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DENDROECOLOGICAL STUDIES OF *RHODODENDRON CAMPANULATUM* D.DON ALONG THE ELEVATIONAL GRADIENT OF MANASLU CONSERVATION AREA, NEPAL HIMALAYA

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Abstract

The increase in temperature due to global warming is affecting forest ecosystems worldwide. At the treeline ecotone growth is usually restricted by low temperatures. Recently, the impacts of climate change have been visible with the upward shift of the Himalaya fir (*Abies spectabilis*) in Nepal. *Rhododendron campanulatum* D. Don grows at the treeline ecotone and subalpine forest. Hardly any studies have been carried on this species in Nepal. The local people have reported that this species has been seen colonizing upper altitude in recent years, however, these needs to be verified with dendroecological studies. The study aims to assess the response of *R. campanulatum* to climatic variability and to evaluate the relationship of its basal diameter (Groundline) and age using dendroecological methods. Results reveal that the basal diameter was found to be significantly correlated with age (r2= 0.824, p<0.00001). Using the basal diameter age equations, attempts were made to study the age distribution along the altitudinal gradient. The species limit was observed at 4090 m asl. The age structure differed along the altitudinal gradient with multi age cohorts below the treeline and younger cohorts above the treeline. Results show that this species is migrating up at a rate of 24.7m per decade.

Key words: Treeline, Climate change, Altitude, Rhododendron, Shift.

Introduction

The global warming is affecting forest ecosystems worldwide. This has mostly affected vegetation at higher altitudes where the growth is mainly restricted by low temperatures (Körner, 2012). Low temperatures severely affect tissue formation and seedling growth (Körner, 2012). High mountain systems such as the Himalayas are highly vulnerable to climate change. In Nepal, the mean annual temperature is reported to be increasing at a rate of 0.04°C-0.06°C/year with a higher rate of increase at high altitudes (Baidya *et al*., 2007; Shrestha *et al*., 1999) resulting in more pronounced effect at higher elevation. Shrinking of permafrost areas and retreating glacial are some prominent effects already being visible at high mountain areas (Fujita *et al*., 1998; Bajaracharya *et al*., 2007; Bolch *et al*., 2012). Altitude, topography and exposure has a strong effect in shaping up the vegetation zonation in the area (Abbas *et al*., 2017). Each species has a limited range to withstand various climatic factors (Corlett & Westcott, 2013). In the context of climate change, vegetation are faced with three options in the either they acclimate, move up or die. Plant population shift up when seeds are dispersed and establish above the current range (Corlett & Westcott, 2013). Various studies clearly indicate an upward shift of woody vegetation at the alpine treeline ecotone (Payette & Filion, 1985; Harsch *et al*., 2009). The rate of shift varies among different species and it is location specific.

Though recently limited studies have focused on few treeline species such as *Betula, Abies* (Gaire *et al.,* 2014; Suwal *et al.*,2016), studies have not focused on *Rhododendron campanulatum* D. Don. *R. campanulatum* which belongs to the Ericaceae family has a wide altitudinal range and is found at the treeline ecotone, timberline and subalpine forest in Nepal (Milleville, 2002). The local people frequently reported that the species has been colonizing upper altitude in recent years. However, this needs to be verified with baseline data and dendroecological studies. Furthermore, age structure studies along the altitudinal gradient also help to generate information to have a proper understanding of the establishment history of that particular plant species over time. Dendroecological investigations were carried out to study the age structure and history of establishment of *R.campanulatum.*The main objectives were (1) To study the age structure of *R. campanulatum* along the altitudinal gradient (2) To evaluate the relation between basal diameter and age, (3) Investigate the upper species limit expansion of *R. campanulatum.*

Study area: The study site lies in Manaslu Conservation Area, a protected site established in 1998 and situated in the northern part of Gorkha District (Fig. 1). With an area of 1663 square kilometers it includes seven villages namely Samagaun, Lho, Prok, Bihi, Chumchet, Chhekampar and Sirdibas (Ano., 2015). There are nine bioclimatic zones ranging from the lower subtropics to the nival zone (Bhuju *et al.,* 2007; Gaire *et al.,* 2014) with minimum basic amenities like brigdes and walking trails. Local people dependon agriculture, animal husbandry and utilization of natural resources for their subsistence.

