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***RESEARCH PAPER***

# POPULATION STRUCTURE OF *RHODODENDRON CAMPANULATUM* D. DON AND ASSOCIATED TREE SPECIES ALONG THE ELEVATIONAL GRADIENT OF MANASLU CONSERVATION AREA, NEPAL

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**ABSTRACT**

Climate change is affecting the forest ecosystems worldwide. Impacts of climate change are more perceptible at higher altitudes and can be easily detected along the elevational gradient. The main aim is to study the impact of elevation on the population structure of *Rhododendron campanulatum* D. Don and associated trees species at Manaslu Conservation Area, central Nepal. A total of 30 quadrats were sampled from 3600-4100 meter above sea level (m asl.) at altitudinal difference of 100 m with 5 quadrates in each altitude. The present study showed that *R. campanulatum, Betula utilis, Abies spectabilis* and *Sorbus microphylla* are the treeline species. *R. campanulatum* was the most dominant species with highest importance value index (IVI) along the altitudinal gradient. At 4000 m asl. *S. microphylla* was the codominant species. *B. utilis* was the codominant species at 3600 -3900 m asl followed by *S. microphylla* and *A. spectabilis*. *R. campanulatum* and *A. spectabilis* showed a sustainable regeneration. No seedling of *B. utilis* was found along the altitudinal gradient indicating that the regeneration of this species might be affected by unfavourable micohabitat (eg. deep shade). *R. campanulatum and S. microphylla* were found above the treeline indicating that the climatic conditions were favourable for their growth. The height, diameter and density of the species differed along the elevational gradient and showed a species specific trend.

**Key words:** Treeline ecotone, Regeneration, Climate change, Elevation gradient, Density

## INTRODUCTION

The average temperature of the Earth's surface has increased by approximately 0.8 °C in the past 100 years (IPCC 2014). Temperature rise is much higher at higher altitudes than at lower (IPCC 2014, Shrestha 1999). High mountain areas where low temperatures limit plant life are highly vulnerable to the impacts of climate change (Grabher *et al*. 1994). Climate change affects the distribution, population structure and regeneration of tree species at high altitudes (Payette *et al.* 1985, Kullman 2002, Camarero & Gutierrez 2004). Different environment gradients are formed on mountain slopes as the air temperature decreases on an average by 0.6°C per 100 m on the altitudinal gradient (Shrestha 1999). Environmental conditions differ greatly with altitude thus the limiting factors related to seedling establishment and tree recruitment might vary with changes in altitude (Block & Tretor 2001, Wangda & Ohsawa 2006, Penuelas *et al*. 2007). The understanding of environmental influences on population structure and regeneration dynamics of the natural forests could be improved by studies that sample across the distributional range (Veblen 1989, Wang *et al.* 2004, Wangda & Ohsawa 2006, Penuelas *et al.* 2007, Lingua *et al.* 2008). Population structure studies along the altitudinal gradient could be instrumental in giving us insight about the influence of environment factors on the regeneration of natural forests (Wang *et al*. 2004). *Rhododendron campanulatum* D. Don a member of Ericaceae family is found at the treeline ecotone, timberline and subalpine forest in Nepal. However, limited studies have been carried and there is lack of baseline data regarding the regeneration potential and population structure of tree species along the altitudinal gradient of High Himalaya, Nepal. Bearing this in mind an attempt was made to assess the impacts altitude and climate on the population structure of *R. campanulatum* and associated tree species at Manaslu Conservation Area.

## MATERIALS AND METHODS

### Study area

The study site lies in Manaslu Conservation Area (MCA) a protected site established in 1998 and situated in central Nepal covering an area of 1663 square kilometers. MCA protects 2,000 species of flowering plants and 11 types of forest have been reported in this area (NTNC 2010). It has a diverse natural resource base with sparse human population and is relatively inaccessible. The area includes nine bioclimatic zones ranging from the lower subtropics to the nival zone minimal infrastructures such as walking trails. Sparsely distributed local people rely on agriculture, animal husbandry and utilization of natural resources for their existence. The sampling site in the sub alpine forests are primarily composed of *Betula utilis* and *Abies spectabilis* with *Rhododendron campanulatum* and *Sorbus microphylla* forming the second tree layer. The species limit of *A. spectabilis* was recorded at 3984 m asl. and its treeline at 3907 m asl. whereas for *B. utilis* the treelimit and treeline was recorded at 3990 m asl. (Gaire *et al*. 2014). The tree canopy of treeline ecotone is formed by *B. utilis* and *A. spectabilis*, *R. campanulatum* and *S. microphylla*. Above the treeline scrubs of *Rhododendron anthopogen* and herbaceous species occur. Records from nearby meteorological stations in Chame reveal that over the past 30 years, the area experienced a decreasing trend in rainfall by 3.9 mm/year and an increasing trend in mean annual temperature by 0.017 °C/year (Gaire *et al*. 2014). Further the monthly mean minimum temperature has been decreasing while monthly mean maximum temperature has been significantly increasing (Gaire *et al*. 2014).

