INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 2, p. 405-412, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Growth-climate correlation of himalayan pine (*Pinus wallichiana*) from ganji forest skardu districts of Gilgit-Baltistan, Pakistan

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Article published on August 24, 2014

Key words:

Abstract

Ring-width chronology of 211 years (AD 1730-2010) was developed using Himalayan Pine (*Pinus wallichiana*) collected from Ganji Skardu mono-specific *Pinus wallichiana* forest near the mix forest of *Pinus wallichiana, Juniperus excelsa* and *Betula utilis* on different aspect and slope angle. Chronology statistics showed that *Pinus wallichiana* have the past climate signal. Strong correlation has been observed between tree growth and previous November temperature indicating that winter warmth is the main factor responsible for tree growth. Correlation analysis between tree ring chronology and grid data also indicates that summer temperature and precipitation is useful for tree growth. More sample collection would prove better results.

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Introduction

Himalayan pine also known as evergreen *Pinus wallichiana* tree which is naturally distributed from Afghanistan to all Himalayan region including Pakistan, India, Nepal and Bhuttan having altitude ranging from 1800-3900 meters (Singh and Yadav, 2007). It usually grows in moist environment both in pure and mixed form. It prefers to grow with Himalayan cedar (*Cedrus deodara*), Himalayan fir (*Abies pindrow*), Himalayan spruce (*Picea smithiana*) at lower elevation and with birch (*Betula utilis*) and juniper (*Juniperus marcopoda*) at higher elevation.

Ganji is one of a small valley of Sub-Division Rundo of District Skardu in northern areas of Pakistan. Ganji is located between 35°.56 N and 74° 98 E with 15° slope and South East facing exposure about 75 km from Skardu District on the upper bank of Indus river. The elevation was3310 m a.s.l while the canopy was closed.

