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DENDROCHRONOLOGICAL POTENTIAL OF *ABIES PINDROW* ROYLE FROM INDUS KOHISTAN, KHYBER PAKHTUNKHWA (KPK) PAKISTAN

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Abstract

The study was conducted to evaluate the dendrochronological potential of *Abies pindrow* Royle from Indus Kohistan, KPK, Pakistan. Forty wood samples in the form of cores were obtained from twenty healthy trees. The results of quality control programs COFECHA showed that the all cores exhibited high correlation with master chronology i.e.0.411 to 0.763, high mean sensitivity 0.186 and mean ring width 1.42 mm. The present study explored the first dated 394 years (1620-2014AD) chronology from Indus Kohistan. On the basis of this investigation, it is suggested that this species show high dendrochronological potential and can be used for the determination of past climatic fluctuations. However, for better results the sample size should be increased, since from year 1620 to year 1700 sample size was small.

Key words: Dendrochronology, Climatic potential, *Abies pindrow*, Indus Kohistan

Introduction

Kohistan "The land of mountains" is one of the most remote areas of Khyber Pakhtunkhwa of Pakistan. It covers about 7,492 km^{2}and lies between 34–35 º North latitude and 72–73º east longitude (Fig. 1). The range of Karakoram, Hindu Kush and western Himalayan collide with each other at Indus Kohistan and serve as a natural vegetation area of Pakistan. According to the nearest meteorological station i.e. Dassu (Upper Kohistan) and Besham (Border of lower Kohistan), June-July are the warmest months (the temperature exceeds to 38ºC) and January-February is the coldest months (below 14ºC mean monthly maximum). However, the instrumental record of temperature obtained from seven different sites of Karakoram and Hindu Kush mountain exhibited that consistently the winter becoming warmer and summer are cool (Fowler & Archer, 2006).

The forest of Pakistan has been originally described by Champion *et al*. (1965) and opined that many species had several climate and ecological amplitude; however, the species confined alone could not be used for climate indication. In Pakistan the science of dendrochronology and it scope was first time introduced by Ahmed (1987). Some other workers were able to conduct the dendrochronological study of various conifer species, concentrating on some parts of Northern area and some others region of Pakistan. Ahmed (1988) explored the age of conifers species and discussed the problem related to age estimation. Subsequently the first dated chronology of *Abies pindrow* from moist temperate area was presented by Ahmed (1989). Ahmed & Sarangzai (1991, a, b), Ahmed *et al*. (2009b) and Siddiqui *et al*. (2013) determined the age and growth rate of some gymnosperm species using dendrochronological technique. Using the isotope data of *Juniperus excelsa*, the first climatic study was conducted by Esper *et al.* (1995) similarly the climatic signal based on extreme year were also exposed by Esper *et al.* (2001; 2002; 2003; 2007). Ahmed & Naqvi (2005) presented the tree-ring chronology of *Picea smithiana* obtained from various ecological zone of Pakistan while Khan *et al*. (2008) presented the dated chronology of the same species from Afghanistan closed to district Dir. Ahmed *et al*. (2009a) presented the climatic response function of *Picea smithiana* from Pakistan similarly the tree-ring chronology and growth climatic response of some conifer tree from upper basin of Karakoram range of Pakistan were presented by Ahmed *et al*. (2010b,2012). Ahmed *et al*. (2011) also explored the climatic potential of various conifer species of Northern area of Pakistan. The dendrochronological potential of *Junipers excelsa* from dry temperate area of Balochistan was conducted by (Sarangzai & Ahmed, 2011). Cook *et al*. (2013) used the tree-ring for reconstruction of five centuries flow of upper basin river Indus while Ahmed *et al.* (2013) presented the dendrochroclimatic and dendrohydrological response of *Picea smithiana* and *Juniperus excelsa* from Gilgit-Baltistan. Recently Zafar *et al*. (2015) explored the 500 years past temperature history with the help of tree-ring, of Karakorum range of Pakistan.

For understanding the climatic history and variability it is necessary to develop a tree-ring data base or network from different locations and ecological zones of Himalayan, Hindu Kush, Karakorumand associated mountain ranges of Pakistan. Therefore present study is an attempt to increase that network since no such study has been conducted at Indus Kohistan. The present research presented the first dated chronology from Indus Kohistan valley of Pakistan.

