CLIMATE CHANGE AND ITS IMPACTS ON TREE GROWTH OF BLUE PINE (PINUS WALLICHIANA) FOUND IN MALAM JABBA, SWAT

Tanvir Hussain[1] and G. M. Nasir[2]

ABSTRACT

A study was conducted to assess the change in climate that has happened in Malam Jabba, Swat Forest Division for the last 30 years i.e. 1985-2015 and its impact on the tree ring widths (growth) of Blue pine (*Pinus wallichiana*). Results of the study showed an increase of 1.20°C in annual temperature and 9.58 mm in annual precipitation for the studied period. Correlation and Response Function Analysis between tree rings and climatic parameters indicated an obvious transformation in both coefficients from June-September of the previous year to current growth years in case of precipitation and during the month of June in case of temperature. Significant positive correlation was found with June of the current growth season in case of mean monthly temperature. Moreover, June temperature along-with availability of rainfall has been found favoring the growth of this tree species.

INTRODUCTION

Climate change is considered one of the greatest environmental, social, and economic challenges in the world today. Maximum warming by the middle of the twenty-first century is predicted to increase by 1.5°C and global maximum temperatures are expected to be 1.5°C warmer in comparison to pre-industrial levels (Schewe *et al*., 2011). Although there is some uncertainty about the mechanisms and impacts of climate change, many predict summers to be warmer and drier while winters are likely to be warmer and wetter (Mote, 2003).

The impact of climate change on forest tree growth has been broadly studied using tree rings (Girardin *et al*., 2008; Lapointe-Garant *et al.,* 2010 and Chen *et al*., 2011). Tree ring analysis is also suitable for assessing and predicting the effects of climate change (Henry and Hou´erou 1996; Meko, 1997; Touchan and Hughes, 1999).

Dendrochronology is a technique of analyzing annual growth rings and using tree rings for dating purposes. It is also often used to date historical variations in climate and explore ecosystem responses to climate variability (García-Suárez *et al.,* 2009). In Pakistan Dendrochronology is a “young science” and has been expanding rapidly and so far substantial progress has been made since the pioneer work of Champion *et al.* (1965), Khan (1968) and Sheikh (1985). These workers used *Pinus gerardiana*, *Pinus wallichiana* and *Juniperus excelsa* from Zhob District and Azad Jammu Kashmir areas for age

1 Assistant Wood Technologist, Pakistan Forest Institute, Peshawar
2 Director, Forest Products Research Division, Pakistan Forest Institute, Peshawar

determination based on simple ring count without applying standard dendrochronological techniques. Studies have shown that conifers could be used in climatic investigations in the Himalayan region (Ahmed, 1987; Bhattacharya and Yadav, 1999; Yadav and Park, 2000; Singh and Yadav, 2007; Singh *et al*., 2009; Ahmed *et al*., 2009, Ahmed *et al*., 2011 a).

In view of these considerations, the present study was conducted, and an attempt was made to report the dendroclimatological potential of *Pinus wallichiana* from Malam Jabba range of Pakistan. The aim of the study was to develop tree-ring chronologies for the species and to explore the relationships between tree-ring growth and climatic variables. These findings are expected to provide baseline data for the regional climate variability in the past.

MATERIALS AND METHODS

To conduct the research work, cores were extracted from the trees of Blue pine (*Pinus wallichiana*) grown in Malam Jabba Swat 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 advanced 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 4-years of prior growth has also been included in the analysis.

RESULTS AND DISCUSSION

Study Site and Climatic Data

The site Malam Jabba is nearly 40 km from Saidu Sharif in Swat Valley of Khyber Pakhtunkhwa province in Pakistan and is considered in moist temperate region (Champion *et al.* 1965; Ali and Qaiser, 1993; Ahmed *et.al*. 2006; Siddiqui *et al.,* 2013). The climatic conditions in the area vary from sub-tropical; boreal to moist temperate. The sub-tropical, semi-arid climate of Saidu Sharif is comparable to that in the lower Malam Jabba (Siddiqui *et al*., 2016).

