Annals of Ecology and Environmental Science
Volume 2, Issue 2, 2018, PP 36-40

Climate Change Impacts on Annual Ring of *Pinus Roxburhii* (Kavreplanchok, Nepal)

Sneha Verma[1], Ram Asheshwar Mandal[1], Narayan Prasad Gaire[2]

[1]*Kathmandu Forestry College, Balkumari Kathmadu,*
[2]*Nepal Academy of Science and Technology Khumaltar, Lalitpur*

***Corresponding Author:** Ram Asheshwar Mandal, Kathmandu Forestry College, Balkumari Kathmadu.*

ABSTRACT

Plant growth ring is highly response to climate variables. Study was objectively done to show trend of climatic variables, assess the response to climate change on ring-width and correlate growth rate-diameter at breast height (DBH) relationship, growth rate- height relationship and DBH-height relationship. The core samples from 22 Pinus roxburghii plants were collected using the increment borer. Data of temperature and rainfall of Kavreplanchok, Nepal was obtained from Department of Hydrology and Meteorology and analyzed. Core samples were dried, mounted and sanded for dating and ring measurement using stereo-zoom microscope and LINTAB attached with PC, TSAPwin software. Average annual temperature had increasing trend and annual rainfall showed erratic fluctuation. Temperature and rainfall showed positive correlation (r^2= 0.29). DBH and height showed positive and high correlation (r^2 0.84). The DBH and ring-width showed positive and moderate correlation (r^2= 0.41). This study will be useful to understand the impacts of climate change.

Keywords: *climate change, tree ring, growth, correlation, DBH, Height;*

INTRODUCTION

Climate of the globe is altering since the formation of the earth including both warming and chilling events. Climate change pertains to variation in the prevailing climate that remains for longer period of time and is determined by using some mathematical methods (IPCC, 2014). Changing of climate is natural phenomena which cannot be stopped. Worldwide averaged combined land and marine surface temperature data shows a warming up of 0.85 (0.65 to 1.06) ^{0}C over the period of 1880 to 2012 (IPCC, 2014). According to 4th assessment report of IPCC, change in climatic condition has increased the risk of flood and drought which has directly affected on agriculture, forestry and other natural resources of South Asia already. Nepal's average temperature was raised at the rate of 0.03 °C - 0.06 °C per annum between 1997 and 1994 with a higher rate in mountainous region than in low land (Gurung, Bhandari,2009, Karki et al., 2009).

Dating of tree-ring to the exact year of its formation to analyze the events occurred in that year is called as Dendrochronology. Dendrochronology refers to all of the studies of tree rings where the annual growth layers have been ascribed with specific calendar years, and the science of restoring historic climate data by use of tree rings is regarded as dendroclimatology. Tree height, DBH and growth rate are used to determine the growth of the tree at a certain time. *Pinus roxburghii* is native to the Himalayas. Nepal has huge altitudinal variation in short distance along which micro climate differs. Therefore, we can't get exact data for the site from distant meteorological stations. Only few researches have been conducted relating ring width and climatic parameters and most of the researches are of Himalayan species. Species like *Pinus roxburghii* has not much been considered disregarding it's potential which can be easily found in hills of Nepal. The annual growth rings of long -lived and fossil trees of many species are very important for paleoclimatic study as they show narrow and wide rings which can reflect climatic variation (Ahmed et al., 2010, Johnston et al 2009). Soft wood species like *Pinus roxburghii* has distinct ring characteristic which is useful for cross dating (Chhettri and Shrestha 2009, Gaire et al. 2013).

The important climatic variables are temperature and rainfall. They fluctuate year by year and their effects are noticed on plant's growth. Suitable climatic condition for illustration favorable temperatures and rainfall help the plant growth. The plant has good growth in the year is when photosynthesis has occurred very well and vice versa. Hence, any change in temperature and rainfall directly affect the photosynthesis process of the plant and the growth as well. In this context, the *Pinus roxburghii* which has clear ring growth can be good indicator to link with the climatic variables. DBH and height of the plant are used as predictor variables (Buba, 2013) to show the relationship like DBH-height, DBH- growth rate and height-growth rate. We can get the actual growth increment of the plant from dendrochronological approach and can find the precise relationship. Considering all the above points, the study is rational. Thus, this study was objectively carried out to show trend of climatic variables, assess the response of climate change on ring-width of *Pinus roxburhii* and correlate growth rate-diameter at breast height (DBH) relationship, growth rate- height relationship and DBH-height relationship.