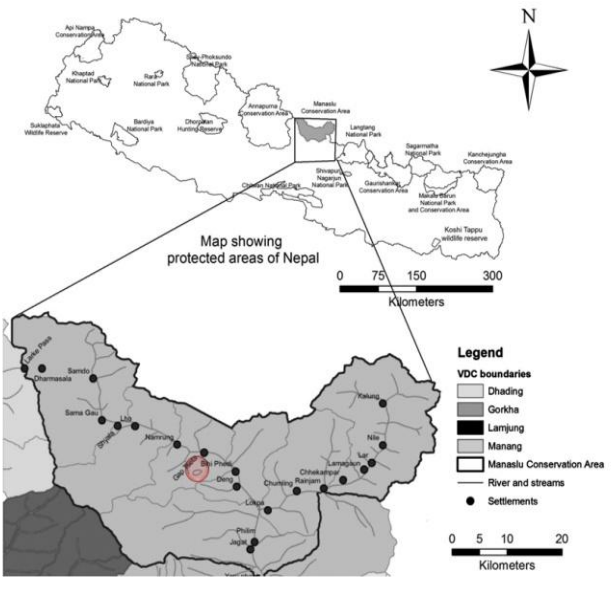


***Fig. 1. Map of the study site, Manaslu Conservation Area, central Nepal.***

### Methodology

Field study was carried in March-April 2012 and 2013 in the north facing mountain slope above and adjacent to the Kalchuman Lake in central Nepal (Fig 1). The population structure of *R. campanulatuam* and tree species were studied using quadrat method**.** A total of 30 quadrats (10m×10m) were sampled from 3600 meter above sea level (m asl.) to 4100 m asl. at an altitudinal difference of 100 m starting from the species limit of *R. campanulatum.* The study area was divided into five vertical transects and in each transect five quadrats were horizontally spaced 50 m apart. In each quadrat *R. campanulatum* and associated tree species were enumerated into three height classes: tree (> 2m), saplings (0.5-2m) and seedling (0.5m) according to Wang *et al*., (2006) and Kullman (2007). Seedling and saplings were also enumerated within the same 10×10m quadrats. In each quadrat all individuals of *R. campanulatum* and associated species were recorded and their height and diameter at breast height (DBH measured at 137 cm above the ground) were measured. The geographical location of each quadrat (longitude, latitude and altitude) was recorded using Garmin e-trex Global Positioning System (GPS). The vegetation data were quantitatively analyzed for basal area, density, frequency according to Kershaw (1973). The IVI of tree species were calculated by summing up the relative values of frequency, density and basal area where the relative value of frequency, density and basal area were derived as the value for a species expressed as percentage of the sum of those values for all the species of the community (Kershaw 1973). Those species having maximum IVI were considered as dominant species. For some of the pair of variables scatter diagram were plotted.

## RESULTS AND DISCUSSION

At 4100 m asl., only seedlings and saplings of *Rhododendron campanulatum* were present. At 4000 m asl., which lies above the treeline *R. campanulatum* was the dominant species with the highest value of IVI180 species and density of 140 trees per hectare and *Sorbus microphllya* was the co-dominant tree species with the IVI value of 120 and density of 80 trees per hectare.