To study the impacts of climatic changes on the tree growth of Blue pine (*Pinus wallichana*) found in this area the climatic data of Malam Jabba was collected from Climate Research Unit (CRU), University of East Angila website: www.cru.uea.ac.uk. For this purpose the co-ordinates of the study site (34° 47'N and 72° 34'E) were given to CRUTEM4-2016-11 grid boxes. Klm and data was extracted at grid size of 0.5 X 0.5 degree (50 km x 50 km) (Harris *et.al*., 2014). The Climate diagram for mean temperature and precipitation was constructed for the time scale of 1985-2015 as shown below in figure 1.

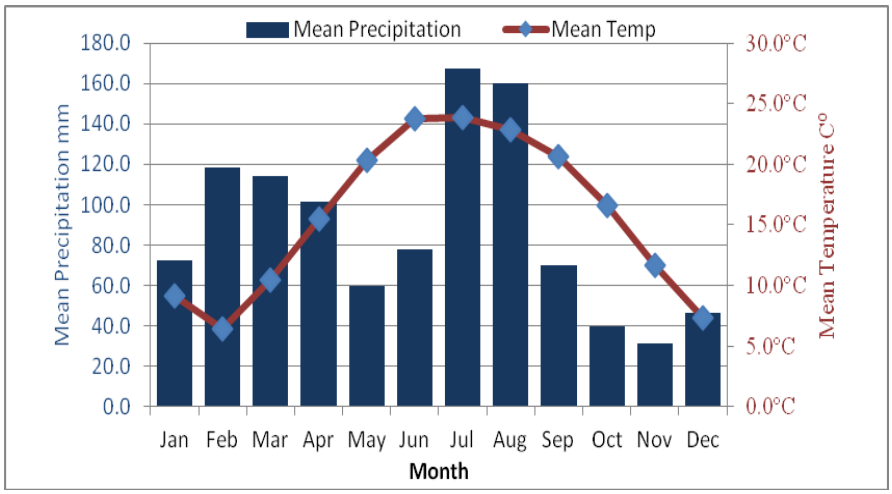

Fig.1 Monthly variation in mean precipitations (bars) and mean temperature (line with squares) in Malam Jabba, Swat, calculated for the period of 1985-2015.

The Climate diagram represented that July is the hottest month with maximum rainfall in this area having mean temperature and precipitation of 23.88°C and 167.27 mm respectively while February was recorded the coldest month with a moderate precipitation of 118.64 mm. During the study period maximum and minimum annual temperature was recorded in the year 2002

(17.44°C) and 1997 (14.31°C) respectively. In case of rainfall, the minimum and maximum precipitation was measured during the year 2000 (61.79 mm) and 2015 (123.50 mm) correspondingly. An increase of 1.20°C in mean annual temperature and 9.58 mm in total annual precipitation was calculated for the study period according to statistical expression given in (Table 1), (Bajwa *et al*., 2015).

Table 1. Climate changes over Malam Jabba, SFD (1985-2015).

Climatic Parameters	Mean ± SE	Δ Change	Statistical Expression	R^2(%)
Mean Annual Temperature (^{0}C)	15.70±0.15	1.2*	Y = - 64.81 + 0.04026 X	0.18
Total Annual Precipitation (mm)	1060.34±35.09	9.58^{ns}	Y = - 6608 + 3.834 X	0.03

*Significant at 95% (p<0.05), ns: Non-significant

Tree Ring Chronology Development

The following Table 1 and Figures 2 show the results of Blue pine tree ring chronologies developed through Computer Based Programs Cofecha and ARSTAN. The Chronologies covered 96 (1919-2015) years and were obtained upto an altitude of 2274- 2384 m a.s.l., 22-30 % slopes with South to East facing of the Malam Jabba Valley of Swat Forest Division.

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

Site	UNFILTERED							FILTERED		
	Chronology span	[1]Corr with Master	[2]Mean msmt	[3]Max msmt	[4]Std Dev	[5]Auto Corr	[6]Mean Sens	[7]Max Value	[8]Std Dev	[9]Auto Corr
SFD	1919-2015	0.185	3.25	97.52	4.031	0.630	0.360	2.97	0.497	-0.014