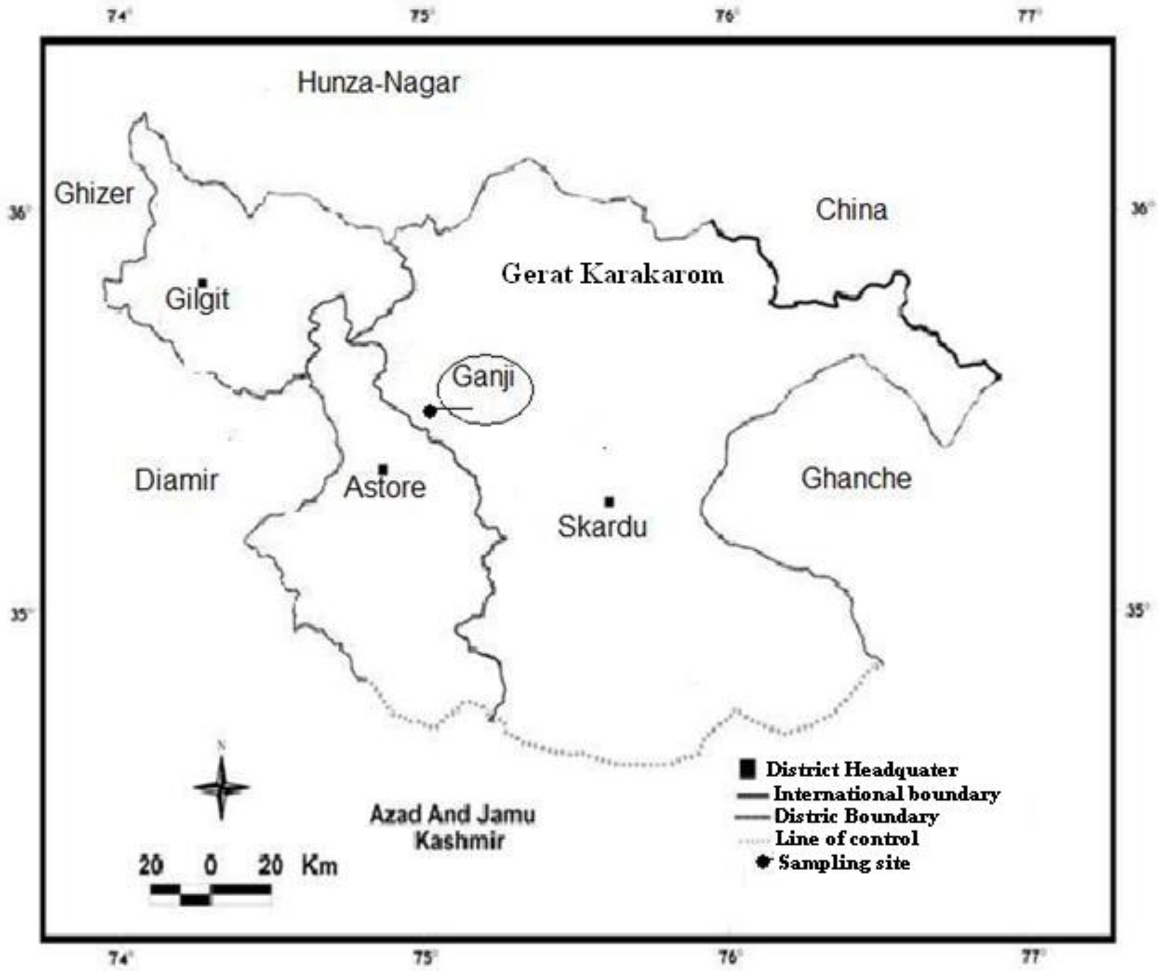


Fig. 1. Map showing the Ganji sampling area from district Skardu circle showed the sampling site.

Many researchers worked in different parts of Pakistan to explore the dedrochronological potential of coniferous tree species in different area of Pakistan.Ahmed (1988) described the problem in age estimation of forest tree species. Ahmed *et al.* (1989) studied tree rings of *Abie spindrow* from Himalayan region of Pakistan. Ahmed and Sarangzai (1991a,b) also applied dedrochronological approached to estimate the growth rate of different tree species and estimate the growth rate of different species respectively Esper *et al.* (1995, 2000) described tree rings of *Juniperu sexcelsa* from Karakorum Range.

Ahmed and Naqvi (2005) described tree rings chronologies of *Picea smithiana*. Khan *et al.* (2008) described the potential of *Picea smithiana* from a site in neighbouring Afghanistan. Ahmed *et al.* 2009a, 2009b) also conducted study to described growth climatic response of *Picea smithiana* and *Abies pindrow*.

Recently,Ahmed *et al.* (2010a) and Ahmed *et al.* (2010b) described choronologies form upper Indus Basin of Karakorum Range. Zafar *et al.* (2010) carried out standardized tree ring choronologies of *Picea smithiana* from Bagrot and Haramosh valleys of Gilgit. Ahmed *et al.* (2011) studied the dendroclimatic potential of conifers from northern Pakistan. Ahmed *et. al* (2012) published Climate/ growth correlations of tree species in the Indus basin of the Karakorum range, north Pakistan.

Up to now *Pinus wallichiana* growing at Ganji valley was not studied therefore the present paper has been designed to explore the dedrochronological response of *Pinus wallichiana* species from Ganji valley.

Material and methods

Site Sampling

Total 30 tree cores were extracted from 15 living trees from Ganj Skardu site and were subjected to standard dendroclimatic procedues of sample preparation, cross matching and dating followed by Stokes and Smiley (1968).

Measurment and Statistical Analysis

Ring width were measured by using Velmex machine. Dating and measurement errors were checked by using COFECHA (Holmes, 1983). After dating, raw tree-ring measurement were detrended using ARSTAN program (Holmes, 1992; Cook, 1985) and ring-width indices were obtained by dividing raw ring value by corresponding smoothed value. A precise correlation analysis was carried out between tree growth and local climate data of Skardu (Fritts, 1976). A set of 13 month window from previous October to current October were used both in case of temperature and precipitation at Skardu for the period of 1972-2011.

Results and discussion

As already discussed that 15 trees were used to extract the cores and nearly 70% of cores (22 from 30 cores) were crossdated showing no associated problem. Portion with two or more series were found only 281 years (1730-2010) which means age of tree were not longer. Series inter correlation was 57% with average mean sensitivity of 0.16.In another study based on *Pinus wallichiana* from Astore and Mushkin (Ahmed *et al.* 2011), quite identical results from chronology statistics were observed. *Pinus wallichiana* from Astore was found to be older than the current study. Similar series inter correlation and mean sensitivity was observed by Singh (2007) in Indian region. Higher values of mean sensitivity in current study show that tree rings were towards complacent side. Mean length of series was more than two hundred years i.e. 211 years with individual series correlation ranging from 0.31 to 0.67. Individual mean sensitivity ranged 0.12-0.19. The highest correlation of 50 years dated segment wit 25 years lagged was observed 0.66 in 1825-1874 and lowest correlation of 50 years dated segment was 0.43 in 1725-1774.

