in the current study would be useful for future studies on forests. The paper has a huge scope for young researchers and scientists working in related field as the study will provide baseline data for future referencing.

Material and Methods

Study Site

Two sites located in Ranikhet mid elevation sites (MES) between an altitude 1725 m and 2000 m between 29° 37´ N latitude 79° 27´ E longitudes at northern aspect of the lesser Himalayan zone in Kumaun were selected. The climatic data were taken from Kalika Research Range, Ranikhet. The mean maximum and minimum annual temperature ranged from 13.02°C to 28.05°C and 3.6°C to 17.32°C respectively. The average annual precipitation was 1347 mm (Table 1).

Two sites located in Munshiyari high elevation sites (HES) between an altitude 3000 m and 3250 m between 30°, 03´ N latitude 80°, 13´ E longitudes at North eastern aspect were selected. Mean monthly maximum and minimum temperature range from 12°C to 26°C and -1°C to 12°C respectively. The mean annual total rainfall is 1959 mm (more than half occurring during the rainy season – about 400 mm in the month of August itself) (Table 1).

| Sites         | Altitudes (m) | Latitude  | Longitude | Aspect     |
|---------------|---------------|-----------|-----------|------------|
| Mid elevation sites (MES) |               |           |           |            |
| Site I        | 2000          | 29°37´ N  | 79°27´ E  | Northern   |
| Site II       | 1725          | 29°37´ N  | 79°27´ E  | Northern   |
| High elevation sites (HES) |               |           |           |            |
| Site I        | 3250          | 30°03´ N  | 80°13´ E  | North –eastern |
| Site II       | 3000          | 30°03´ N  | 80°13´ E  | North –eastern |

Tree Layer Analysis

Total of 2 ha area was selected at each site for placing ten quadrats of 10 m x 10 m for determining the vegetational parameters following. Equitability (EC) or species evenness was calculated following. Species diversity (H) for each species was determined by using Shannon-Weiner index. Concentration of Dominance (CD) was calculated by Simpson’s index.

Result and Discussion

Tree Layer Analysis

In MES (Site I) The total density of trees was 1400 trees/ha. The density of trees ranged between 10 and 490 trees/ha. The basal area was 46.30
The basal area ranged between 0.004 and 13.05 m²/ha. Least important species was *Prunus cerasoides* (5.9) in terms of IVI. The forest was *Quercus leucotrichophora*, *Rhododendron arboreum* and *Pinus roxburghii* mixed forest. (Table 2).

### Table 2: Vegetational parameters of tree species in mid elevation site I (MES I) at Ranikhet

| Species                        | Density (trees/ha) | Frequency (%) | Abundance | A/F | Basal area (m²/ha) | IVI |
|-------------------------------|--------------------|---------------|-----------|-----|-------------------|-----|
| *Pinus roxburghii*            | 160                | 70            | 2.2       | 0.03| 13.05             | 62.9|
| *Quercus leucotrichophora*    | 490                | 80            | 6.1       | 0.07| 9.33              | 58.4|
| *Rhododendron arboreum*       | 260                | 90            | 2.8       | 0.03| 12.52             | 58.4|
| *Myrica esculenta*            | 240                | 80            | 4.6       | 0.05| 9.95              | 58.4|
| *Quercus glauca*              | 10                 | 50            | 2         | 0.04| 0.40              | 18.9|
| *Cedrus deodara*              | 70                 | 40            | 1.7       | 0.04| 0.51              | 14.4|
| *Cupressus torulosa*          | 80                 | 30            | 2.6       | 0.08| 0.51              | 15.3|
| *Fraxinus micrantha*          | 70                 | 40            | 1.7       | 0.04| 0.17              | 13.9|
| *Prunus cerasoides*           | 20                 | 20            | 1         | 0.05| 0.004             | 5.9 |

Total 1400   46.30  300.00

In MES (Site II) Total tree density was 1300 trees/ha. The density of trees ranged between 20 and 250 trees / ha. The basal area was 49.37m²/ha. The basal area ranged between 0.59 and 13.69 m²/ha. Least important species observed was *Myrica esculenta* (12.2) in terms of IVI. The forest was *Quercus leucotrichophora* and *Rhododendron arboreum* mixed forest. (Table 3). Across both the sites at mid elevation tree richness ranged between 9 and 14 (Table 6).