Material and Methods

For present study, Sharakot valley of lower Kohistan having altitude 2727 meter, latitude 35 °01 47.8´ (N) and longitude 73° 03 28.9´ (E), North-East aspect and 48° steep slope was selected (Fig. 1). Wood samples from 40 healthy *Abies pindrow* trees were collected using the Swedish increment borer. The coring technique and samples preparation were carried out following the method given by Stoke & Smiley (1968). The visual cross dating of core were conducted using the binocular microscope and skeleton plot technique. Some cores were rejected due to complacent ring and some other problem in their ring width. The cores showing good cross-matching were measured using the Velmex stage machine (nearest 0.001mm) attached to a computer program and camera. For checking the measurement accuracy and possible dating error in tree-ring series, a quality control programs COFECHA was used (Holmes *et al*., 1986; Grissino-Mayer, 2001). To obtain the standard site chronology the cross dated tree-ring series were then subjected to computer software ARSTAN developed by Cook (1985).

Results and Discussion

Fig. 1 shows the location map of Pakistan and site location on Indus Kohistan area while Table 1 is a statistical summary of all wood samples (cores) after visual cross-dating, ring measurement and using quality control program COEFCHA. It shows that cores not only properly cross dated but are also free of any measurement problem. Oldest core had 394 rings while youngest sample was 171 years old. Many chronologies produced in Pakistan covering the same time while Ahmed *et al.* (2011), Cook *et al*. (2013) and Zafar *et al.* (2015) established 500 years long chronologies. Average correlation with master chronology was 0.622 with a mean ring width of 1.42 mm. Similar results were obtained by Ahmed (1989), Khan *et al*. (2008) and Ahmed *et al*. (2010a) for *Abies pindrow* and other pine species of northern Pakistan.

Autocorrelation, which shows all factors responsible for growth, was considerably higher (0.823) however after detrending of the series it reduced to -0.026. Higher values of autocorrelation was reported by many researchers i.e. Ahmed, (1989), Ahmed & Naqvi (2005); Ahmed *et al*. (2010 a, b; 2011) in different pine species of Pakistan. Hughes & Davies (1986) also reported high autocorrelation in *Abies pindrow* from Indian Kashmir area. According to Ahmed & Ogdom (1985), amount of higher autocorrelation may be due to size, inter and intra species competition among trees in area. LaMarche (1974); Ahmed (1989) stated that high values may be due to retention of leaves for several decades. All above mentioned reasons may be associated with our autocorrelation values.

Mean sensitivity, which show ring to ring variability determined positive character of tree-rings for higher dendrochronological research, was 0.186. Since present sampling area belong to dry temperate area, our result is close to the same species of Astore (dry temperate) while lower than Ayubia (moist temperate) of Pakistan (Ahmed, 1989; Ahmed *et al*., 2010a). However according to LaMarche (1982) low mean sensitivity does not mean that the strong climatic signal area absent. Raw ring width chronology (Fig. 2a) included all factors responsible for tree-ring or plant growth. It is indicated that from 1630 to 1970 AD growth rate was higher and above average with a few years of below average growth around the year 1650, 1725, 1775. Growth rate decreased from 1780 to 1850 for a few short periods over or under average growth. It was further decreased from the year 1860 to 2010 AD, showing below average growth rate. The possible reason of slow growth is due to the start of anthropogenic disturbances or may be the old age of the trees.

All sample occupied the same common years up to 1830 AD, while beyond this year sample size decreased but still satisfactory until the year 1740, however (Fig. 2b) indicated low sample size before this period. Therefore it is suggested that more samples are needed to obtain more statistical sound chronology for not only this period but should be extended further back in time.

