CLIMATE-GROWTH RELATIONSHIP OF SPRUCE (*PICEA SMITHIANA*) GROWN IN KAGHAN FOREST DIVISION

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ABSTRACT

The present study was conducted to assess the climate-growth relationship of Blue Pine (*Picea smithiana)* grown in moist temperate areas of Kaghan Forest Division. The climatic parameters including mean annual temperature and precipitation were taken into consideration for the determination of relationship over time scale of 44 years (1971-2015). After visual cross-dating of cores, the total ring width (TRW) was measured with the help of advanced WinDendro System. The chronology of Spruce for the area was developed by verification of data through statistical program Cofecha and elimination of the edaphic factors after detrending and standardization through the computer based program Auto-Regressive Standardization (ARSTAN) and its empirical modeling was done by the software Dendroclimb 2002. Tree-ring chronology showed a strong positive response to precipitation ($p<0.05$) and weak response to temperature. Significant positive correlation was found with January of the current growth season in case of annual temperature and August to precipitation. These findings showed that the *Pinus wallichiana* growth is mainly limited to precipitation rather than temperature, and the species has potential for the climate reconstruction in the study area.

INTRODUCTION

It is widely accepted that the world's climate is changing. Developed countries are spending billions of dollars each year to obtain information about the likely effects of climate change and supporting professional staff to identify the primary risks to their economy such as forestry, agriculture, water-supply, hydroelectricity and pests and diseases. Every country wants to know what changes might happen to them so that they may prepare or adapt. However, a main limitation to being able to accurately model the future scenario is a lack of long or detailed information on past climate systems and their behavior. Consequently there has been a widespread international effect to find and use other reliable indicators. One of the best "tools" to provide this information has been tree-rings; the science of dendrochronology (Ahmed, 2009). The influence of climatic conditions on tree growth has been a major interest in dendrochronological studies (e.g. Fritts 1976; Cook and Kairiukstis 1990) and even increased in relevance considering the current research efforts to study the impact of global climate change. Climate change can affect the distribution, population structure, and growth dynamics of tree species (Camarero and Gutie´rrez 2004; Devi *et al*., 2008; Kullman 2002) and even complete forest

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ecosystems (Pederson *et al*., 2004).

Trees monitor environmental conditions that limit their biological processes, and this information is stored in the structure of the annual ring (Fritts, 1976; Schweingruber, 1988). The radial dimensions of a cell and cell wall is influenced by temperature and water availability. Increasing temperature during earlywood formation period causes shortage of phase of radial expansion of young wood cells and therefore, the radial dimensions of cells are smaller than normal. If the tree experiences higher temperatures during latewood formation period, the phase of radial expansion is prolonged. The maturing period extends if the temperature of environment is high for both earlywood and latewood that leads to the significantly thicker cell wall. Precipitation also affects positively the radial growth period and maturing period and causes prolongation of these. Wood density (an indirect measure of xylem anatomy) has also been shown its great potential to record climatic conditions. It has been reported that wood density components measured in tree- rings are highly sensitive to climate (Schweingruber *et al.,* 1978; Briffa *et al.,* 2001; Roderick & Berry 2001; Bouriaud *et al.,* 2005; De Micco *et al.,* 2007; Novak *et al.,* 2013).

The proposed study has been designed with the objective to gather information about the climatic changes that have happened in the last 44 years and to find relationship between the climate and growth of Spruce (*Picea smithiana*) grown in moist climatic conditions of Kaghan Forest Division.

MATERIALS AND METHODS

To conduct the research work, the cores extracted from the trees of Spruce (*Picea smithiana*) were prepared for measurement by first being glued onto wooden core holders and then progressively sanded with sandpapers (60, 80, 120 grades) until a highly polished surface was produced. Then using a low powered microscope, the ring width growth patterns were matched within and between tree i.e. cross dated and exact calendar years assigned. The process follows the techniques described by Stocks and Smiley (1968). The rings width of cores were 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 (Holmen 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 tree 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. Included in the analysis was the investigation of the contribution for 3-years of prior growth.

RESULTS AND DISCUSSION

Climatic data of Balakot Meteorological Observatory was used to study the impacts of climatic changes on the tree growth of Spruce grown in this area. The Climatogram for mean temperature and precipitation was constructed for the time scale of 1971-2015 as given in below Figure 1.