MATERIALS AND METHODOLOGY

Kavrepalanchowk district lies $85^0$20'11" E and 27^0 42'59"N. The mean annual temperature varies from 9°C (winter) to 28°C (summer). The district experiences sub-tropical to cool temperate climate with an average annual rainfall varying from 1300-2687 mm depending on the sites. Bhusunepakha community forest of Dhungkharka of Kavreplanchowk was selected for study site. The community forest has mostly dry and stony. Main Vegetation of the community forest is *Pinus roxburghii*, *Pinus wallichiana*, *Alnus nepalensis*, *Rhododendron ferrugineum*, *Ficus nemoralis*, *Schima wallichi*, *Castanopsis tribuloides* and some ground grasses. The site is also famous for short trekking to Narayanthan. The land has exposure of South, South-West and West.

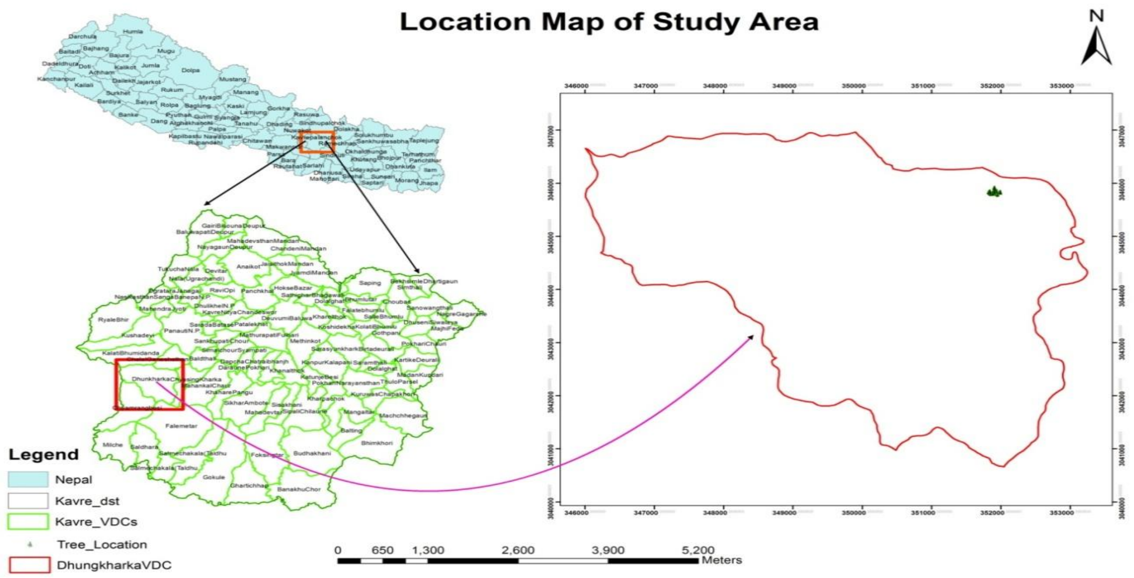

Figure1. *Map of study area*

Sampling and Sample Collection

Altogether twenty one healthy *Pinus roxburghii* was selected purposively for the study. Purposive Height and DBH of selected plants were measured using Clinometer and D-tape respectively January, 2017. Total forty two cores samples were collected. Specifically, two core samples were collected from each tree using Swedish increment borer. Core samples were taken at breast height and at 90^0 and 180^0 parallel to topographic contour. All the samples were carefully stored in plastic straw and were labeled. GPS was used for collecting data like tree location and elevation (Gaire et al., 2013). Minimum elevation for data collection was 1776 m and maximum elevation was 1907 m.

Sample Preparation and Counting Rings

Collected sample were air dried and mounted in wooden frame with cross-sectional side facing upward. Manual sanding was carried out using sand paper of different grid size from 60 to 400 progressively until annual rings were clearly visible. Each ring from core sample was counted under stereo zoom microscope from which age of tree was determined. Cross-dating was carried out in the sequences exact to calendar year of their formation which involves matching of similar ring-width patterns between different trees. This process also helps to find out missing rings or false rings (Gaire et al., 2013).