**Table 1. Frequency, density, total basal area (TBA) and important value index (IVI) of *Rhododendron campanulatum* and associated tree species along the elevational gradient.**

| Altitude | Species | Frequency (%) | Density of trees /ha | TBA $m^2$/ha | IVI |
|---|---|---|---|---|---|
| 3600 m asl | *Rhododendron campanulatum* | 100 | 940 | 10.81 | 144 |
| | *Betula utilis* | 100 | 200 | 11.23 | 91 |
| | *Abies spectabilis* | 40 | 40 | 2.30 | 25 |
| | *Sorbus microphylla* | 80 | 160 | 0.76 | 25 |
| 3700 m asl | *Rhododendron campanulatum* | 100 | 400 | 6.06 | 140 |
| | *Betula utilis* | 80 | 180 | 4.34 | 89 |
| | *Abies spectabilis* | 40 | 40 | 0.38 | 23 |
| | *Sorbus microphylla* | 60 | 120 | 1.34 | 49 |
| 3800 m asl | *Rhododendron campanulatum* | 100 | 580 | 8.13 | 138 |
| | *Betula utilis* | 80 | 180 | 7.67 | 87 |
| | *Abies spectabilis* | 60 | 60 | 0.9 | 31 |
| | *Sorbus microphylla* | 60 | 60 | 1.71 | 44 |
| 3900 m asl | *Rhododendron campanulatum* | 100 | 820 | 10.69 | 168 |
| | *Betula utilis* | 100 | 220 | 4.95 | 82 |
| | *Abies spectabilis* | 0 | 0 | 0 | 0.0 |
| | *Sorbus microphylla* | 100 | 140 | 0.89 | 51 |
| 4000 m asl | *Rhododendron campanulatum* | 40 | 140 | 1.00 | 180 |
| | *Betula utilis* | 0 | 0 | 0 | 0 |
| | *Abies spectabilis* | 0 | 0 | 0 | 0 |
| | *Sorbus microphylla* | 20 | 80 | 0.83 | 121 |
| 4100 m asl | Only seedlings and sapling of *Rhododendron campanulatum* was found. | | | | |

At 3900 m asl which is below the treeline *R. campanulatum* was the dominant species with an IVI of 168 and density of 820 trees per hectare other associated tree species were *Betula utilis* and *S. microphylla*. The high density of *R. campanulatum trees* at this altitude with high basal area (10.69 $m^2$/ha) might have created an unfavorable niche for seedling and sapling establishment of *R. campanulatum* and associated tree species as seen in Table 1 (Fig. 2 & 3). *Rhododendrons* are also reported to have alleopathic effect which affects seedling establishment (Schickhoff *et al*. 2015). At 3800 m asl. *R. campanulatum* was the dominant species with IVI of 138 and density of 580 trees per hectare. Other associated tree species recorded were *B. utilis*, *A. spectabilis* and *S. microphylla*. The density and IVI for of *A. spectabilis* peaked at this altitude indicating that this altitude is favourable for its growth. At 3700 m asl. *R. campanulatum* was still the dominant species. *B. utilis* showed a similar trend of IVI and density at 3800 m asl., 3700 m asl. and 3600 m asl. The density of *R. campanulatum* decreased from 3900 m asl to 3700 m asl and slightly increased at 3600 m asl. The decrease in density may be due to low precipitation and low moisture at lower elevation and competition between species. According to Whittaker (1956), Block and Tretor (2001) low precipitation and low soil moisture at the low elevations could restrict growth and development of plants in the soil. The change in overall density of woody species due to change in elevation is closely related to both temperature and precipitation along steep elevational gradients along with other factors (Bai *et al*. 2011).

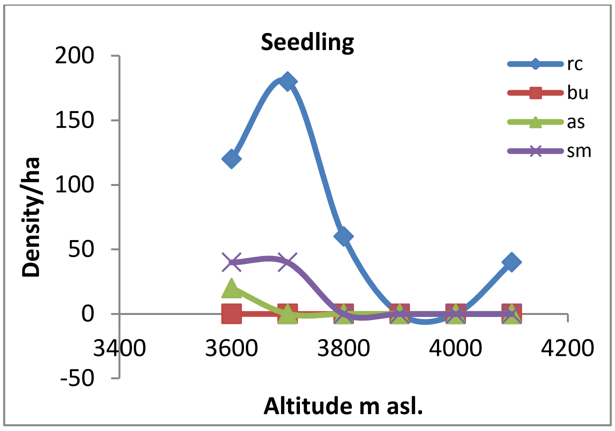


***Fig. 2. Seedling density of Rhododendron campanulatum (rc), Betula utilis (bu), Abies spectabilis (as) and Sorbus microphylla (sm) along the elevation gradient in Manaslu Conservation Area, central Nepal.***

