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DENDROCLIMATIC AND DENDROHYDROLOGICAL RESPONSE OF TWO TREE SPECIES FROM GILGIT VALLEYS

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Abstract

Picea smithiana and *Juniperus excelsa* are two tree species growing in Gilgit valleys are used to explore growth climate and growth river flow response. About 100 wood samples in the form of cores from three sites were collected. *Picea smithiana* from Bagrot and Haramosh (only chronologies published) and *Juniperus excelsa* from Nalter were sampled. A large number of *Juniperus excelsa* samples were rejected due to various associated problems. Crossmatched and standardized chronologies of three sites were compared with temperature, precipitation (meteorological and gridded data) and instrumental Indus river flow data. *Juniperus excelsa* showed strong lag year response. These species showed significant negative relationship of tree ring index with May- June temperature and positive response with March-April precipitation using instrumental and gridded data. Tree ring of these species indicate significant positive response with May-June river flow. It is shown that these species have potential to evaluate past climatic variations of the area and past water flow response of Indus River.

Introduction

Gilgit valley in northern areas of Pakistan is famous for its tourism and has economic, social and environmental importance. The valley is situated at 1500 meters (4921 feet) while the surrounding mountains are 1830 to 2286 meters above sea level. Area falls under dry temperate area with scanty of rainfall averaging 120-240 mm annually (4.7-9.4 inches). The summer is hot and short and the dominant season is winter. It is the junction of three great mountainous ranges i.e., the Hindukush, the Himalayas and the Karakoram. The climate ranges of Himalayas varies from dry cold desert and wet temperate to subtropical (Borgaonkar *et al*., 2008). Below the snow covered peaks, green belt of *Picea smithiana and Pinus wallichiana* are distributed while in the dry areas scattered *Juniperus excelsa* trees are distributed with various shrubs and herbs. Melting snow, springs, streams and Gilgit River play an important role for its agriculture orchids and domestic use. How changing climate (global warming) will affect natural resources and the daily life of the people of this area is an immediate interest and concern.

In addition, floods and droughts affect and future variation of temperature, precipitation and river flow of this area will not only affect this valley but also other parts of the country. However, for reliable modeling for future prediction, a long term meteorological record is needed (Xiang *et al*., 2000) therefore tree rings of suitable tree species are being used to obtain long term past climatic or hydrological record (Stockton, 1971; 1990).

Dendrochronological work started in Pakistan when Ahmed (1987) presented Dendrochronological potential of gymnospermic tree species of northern areas of Pakistan. He also described (1988 a,b) age and growth rate of forest tree species and problems encountered in their age estimation. Treydte *et al*., (2006) reconstructed July precipitation for the millennium, based on Oxygen isotope concentration using *Juniperus excelsa* from northern Pakistan. Ahmed *et al*., (2010; 2011b) created growth-climate correlations by using four species including *Picea smithiana, Juniperus excelsa, Pinus gerardiana,* and *Cedrus deodara* from seven sites. Ahmed *et al*., (2011a) also developed growth climate reponse using 28 tree ring chronologies from six species extended back 700 years. Recently Cook *et al*., (2013) used tree ring chronologies to reconstruct 500 years of flow of Indus River.

In this paper, we are presenting dendroclimate and dendrohydrological potential of *Juniperus excels*a and *Picea smithiana* from three new sites of Gilgit valleys of northern areas of Pakistan.

Materials and Methods

For the selection of sampling sites, we targeted high elevations because rings of trees were supposed to be quite sensitive there. Trees with higher dbh (diameter at the breast height) were selected and wood samples in the form of cores were obtained using Swedish increment borer. These cores were kept in plastic straws and were air dried in laboratory for further processing. Sand papers of different grades were used for surfacing then rings were crossdated under powerful microscope followed by Stokes & Smiley (1968). The ring's widths were measured in millimeter using measure J2X and then subjected to COFECHA (Holmes *et al*., 1986 and Grissino-Mayer, 2001) to check the quality of visual crossdating. For this purpose, default commands were followed in which 32 year cubic spline, 50 years segment with 25 years overlap and critical level of correlation were maintained. Trends (systematic changes) in the trees were removed from the software ARSTAN (Cook, 1985) and three types of standardized chronologies were obtained i.e. raw chronology, standard chronology and residual chronology. To determine which chronology best suited our study; we developed a preliminary correlation between climatic data of Gilgit and three chronologies one by one. We selected standard chronology to check out the previous year growth effect. However Residual chronology was also used to investigate result similarities. These chronologies were compared with meteorological, gridded and river flow data and percent variance for correlation was obtained by software known as correlation function introduced by Fritts, (1976). In this region, tree growth is generally considered to start in March and end in September so the set of thirteen months window from previous October to current October in all cases was used and for standard chronology we used 3 lag years effect.