The study was carried in March-April 2012 & 2013 in the north facing mountain slope adjacent to Kalchuman Lake. The study area can be reached after six days of trekking along the trekking trail from the nearest access to roads. A dense forest lies between the closest human settlements which are located at around 2500 m asl. The treeline ecotone is formed by *A. spectabilis, Betula utilis, Sorbus microphylla* and *Rhododendron campanulatum.*

Local climatic trends: Thirty years (1980-2009) of climatic data from the nearby station at Chame, Manang was taken into account. The analyzed data demonstrates the following pattern in temperature and precipitation (Figs. 2 & 3). During the past 30 years a decreasing trend of rainfall by 3.85 mm/yr was observed which is statistically insignificant (n=30, R^2=0.014, p=0.52) (Fig. 2). Data reveal that after the year 2000 there has been a decrease in the mean minimum temperature and significant increase in mean maximum temperature (Fig. 3).

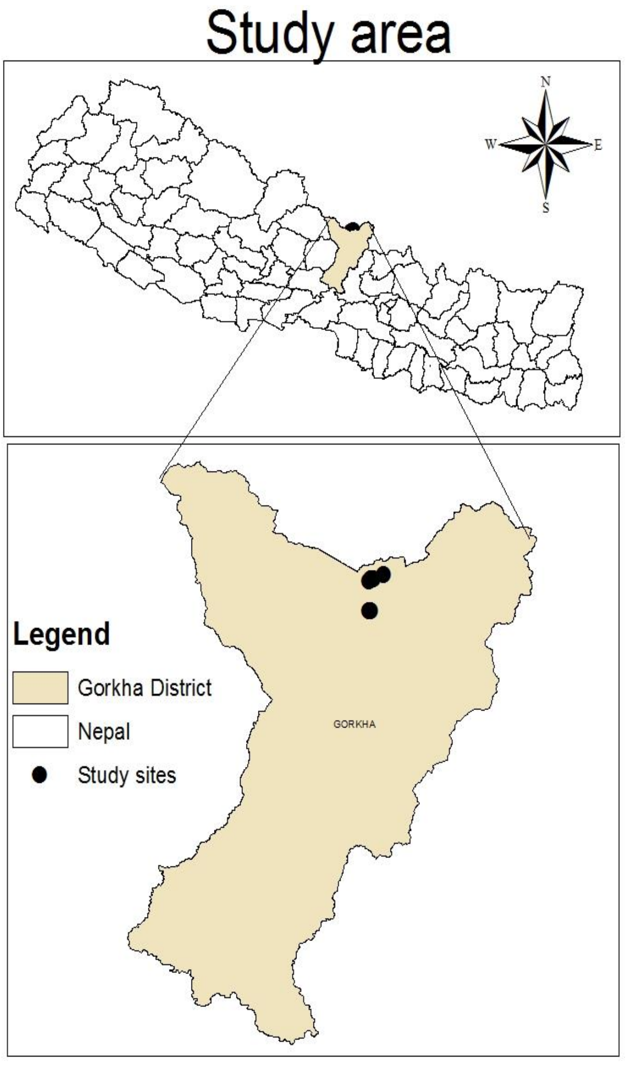

Fig. 1. Location map of the study area.

Materials and Methods

The field study was carried in March-April of 2012 & 2013**.** Five vertical transects were laid in the study site and in each transect quadrates were laid 100m apart at an elevation gradient from 3600 meter above sea level (m asl.) to 4100 m asl. A total of 30 quadrates were laid. In each plot, *R. campanulatum* 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). In each plot, all individuals of *R. campanulatum* were recorded and their height and groundline diameter were measured. Similarly, Geographical Position System (GPS) location, altitude, slope and aspect of each quadrate were also recorded. In addition, canopy cover (coverage) was estimated visually.

For dendro-ecological analysis of *R. campanulatum*, groundline diameter classes were formed at 5 cm intervals. At least 3 samples per basal diameter class and two cores per tree wherever possible were extracted using the increment borer (Haglof, Sweden) following standard methods of Fritts (1976) and Speer (2010). For seedling and sapling, cut stumps were collected. A total of 105 cores and cut stumps were collected. The samples were stored in plastic straw with labels. All samples were brought to the Dendro Laboratory of Nepal Academy of Science and Technology (NAST) for further analysis. Cores were mounted, sanded using sandpaper of increasingly finer grain up to 1000 grits. Each ring was counted under the stereo zoom microscope and assigned a calendar year with the help of known date of outer ring formation and dated. All the tree cores and cut stumps were visually cross-dated by looking the pattern of wide and narrow rings (Stokes & Smiley, 1968).