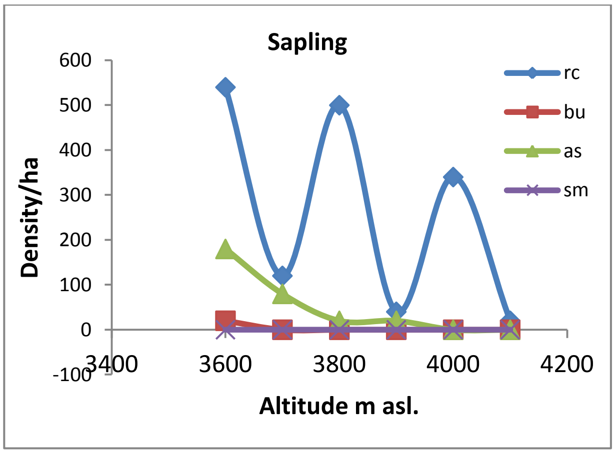


***Fig. 3. Sapling density of Rhododendron campanulatum (rc) and Betula utilis (bu), Abies spectabilis (as) and Sorbus microphylla (sm) along the elevation gradient in Manaslu Conservation Area, central Nepal.***

Altogether three tree species viz. *A. spectabilis, S. micropylla* and *B. utilis* were found to be associated with *R. campanulatum* (Table 1). Gaire *et al.* (2014) also reported these species as treeline species in Manaslu Conservation Area. The density of *R. campanulatum* and associated species showed a fluctuating trend along the altitudinal gradient. The variation among the density of seedling, saplings and trees may be due to climatic (temperature and moisture) as well as edaphic factors. Tasfeye *et al*. (2010) reported similar variation in seedling density along the altitudinal gradient in Southern Ethopia.

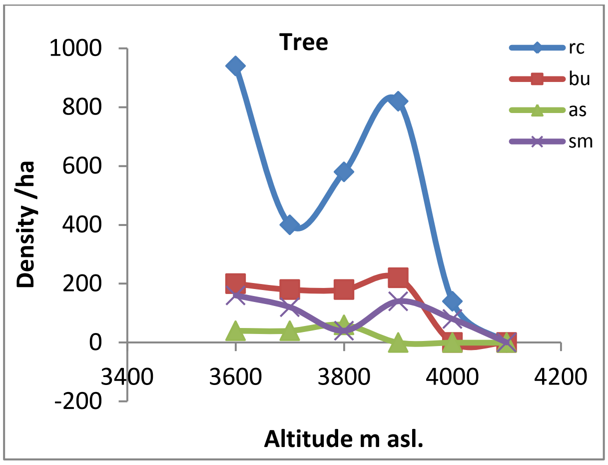


***Fig. 4. Tree density of Rhododendron campanulatum (rc) and Betula utilis (bu), Abies spectabilis (as) and Sorbus microphylla (sm) along the elevation gradient in Manaslu Conservation Area, central Nepal.***

The density of tree, sapling and seedling of *R. campanulatum* peaked at 3600 m asl, 3800 m asl and 3700 m asl respectively (Fig., 2, 3 & 4). At 3900 m asl, high basal area, density and allelopathic effect of Rhododendron may have been detrimental for the survival of seedlings and saplings of *R. campanulautum* and associated species at this altitude (Fig. 4). The density of seedling of *R. campanulatum* and *S. microphylla* were higher at 3600 m asl and 3700 m asl. a mixed forest of *R. campanulatum*, *B. utliis*, *A. spectabilis* and *S. microphylla* (Fig. 2). Wardle (1971) reported that seedling density often increases with decreasing altitude. *R. campanulatum* saplings fluctuated along the altitudinal gradient while *A. spectabilis* saplings increased at 3600 m asl. and 3700 m asl. Higher presence of seedlings in gaps could be attributed to many factors such as better germination capacity, higher percentage survival in gap areas etc. (Arista 1995, Liu 2004). Hardly any seedling and saplings of *B. utilis* was recorded. Since this is an early successional species, it requires direct sunlight (e.g. in gaps) for seedling establishment. *R. campanulatum* often forms dense stand with deep shade where seedling establishment of *Betula* is almost impossible. Lack of seedling of *Betula* might be due to unfavorable microhabitat (e.g. deep shade) (Shrestha *et al.* 2010). Gaire *et al.* (2014) also reported a similar finding in his study at Manaslu Conservation Area. The deep shade made by shade tolerant species will replace shade intolerant species (Grime 2001). Therefore, *B. utilis* could be replaced by a shade tolerent *A. spectabilis* at lower elevations. Liang *et al*. (2014) reported that the growth of *Betula* at the upper timberlines is limited by moisture. Sujakhu (2013) also emphasized that the current environment conditions were not favourable for the establishment of *B. utilis* seedlings. Moisture and deep shade might be detrimental for seedling establishment. The total sapling density of all tree species was higher than seedling density which is not a normal demographic development. Similar trend was also observed by Gaire *et al*. 2010 at Langtang and Sujakhu (2013) at Samagoan. There is a positive relationship between total basal area and seedling and sapling (Fig. 5 & 6). However, the relation between seedling and stand is weak.