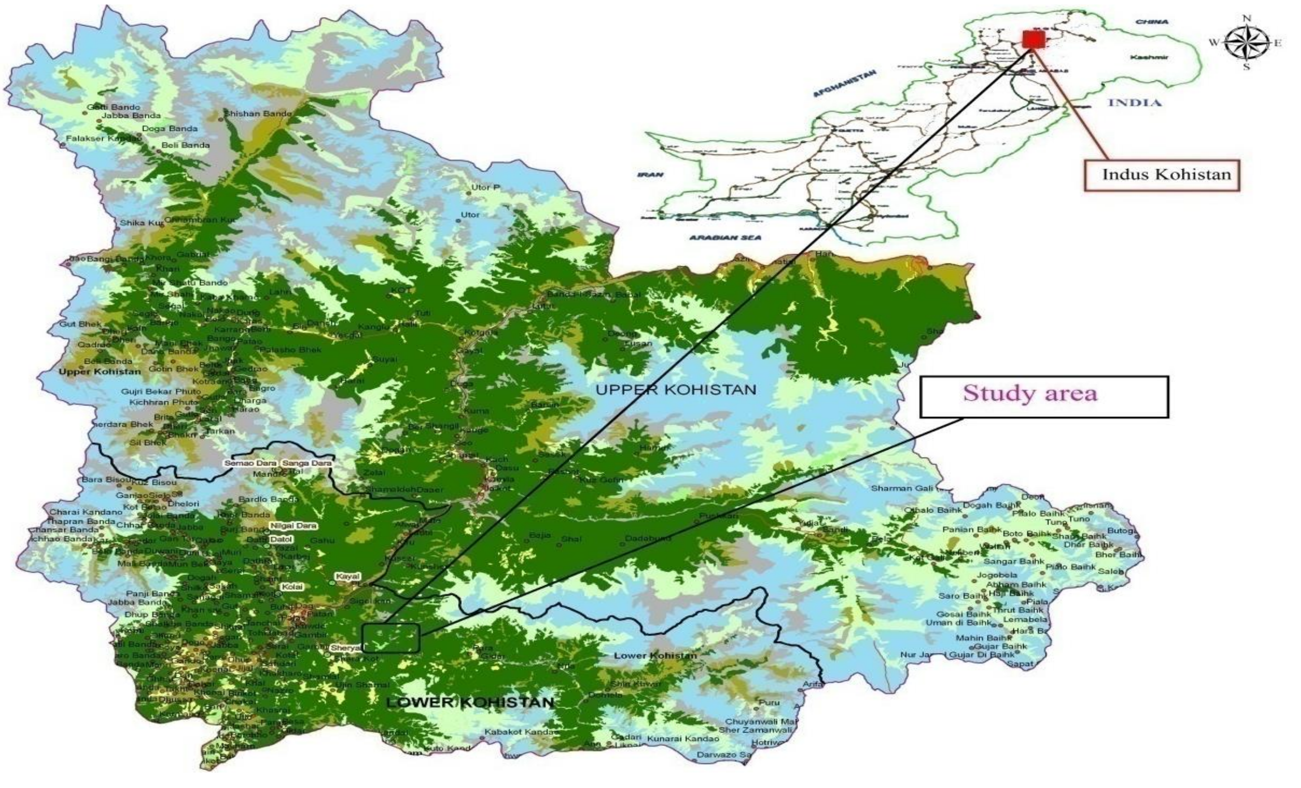

Fig. 1. Showing Indus Kohistan in Pakistan and main location of study area.

Table 1. Showing the descriptive statistics using cofecha program.