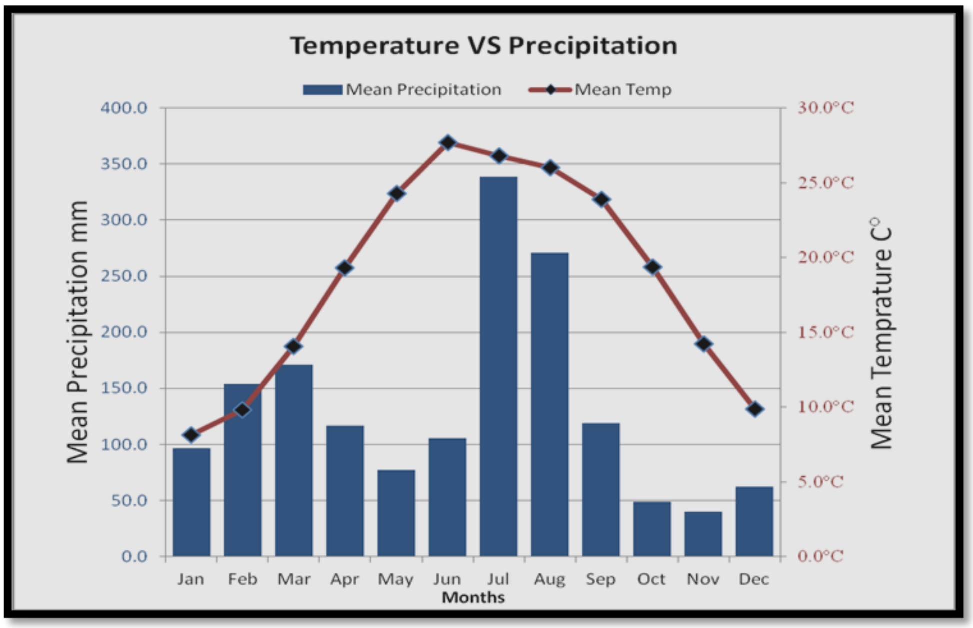

Fig. 1. Climate diagram for Balakot Meteorological station and the calculated mean climatic features for the period 1971-2015.

It is evident from the figure above that mean maximum temperature value was recorded during the month of June (27.69°C) with precipitation measurement of 96.71 mm while its minimum value was found during the month of January and December. In case of precipitation, the maximum values were observed during the month of July (338.58 mm) and August (271.24 mm) with temperature values of 26.81°C and 25.99°C respectively while its minimum value was measured during the month of November. An increase of 0.5°C in annual mean temperature and a decrease of total annual -465.52 mm in precipitation were recorded for the studied period.

The following Table 1 and Figures 2a&b showed the results of Spruce chronologies developed through Computer Based Programs Cofecha and ARSTAN.

Table 1. Summary Statistics of Cofecha for Spruce (*Picea smithian*) ring width.

Site	UNFILTERED							FILTERED		
	Chronology span	Corr with Master	Mean msmt	Max msmt	Std Dev	Auto Corr	Mean Sens	Max Value	Std Dev	Auto Corr
KFD	1873-2015	0.553	4.92	41.74	1.222	0.624	0.158	2.88	0.414	-0.020

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, KFD= Kaghan Forest Division

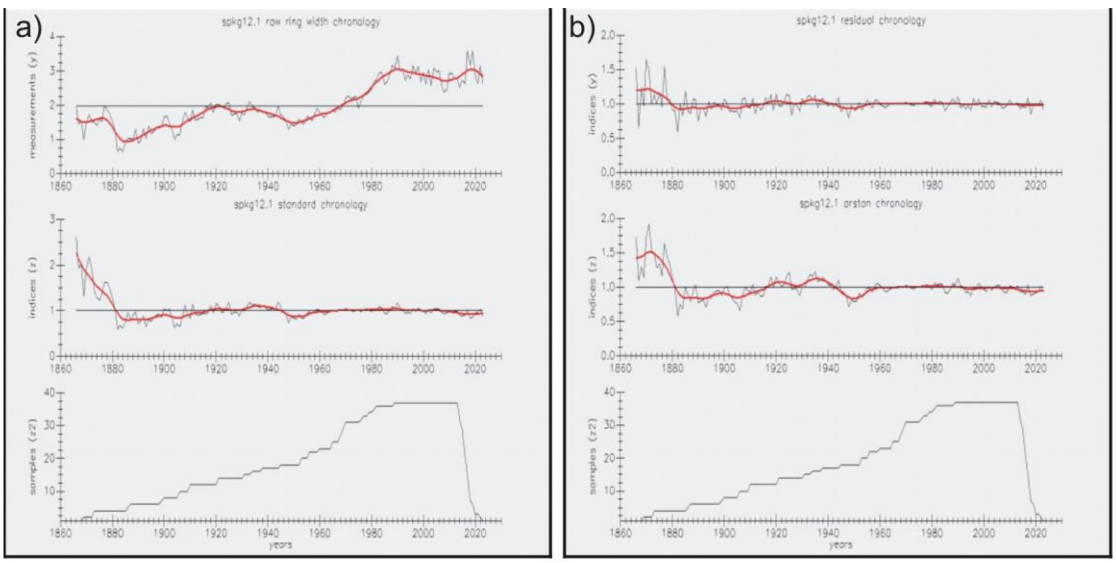

Fig. 2. Outcome of standardization program ARSTAN. a) Raw and Standard Chronology b) Residual and Arstan Chronology of Spruce.

