

Environmental Science

DYNAMICS OF *Pinus roxburghii* IN RESPONSE TO CLIMATE VARIABILITY IN PANCHASE AREA, WESTERN NEPAL

Raju Chauhan^{1*}, Dinesh Raj Bhuj^{2,3}, Sijar Bhatta²,
Man Kumar Dhamala²

¹Amrit Campus, Thamel Kathmandu

²Goldengate International College, Battisputali Kathmandu

³National Academy of Science and Technology, Lalitpur

*Correspondence: chnraju@outlook.com

Abstract

Variation of climatic parameters from the normal has brought significant changes in species' demographic patterns and ranges. Based on tree ring data and age stand distribution, the dynamics of *Pinus roxburghii* in response to climate variability in Panchase area of Parbat district was studied. Transect walk, tree core collection and dendrochronological analysis were adopted for data collection. The upward shift of *P. roxburghii* was estimated to be 1.7 m year⁻¹. Majority of pine trees in the hill stand were middle aged (50-100 years). Ring growth was positively correlated with monthly minimum temperature of all the months, monsoon precipitation (Jun, July and Aug), and winter precipitation (Dec, Jan and Feb) but negatively correlated with the maximum monthly temperature indicating that upward shifting is because of moisture stress resulting from increasing maximum monthly temperature. The findings suggest that plant communities are sensitive to climate change not only in the treeline ecotone but also in the hill slopes.

Key words: Dendrochronology, Vegetation dynamics, Panchase, Pine

Introduction

The year to year fluctuation of climatic parameters around the normal is climate variability (1). Unfavourable climatic conditions such as low temperatures or drought, may govern the limits of species' ranges and any change in environmental conditions can lead to significant changes in a species' demographic patterns (2). There is some indication from individuals, for example radial and height growth increases (3) and from population patterns, for example shifts in forest composition or plant distribution (4) that recent climatic change has affected tree species. In mountain regions, climate change in the form of warming may lead to an upward movement of the treeline species (5). Properties of tree rings can vary in response to climate change. Therefore, studying the tree rings and comparing with the climatic data will help to identify the irregularities in tree growth in response to climate and past variation in climate. Using dendrochronological technique, this study aims to determine the upper limit, stand structure and

assess the dynamics of *Pinus roxburghii* forest in Panchase area of western Nepal.

Materials and methods

Study area

This study was carried out in a hillslope of Rangsepatale Community Forest of Arthar-Panchase, Parbat district located between Lat 28.2001° N, Long 83.76827 ° E and Lat 28.19896° N, Long 83.77031° E. The study site is a south east facing hill slope that ascends from an elevation of 1390m to 1788m. The soil in the hill slope was dry and seems to have little humus and well drained. Tree species such as *Schima wallichii*, *Castanopsis indica*, *Rhododendron arboretum* were present in the hill along with large stand of *Pinus roxburghii*. The climate of the study area is monsoon dominated. The mean annual rainfall over the past 36 years (1977–2013) at nearby meteorological station was 2466.9 mm and average monthly temperature was 22.4°C.