The upper species limit advance within the study area was calculated by subtracting the elevation of oldest position down slope from the present species position upslope using the equation of Gamache & Payette, 2005. The rate of shift of *R. campanulatum* within the study area was calculated according to equation of Gamache & Payette (2005) as follows:

$$\text{Rate of shift} = \frac{\text{Recent position-oldest position}}{\text{Number of years taken}} \times 10 \text{ (m/decade)}$$

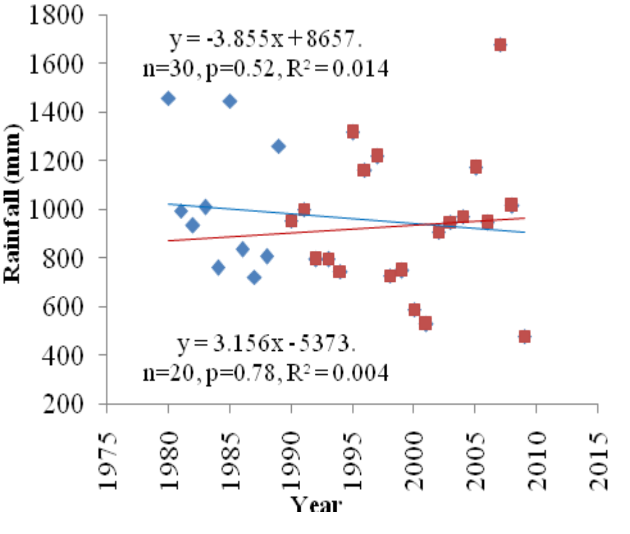

Fig. 2. Variation of rainfall with time at Chame, Manang.

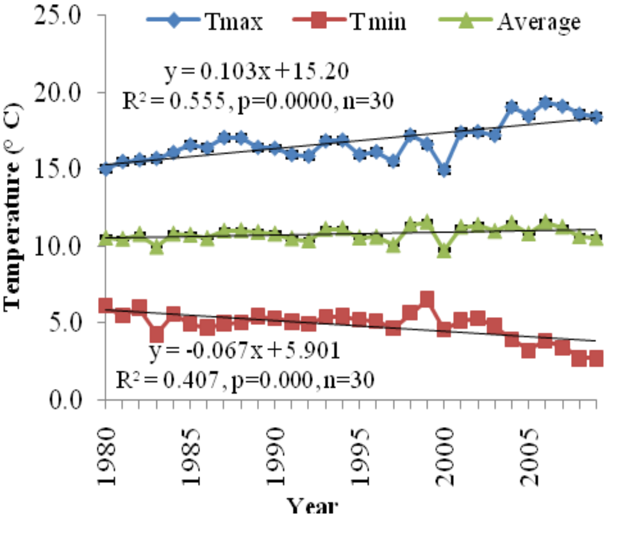

Fig. 3. Mean monthly (1980-2009) rainfall and temperature at Chame, Manang.

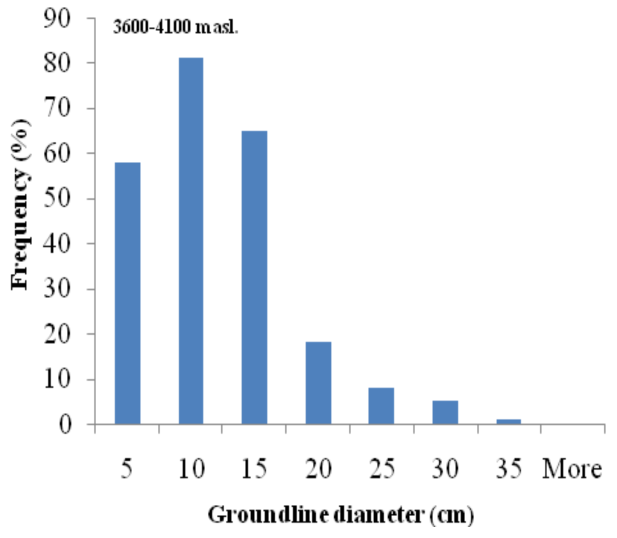

Fig. 4. Distribution of groundline diameter.