The Chronologies covered 142 (1873-2015) years and were obtained between an altitude range of 2143-2332 m a.s.l., 69-95 % slopes with north-west facing of the mountains of Kamalban. It is evident from table 1 that the chronology has significant value of correlation coefficient with master chronology representing a good cross dating among all tree cores ring width which is required for further dendroclimatic studies. The high value of standard deviation indicated the fast growth of this species under the prevailing condition of this area. The values of autocorrelation dropped significantly from 0.62 to -0.020 after filtering which help for construction of climate-growth model. Although the mean sensitivity characterizing the year to year variability in tree rings showed a low value but it is acceptable internationally for study of climate change. 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 chronologies was removed by the auto-regressive model (ARSTAN) before the final chronology constructed.

Autoregressive Standardization (ARSTAN) program was designed to remove the non-climatic factors from the tree-rings features. After standardization, tree-ring widths are converted to tree ring indices and four chronologies are 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 and therefore ARSTAN chronology was created by reincorporating the pooled auto regression model (PAR) into residual chronology (Fig. 2a&b).

The following Figures 3a & b represented the results of climate and tree growth relationship explored through Correlation and Response Function Analysis (RFA) by using Computer Based Program DendroClim 2002. This software does not measure the climate-growth response, rather it describes the nature of the climatic factors that influence the tree growth and also show the direction and strength of this relationship.

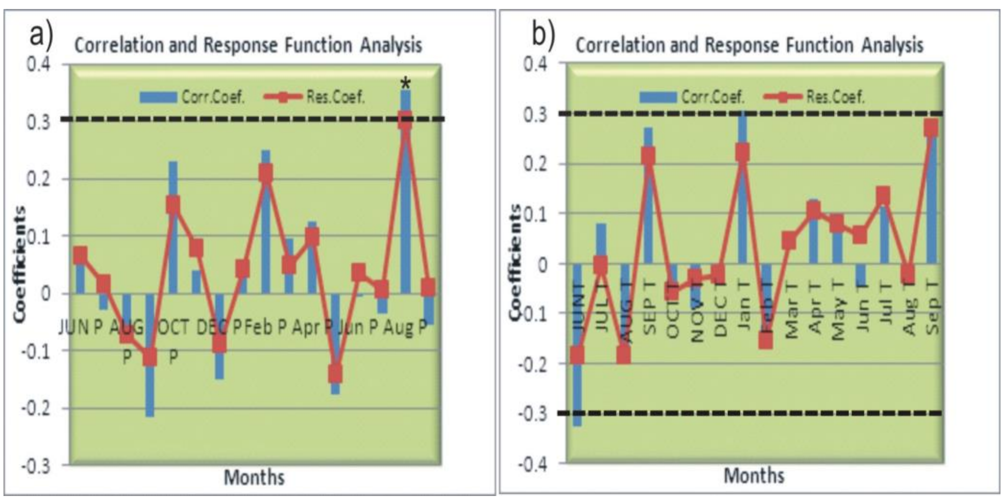

Fig. 3. Correlation (histograms) and Response Function (lines) between Tree ring series and a) annual precipitation (mm) b) monthly mean temperature (C^0).

Correlations were calculated from June of the year prior to tree-ring growth to September of the current growth year over the common period (1971–2015). 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 evident from figure 3(a) that a prominent change in both correlation and response of Spruce trees to annual precipitation took place from previous to current August of growth season i.e. non-significant negative correlation to precipitation converted into highly significant positive. Further, the annual precipitation of current August also influencing tree growth significantly indicating it as a limiting factor for growth of Spruce trees in these areas. Another non-significant transformation of correlation is apparent during the month of previous to current June where correlation between tree ring series and precipitation changed from positive to negative. Positive correlation and responses to October in the prior growth years and February precipitation of the growing season are also obvious by this species. In case of temperature (Fig.3b) the response behavior of Spruce also showed a change from previous to current June with modification from negative to non-significant positive. During the growth period (January-April), positive and significant correlation between tree ring width and temperature of January was calculated but the response of trees did not reach upto significance level. September temperature in prior and current years of growth showed positive correlation and response values but with no outstanding transformation. It is generally expected that in the moist temperate forest the precipitation and low temperature act as a limiting factors for the growth of conifers in Pakistan and the results of this study also confirm this perception.

CONCLUSION/ RECOMMENDATIONS

From the results it can be concluded that:

- The trend of increase in temperature and decrease in precipitation of Kaghan Forest area prominently affects tree growth of Spruce (*Picea smithiana*).
- The developed tree ring chronology spanned from 1971 to 2015 may be a useful tool for the reconstruction of temperature and precipitation of the area.
- Positive correlation and Response Function Analysis clearly indicates sensitivity of Spruce to the changing climatic conditions.

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