Measurement of Tree Ring Sample

After cross-dating, width of each ring was measured upto 0.01mm precision using LINTAB measuring system attached to computer. Individual rings were measured by moving the core samples on the sliding stage under a Lin-tab measuring system attached to the PC having TSAP (Time Series Analysis and Presentation Program) with professional 0.62, a computer program. The measurements were subsequently recorded in the computer. The growth pattern of the target species were determined by measuring the distance between ring widths of the annual rings.

Detection of Error In Dating

For location of possible errors in cross-dated rings, program COFECHA, a computer assisted quality control program was used (Holmes, 1983). COFECHA cross checks the error occurred in cross dating due to measurements and other ring-width irregularities that decreases the efficiency of ring-width time series for the tree-ring analysis. The cores that were poorly correlated with the mean chronology, or had higher correlations when the dating of the core chronology was shifted, were rechecked and either corrected or eliminated (Gaire et al., 2013).

Chronology Development

The corrected ring-width data were standardized using the computer program ARSTAN (Cook, 1987). It removes growth trends related to age and stand dynamics and retained maximum common signal. ARSTAN produces three mean index chronologies viz., the standard, residual and arstan chronologies. These three types of chronologies have unique time series characteristics. Moreover, The ARSTAN methodology uses autoregressive (AR modeling to remove any autocorrelation effects).

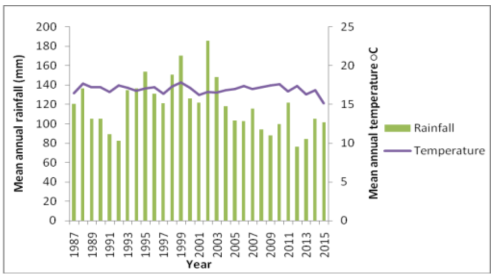

Figure2. *Annual average temperature vs. annual average temperature*

DBH-Height-Growth Rate Analysis

Data of DBH and height of individual tree was obtained from field and growth rate obtained after measurement and cross-dating of growth-rings. The analysis was carried out with the help of Ms excel.

Results and Discussion

Rainfall and Temperature

Figure 2 presents the pattern of climatic parameters i.e. rainfall and temperature from year 1987 to 2015. Year 2002 was the wettest year having rainfall of 185.67cm whereas 2012 was the driest year having rainfall of only 76.38 cm. Similarly, 1999 was warmest of all having mean annual temperature of 17.80 °C and 2015 was less warmer than rest others having mean annual temperature of 15.12 °C. Comparing rainfall and temperature pattern year 1999 was both wet and warm than other year. Rainfall trend shows first decrease and then increase and again decrease in pattern. Temperature trend shows first increase and then decrease and again increase in patterns. Decade 1993 to 2003 portrays that the years were both warm and wet. Overall, it was found to be average annual rainfall shows erratic fluctuation and average annual temperature is in increasing trend. Last decade had many such years having minimal rainfall amount (Bhattacharyya et al, 1992,PSN, 2005, MoPE, 2017).

Relationship between Chronology and Climate

Out of 42 core samples only 20 samples were used to define the correlation between tree ring and climatic data because of small age of trees, breakage of core sample and unhealthy sample. Oldest tree found from dendrochronological study was of 98 years. One hundred and five years of chronology has been prepared based on 20 cores from 21 trees of *Pinus roxburghii* which extends for 1912 to 2016.