### Table 3: Vegetational parameters of tree species in mid elevation site II (MES II) at Ranikhet

| Species                        | Density (trees/ha) | Frequency (%) | Abundance | A/F | Basal area (m²/ha) | IVI |
|-------------------------------|--------------------|---------------|-----------|-----|-------------------|-----|
| *Quercus leucotrichophora*    | 250                | 80            | 3.1       | 0.03| 10.71             | 43.65|
| *Rhododendron arboreum*       | 220                | 70            | 3.1       | 0.04| 13.69             | 43.5 |
| *Pinus roxburghii*            | 190                | 50            | 3.8       | 0.07| 8.86              | 33.97|
| *Cedrus deodara*              | 140                | 50            | 2.8       | 0.05| 3.48              | 25.62|
| *Pinus petula (Planted)*      | 100                | 50            | 2         | 0.04| 3.12              | 23.87|
| *Acacia menenzi*              | 60                 | 50            | 1.2       | 0.02| 1.82              | 20.69|
| *Aesculus indica*             | 20                 | 20            | 1         | 0.05| 1.06              | 16.65|
| *Quercus glauca*              | 20                 | 20            | 1         | 0.05| 0.85              | 15.83|
| *Acer oblongum*               | 80                 | 20            | 4         | 0.2 | 1.74              | 14.55|
| *Pinus gragaii*               | 20                 | 20            | 3.5       | 0.17| 0.84              | 14.20|
| *Cupressus torulosa*          | 50                 | 20            | 2.5       | 0.12| 1.03              | 12.02|
| *Robinia pseudocacia*         | 40                 | 30            | 1.3       | 0.04| 0.59              | 11.86|
| *Fraxinus micrantha*          | 60                 | 20            | 3         | 0.15| 0.89              | 11.58|
| *Myrica esculenta*            | 50                 | 20            | 2.5       | 0.12| 0.69              | 12.2 |

Total 1300   49.37  300.0

In HES (Site I) The total tree density was 1040 trees/ha. The density of trees ranged between 20 and 190 trees / ha. The basal area was 68.56 m²/ha. The basal area ranged between 1.24 and 9.41 m²/ha.
Least important species observed was *Fraxinus floribunda* (11.7) in terms of IVI. *Rhododendron campanulatum* dominated the under canopy species whereas the canopy vegetation was dominated by *Quercus semecarpifolia* (Table 4).

### Table 4: Vegetational parameters of tree species in high elevation site I (HES I) at Munshiyari

| Species                          | Density (trees/ha) | Frequency (%) | Abundance | A/F | Basal area (m²/ha) | IVI |
|---------------------------------|--------------------|---------------|-----------|-----|--------------------|-----|
| *Rhododendron campanulatum*     | 190                | 80            | 2.3       | 0.02| 2.21               | 35.2|
| *Quercus semecarpifolia*        | 50                 | 30            | 1.6       | 0.05| 9.41               | 25.4|
| *Betula utilis*                 | 110                | 50            | 2.2       | 0.04| 6.01               | 24.7|
| *Betula alnoides*               | 90                 | 40            | 2.2       | 0.05| 6.45               | 22.2|
| *Juglans regia*                 | 30                 | 20            | 1.5       | 0.07| 5.51               | 21.1|
| *Cupressus torulosa*            | 80                 | 40            | 2         | 0.05| 5.21               | 20.8|
| *Taxus baccata*                 | 40                 | 20            | 2         | 0.1 | 6.15               | 19.7|
| *Leyna ovalifolia*              | 20                 | 20            | 1         | 0.05| 3.36               | 19   |
| *Carpinus veminia*              | 70                 | 30            | 2.3       | 0.07| 5.45               | 18.7|
| *Cedrus deodara*                | 70                 | 30            | 2.3       | 0.07| 4.53               | 17.7|
| *Abies spectabilis*             | 70                 | 40            | 1.7       | 0.04| 2.43               | 17.5|
| *Alnus nepalensis*              | 70                 | 30            | 2.3       | 0.07| 4.24               | 17.4|
| *Rhododendron arboreum*         | 60                 | 30            | 3         | 0.1 | 4.38               | 17.3|
| *Pyrus pashia*                  | 40                 | 20            | 2         | 0.1 | 1.98               | 11.6|
| *Fraxinus floribunda*           | 50                 | 20            | 2.5       | 0.1 | 1.24               | 11.7|

**Total** 1040 68.56 300.0

### Table 5: Vegetational parameters of tree species in high elevation site II (HES II) at Munshiyari

| Species                          | Density (trees/ha) | Frequency (%) | Abundance | A/F | Basal area (m²/ha) | IVI |
|---------------------------------|--------------------|---------------|-----------|-----|--------------------|-----|
| *Aesculus indica*               | 20                 | 10            | 0.2       | 0.02| 20.44              | 48.8|
| *Rhododendron campanulatum*     | 150                | 70            | 2.1       | 0.03| 2.43               | 42.4|
| *Carpinus veminia*              | 80                 | 50            | 1.6       | 0.03| 5.59               | 28.5|
| *Cedrus deodara*                | 50                 | 40            | 1.2       | 0.03| 9.12               | 26.5|
| *Taxus baccata*                 | 60                 | 30            | 2         | 0.06| 8.91               | 23.4|
| *Cupressus torulosa*            | 60                 | 30            | 2         | 0.06| 5.97               | 21.3|
| *Quercus semecarpifolia*        | 10                 | 10            | 0.1       | 0.01| 4.05               | 21.4|
| *Abies spectabilis*             | 50                 | 40            | 1.2       | 0.03| 1.50               | 19.5|
| *Betula utilis*                 | 30                 | 30            | 1         | 0.03| 1.75               | 14.8|
| *Betula alnoides*               | 40                 | 20            | 2         | 0.1 | 2.18               | 13.7|
| *Alnus nepalensis*              | 40                 | 20            | 2         | 0.1 | 2.18               | 13.8|
| *Lyena ovalifolia*              | 0.2                | 10            | 0.2       | 0.02| 3.86               | 13.8|
| *Fraxinus micrantha*            | 30                 | 20            | 1.5       | 0.07| 0.94               | 12.1|