Climate and river flow data: Fig. 1a reveals average monthly temperature and total monthly rainfall of nearby Gilgit meteorological station. The data is short just approximately 50 years back. Another world wide problem with the station data is that it is away from tree ring sampling sites. According to Ghaffar *et al*., (2011), temperature and rainfall of Gilgit decrease in pre-monsoon while in summer, temperature decreases and rainfall increases. In post monsoon, temperature decreases more while rainfall remains same. Our station data suggests that highest rainfall occurs in late spring (April-May which is also known as pre-monsoon period) and high temperature in summer (June-August, monsoon period).

In case of gridded data, the maximum temperature occurs in the months of June, July and August and minimum temperature occurs in the months of December, January and February while maximum rainfall occurs in the months of March and April and minimum rainfall occurs in the months of October and November.

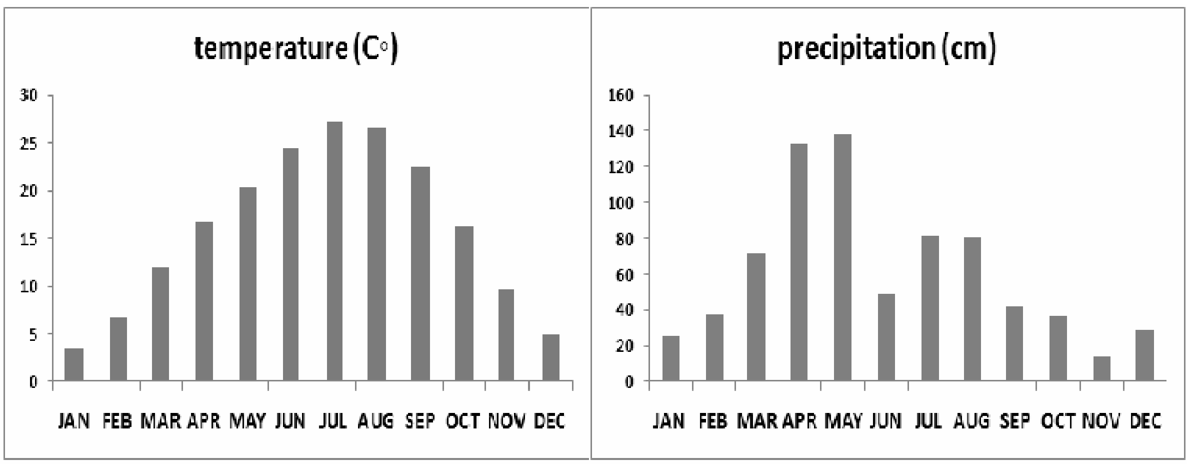

Fig. 1a. Average monthly temperature in C° and total rainfall in centimeter of Gilgit meteorological station based on the data period (1955-2009).

River flow data applied in parallel for comparison with standard chronology is from River Indus at Partab Bridge. The data is short about 38 years (1962-1996). Months of June, July and August have high river flow and the lowest river flow occurs in the months of February and March (Fig. 1a & 1b).

The numbers of trees used in the chronology are usually less than that of total trees taken for site collection since there was problem of crossdating. The COFECHA and ARSTAN summary statistics from three sites are presented in Table 1. Mean sensitivity, series intercorrelation and master series were obtained from program COFECHA while EPS, SNR and rbar values were attained from program ARSTAN. Mean sensitivity, series intercorrelation and master series of *Juniperus excelsa* from Nalter are 0.23, 56% with 395 years and EPS, SNR and rbar values are 0.89, 8.94, and 0.35 respectively.

Figure 2 shows raw ring width, standard, residual, arstan chronologies and sample size. Raw ring width chronology of *Juniperus excelsa* Nalter exhibited good growth up to 1700AD, then after little decrement, growth curve again increased around 1740AD and then growth of trees gradually decreased from 1770 to 1970AD. Twelve samples represented common years up to 1830AD while beyond these years sample size was also gradually decreasing.