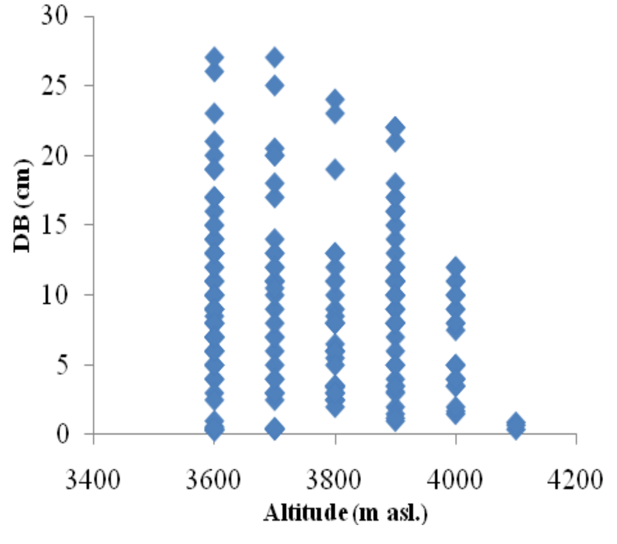

Fig. 5. Distribution of groundline diameter along the altitudinal gradient.

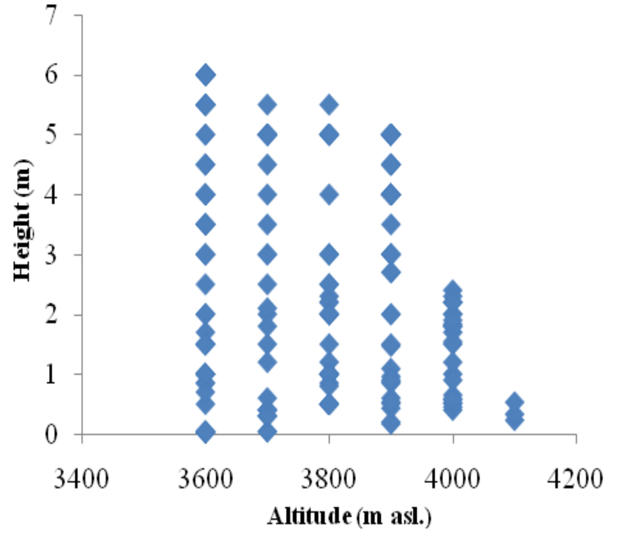

Fig. 6. Distribution of height along the altitudinal gradient.

Result and Discussion

Diameter class: The diameter class exhibited a nearly inverse J shaped frequency distribution which is an indication of sustainable regeneration (Fig. 4). Similar observation was also reported for *R. ponticum* (Esen *et al.*, 2004) and *R. campanulatum* (Gaire *et al.*, 2010). Groundline diameter class showed highest frequency for 5-10 cm followed by 10-15 cm and 0-5 cm class and with comparatively lower frequency for higher frequency classes. The groundline diameter decreased with altitude (Fig. 5); similarly the height (Fig. 6) of *R. campanulatum* decreased with altitude. The recorded maximum height *of R. campanulatum* was 6 meters.

Tree rings: A lot of the studies on tree rings have been carried out on gymnosperms or soft wood like Pine (*Pinus* sp.), Spruce (*Picea* sp.), Fir (*Abies* sp.) etc. (Gaire *et al.*, 2013). However, limited studies have been carried out in hard wood like *Rhododendron* sp. (Liang & Eckstein, 2009; Esen *et al.*, 2004). Clear rings were observed in the tree cores and cut stumps under stereomicroscope revealing that this particular species can be used for tree ring studies (Fig. 7). Xing *et al.* (2012) mentioned that all the species do not show distinct visible rings. In their study out of 8 species only four species: *Pinus massaoniana*, *Schima superba*, *Cunninghamia lanceolata* and *Quercus serrata* showed clearly visible rings.

Age diameter relation: The basal diameter was significantly correlated with age (r^2=0.824 p<0.00001) (Fig. 8). Similar results were reported for *Rhododendron ponticum* L. in Turkey (Esen *et al.*, 2004). Significant correlation (p<0.01) was observed between age and dbh in *Pinus wallichiana* and *Picea smithiana* (Iqbal *et al.*, 2017). The developed equations were used to estimate the age structure *R. campanulatum* along the altitudinal gradient. *R. campanulatum* which is a small tree or sub tree (Noshiro & Sujuki, 2001) showed dichotomy of shrub like form at higher altitude and tree like form at lower altitudes growing up to 6 meters in height. Therefore, groundline diameter was chosen over diameter at breast height (DBH) for regression analysis. Similarly, Csontos *et al.* (2001) also considered the basal diameter measurements of *Fraxinus ornus* L. a deciduous tree, in place of the diameter at breast height due to the presence of individual branches near to the soil. For *R. campanulatum* basal diameter was found to be excellent predictor of tree age.

