

EFFECT OF CLIMATE CHANGE ON GROWTH OF BLUE PINE (*PINUS WALLICHIANA*) GROWN IN CHITRAL FOREST DIVISION

Tanvir Hussain¹ and G. M. Nasir²

ABSTRACT

Tree ring width chronology of Blue pine (*Pinus wallichiana*) from dry temperate forest of Bomborat, Chitral Forest Division was developed to identify the effect of climate change happened in this area for the last 30 years. The climatic parameters including mean monthly temperature and precipitation were taken into consideration for the determination of impact over time scale (1985-2015). Results showed an obvious transformation in both correlation and response coefficients of this tree species during the months of August and September of the previous growth year to current growth year because of monthly mean temperature and precipitation. Temperatures during the spring season coupled with the availability of water from precipitation found important for the growth of these trees and this relationship may be used to reconstruct the temperature from the developed chronology for Chitral area.

INTRODUCTION

The science of studying tree rings to learn something about changes in the environment is called dendroclimatology, and it can be used to analyze patterns of processes and events in the natural, physical, and cultural sciences. Since the growth rate of a tree is sensitive to both natural and human-induced events, conditions during a given year, will be either favorable or unfavorable for the tree growth resulting in a variation in ring width from year to year throughout the life of a tree. This pattern of wide and narrow growth rings can serve as an indicator to monitor environmental processes in most regions around the world (Camarero and Gutierrez 2004; Devi *et al.*, 2008; Kullman 2002; Smith, 2011).

Trees and tree growth can be a useful indicators of processes and events that occur in the natural environment and this is particularly true in climates with variable seasons, where the annual growth rings of trees as seen in tree-trunk cross sections, are easy to distinguish from each other (Fritts 1976; Cook and Kairiukstis, 1990). In coniferous trees, the cells created during the spring season are less dense and thin-walled forming a light-colored zone called early-wood. Towards the end of the growing season, smaller and thicker-walled cells are produced in a darker-colored zone called the latewood. Together, the early-wood and latewood zones of wood are considered the annual growth ring.

Blue pine (*Pinus wallichiana*) also known as Himalayan pine is a very

¹ Assistant Wood Technologist, Pakistan Forest Institute, Peshawar

² Director, Forest Products Research Division, Pakistan Forest Institute, Peshawar

important tree of Himalayan region including Pakistan, India, Nepal and Bhutan. It is naturally distributed with an altitude ranging from 1800-3900 meters (Singh and Yadav, 2007) and the typical habitats of this tree are mountain's scree and glacier forelands, but it also forms old growth forests as primary species or in mixed forests with other coniferous and broad-leaved tree species and also sometime found in pure stand (Sheikh, 1993; Earle, 2009). Past studies have shown the potential of this species for the multiple aspects of dendroclimatological studies (Cook *et. al.*, 2003; Haibat *et.al.*, 2014).

Blue pine growing at Chitral valley has not yet been explored for dendroclimatological studies. The present study has been designed with the objective to gather information about the climatic changes that have happened within 30 years and to find relationship between the climate and growth of Blue pine (*Pinus wallichiana*) grown in dry climatic conditions of this areas.

MATERIALS AND METHODS

To conduct the research work, cores were extracted from the trees of Blue pine (*Pinus wallichiana*) and prepared for measurement by first being glued onto the wooden core holders and then progressively sanded with sandpapers (60, 80, 120 grades) until a highly polished surface was produced. Then using microscope, the ring width growth patterns were matched within and between trees i.e. cross dated and exact calendar years assigned. The process follows the techniques described by Stocks and Smiley (1968). The width of rings in cores was measured using the latest and most advance WinDendro System. The measurement series from each core was then cross-checked for possible dating errors using the software Cofecha (Holmes, 1983; Grissino-Mayer, 2001).

The cross dated series were then compiled into site chronology using the program Arstan (Cook, 1985). The age related growth effects were removed by single detrending using the Friedman variable-span smoother in the program options. For similar reason, the "residual" chronologies from the ARSTAN output were selected for subsequent climate response modeling. To provide more insight into the relationship between the trees growth and climate, the Response function Analyses (RFA) were calculated by using computer based program Dendroclim 2002 (Biondi, 2002). The period of tree growth in the region is generally thought to commence around March and cease by the end of September, so the 12-month interval of October in the previous year to the end of current growing season (September) was selected. Further, the investigation of the contribution for 2-years of prior growth has also been included in the analysis.