**Total** 640 68.92 300.0

In HES (Site II) The total tree density was 640 trees/ha. The density of trees ranged between 20 and 150 trees/ha. The basal area was 68.92 m²/ha. The basal area ranged between 20.44 and 94 m²/ha. *Rhododendron campanulatum* dominated the under canopy species whereas the canopy vegetation was
dominated by Aesculus indica. Least important species observed was Fraxinus micrantha (12.1) in terms of IVI (Table 5). The tree richness ranged between 13 and 15 across both the sites at high elevation.

Table 6: Variations in tree evenness, diversity and concentration of dominance

| Site          | Elevation (m) | Evenness | Diversity (ΣH) | Richness | ΣCD |
|--------------|--------------|----------|----------------|----------|-----|
| MES(Site I)  | 2000         | 0.91     | 2.49           | 9        | 0.04|
| (Site II)    | 1725         | 0.39     | 2.60           | 14       | 0.1 |
| HES (Site I) | 3250         | 0.61     | 7.10           | 15       | 0.04|
| (Site II)    | 3000         | 0.34     | 7.69           | 13       | 0.87|

Tree Diversity and Evenness
In MES across both elevations species evenness ranged between 0.39 and 0.91. Tree diversity ranged between 2.49 and 2.60. Tree richness ranged between 9 and 14. The concentration of dominance ranged between 0.04 and 0.1. (Table 6).

In HES across both elevation species evenness ranged between 0.34 and 0.61. Tree diversity ranged between 7.10 and 7.69. Tree richness ranged between 13 and 15. The concentration of dominance ranged between 0.04 and 0.87. (Table 6).

The vegetation of Himalaya varies due to different physiognomic conditions and altitudinal range coupled with different climatic and biotic factors. The forest sustainability highly depends upon regeneration potential of various species composition in Himalayan region. The dominated forests at MES sites were of Quercus leucotrichophora and Pinus roxburghii mixed forests. At HES site II Rhododendron campanulatum dominated the undercanopy vegetation where as the canopy vegetation was dominated by Aesculus indica. Certain species of Ericaceae yield toxic diterpenes, named grayanotoxins. It causes various livestock poisoning and food intoxication. Due to toxic nature of some Rhododendron species, animal avoid grazing them or it is non-palatable. This can be a major cause of higher density of R. campanulatum in higher altitudes. Forest ecosystem diversity is directly linked to tree species diversity and differs very much. HES showed high species richness than MES. Low anthropogenic disturbance can be related to higher species richness. As a result certain MES forest areas have decreased, modified and developed dry conditions. Negative correlation has been reported between elevation and tree species diversity. In present study the pattern was different. Across MES and HES sites the highest tree diversity (7.69) was observed at HES. The forests of this area showed less or no anthropogenic disturbances. This reason has been instrumented in enabling many tree species to form stable communities. Basal area was found maximum (68.92) at HES sites. The range of basal area was 56-126$m^2$/ha at Garhwal Himalaya. Forest plots with higher basal area have been reported at higher elevation by various researchers. For Q. semecarpifolia forest high value of Basal area (72.90) has also been reported earlier. The tree species richness was higher at HES sites than MES sites. High species richness in broad leaved forest of Garhwal Himalaya has also been reported earlier. The highest CD 0.87 was recorded at HES. Increase in dominance has been related with increase in altitude. The maximum concentration of dominance might be due to the lesser rate of development and diversification of the communities. The concentration of dominance for tree layer was 0.1 - 0.99 at Okalhoma upland forest. Concentration of dominance (0.1-0.5) has also been reported earlier in Nainital forest area of Kumaun.

Conclusion
Assessment of tree vegetation and diversity is important for management, sustainable use and conservation of forests. Baseline data is essential for carrying out future studies on forest vegetation particularly in a changing climate regime. There are several researches to indicate that already certain
tree and shrub species like *R. campanulatum* (which are non palatable) are marching into the alpine meadows which are repositories of important Himalayan medicinal plants. The present study clearly indicates the domination of *R. campanulatum* at sites adjacent to these alpine areas. It is essential to concentrate and carry on such studies to further investigate such movements.

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**Conflict of Interest**
The authors do not have any conflict of interest.

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