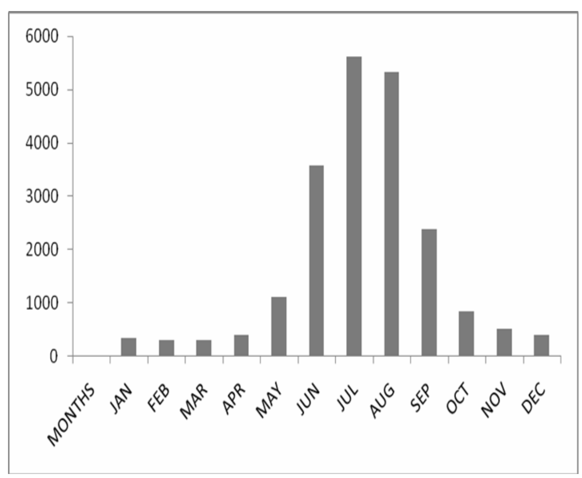

Fig. 1b. The mean monthly discharge in (Cumecs) of Upper Indus Basin at Partab Bridge from 1962-1996.

Results

The tree growth climate and river flow relationship are summarized in Table 2 and only significant correlations are listed. It is illustrated from Table 2 that there are 113 significant correlation coefficients out of which more than half of coefficients are related with current year growth. *Juniperus excelsa* from Nalter exposes previous year effect in all cases except with temperature of Gilgit station. *Picea smithiana* from Haramosh and Bagrot sites show approximately 3 year's lag effect in gridded precipitation and water flow but not in the case of temperature.

Comparison between chronologies and temperature (station): When comparison was made among chronologies i.e., standard and residual with temperature of Gilgit station showed significant positive correlation in the month of previous December for *Picea smithiana* Haramosh and Bagrot and negative correlation in the month of June. However, residual chronology of Haramosh and Bagrot presented negative correlation in current April-June. *Juniperus excelsa* represented positive correlation in the month of March only in case of residual chronology while negative correlation was found in July to October.

Comparison between chronologies and temperature (gridded): Standard chronology of *Juniperus excelsa* exhibited positive correlation in the months of previous November, and December, current January and current April and negative correlation in the month of July and August. Standard chronology of *Picea smithiana* Haramosh showed negative correlation in the months of previous December, current March and April. *Picea smithiana* from Bagrot expressed only negative correlation in the month of May. Residual chronology of *Juniperus excelsa* from Nalter represented negative correlation in the month of June and July. In case of standard chronology, *Picea smithiana* from Haramosh showed negative correlation in the months of previous October, current May and March and same is the case with standard and residual chronology of *Picea smithiana* from Bagrot represented negative correlation in the months of May.

Table 1. Statistics of Cofecha and Arstan from three sites.

Cofecha and Arstan	*Juniperus excelsa* Nalter	*Picea smithiana* Haramosh	*Picea smithiana* Bagrot
No. of cores (trees)	40(20)	30(15)	30(15)
Cross dated cores	12	20	20
Mean sensitivity	0.236	0.319	0.304
Series intercorrelation	0.563	0.696	0.693
Master series	1614-2009	1467-2007	1480-2009
Expressed population signal (EPS)	0.899	0.98	0.91
Signal-to-Noise ratio (SNR)	8.945	54.78	10.50
Rbar	0.359	0.73	0.60

Haramosh & Bagrot chronologies published (Zafar *et al*., 2010). In brackets values are the numbers of trees sampled

Comparison between chronologies and precipitation (station): Comparison between standard chronology of *Juniperus excelsa* and total monthly precipitation of station showed positive correlation in the month of June while no correlation was found with residual chronology. *Picea smithiana* from both Haramosh and Bagrot exhibited same results indicating negatively correlated in the month of February and positive correlation in the month of March and April while Bagrot represented positive correlation in the month of May also.

Comparison between chronologies and precipitation (gridded): *Juniperus excelsa* postulated different results in case of standard and residual chronology i.e. positively correlated in the months of previous December, February, March, May and June. *Picea smithiana* from both sites expressed positive correlation from February to May.

Comparison between chronologies and water flow: Water flow was positively correlated with February and May in both chronologies of *Juniperus excelsa* and negatively correlated in the month of previous December. Standard chronology offered positive correlation in the month of June. *Picea smithiana* of Haramosh and Bagrot expressed negative correlation in previous December, positive correlation in current February, June and negative correlation in July and August.