Here we have presented various statistics of *Pinus wallichiana* from Ganj got the EPS value of 0.89 by using common period analysis of 100 years from 1900-2000 as shown in the table 1. Five cores failed to negative exponential curve fit and changed to linear regression (any slope). SNR and Rbar values are 8.29 and 0.298 respectively. Rbar values within trees and between trees varied from 0.65 and 0.27 respectively. Moderate values of mean sensitivity represented good dendroclimatic potential of the species (Fritts, 1976) whereas high values of SNR, EPS greater than 0.85 (Wigley *Et al.* 1984) and R bar show that chronology is useful for the determination of past climatic signals.

All cores showed positive autocorrelation ranging from 0.31-0.87. All series common period principal component analysis exhibited that first six PCs obtained having the eigen value greater than one with total variance of 80.2 percent satisfying the eigen value criterion. First PC eigen value is 6.055 with a cumulative variance of 28.8 percent.

Table 1. Dendrochronological characteristics of the ring-width chronology from *Pinus wallichiana* Ganj (Skardu). COFECHA and ARSTAN statistics based on 50-years segments lagged 25 years. Critical level of correlation at 99% confidence level.

Mean sensitivity	0.16
Series intercorrelation	0.57
Total absent rings in all series	0
Common years interval	1900-2000 (100 years)
Expressed population signal	0.89
Signal to noise ratio	8.92
Rbar	0.298
Rbar within the trees	0.65
Rbar between the trees	0.27

The Fig. 1 shows the raw ring-width, standard, residual, arstan chronologies and sample depth graphs respectively. *Pinus wallichiana* Ganj chronology spans more than 250 years. Sample depth increases gradually from 1800 AD (see Fig.1, sample size). Nearly twenty cores attained the age of 150 years (1850-2000 AD). Period of above average growth was seen upto 1800 AD and declined period from average growth was observed in the last century i.e. 1900-2000 AD while 1800-1850, period of below average growth occurred whereas from 1850 to 1900, period of above average growth occurred (see Fig.1, Raw chronolgy)

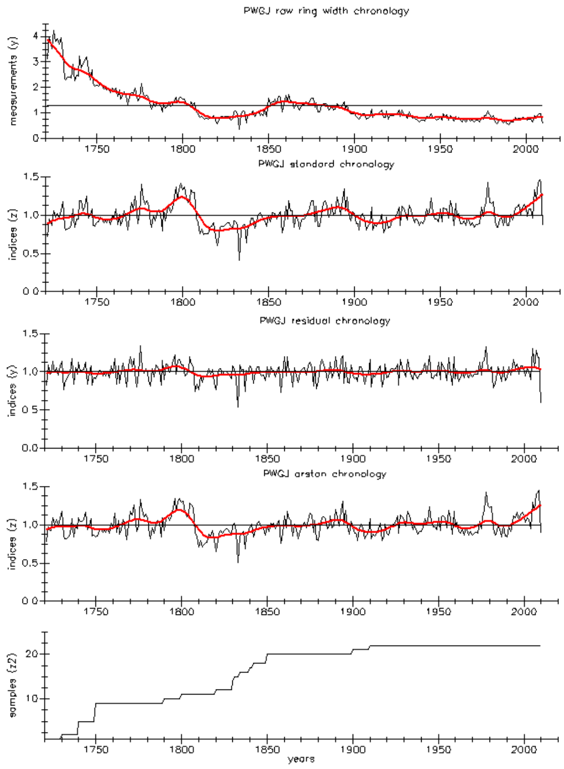


Fig. 2. Raw, standard, residual, arstan and sample size are represented respectively.