RESULTS AND DISCUSSION

Climatic data of Chitral collected from Meteorological Observatory was

used to study the impacts of climatic changes on the tree growth (ring width) of Kail (*Pinus wallichiana*) grown in this area. The Climatogram for mean temperature and precipitation was constructed for the time scale of 1985-2015 as shown below in figure 1.

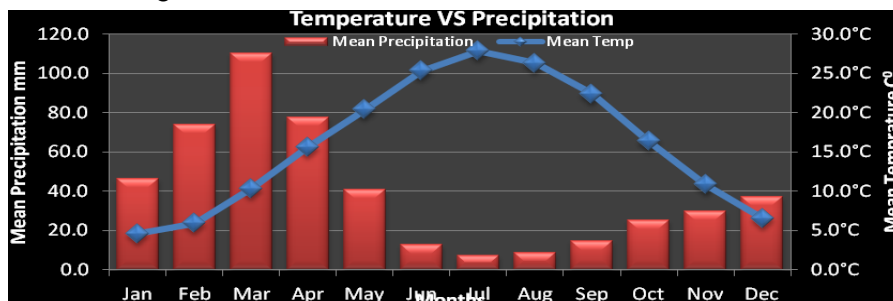


Fig.1 Climate diagram for Chitral Meteorological station and the calculated mean climatic features for the period 1985-2015.

It is evident from above figure 1 that July was the hottest month with mean temperature of 27.8 °C and monthly mean rainfall of 7.2 mm. The coldest month was recorded January (4.6 °C) with a precipitation of 46.1 mm . The maximum rainfall of 110 mm was measured on March along with monthly mean temperature of 10.3 °C. An increase of 0.44 C⁰ in annual temperature and a decrease of -30.5 mm in total annual precipitation was calculated for this studied period.

The following Table 1 and Figures 2 showed the results of Kail Tree ring chronologies developed through Computer Based Programs Cofecha and ARSTAN.

Table 1. Summary Statistics of Cofecha for Ring width of Kail (*Pinus wallichiana*)

Site	UNFILTERED						FILTERED		
	Corr with Master	Mean msmt	Max msmt	Std Dev	Auto Corr	Mean Sens	Max Value	Std Dev	Auto Corr
CFD	0.292	1.88	9.95	1.678	0.888	0.290	2.86	0.462	-0.065

Note: 1= correlation with master chronology, 2= Mean ring width, 3= Maximum ring width, 4 and 8= Standard deviation, 5 and 9= Autocorrelation, 6= Mean sensitivity, 7= Maximum value, CFD= Chitral Forest Division

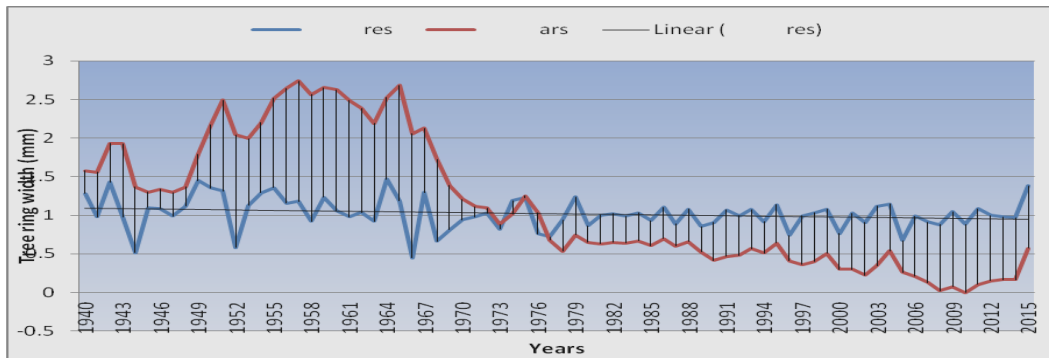


Fig. 2. Outcome of standardization program ARSTAN for Residual and Arstan Chronology of Kail.