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, SFD= Swat Forest Division

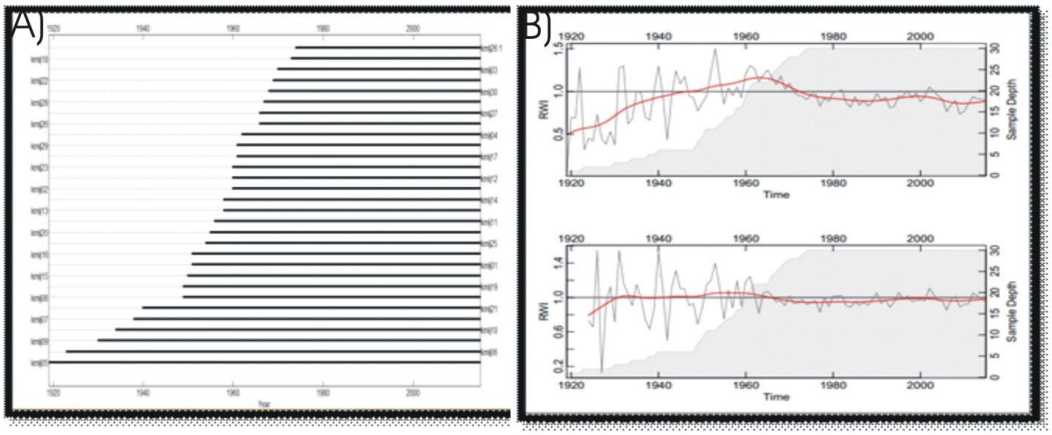

Fig.2. Tree ring chronology development A) The time span of each tree ring series in dataset. B) Residual chronology and c) Arstan Chronology of Blue pine after detrending and standardization.

It is obvious from the table 1 that the high value of standard deviation (4.031) indicated the fast growth of the species under the prevailing condition of this area. Although this chronology has low value of correlation with master one but the mean sensitivity value of this species is sophisticated (0.36) and acceptable internationally for dendroclimatic studies. The values of autocorrelation dropped significantly from 0.630 to -0.014 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 values are converted into tree ring indices and four chronologies were developed i.e. Raw, Residual, Standard and Arstan. Residual Chronology (without auto-correlation) has stronger climatic signal and statistically more robust than standard chronology (Fig.2), therefore this chronology was used for climate-growth modeling.

Climate-Growth Relationship

The climate–growth relationship at moist temperate sites is often more diffusing and challenging (Drew *et al*., 2013). However, armed with good knowledge of the species and study region, a proper site selection may lead to significant correlations between tree rings and a climate factor. According to

Wei *et al*., 2013, tree-ring series derived from extreme sites often have the advantage that one particular climate variable such as summer temperature can easily be identified as the principal limiting factor for growth. At higher elevation, rainfall not only reduces the sunshine period and photosynthesis, it also drops the temperature leading to reduced physiological activity, with the net result being reduced growth in trees. Therefore, it seems reasonable that at higher elevations even during the summer period above average rainfall may reduce growth and the increased temperature in these months is favorable for growth.

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). 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.

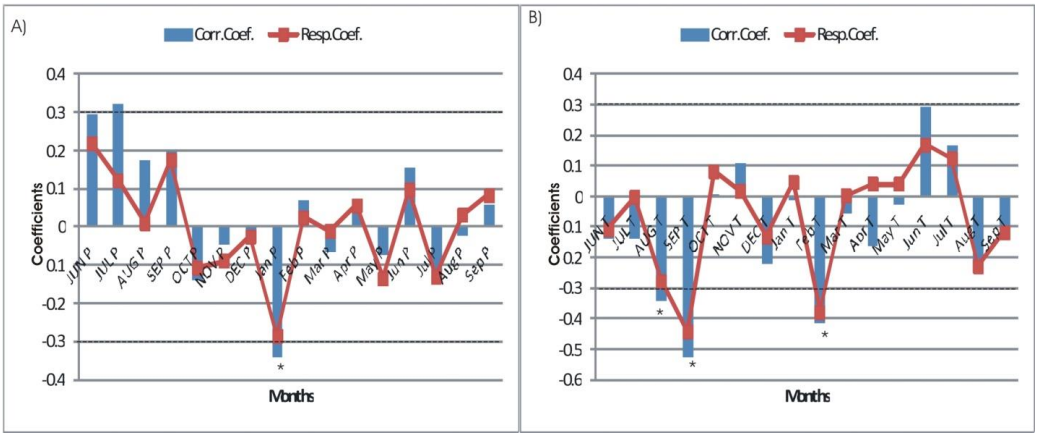

Fig.3. Correlation (histograms) and Response Function (lines) between Tree ring series and A) annual precipitation (mm) B) monthly mean temperature (°C). Correlations were calculated from June of previous year (Jun-Dec.) to September of the current growth year (Jan-Sep.) over the common period (1985–2015) (Bhattachyryya, 1990). 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.