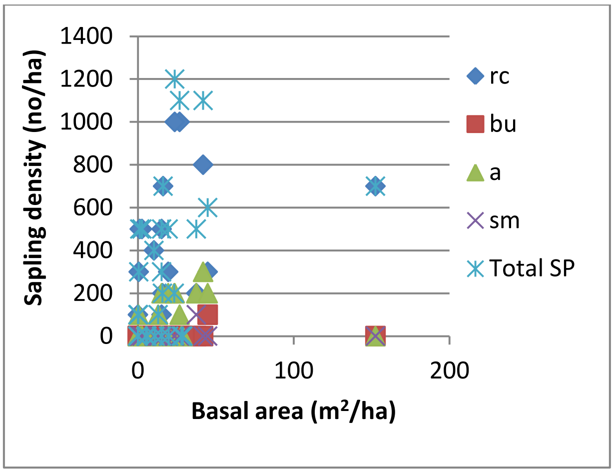


***Fig. 5. Scatter diagram showing variation of sapling density with basal area of Rhododendron campanulatum and associated tree species in Manaslu Conservation Area, central Nepal.***

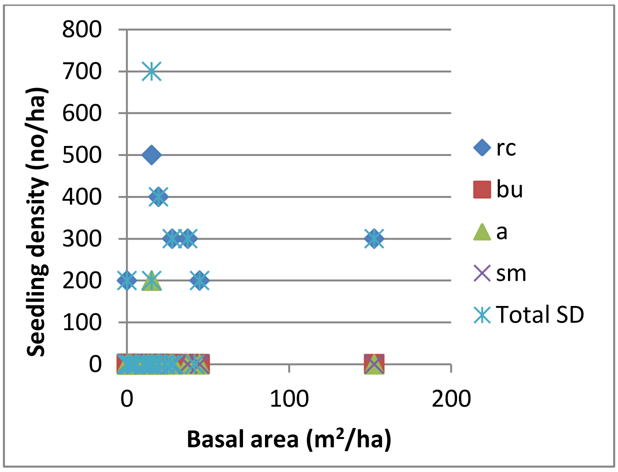


***Fig. 6. Scatter diagram showing variation of sapling density with basal area of Rhododendron campanulatum and associated tree species in Manaslu Conservation Area, central Nepal.***

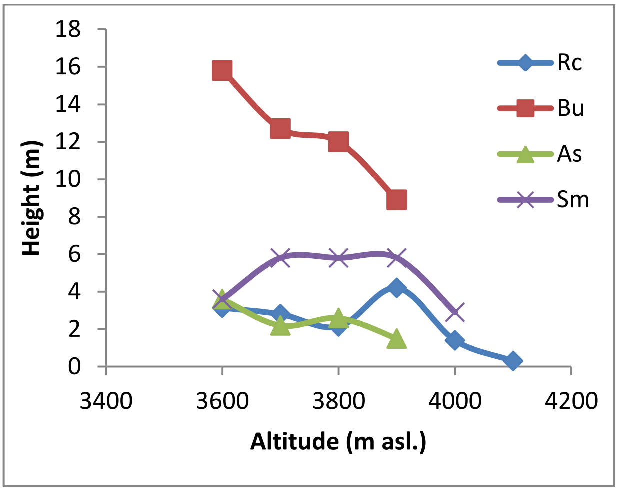


***Fig. 7. Average height of Rhododendron campanulatum and associated tree species along the elevational gradient in Manaslu Conservation Area, central Nepal.***