Age structure and upper species limit expansion: The age class distribution shows an inverse-J shaped to unimodal bell shaped (Fig. 9), indicating elevation specific regeneration condition. The oldest *R.campanulatum* recorded was164 years old at 3700 m asl. (N 28°30'214''and E 28°48'303''). Colak (1997) reported that Rhododendrons lived as long as 100 years. Khadga (2013) reported that the oldest *Rhododendron arboreum* Sm. tree to be of age127 at Manaslu Conservation Area. Elliot & Vose (2012) stated that the oldest *Rhododendron maximum* L. was of 127 years of age in their study in North Carolina.

Fig. 7. Tree cores and cut stumps samples and after sanding with 1000 grits of sandpaper.

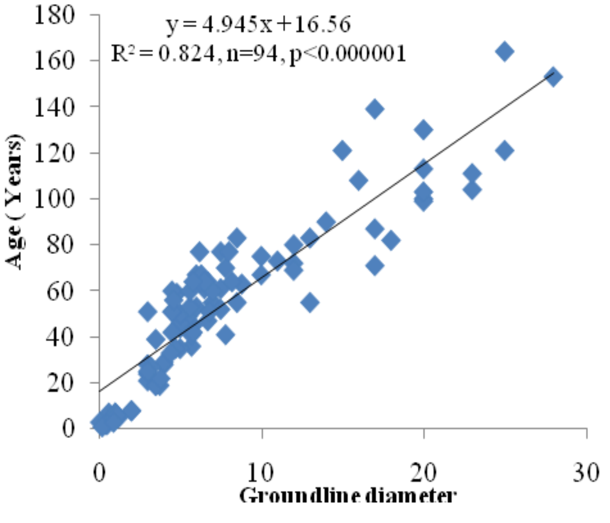

Fig. 8. Relationship between age and groundline diameter.

The age structure *R. campanulatum* varied with altitude (Fig. 9). Age structure along the altitudinal gradient gives an insight about the historical establishment of plant species (Namikawa, 1996; Abrams *et al*., 1999). The study revealed that *R. campanulatum* was established around the 1848s at 3700 m asl. (Fig. 10). Gaire *et al*. (2014) reported that *A. spectabilis* was established around 1850s and *B. utilis* in 1820s in the same study site. After establishment at 3700 m asl *R. campanulatum* colonized 3600 m asl. and 3800 m asl. about 16 and 13 years later respectively. After reaching 3800 m asl. it progressively moved up until it reached the species limit of 4090 m asl. around 2007 AD (Figs. 9 & 10).

The species limit of *R. campanulatum* was observed at 4190 m asl. (N 28°29'709''and E 084°48'222'') (Fig. 11). Gaire *et al*. (2014) reported the species limit of *A. spectabilis* at 3984 m asl. Only seedlings of *R. campanulatum* were present at the tree species limit. Above the treeline at 4000 m asl. the age structure of *R. campanulatum* decreased drastically (Figs. 8 and 9). The groundline diameter and height of *R. campanulatum* also decreased with altitude. The present study reveals that *R. campanulatum* is shifting up and rate of shift is 24.7 m per decade. This finding supports the local peoples view that *R. campanulatum* has been shifting up in recent years. Similarly, Suwal *et al.* (2016) and Gaire *et al.* (2014) reported that *A. spectabilis* is moving up at a rate of 26.1 meters per decade at Manaslu Conservation Area. The study site is located in a remote protected site with hardly any anthropogenic disturbance. The meteorological data also revealed that temperature is increasing in this area, this may have favored the establishment of *R. campanulatum* seedlings at higher altitudes. High speed winds may have aided the dispersal of *R. campanulatum* seeds to higher altitudes. *R. campanulatum* is also reported to be poisonous and unpalatable to cattle's and wild animals (Steffens, 2003; Kunwar *et al*., 2010). This may be another factor that attributes to higher survival rates of their seedlings along with climatic factors. During the study, it was observed that less canopy cover and open places favoured the growth of the seedlings of Rhododendron. Light maybe required for germination of *Rhododendron* seeds. Therefore, open areas above the forest line could provide a suitable habitat for their growth under changing climatic conditions. Naito *et al.* (1999) reported that growth and survival of seedlings of *Rhododendron metternichii* Sieb. Et Zucc. var. *hondoense* Nakai were affected by the canopy cover in Mt. Kamakuraji of Hiroshima Prefecture, Japan. The recent anthropogenic climate change may have induced the upward shift of species.