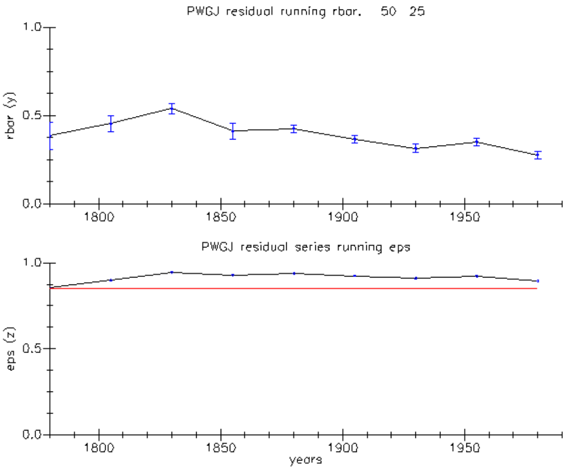


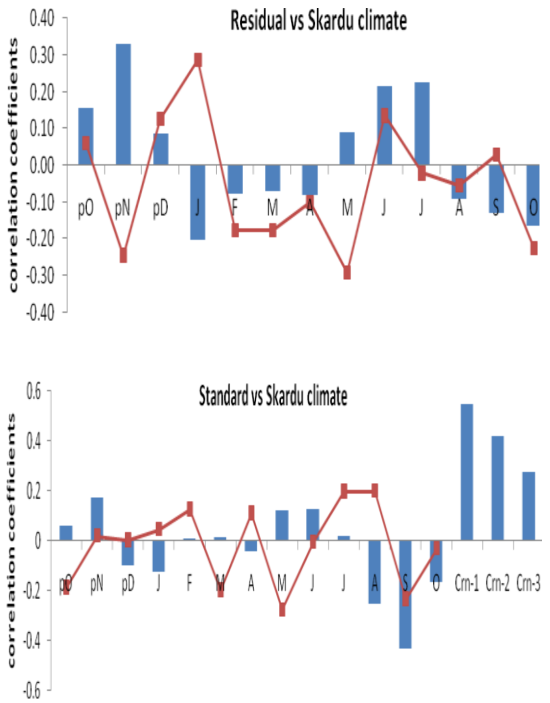
Fig. 3. The output file obtained from program ARSTAN describes the running EPS and Rbar for *Pinups wallichaina* Ganj which shows the reliability of chronology with respect to time. The graph of EPS for *Pinus wallichiana* indicates that chronology is suitable to 1790.

Correlation and response analysis

Correlation and response function analysis were performed among residual and standard chronologies with skardu station and corresponding grid data (Fig.3 and Fig.4). The parallel use of correlation and response analysis was performed to pick the similarities in the results. The total variance explained was 57.12% in correlation analysis (residual chronology vs Skardu climate) whereas the variance obtained from correlation analysis of residual chronology with grid climate was 43.92%.

The results of all analysis (correlation and response functions) are difficult to explain because of not having the clear picture (dissimilarities in findings) therefore we concentrated over correlation analysis between standard chronology and grid climate. The reason is that standard chronology showed the lag year effect and we have strong previous lag year effect in terms of tree growth while the grid climate expressed the reasonable correlation.

Analysis showed that temperature of previous October and November were significantly positively correlated with tree growth. In the same way, July temperature was found to be positive significant correlated in the analysis. In case of precipitation, the same month was observed positively significantly correlated with tree-ring chronology.



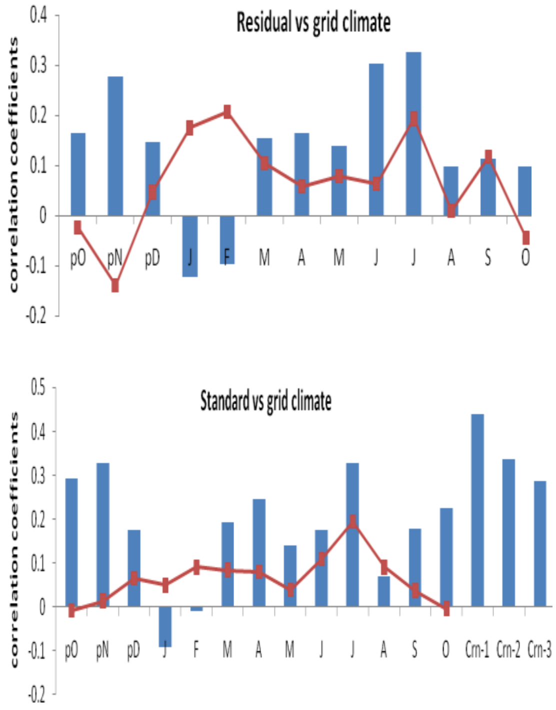


Fig. 4. Correlation function of residual and standard chronologies with mean monthly temperatureand total monthly precipitation of Skardu station and grid data from previous October to current October. Bars in the graph represent correlation of chronology with temperature and line represent correlation with precipitation.Crn-1, Crn-2 and Crn-3 represent the prior growth effect respectively.

In Himalayan region, availability of long term climatic data is problem and same is the case with the present study. Another problem is that meteorological stations are situated far from high altitude tree ring sites. We used Skardu station data having the length of just 39 years. Chronology was also compared with grid climate that covers the duration of 100 years. The results obtained in comparison of tree ring chronology and grid data are quite useful as compared to local climate data.

The mean monthly temperature showed direct relationship with tree growth having the significance in previous October and November in case of grid comparison. It means that species continue photosynthesis during warm winters and reserves are used in growing season. Correlation analysis between tree ring chronology and grid datashowed significant positive relationship in July temperature and precipitation. As our sampling site is situated at high elevation where spring season is short, therefore for the growth of plants, July temperature will be better and in the meanwhile precipitation will promote the tree growth which will be handy.