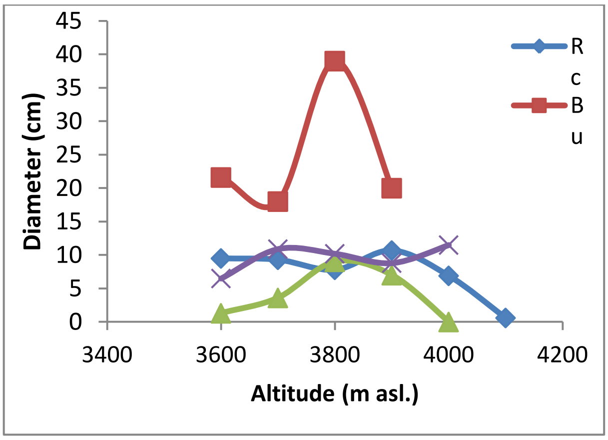


***Fig. 8. Average diameter of Rhododendron campanulatum and associated tree species along the elevational gradient in Manaslu Conservation Area, central Nepal.***

The average height of *R. campanulatum* and associated tree species showed a different trend along the altitudinal which was species specific (Fig. 7). The height of *B. utilis* decreased with elevation. The average height (m) of *R. campanulatum* peaked at 3900 m asl. tapering towards higher and lower altitude. The average height (m) of *S. microphylla* peaked at 3700 m asl., 3800 m asl. and 3900 m asl. The height (m) of *A. spectabilis* also decreased with increasing altitude. The average diameter (cm) of *R. campanulatum*, *B utilis*, *A. spectabiis* and *S. microphylla* peaked at 3900 m asl., 3800 m asl. and 4000 m asl. respectively (Fig. 8).

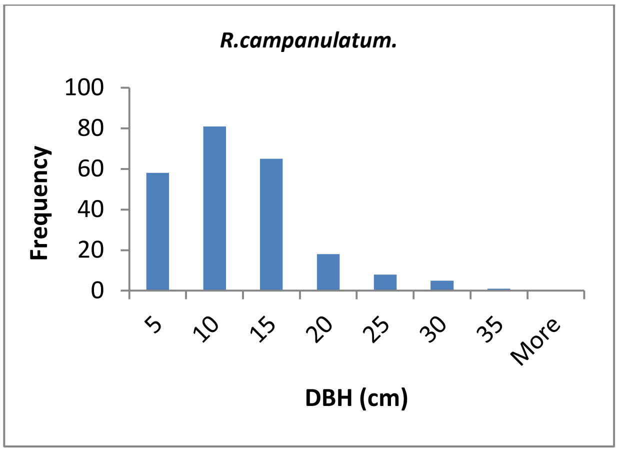


***Fig. 9. DBH class distribution of Rhododendron campanulatum, Kalchuman Tal area of Manaslu Conservation area, central, Nepal.***

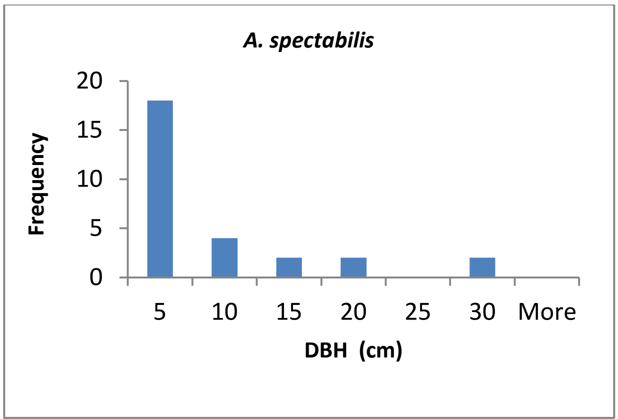


***Fig. 10. DBH class distribution of Abies spectabilis, Kalchuman Tal Area of Manaslu Conservation Area, central, Nepal.***