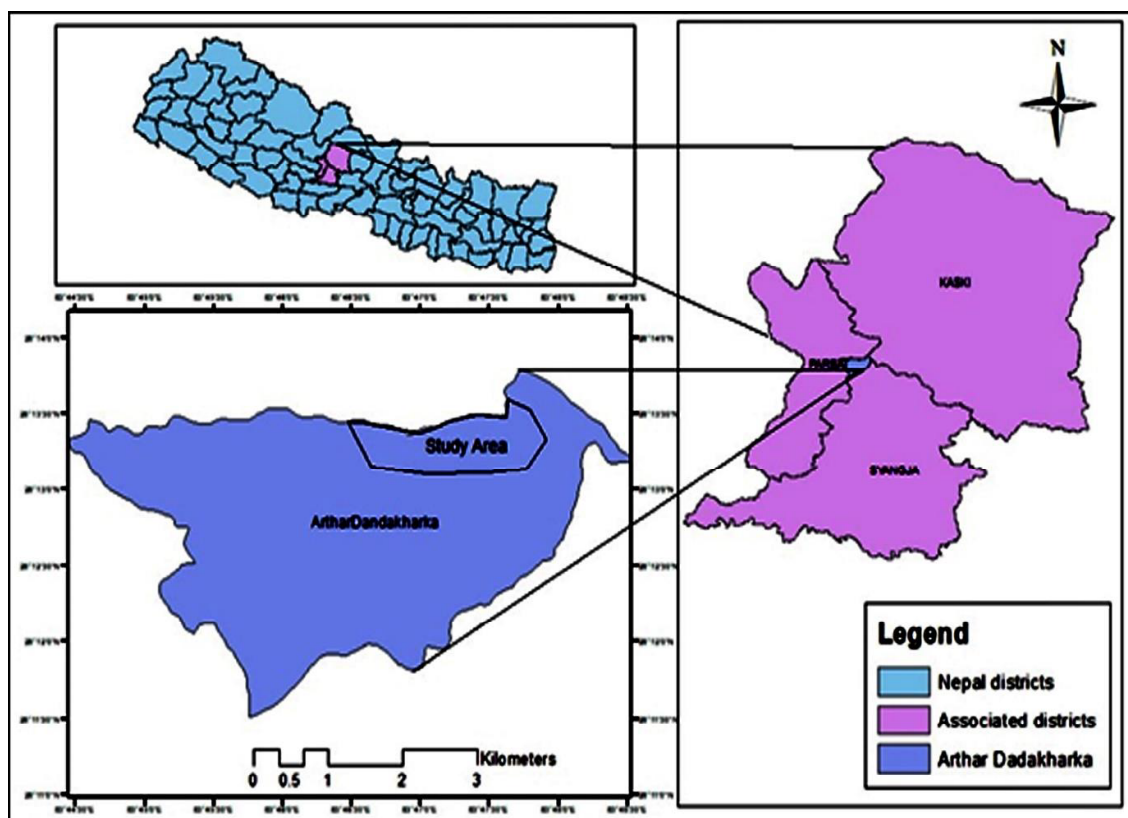


Figure 1. Study Area

Methods

Upper limits of *P. roxburghii* was determined by making transect walk. Tree cores were collected using the increment borer (Haglöf, Sweden) following the standard technique (6). A total of 76 tree cores of *Pinus roxburghii* were collected from 38 trees. GPS locations, aspect, height and DBH for of trees were recorded. The species limit was determined by using:

$$\text{Rate of shift} = \frac{\text{recent position} - \text{old position}}{\text{time difference between two positions}} (\text{m/year}). \quad (7)$$

Collected tree core samples were handled, air dried, stored, glued and polished following the standard methods (6). The cores were subjected to visual cross-dating under a stereoscopic microscope to locate any missing and false (double) rings. The width of each ring was measured to the nearest 0.01mm precision with the LINTABTM measuring system attached to a PC with the TSAP Win software package (8) at the Dendro-lab of the Nepal Academy of Science and Technology. Cross dating was done using the alignment plotting technique and also looking the math graphs. Crossdating were refined using the COFECHA program (9). The meteorological data of two stations Karkineta and Kusma were collected from Department of Hydrology and

Meteorology, Kathmandu. The ring-width chronology was developed using the computer program ARSTAN (10). Pearson's correlation coefficient was used to establish relationships between tree-ring chronologies and monthly maximum, minimum and average temperature and total monthly precipitation.

Results and discussions

Upper limit of *Pinus roxburghii*

By walking downhill both vertically and horizontally in transect from the peak, the sapling of *P. roxburghii* were found at maximum elevation of 1631.6m (Lat 28.200095° N, Long 83.768271° E) from mean sea level (GPS *etrex 10*). The sapling was found 156.3 m below the peak. Various walking surveys were also made around the study area to confirm that this elevation was the highest for this species in natural stand of Arthar and adjacent Panchase protected forest. Some young planted saplings of *P. roxburghii* were observed in other sites above study site however, to the current time none of these planted trees were regenerating. *Pinus roxburghii* generally occurs up to 1200m, but at some sites it extends to over 2000m on exposed, dry south facing slopes, and well drained area (11)

Stand structure and dynamics of *Pinus roxburghii*

The age distribution of *P. roxburghii* showed that the proportion of middle aged trees was higher than the proportion of young and old trees (Figure 2a). The proportion of middle aged trees