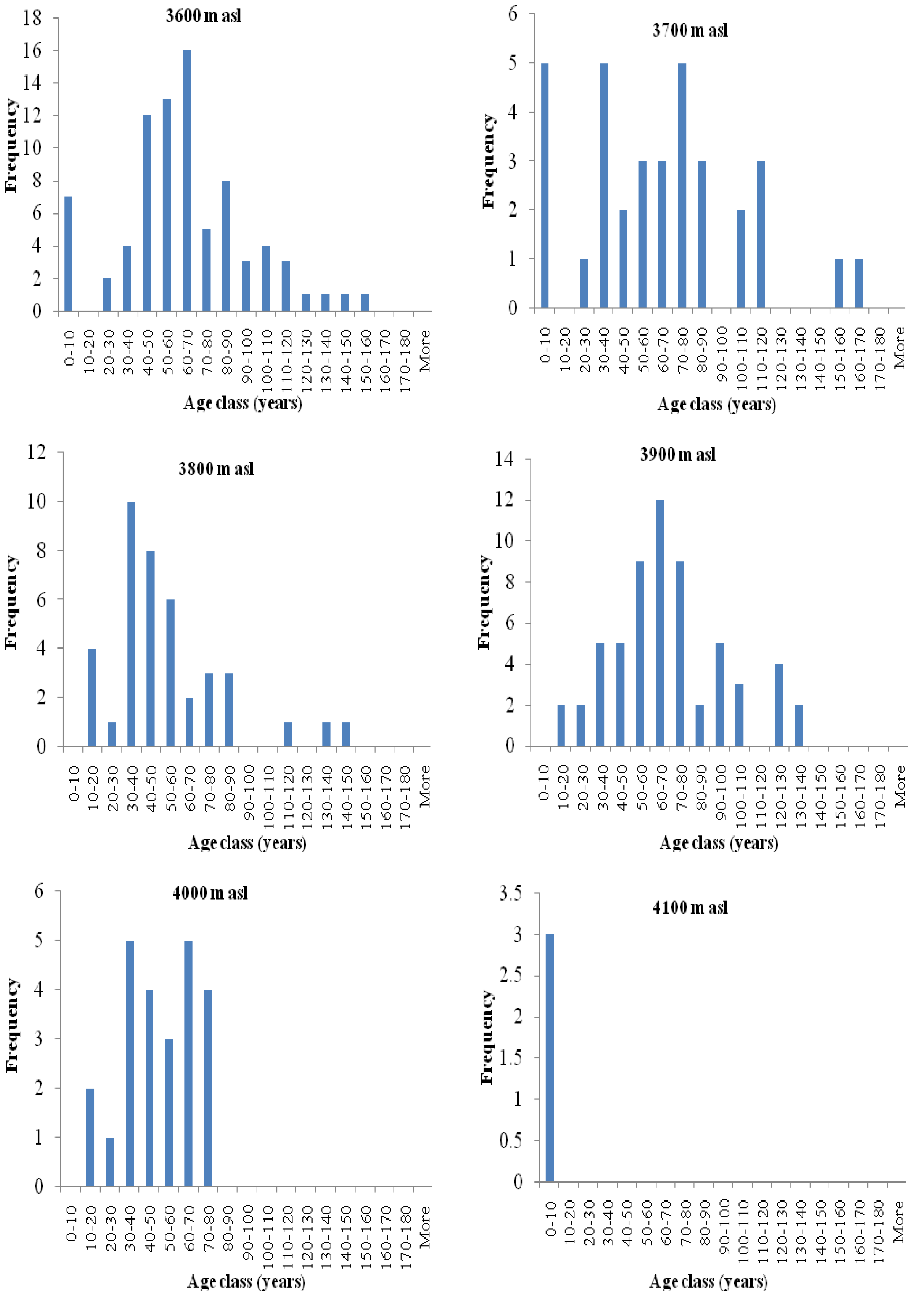

Fig. 9. Age structure along the altitudinal gradient.

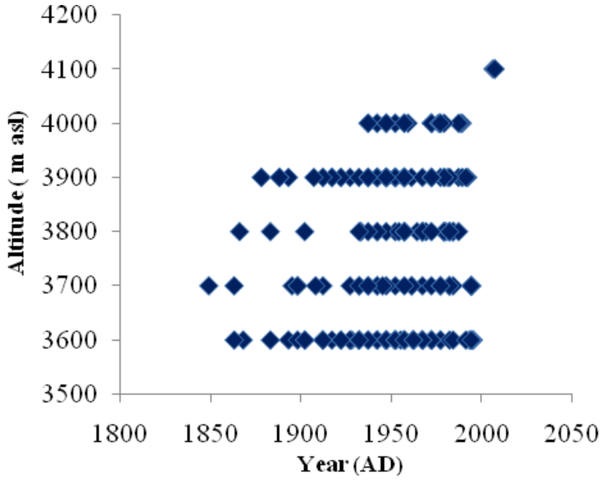

Fig. 10. The recruitment pattern along the altitudinal gradient.