Seq series	Interval		No. years	No. segmt	[1]No. flags	[2]Corr with master	//------------- Filtered ------------------------\\					//----------Unfiltered------------\\			
							[3]Mean msmt	[4]Max msmt	[5]Std. dev.	[6]Auto corr	[7]Mean sens	[8]Max value	[9]Std. dev.	[10]Auto corr	[11]AR ()
1 ABPI002A	1620	2013	394	15	0	0.637	1.01	4.14	0.445	0.753	0.201	2.53	0.295	-0.017	1
2 ABPI006A	1724	2013	290	12	0	0.662	1.06	2.30	0.382	0.818	0.168	2.59	0.310	-0.040	1
3 APBI007A	1732	2014	283	11	0	0.543	1.03	2.84	0.587	0.901	0.194	2.70	0.354	-0.010	1
4 ABPI008A	1669	2014	346	14	0	0.688	0.95	3.31	0.528	0.905	0.167	2.76	0.342	-0.004	1
5 ABPI009A	1725	2014	290	11	0	0.662	1.17	3.28	0.452	0.751	0.198	2.58	0.370	-0.023	1
6 ABPI010A	1734	2014	281	11	0	0.516	1.14	2.89	0.502	0.847	0.185	2.40	0.238	-0.052	1
7 ABPI012A	1673	2013	341	14	0	0.606	0.87	2.07	0.456	0.879	0.203	2.48	0.290	-0.034	1
8 ABPI013A	1830	2000	171	7	0	0.528	0.75	1.50	0.187	0.467	0.206	2.68	0.431	-0.034	2
9 ABPI016A	1760	2014	255	10	0	0.411	1.20	2.88	0.540	0.797	0.220	2.65	0.379	0.003	1
10 ABPI017A	1685	2014	330	13	0	0.572	0.86	3.00	0.378	0.864	0.176	2.63	0.410	-0.032	1
11 ABPI019A	1716	2014	299	12	0	0.681	1.12	3.64	0.445	0.781	0.184	2.41	0.227	-0.042	1
12 ABPI021A	1720	2014	295	12	0	0.524	1.13	3.24	0.540	0.885	0.156	2.57	0.356	-0.021	1
13 ABPI023A	1750	2014	265	10	0	0.632	0.95	2.42	0.334	0.749	0.183	2.91	0.502	-0.013	2
14 ABPI023B	1690	2014	325	13	0	0.661	1.06	3.46	0.564	0.826	0.194	2.95	0.341	-0.037	1
15 ABPI025A	1629	2013	385	15	0	0.616	1.02	3.00	0.576	0.890	0.199	2.68	0.383	0.005	3
16 ABPI027A	1690	2014	325	13	0	0.721	0.86	3.07	0.399	0.781	0.188	2.78	0.353	-0.010	1
17 ABPI027B	1700	2014	315	12	0	0.675	0.93	3.00	0.382	0.739	0.223	2.54	0.333	-0.046	1
18 ABPI028A	1760	2014	255	10	0	0.578	1.15	2.71	0.504	0.864	0.193	2.47	0.353	-0.073	1
19 ABPI029A	1670	2014	345	14	0	0.734	0.84	2.61	0.418	0.885	0.169	2.53	0.331	-0.037	1
20 ABPI032A	1750	2004	255	10	0	0.544	1.22	3.96	0.536	0.867	0.167	2.69	0.422	0.039	2
21 ABPI036A	1750	2011	262	10	0	0.630	1.08	2.37	0.456	0.844	0.173	2.57	0.299	-0.046	1
22 ABPI036B	1756	1999	244	9	0	0.763	11.79	27.77	4.583	0.838	0.145	2.60	0.359	-0.048	1
Total or mean			**6551**	**258**	**0**	**0.622**	**1.42**	**27.77**	**0.617**	**0.823**	**0.186**	**2.95**	**0.346**	**-0.026**	

Note: 1 = No of problems, 2 = Correlation with master, 3 = Mean measurement, 4 = Maximum measurement, 5, 9 = Standard deviation, 6, 10= Autocorrelation, 7= Mean sensitivity, 8=Maximum value, 11= Autoregressive model

Table 2. Statistical summary of autoregressive standardization (ARSTAN) analysis.

A. Arstan chronology auto and partial autocorrelations

lag	t-1	t-2	t-3	t-4	t-5	t-6	t-7	t-8	t-9	t-10
acf	0.504	0.323	0.150	0.050	-0.016	-0.044	-0.081	-0.041	-0.084	-0.068
pacf	0.504	0.092	-0.060	-0.038	-0.034	-0.017	-0.050	0.039	-0.075	-0.008
95% c.l	0.101	0.124	0.132	0.134	0.134	0.134	0.134	0.134	0.135	0.135

A. Standard chronology statistics

First year	Last year	Total years	Mean Index	Stdrd dev	Skew coeff	Kurtosis coeff	Mean sens	Serial corr
1620	2014	395	0.980	0.215	1.521	17.932	0.143	0.463

B. Residual chronology statistics

First year	Last year	Total years	Mean Index	Stdrd dev	Skew coeff	Kurtosis coeff	Mean sens	Serial corr
1620	2014	395	0.991	0.171	-0.517	10.218	0.180	0.044

C. Arstan chronology statistic

First year	Last year	Total years	Mean Index	Stdrd dev	Skew coeff	Kurtosis coeff	Mean sens	Serial corr
1620	2014	395	0.993	0.201	0.144	6.865	0.140	0.506

Table 2 and Fig. 2c, d and e shows the statistical summary of autoregressive standardization and 3 types of chronologies produced by running ARSTAN program. It removed most of the non-climatic effect from the chronologies.