The Chronologies covered 75 (1940-2015) years and were obtained between an altitude range of 2060-2560 m a.s.l., 35-60 % slopes with East to North facing of the mountains of Bambarate, Kalash Valley of Chitral Forest Division. It is obvious from the table 1 that the high value of standard deviation (1.67) indicated the fast growth of the species under the prevailing condition of this area. Although this chronology has low value of correlation with master ones but the mean sensitivity value of this species is sophisticated and acceptable internationally for dendroclimatic studies. The values of autocorrelation dropped significantly from 0.888 to -0.0265 after filtering which help for construction of climate-growth model. Auto correlation is a degree to which ring-width of one year is correlated with the growth of the previous year. This persistence may be climatic or non-climate related. The high values of auto-correlation create problem during climate-growth modeling therefore, auto-correlation properties of the chronology was removed by the auto-regressive model (ARSTAN) before the final chronology was constructed.

Autoregressive Standardization (ARSTAN) program was designed to remove the non-climatic factors from the tree-rings features. After standardization, tree rings width are converted into tree ring indices and four chronologies were developed i.e. Raw, Residual, Standard and Arstan. Residual Chronology (without auto-correlation) has more strong climatic signal and statistically more robust than standard chronology (Fig.2), therefore this chronology was used for climate-growth modeling.

The following Figures 3A & B represent the effects of climate change on tree growth of Blue pine (*Pinus wallichiana*) explored through Correlation and Response Function Analysis (RFA) by using Computer Based Program DendroClim 2002. This software does not measure the climate-growth relationship, rather it describes the nature of the climatic factors that influence the tree growth and also show the direction and strength of this association.

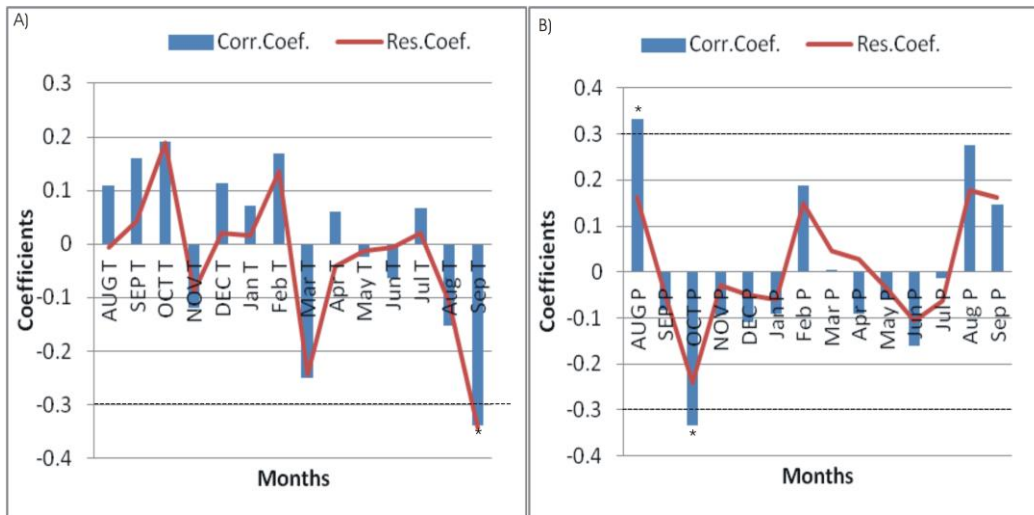


Fig. 3. Correlation (histograms) and Response Function (lines) between Tree ring series and A) monthly mean temperature (C⁰)

B) monthly mean precipitation (mm). Correlations were calculated from August of the year prior to tree-ring growth to September of the current growth year over the common period (1985–2015). The horizontal dotted lines denote the 95 % confidence level for the correlation function. Response functions significant at the 0.05 level are marked with an asterisk.

It is obvious from figure 3(A) that a prominent change in both correlation and response coefficients of Kail trees to monthly mean temperature took place from previous to current September of growth season i.e. non-significant positive to significant negative. In addition positive correlation of this species with the mean temperature also altered into negative from previous to current year of growth during the month of August. Further, the modified behavior of response in August indicated that decrease in temperature for the last thirty years did not favoring its growth. During the growth period (January-April) another outstanding change was found where both correlation and response of this species changed into negative during the month of March representing that ring formation also affected by this change.

Fig.3B showed that in case of precipitation a major transformation in correlation behavior is prominent during the month of September where both negative correlation and response coefficients changed into positive but not significant. Another minor conversion of correlation between precipitation and tree ring chronology happened from previous to current month of August i.e. significant correlation changed into non-significant. During growth ring formation

period, precipitation was found contributing positively along with mean temperature of February.