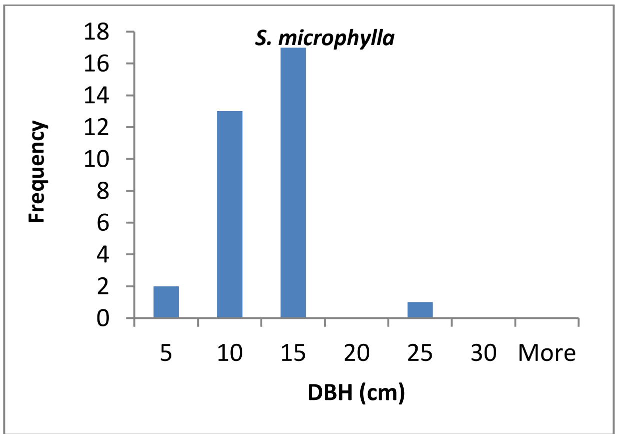


***Fig. 11. DBH class distribution of Sorbus microphylla , Kalchuman Tal Area of Manaslu Conservation Area, central, Nepal.***

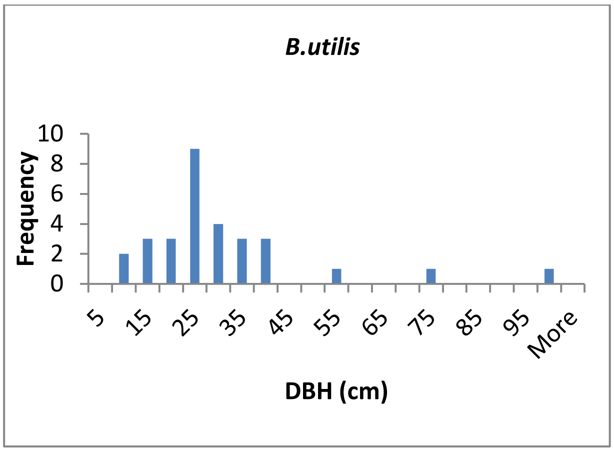


***Fig. 12. DBH class distribution of Betula utilis, Kalchuman Tal Area of Manaslu Conservation Area, central, Nepal.***

The diameter class showed an inverse J frequency distribution for *Rhododendron campanulatum* and *Abies spectabilis* which is an indication of sustainable regeneration (Fig. 9 & 10). Paul (2008) reported similar findings from temperate broadleaf forest of Rhododendrons. Gaire *et al*. (2010) reported inverse J shaped diameter class distribution was observed for *R. campanulatum* in Langtang. Whereas, *Betula utilis* and *Sorbus microphylla* showed a bell shaped distribution which indicates lower regeneration in recent years (Fig. 11 & 12). Shrestha *et al*. (2007) reported that *B. utilis* both in mixed and pure forests nearly resembled a reverse J shaped in the forest of trans Himalaya dry valley in Manang, Central Nepal. Gaire *et al.* (2015) reported a slightly inverse J and bell shaped DBH distribution for *A. spectabilis* and *B. utilis* respectively at Sagarmatha (Everest) National Park. Bhuju *et al.* (2010) reported a bell shaped diameter class for *A. spectabilis* and *B. utilis* at Yaren plot and Debuche plot (Everest region of Nepal) respectively while A. *spectabilis* and *B. utilis* showed a reverse J distribution in Debuche and Yaron plot respectively. Ghimire and Lekhak (2007) found an inverse J shaped size class distribution for *B. utilis* and *A. spectabilis* in the northern aspect of Manang. The diameter class distribution class of *A. spectabilis* and *B. utilis* is site specific. *R. campanulatum* and *S. microphylla* were also found above the treeline.

## CONCLUSION

The present study shows that *Rhododendron campanulatum, Betula utilis, Abies spectabilis* and

*Sorbus microphylla* are the treeline species in the study site. Results reveal that *R. campanulatum* was the most dominant species along the elevational gradient with highest IVI value. At 4000 m asl *S. micorphylla* was the codominant species. *B.utilis* was the codominant species from 3600 to 3900 m asl followed by *S. microphylla* and *A. spectabilis*. *R. campanulatum* and *A. spectabilis* showed a sustainable regeneration pattern. While *B. utilis* and *S. microphylla* showed poor regeneration. Lack of seedling of *Betula* might be due to unfavorable microhabitat (dense) which may lead to replacement by more shade tolerant *A. spectabilis* at lower elevation. At higher elevation just below the treeline dense *R. campanulatum* may be crucial factor inhibiting seedling growth. The height, diameter and density differed along the elevational gradient and showed a species specific trend. The data obtained from this study could be used as baseline reference for future studies.

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