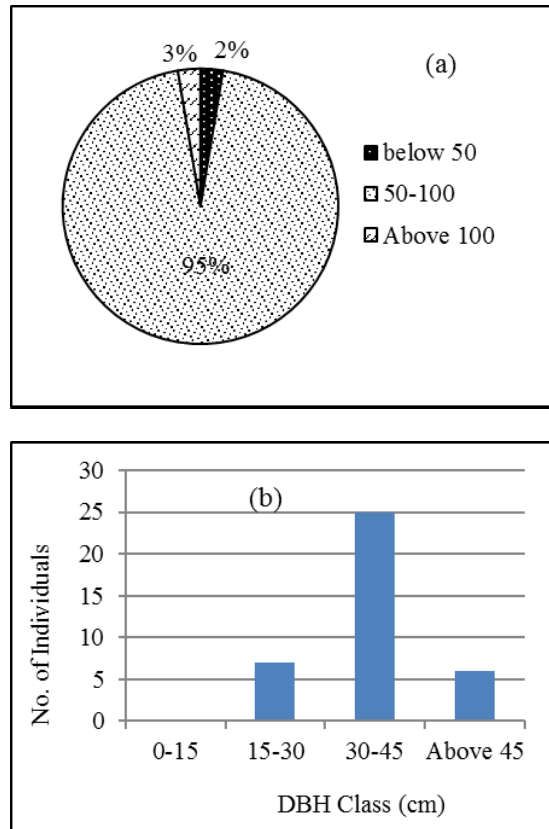


Figure 2. Age (year) distribution (a) and DBH class distribution (b) of *P. roxburghii*

The DBH of majority of the *P. roxburghii* was found to be 30-45 cm (Figure 2b). *P. roxburghii* having DBH class 30-40 were more than the trees with DBH class above 45cm while none of the individuals sampled had DBH below 15 cm. Both the age structure and DBH distribution

was 95% compared to young trees (2%) and old trees (3%). The proportion of older trees is higher than the proportion of younger trees. The maximum age of *P. roxburghii* in the study area was found to be 110 years.

indicate that the stand contains less number of young trees but maximum trees are near maturity. This reflects that the regeneration of *Pinus roxburghii* in the hill is slow. This is probably because of unfavorable climatic condition since the climate data of nearest station shows a fluctuating trend of precipitation. The DBH class distribution also shows that the stand of *Pinus roxburghii* consist of intermediate trees and are heading towards maturity. The oldest tree was established before 110 years and the youngest tree at the highest elevation from which the core was taken was 23 years old.

The youngest sapling of *P. roxburghii* was present at 1631.6m elevation while the oldest tree of the whole stand was found at 1477.2 m elevation. The upward shifting of the distribution limit of *P. roxburghii* was found to be 1.7 m/year. The upward shift of tree line is almost globally accepted phenomenon, although the magnitude and rate of advancement, population growth and stand densification vary on local environmental conditions (12, 13, 14). Like treeline shifting, vegetation shifting can also be studied in the hills with enough space for the species to expand attitudinally. Anthropogenic activities can be a major problem in studying the vegetation dynamics in hill slopes.

Response of tree growth to climate variability

The average rate of growth of *P. roxburghii* is 1.94 mm/ year. The actual growth pattern from the year 1905 to 2014 A.D. is given in Figure 3.

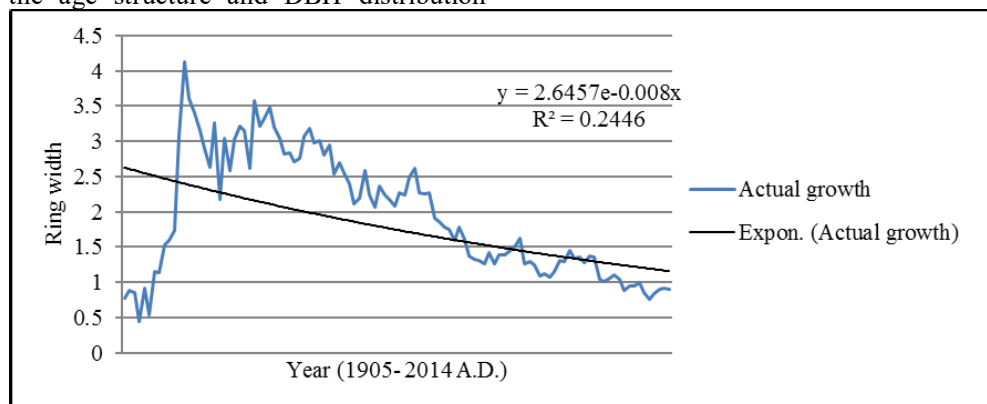


Figure 3. Actual growth (1905- 2014 A.D.)

Tree ring width was positively correlated with the average annual precipitation (Figure 4a) and average annual temperature (Figure 4b). The correlation between precipitation and ring width was found to be +0.066 while the correlation between temperature and ring width was found to be +0.136 indicating that for the particular stand of *P. roxburghii* temperature is more dominant factor than precipitation ($p < 0.05$).