The outcomes of correlation and response function analysis between tree growth (ring widths) and precipitation (Fig.3A) indicated a prominent change from June-September of previous year to current growth years. A transformation from positive to non-significant negative in both coefficients was observed during the month of July from previous to current year representing that maximum rainfall

during this studied period is imposing negative impact on the growth of trees. During the growth season (January-April) precipitation was found significantly negatively correlated and responded during the month of January.

Figure 3B represents the results of RFA between tree ring widths and temperature for the time period 1985-2015. A change in both the coefficients of correlation and response was observed from June-July of previous year to current growth year indicating that highest temperature of these months favoring its growth in contrary to the previous years. During tree ring formation period (January-April) no prominent effect of temperature was observed and in addition February temperature was found significantly negatively responding to the growth of this species. Zhang and Hebda,2004 and Peng *et al.,* 2008 also demonstrated strong positive correlation with July temperature from high elevation and the results of present study also reflected that the high temperature of June along with the availability of rainfall favoring the growth of this tree species in the changing scenario of climate for the studied era.

CONCLUSION

Based on the results it can be concluded that during the period 1985-2015 significant change in the temperature of Malam Jabba have been occurred. Increase in both temperature and rainfall positively influenced the growth of *Pinus wallichiana*. Particularly the June temperature along-with the availability of rainfall favored the growth of the species.

REFERENCES

Ahmed, M. 1987. Dendrochronology and its scope in Pakistan. Proc. 3rd Nat. Conf. Plant Scientist. Peshawar University, Pakistan.

Ahmed, M., T. Hussain, A. H. Shaikh, S. S. Hussain and M. F. Siddiqui. 2006. Phytosociology and Structure of Himalayan Forests from Different Climatic Zones of Pakistan. Pak. J. Bot. 38(2): 361-383.

Ahmed, M., N. Khan and M. Wahab. 2009a. Dendroclimatic investigation in Pakistan using *Picea Smithiana*, A preliminary results. *PakistanJournal of Botany* 41(5): 2427-2435**.**

Ahmed, M., Palmer, J., Khan, N., Wahab, M., Fenwick, P., Esper, J. and E. Cook. 2011a. The Dendroclimatic potential of conifers from northern Pakistan. *Dendrochronologia* 29(3): 212-235.

Ali, S. I., and M. Qaiser (Eds.). 1993-2008. Flora of Pakistan Nos. 194-215. Karachi.

Bajwa, G. A., Shahzad, M. K. and H. K. Satti. 2015. Climate change and its impacts on growth of Blue Pine (*Pinus wallichiana*) in Murree Forest Division, Pakistan. Science, Technology and Development 34 (1): 27-34, 2015.

Bhattacharyya, A. and R. R. Yadav. 1990. Growth and Climate Relationship in *Cedrus deodara* from Joshimath, Uttar Pradesh. Palaeobotany 38:411-414.

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.

Bhattacharyya, A. and R. R. Yadav. 1999. Climatic reconstructions using tree-ring data from tropical and temperate regions of India. A review. *IAWA Journal* 20(3): 311 -316.

Champion, G. H., Seth, S. K. and G. M. Khattak. 1965. Forest types of Pakistan. Pakistan Forest Institute Peshawar, pp: 238.

Champion, H., Seth, S. K. and G. M. Khattak. 1965. Forest types of Pakistan. Pakistan. Forest Research Institute, Peshawar. Bulletin No.7.

Chen, F., Yuan, Y. and W. Wei. 2011. Climatic response of *Picea crassifolia* tree-ring parameters and precipitation reconstruction in the Western Qilian Mountains, China. J Arid Environ. 75:1121–1128.

Cook, E. R. 1985. A time series analysis approach to tree-ring standardization. Ph.D. Thesis, University of Arizona, Tucson, AZ. U.S.A.