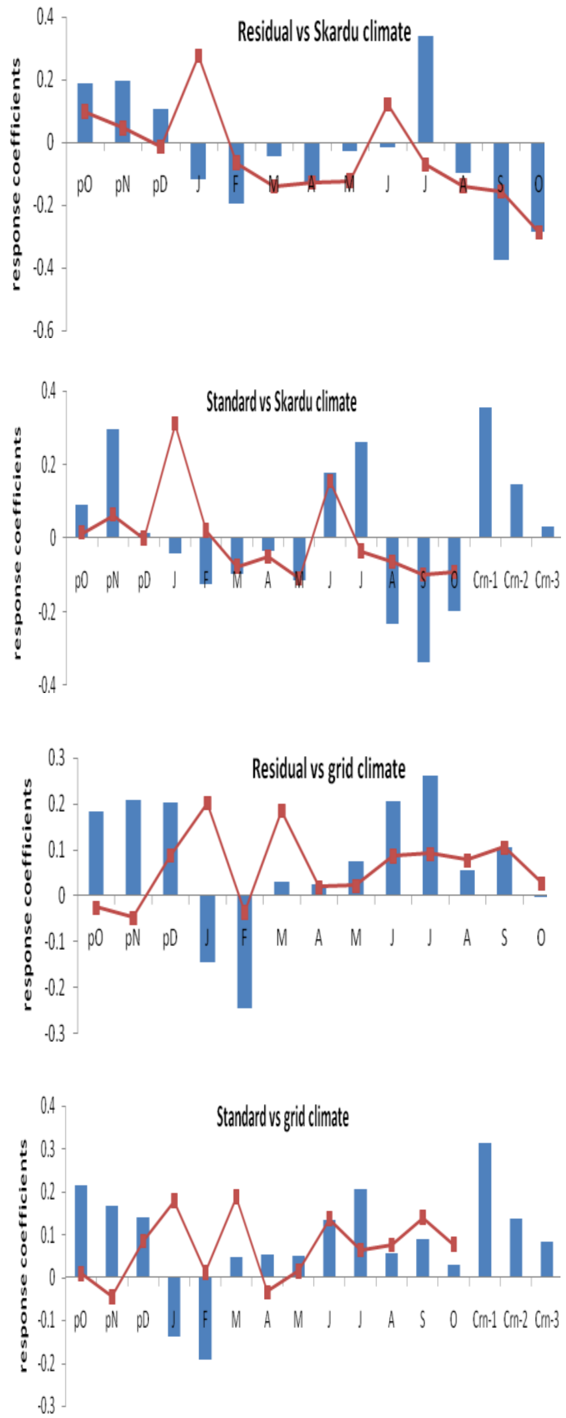


Fig. 5. Response function of residual and standard chronology with mean monthly temperature and total monthly precipitation of Skardu station and grid data from previous October to current October. Bars in the graph represent response of chronology with temperature and line represent response with precipitation. Crn-1, Crn-2 and Crn-3 represent the prior growth effect respectively.

We compare our study site with that of *Pinus wallichiana* of Astore (Rama) and Mushkin Ahmed *et al.* (2011). Our results match with the conclusion of Astore (Rama) in case of temperature, where chronologies showed significant positive relationship in June-July temperature but the similar agreement was not seen in current study site and Mushkin.

The reason might be the elevation. Our study site elevation (3310m) is more or less similar with that of Astore (Rama) (3450 m), therefore expressed similar results while *Pinus wallichiana* from Mushkin was from lower elevation (2750 m) therefore expressed different results. The same results were also highlighted by Treydte *et al.* (2006) who worked over the elevations of different species situated at Bagrot site and concluded that sites situated at different elevations showed different response.

And in case of precipitation, *Pinus wallichiana* from present study showed positive relationship in June-July while *Pinus wallichiana* did not represent any significant relationship with precipitation. *Pinus wallichiana* from Mushkin showed positive relationship in January, February and May.

Ahmed *et al.* (2011) did not report any sign of significance in the month of previous November based on *Pinus wallichiana* from Astore and Mushkin. Similar observations have been noticed in neighboring India with the Himalayan pine trees growing at lower elevation (Yadav *et al.* 1997). Also other studies showed that several pine species continues its growth during warm winter (Hepting, 1945; Kramer, 1958).

Conclusion

Finally, it is concluded that *Pinus wallichiana* from Ganji valley Skardu produced some helpful results in Growth-Climate response modeling. The chronology covered a period of more than 200 years. Our chronology created similar findings with *Pinus wallichiana* of neighboring India but duration of the chronology was short in current study. It is suggested older trees should be sampled in future to extend the chronology.

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