Fig. 11. Seedlings of *R. campanulatum* at the species limit.

Conclusions

There was a strong correlation between age and groundline diameter of *R. campanulatum*. The oldest *R.campanulatum* in the study was 164 years of age. The age structure varied along the altitudinal gradient with multi age cohort below the treeline and younger cohorts above the treeline and only seedling at the upper species limit. The recent anthropogenic climate change has influenced this species and as it is moving up at a rate of 24.7m per decade.

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References

Abbas, Z., S.U.M. Khan, J. Alam and Z. Ullah. 2017. Species diversity and phyto-climatic gradient of a montane ecosystem in the Karakorum range. *Pak. J. Bot*., 49(SI): 89-98.

Abrams, M.D., C.A. Copenheaver, K. Terazawa, K. Umeki, M. Takiy and N. Akashi. 1999. A 370 year dendro ecological history of an old growth *Abies-Acer-Quercus* forest in Hokkaido, northern Japan, *Can J. Res*., 29: 1891-1899.

Anonymous. 2015. Protected areas of Nepal, (Ed.): Dhakal, M. Department of National Park and Wildlife Conservation (DNPWC), Babarmal, Kathmandu, Nepal.

Baidya, S.K., R.K. Regmi and M.L. Shrestha. 2007. Climate Profile and Observed Climate Change and Climate Variability in Nepal. Department of Hydrology and Meteorology, Kathmandu.

Bajaracharya, S.M., P.K. Mool and B.R. Shrestha. 2007. Impacts of climate change on Himalayan glaciers and glacial lakes: case studies on GLOF and associated hazard in Nepal and Bhutan, ICIMOD and UNEP, Kathmandu.

Bhuju, U.R., P.R. Shakya, T.B. Basnet and S. Shrestha. 2007. *Nepal Biodiversity Resource Book*. Protected Areas, Ramsar Sites, and World Heritage Sites. International Centre for Integrated Mountain Development, Ministry of Environment, Science and Technology, in cooperation with United Nations Environment Programme, Regional Office for Asia and the Pacific. Kathmandu, Nepal. ISBN 978-92-9115-033-5. pp. 119-130.

Bolch, T., A. Kulkarni, A. Kääb, C. Huggel, F. Paul, J.G. Cogley, H. Frey, J.S. Kargel, K. Fujita, M. Scheel, S. Bajracharya and M. Stoffe. 2012. The state and fate of Himalayan glaciers. *Science*, 336: 310-314.

Colak, A.H. 1997. Investigations on the silvicultural characteristics of *Rhododendron ponticum* L Ph.D. thesis, University of Istanbul, Turkey, 181 pp.

Corlett, R.T. and D.A. Wescott. 2013. Will plant movements keep up with climate change? Tree Elsevier Ltd. http;//doi.org/10.1016/-tree 2013. 04.003.

Csontos, P. J. Tamas and T. Kalapos. 2001. Correlation between age and basal diameter of *Fraxinus ornus* L. in three ecologically constrasting habitats. *Acta Botanica Hungarica*, 43(1-2): 127-136.

Elliot, K.J. and J.M. Vose. 2012. Age and distribution of an evergreen clonal shrub in the Coweeta Basin: *Rhododendron maximum* L. *Journal of the Torrey Society*, 139(2): 149-166.

Esen, D., S.M. Zeajer, J.L. Kirwan and P. Mou. 2004. Soil and site factors influencing purple-flower Rhododendron (*Rhododendron ponticum* L) and eastern beech forest (*Fagus orientalis* Lipsky) in Turkey. *Forest Ecol. & Manag.*, 203: 229-240.

Fritts, H.C. 1976. Tree Rings and Climate, Cambridge University Press, Cambridge, pp. 567

Fujita, K., N. Takeuchi and K. Seko. 1998. Glaciological observations of Yala Glacier in Langtang Valley, Nepal Himalayas 1994 and 1996. *Bull. Glacier Res.*, 16: 75-81.

Gaire, N.P., D.R. Bhuju, M. Koirala and H.P. Borgaonkar. 2014. Treeline dynamic with climate change at the central Nepal Himalaya. *Climate of Past*, 10: 1227-1290.