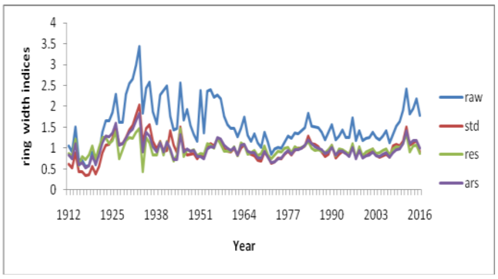

Figure3. *Tree ring chronology of Pinus roxburghii*

Figure 4 depict the seasonal correlation between tree ring and rainfall of Dhulikhel. Radial growth was negatively correlated with current June (r = -0.39) and August (r = -0.35) of and also with previous June (r = -0.24) and August (r = -0.33). Figure 5 portrays the relationship between ring- width of *Pinus roxburghii* and monthly temperature of Kavreplanchok. Radial growth correlated positively with both current May (r =0.19) and June(r = 0.40) and previous May and June. It negatively correlates with both previous July, August, September, October, November and December. However it correlates positively with current January and February and negatively with current March and April but correlates negatively with previous January and February and positively with previous March and April. Pre-monsoon climatic parameters control the tree-ring width which was negatively correlated (*Pant*, 2000, Cook et al., 2003). This indicates that less moisture availability and sudden raise in temperature create stress in trees and limited the growth of ring (Cook et al., 2013). Most of the study done in western Himalaya, using conifer, has similar results that almost all the chronologies (Sano, Kobayashi 2005), in western Himalaya, north central-north eastern India and in north eastern part of Pakistan, has shown negative correlation with pre monsoon temperature.

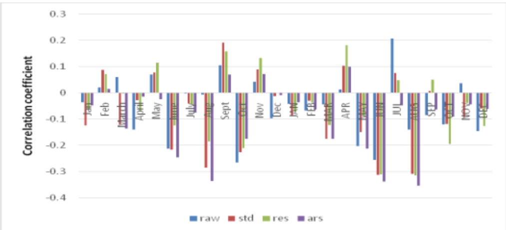

Figure4. *Correlation between precipitation and ring-width of Pinusroxburghii*

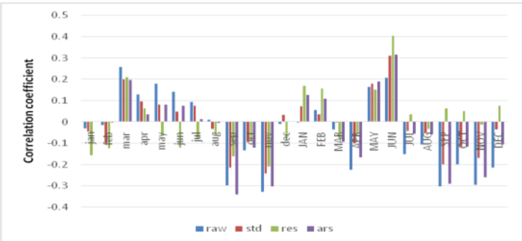

Figure5. *Correlation between temperature and ring-width of Pinusrox burghii*

Relationship between DBH, Height and Mean Growth

Only the data from the tree from which the core sample was used to find the relationship among tree DBH, height and growth. Maximum DBH, height and growth found was respectively. Maximum DBH, height and mean growth was found to be 121.92 cm, 29.812 m and 2.65 mm respectively. Similarly mean DBH, height and mean radial growth were found to be 95.15 cm, 26.93 m and 1.64 mm respectively.

Figure 6 renders the relationship between diameter at breast height and height of the tree. Coefficient of determination (r^2) 0.845 was obtained which means that DBH and height of *Pinus roxburghii* at the study area was positively and highly correlated. Figure 7 passes down the relationship between DBH and mean growth of the selected species. Coefficient of determination (r^2) 0.42 was obtained which means that DBH and mean growth of the tree of the study area is positively and moderately correlated. Figure 8 evinces the relationship between height and mean growth of the tree. Coefficient of determination (r^2) 0.418 means there is positive and moderate correlation between height and mean growth of the selected species. The growth ring is affected due to climatic conditions (Khan et al., 2013). The DBH, height and growth of the plant are highly correlated (Chettri, Thapa, 2010, Panta 2013).

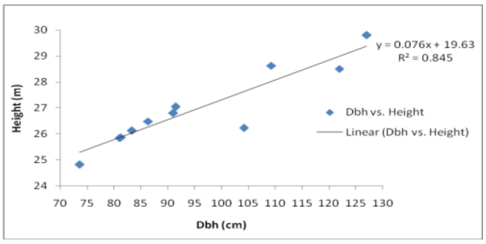

Figure6. *Relation between DBH and height of Pinus roxburghii*

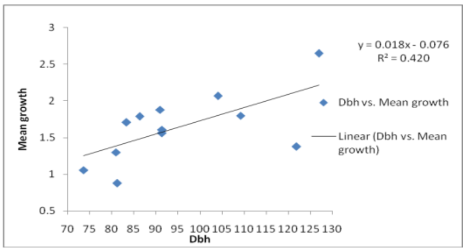

Figure7. *Relationship between DBH and Mean growth of Pinus roxburghii*

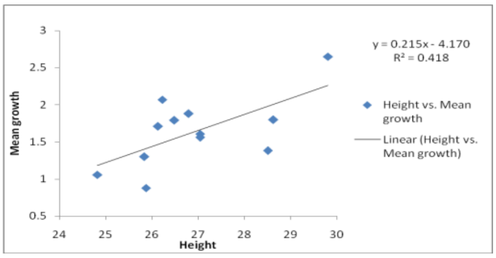

Figure8. *Relationship between height and mean growth of Pinus roxburghii*

Conclusion and Recommendation

Erratic fluctuation was observed in rainfall pattern. July received the highest rainfall while December was found to be driest. Similarly, increasing trend was observed in average annual temperature. June was found to be warmest month whereas January was the chilliest one. Because of high temperature and low rainfall, pre-monsoon climate created stress in rings and limited the growth of ring. DBH and height of the species had high and positive correlation. DBH and ring-width also showed positive and moderate correlation. Detail study about the correlation between growth and climatic parameter should be done.