Drew, D. M., Allen, K., Downes, G. M., Evans, R., Battaglia, M. and P. Baker. 2013. Wood properties in a long-lived conifer reveal strong climate signals where ring-width series do not. *Tree Physiol.* Vol. 33 (1),2013 pp:37–47.

Garcıá-Suárez, A. M., C. J. Butler, M. G. L. Baillie. 2009. Climate signal in tree-ring chronologies in a temperate climate: a multi-species approach. Dendrochronologia. 27:183–198.

Girardin, M. P., Raulier, R., Bernier, F. Y. and J. C. Tardif. 2008. Response of tree growth to a changing climate in boreal central Canada: a comparison of empirical, process-based, and hybrid modeling approaches. Ecol Model. 213:2909–3228.

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 .

Harris, I., Jones, P.D., Osborn, T.J. and D. H. Lister. 2014. Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset. Int. J. Climatol., 34: 623–642.

Holmes, R. L. 1994. Dendrochronology program manual of Tree Ring Research. Tucson, Arizona, U.S.A. 738

Henry, N. and L. Hou´erou. 1996. Climate change, drought and desertification. J Arid Environ. 34:133–185.

Khan, A. H. 1968. Ecopathological observation in Trarkhal Forest. Part.1 Regeneration status of the forest. Pakistan Journal of Forestry 18:169-228.

Lapointe-Garant, M. P., Huang, J. G., Gea-Izquierdo, G., Frédéric, R., Bernier, P. and F. Berninger. 2010. Use of tree rings to study the effect of climate change on trembling aspen in Québec. Global Change Biol. 16:2039–2051.

Meko, D. 1997. Dendroclimatic reconstruction with time varying predictor subsets of tree indices. J Climate. 10:687–696.

Mitchell, T. D., and P. D. Jones. 2005. An improved method of constructing a database of monthly climate observation s and associated high resolution grids. Int J Climatol. 25:693–712.

Mote, P. W. 2003. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. Northwest Sci. 77:271–282.

Peng, J., Gou, X., Chen, F., Li, J., Liu, P. and Y. Zhang. 2008. Altitudinal variability of Climate-tree growth relationship a consistent slope of Anyemaqen Mountains, northern Tibetan Plateau. Dendrochronologia, 26: 87-96.

Schewe, J., Levermann, A. and M. Meinshausen. 2011. Climate change under a scenario near 1.5 °C of global warming: monsoon intensification, ocean warming and steric sea level rise. Earth Syst. Dynam. 2:25–35.

Siddiqui, M. F., Shaukat, S. S. Ahmed, M., Khan, N. and I. A. Khan. 2013. Vegetation Environment Relationship of Conifer Dominating Forests of Moist Temperate Belt of Himalayan and Hindukush Region of Pakistan. Pak. J. Bot. 45(2): 577-592.

Siddiqui, M. F., Siddiqui, A., Hussain M. I. and J. Iqbal. 2016. Assessment of understory vegetation of Malam Jabba Forest, KPK after cleanup operation using multivariate techniques. Jurnal Teknologi (Sci. & Eng.) Vol. 78(4), 2016 pp: 9–17.

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

Singh, J., R. R. Yadav and M. Walking. 2009. A 694 year tree-ring base rainfall reconstruction from Himachal Pradesh India. *Climate Dynamics* 33(7-8): 1149-1158.

Sheikh, I. S., 1985. Afforestation in Juniper forests of Balochistan. Pak. Forest Institute, Peshawar.

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

Touchan, R., and M. K. Hughes. 1999. Dendrochronology in Jordan. J Arid Environ. 42:291–303.

Wei, L., Heinrich, I. Simard, S., Helle, G., Linan, I. D. and T. Heinken. 2013. Climate signals derived from cell anatomy of Scot pine in NE Germany. Tree Physiol. Vol.33(8), 2013 pp: 833-844.

Yadav, R. R and W. K. Park. 2000. Precipitation reconstruction using ring width chronology of Himalayan Cedar from western Himalaya: Preliminary results. *Journal of Earth System Science* 109(3): 339-345.

Zhang, Q. B. and R. J. Hebda. 2004. Variation in radial growth Pattern of *Pseudotsuga menziesii* on the central coast of British Columbia-Canada. Canadian J. of For. Res., 34: 1946-1954.