Discussion

The dendrochronological potential of two species with different sites is offered here. The annual rings of *Juniperus excelsa* are even distinct but are difficult to crossdate. On the basis of low statistical values of COFECHA and ARSTAN it may be anticipated that *Juniperus excelsa* has low climatic signals as compared to Haramosh & Bagrot. Average mean sensitivity is low as compared to other two sites. Signal-to-Noise Ratio (SNR), expressed population signal (EPS) and rbar values are also less than Haramosh & Bagrot chronologies (Zafar *et al*., 2010). According to Wigley *et al*., (1984), the values of Signal-to-noise ratio (SNR) and expressed population signal (EPS≥0.85) show the usefulness of chronologies for past climatic signal and our values satisfy the condition; in case of SNR, our values are 54.78, 10.50 and 8.94 for Haramosh, Bagrot and Nalter respectively while in case of EPS, values are 0.98, 0.91 and 0.899 respectively.

The standardization obtained from program ARSTAN attempts to minimize the unwanted signals (noise) and to emerge the desired information (signals) (Cook & Holmes, 1986). The standard chronology with mean index value of 1.0 as shown in figure 1 with autocorrelation with previous year effect and residual chronology without lag are further discussed. The precise analysis of climate tree growth relationship can be obtained by correlation and response function analyses to examine how monthly mean temperature and precipitation influence on tree growth (Fritts, 1976; Fritts & Xiangding, 1986). Here we only apply simple correlation function to ring width indices. According to Biondi (1997), Correlation analysis is univariate estimate of Pearson's Product moment Correlation and it is used with bootstrapped confidence interval to reduce potential error. We chose standard chronology to check previous year's growth effect on current years. *Juniperus excelsa* indicated strong previous year's effect with low climatic and water flow signals as compared to *Picea smithiana* of Haramosh & Bagrot. The correlation function applied to the following climatic parameters: Temperature and precipitation data of Gilgit meteorological station, water flow of Partab Bridge and gridded data Gilgit.

Table 2. Significant correlation coefficient of thirteen months back is shown in the table. Chronologies without significant correlation are not included in this table.

Months	pOct	pNov	pDec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	1	2	3
J.e-nlt						⊕				-⊖	-	-	-			
p.s-hr		+	+⊕		+		⊖	⊖	⊖-							
p.s-bg			+⊕				⊖	⊖-	⊖-							
Mean monthly temperature (station) vs. standard and residual chronology																
J.e-nlt		+	+	+			+		○ -	-⊖	-			+	+	+
p.s-hr	⊖-					⊖-	⊖-									
p.s-bg		+						⊖-			⊖					
Mean monthly temperature (grid) vs. standard and residual chronology																
J.e-nlt									+					+	+	+
p.s-hr				○+	+⊕	○+								+		
p.s-bg				○+	+⊕	+⊕	○+							+		
Total monthly precipitation (grid) vs. standard and residual chronology																
J.e-nlt			+		○+	+		○+	○+	+				+	+	+
p.s-hr						○+	○+	+⊕						+	+	+
p.s-bg					○+	○+	+⊕	+⊕						+	+	
Total monthly precipitation (station) vs. standard and residual chronology																
J.e-nlt			-		+⊕	○+		+⊕	+					+	+	+
p.s-hr		○ -	⊖-		+				+	⊖	-			+		+
p.s-bg			-		+⊕	+		+	+⊕	⊖	-			+	+	
Water flow vs. standard and residual chronology																

1, 2 and 3 explain the lag year effect respectively. Sign in circular show significant correlation in residual chronologies.
J.e-nlt= *Juniperus excelsa* from Nalter; **P.s- hr**= *Picea smithiana* from Haramosh; **P.s- bg**= *Picea smithiana* from Bagrot.

Ahmed *et al*., (2011a) explained growth climate response (temperature and precipitation) using 28 sites. They described significant positive response of tree ring indices with temperature in the months of previous November and previous December and significant negative response in the month of current May and current June while in case of precipitation; ring width indices showed positive response with current March-May (spring). Singh *et al*., (2006) used *Cedrus deodara* of 13 sites in the Western Himalayas of India to reconstruct spring (March-May) precipitation. Our results suggest positive response of temperature with standard and residual ring width chronologies in the previous month of November and December and negative response in the current month of April, May and June while positive response of precipitation in current Month of February-April are similar to the results of Ahmed *et al*., (2011a) and Singh *et al*., (2006).

Ahmed *et al*., (2011c) reported May-September reconstruction of Upper Indus River Flow with the help of tree ring chronologies using river monthly flow data at Partab Bridge. Our results support the findings that any reconstruction related to Upper Indus Basin should include May-September months. The negative response in the month of previous December and positive response in the month of current February are also supports the previous findings.