ACKNOWLEDGE

This study would not have been possible without moral, academic and material support rendered from Kathmandu Forestry collage, Kathmandu, Nepal Academy of Science and Technology, Khumaltar, Lalitpur, District forest office KAvreplanchok. We like to thank Mr. Prem Prasad Khanal for his co-operation and community forest members.

REFERENCES

[1] Ahmed, M., Wahab, M., Khan, N., Palmer, J.,Nazim, M., Khan, U., Siddiqui, M.F.,(2010). Some Preliminary Results of Climatic Studies Based On Two Pine Tree Species of Himalayan Area of Pakistan, Pakistan Journal of Botany. 42.

[2] Bhattacharyya, A., Lamarche, VC., J.R., and Hughes, M.K., (1992). Tree- Ring Chronologies from Nepal, Tree- Ring Bulletin. 52.

[3] Buba, T. (2013) : Relationships between stem diameter at breast height (DBH), tree height, crown length, and crown ratio of Vitellariaparadoxa C.F. Gaertn in the Nigerian Guinea Savanna.

[4] Chhetri, P.K. and Thapa, S. (2010): Tree Ring and Climate change in Langtang National Park, Central Nepal.

[5] Chhettri, P.K. and Shrestha, K.B. (2009): Dendrochronology and Climate change study in Nepal: Ban Ko Jankari (2009). Department of Forest Research and Survey, Kathmandu Nepal.

[6] Cook, ER. (1987): The decomposition of tree-ring series for environmental studies. Tree-Ring Bulletin 47: 37–59.

[7] Cook, E.R., Krusic, P.J. and Jones, P.D. (2003): Dendroclimatic signals in long tree ring chronologies from the Himalayas of Nepal.

[8] Cook, E.R., Krusic, P.J. and Anchukaitis, K.J. (2013): Tree-ring reconstructed summer temperature East Asia scince 800 C.E.

[9] Gaire, N.P. Bhuju, D.R. and Koirala, M. (2013) : Dendrochronological studies in Nepal: Current status and future prospects.

[10] Holmes, R.L. (1983): A computer-based quality control program. Tree Ring Bulletin, 43, 69–78. IPCC, 2014. Climate change 2014 synthesis report. Intergovernmental Panel on climate change.

[11] Khan, N., Ahmed, M. and Shaukat, S.S.(2013): Climatic Signal in tree-ring chronologies of Cedrus deodar from Chitral Hindu-Kush range of Pakistan.

[12] Sano, M. Kobayashi, O. (2005): Temperature variations since the mid-18th century of Western Nepal, as reconstructed from tree-ring width and density of Abies spectabilis: Dendrochronolia.

[13] Johnston, M., Campagna, C., Gray, P., Kope, H., Loo, J., Ogden, A., Neill, AN., Price, D., and Williamson, T. (2009). Vulnerability of Canada's Tree Species to Climate Change and Management Options for Adaptation: An Overview for Policy Makers and Practitioner.

[14] MoPE, (2017). Observed Climate Trend Analysis in the Districts and Physiographic Zones of Nep Ministry of Population and Environment

[15] PSN, 2005. Temporala and Spatial Variability of Climate Change over Nepal (1976- 2005) Practical Solution Nepal.

[16] Panta, S. (2013) :Response of Pinus wallichiana to Climate Change: A Case Study from Manaslu Conservation Area, Western Nepal.

[17] Pant, G.B., Kumar, K.R., Borgaonkar, H.P., Okada, N, Fujiwara, T. and Yamashita K. (2000) : Climatic response of Cedrusdeodara tree-ring parameters from two sites in the western Himalaya.

[18] Gurung, G.B. and Bhandari, D. (2009): Integrated approach to climate adaptation. Journal of forest and livelihood.