Gaire, N.P., M. Koirala and D.R. Bhuju. 2013. Dendrochronological Studies in Nepal: Current Status and Future Prospects. *FUUAST J. Biol.*, 3(1): 1-14.

Gaire, N.P., Y.R. Dhakal, H.C. Lekhak, D.R. Bhuju and S.K. Shah. 2010. Vegetation dynamics in treeline ecotone of Langtang National Park, Central Nepal. *Nepal J. Sci. & Technol.*, 11: 107-114.

Gamache, I. and S. Payette. 2005. Latitudinal response of subartic tree lines to recent climate change in eastern Canada. *J. Biogeogr.*, 32: 849-62.

Harsch, M.A., P.E. Hulme, M.S. McGlone and R.P. Duncan. 2009. Are treelines advancing? A global meta-analysis of treeline response to climate warming. *Ecol. Lett.*, 12: 1040-1049.

Iqbal, J., M. Ahmed, M.F. Siddiqui, A. Khan and M. Wahab. 2017. Age and radial growth analysis of conifer tree species from Shangla, Pakistan. *Pak. J. Bot.*, 49(SI): 66-72.

Khadga, L. 2013. Age structure and regeneration of *Rhododendron arboreum* Sm. along an altitudinal gradient of Manaslu Conservation Area, Nepal Himalaya. A dissertation submitted to Central Department of Environmental Science, Tribhuvan University, Kirtipur, Kathmandu, Nepal.

Körner, C. 2012. Alpine Treelines: Functional ecology of the global high elevation tree limits. DOI 10.1007/978-3-0348-0396-0. Springer Basel Heidelberg New York Dordrecht London.

Kullman, L. 2007. Tree line population monitoring of *Pinus sylvestris* in the Swedish Scandes, 1973–2005: implications for tree line theory and climate change ecology, *J. Ecol.*, 95: 41-52.

Kunwar, R.M. 2010. Traditional herbal medicine in Far-west Nepal: a pharmacological appraisal. *Journal of Ethnobiology and Ethnomedicine*, 6: 35 http://www.ethnobiomed.com/content/6/1/35

Liang, E. and D. Ekstein. 2009. Dendrochrological potential of the alpine shrub *Rhododendron nivale* on the south- eastern Tibetan Plateau. *Ann. Bot*., 104 (4): 665-670.

Milleville, 2002 The Rhododendrons of Nepal. Himal Books, Lalitpur, Nepal. 136 pp.

Naito, K., Y. Isagi, Y. Kameyama and N. Nakgoshi. 1999. Population structures in *Rhododendron metternichii* var. *hondoense* assessed with microsatellites and their implication for Conservation. *Journal of Plant Research*, 11(4): 405-412.

Namikawa, K. 1996. Stand dynamics during a 12 year period in an old-growth, cool temperate mixed forest. *Ecol. Res*., 11: 23-33.

Noshiro, S. and M. Suzuki. 2001. Ontogenetic wood anatomy of tree and sub tree species of Nepalese Rhododendron (Ericaceae) and characterization of shrub species. *Amer. J. Bot.*, 80(4): 560-569.

Payette, S. and L. Filion. 1985. White spruce expansion at the tree line and recent climatic change. *Can. J. For. Res.,* 15: 241-251.

Shrestha, A.B., C.P. Wake, P.A. Mayewski and J.E. Dibb. 1999. Maximum temperature trend in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94. *J. Climate,* 12: 2775-2789.

Speer, J.H. 2010. Fundamentals of tree ring research, The University of Arizona Press, Tucson.

Steffens E. 2003. The ecology of the Rhododendrons on Milke Danda Ridge, Eastern Nepal. *J. Amer. Rhododen. Soc.*, 52.1

Stokes, M.A. and T.L. Smiley. 1968. An introduction to tree-ring dating. University of Chicago Press, Chicago, 111

Suwal, M.K., K.B. Shrestha, L. Guragain, R. Shakya, K. Shrestha, D.R. Bhuju and O.R. Vetaas. 2016. Land-use change under a warming climate facilitated upslope expansion of Himalayan silver fir *Abies spectabilis* D. Don Spach. *Plant Ecol*., DOI 10.1007/s11258-016-0624-7.

Wang, T., Q.B. Zhang and K. Ma. 2006. Tree line dynamics in relation to climatic variability in the central Tianshan Mountains, north- western China. *Global Ecol. Biogeogr*., 15: 406-415.

Xing, P., Q.B. Zhang and P.J. Baker. 2012. Age and radial growth pattern of four tree species in a subtropical forest of China. *Trees*, 26: 283-290.

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