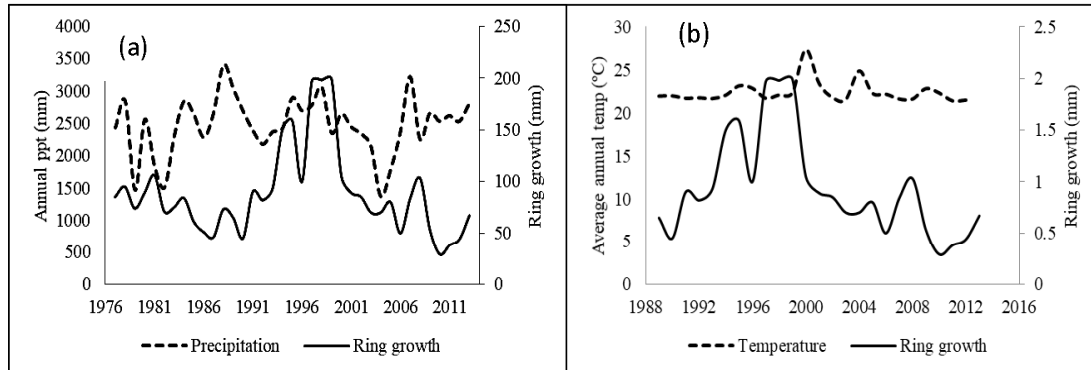


Figure 4. Relationship between ring growths with annual precipitation (a) and ring growth and average annual temperature (b)

The radial growth was positively correlated with the monsoon precipitation (Jun, July and Aug) and winter precipitation (Dec, Jan and Feb). Radial growth was also positively correlated with the average annual temperature but the positive correlation was due to the minimum temperature and not by the influence of maximum temperature. Maximum temperature was positively correlated only in the month of May (Figure 5).

Growth of tree species depends on various factors like soil condition, nutrient availability, water regime, light including climate (6). The rate of growth of *Pinus roxburghii* was about 2mm/year. This growth rate is much lower than determined by Bhuju and Gaire (2012) in the *Pinus roxburghii* of Kathmandu (11). The lower growth rate can be because of the drier soil and steep and rugged topography. The radial growth fluctuated over time with changing climate and constant increment or decrement in the growth was not observed. The negative relationship with the maximum monthly temperature may cause the increase in evapo-transpiration which leads to soil-moisture deficit and limits the tree-growth (15).

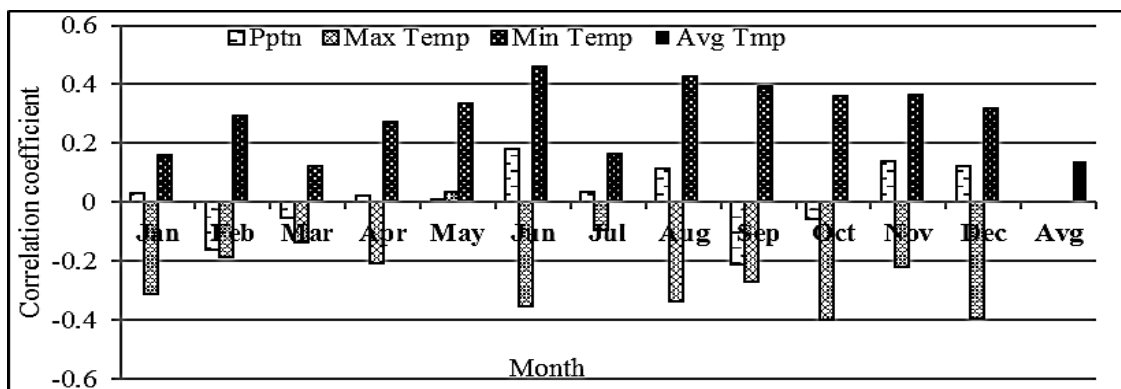


Figure 5. Relationship between *P. roxburghii*'s radial growth with climate data (monthly precipitation, maximum monthly temperature, minimum monthly temperature and average annual temperature)

Conclusion

The present study determined the dynamics of *P. roxburghii* in Panchase area. Rate of upward shift was estimated. *P. roxburghii* was found to respond positively with monsoon and winter precipitation and minimum temperature but negatively with maximum monthly temperature. Conifers like pines favor lower temperature. With the increase in temperature they respond by moving upward whether it be in the treeline ecotone or in the hill slopes. Demarking the upper altitudinal limit for the *Pinus roxburghii* will help to study further shift and effect of climate change in species distribution. Detailed studies on the relationships between climatic change and forest regeneration and dynamics incorporating multiple species and covering other proxy evidence are needed.

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