From the above results it is evident that high temperatures during the spring season (pre-monsoon) coupled with the availability of water from precipitation during the same period, are of critical importance for tree growth. Using this climate-growth relationship it is possible to reconstruct the pre-monsoon temperature from this chronology for this area. However, it is suggested that due to some unexplainable responses, further response function analysis with data from some additional meteorological stations in the analysis of dendroclimatic modeling may be carried out.

The interpretation of the present results is simply a guide to the climatic variables that influence tree growth and the direction and relative strength of the relationship until verified by further investigations.

CONCLUSION

Based on the results it can be concluded that in Chitral valley the climate has been prominently changed and caused significant impact on the growth of Blue pine tree species. High temperature during pre-monsoon and availability of water from precipitation have been found of critical importance for the growth of the tree species and the relationship between the climate and tree ring width (growth) can be used to reconstruct the pre-monsoon temperature from this chronology.

REFERENCES

- Biondi, F. and K. Waikul. 2004. DENDROCLIM 2002; A C++ program for statistical calibration of climate signals in tree-ring chronologies. *Computers & Geosciences* 30(3): 303-311.
- Cook, E. R. 1985. A time series analysis approach to tree-ring standardization. Ph.D. Thesis, University of Arizona, Tucson, AZ. U.S.A.
- Cook, E.R. and L.A. Kairiukstis.1990. Methods of dendrochronology. Kluwer Academic Press, Netherlands.
- Cook, E.R., P.J. Krusic and P.D. Jones. 2003. Dendroclimatic signals in long tree-ring chronologies from the Himalayas of Nepal. *International Journal of Climatology* 23(7): 707-732.

Camarero, J.J. and E. Gutie´rrez.2004. Pace and pattern of recent treeline dynamics: response of ecotones to climatic variability in the Spanish Pyrenees. *Clim Change* 63:181–200.

Devi, N.,F. Hagedorn, P. Moiseev, H. Bugmann, S. Shiyatov V. Mazepa, A. Rigling.2008. Expanding forests and changing growth forms of Siberian larch at the Polar Urals treeline during the 20th century. *Glob Change Biol* 14:1581–1591.

Earle, C.J. 2009. Gymnosperm database: *Pinus wallichiana* AB Jacks. Available at:http://www.conifers.org/pi/Pinus_wallichiana.php

Fritts, H.C. 1976. *Tree-Ring and Climate*. Academic Press, London. 545 pp.

Grissino-Mayer, H.D.2001. Assessing Cross-dating Accuracy: A Manual and Tutorial for the Computer Program COFECHA. *Tree-Ring Research* 57(2): 205-221 .

Holmes, R.L.1983. Computer-assisted quality control in tree-ring dating and measurement. *Tree-Ring Bulletin* 43: 69-78.

Kullman, L. 2002. Rapid recent range-margin rise of tree and shrub species in the Swedish Scandes. *J Ecol* 90:68–77.

Muhammad A., M. Ahmed, M. U. Zafar, A.H.S. Hyder, S. Ali, F. H.M. Raza, G. Raza, and K. Ali.2014.Growth-climate correlation of Himalayan pine (*Pinus wallichiana*) from ganji forest Skardu Districts of Gilgit-Baltistan, Pakistan. *J. Bio. & Env. Sci.* 2014, Vol. 5, No. 2, p. 405-412, 2014.

Singh, J. and R.R. Yadav. 2005. Spring precipitation variations over the western Himalaya, India, since A.D. 1731 as deduced from tree rings. *Journal of Geophysical Research: Atmospheres* 110(D1): D01110, DOI 10.1029/2004JD004855.

Singh, J. and R.R. Yadav.2007. Dendroclimatic potential of millennium long ring-width chronology of *Pinus gerardiana* from Himachal Pradesh, India. *Current Science* 93(6): 833-836.

Smith, J. B. and D. A. Tirpak. 2011. The potential effects of global climate change on the United States, Appendix D: Forests. EPA-230-05-89-054. U.S. Environmental Protection Agency, Washington, DC (Chapter 3).

Stockes, M.A. and T.L. Smiley.1968. *An Introduction to tree-ring dating*. University of Chicago Press, Chicago, 73pp.