The study provides additional evidences for understanding growth/climatic response of these species. Therefore it is concluded that these two species and areas are highly potential to reconstruct past climate and river flow history, however older tree samples are required to extend tree ring chronologies in the near past.

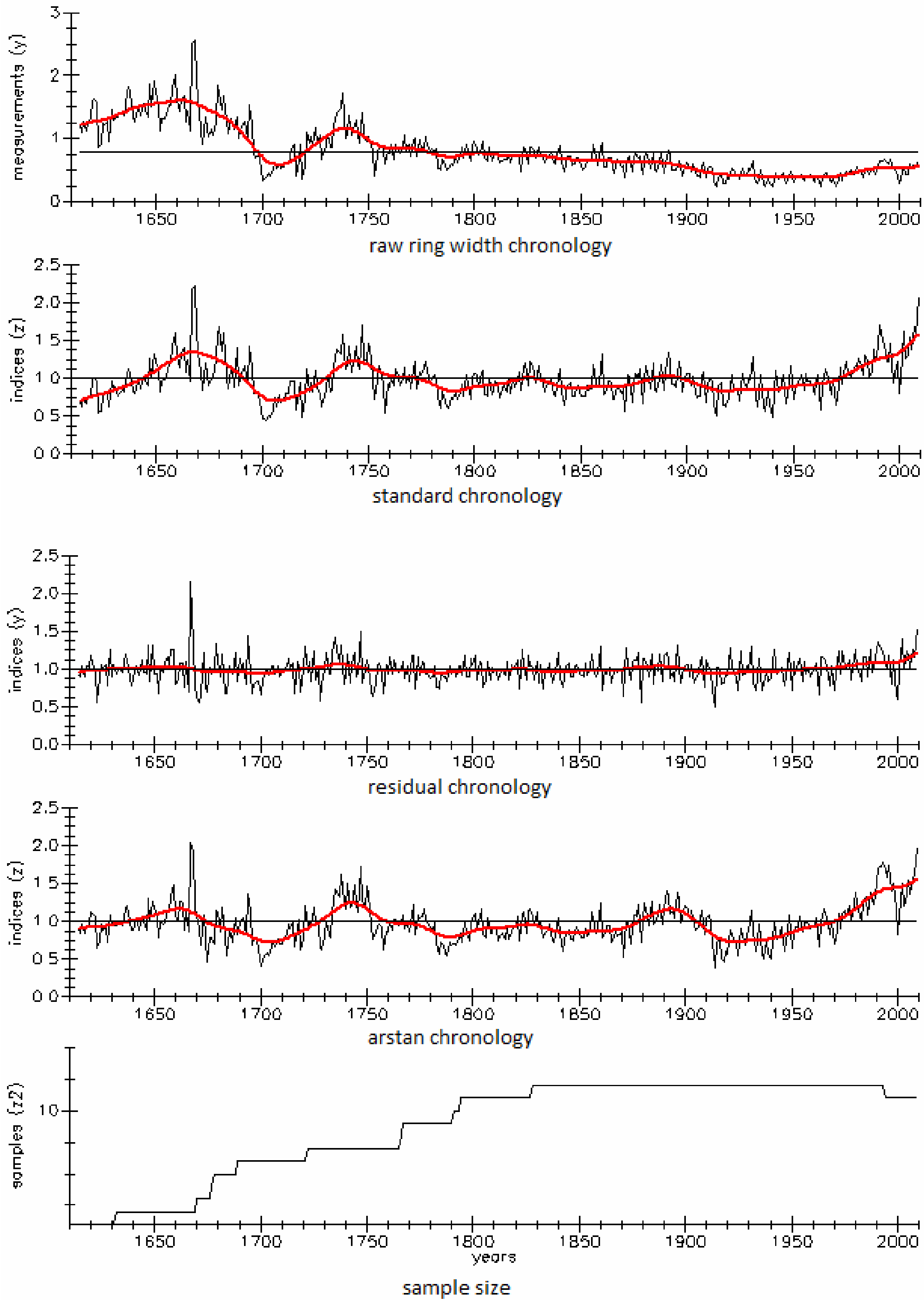

Fig. 2. *Juniper excelsa* Nalter, tree ring width and three chronologies respectively from (1680-2010). Chronologies of *Picea smithiana* are presented in Zafar *et al*., (2010).

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