The three chronologies are:

1) Residual chronology: The auto regressive modeling of standardized value (mean index=1) with no lag (previous) year effect produced residual chronology.
2) Standard chronology: If there is no auto regressive modeling and chronology having lag year effect then they produced standard chronology.
3) Arstan chronology: This chronology is produced by the reincorporating of pooled auto regressive model with some lag year effect.

Arstan and Residual chronology show almost same mean index value but standard deviation was higher in Arstan chronology (Table 2). The EPS value of this study decrease before 1705 from threshold value of 0.85 (Wigley *et al*., 1984) whereas SNR (Signal-to-noise ratio) and Rbar were 9.948 and 0.531 respectively. Lowest mean index value (0.980) with highest (0.215) standard deviation was recorded in stand chronology. Due to inclusion and exclusion of lag year these chronologies are slightly different. Further detailed analyses (Response, correlation and Transfer function analyses) will determine that which chronology is most suitable and produce positive results. At present this was beyond the scope of this paper. However, On the basis of this results and discussion it is concluded that *Abies pindrow* of Sharakot valley has valuable climatic signal for reconstruction of past climate. However, it is suggested that the sample size and sites should be increased for the realistical determination of the past climatic fluctuations.

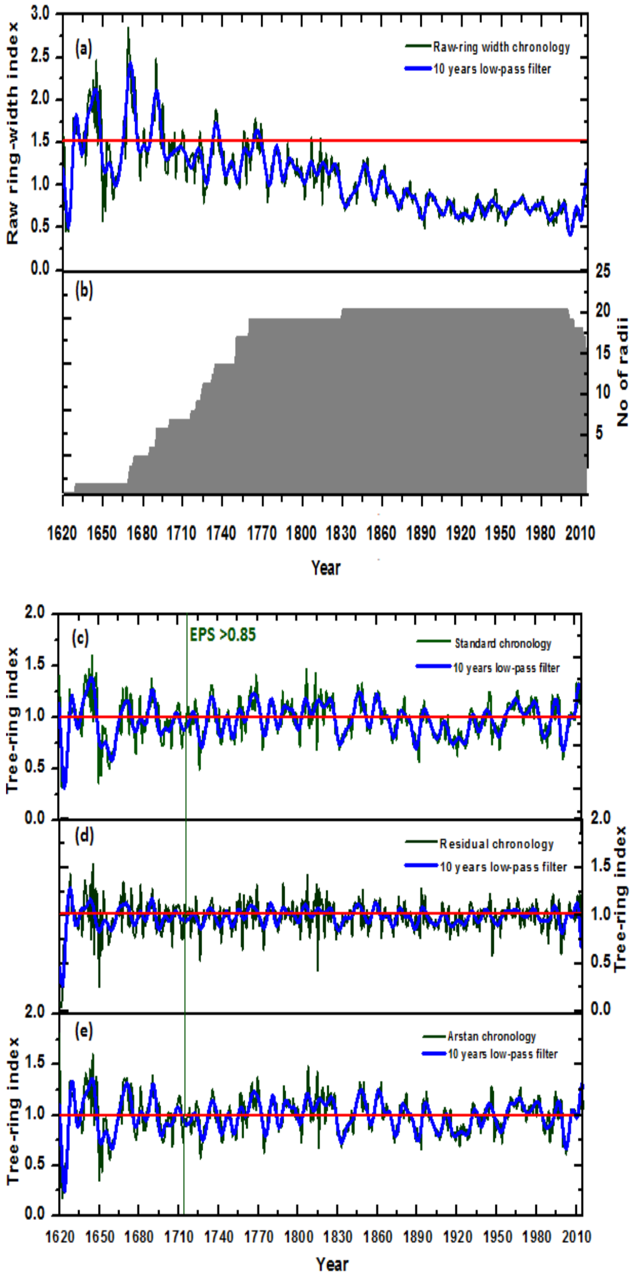

Fig. 2. Raw ring-width measurement (a), sample depth (b) and different chronological versions (c = Standard, d = Residual and e = Arstan) of *Abies pindrow* from Sharakot (Palas valley) of Indus Kohistan, KPK, Pakistan.

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