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DENDROSEISMOLOGICAL POTENTIAL OF PINE TREE SPECIES OF AZAD JAMMU AND KASHMIR-PAKISTAN: A PRELIMINARY STUDY

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Abstract

The present study deals with the dendroseismological potential of five pine tree species of Azad Kashmir-Pakistan, i.e., *Pinus wallichiana* A.B. Jackson, *Pinus roxburghii* Sargent, *Picea smithiana* (Wall) Boiss., *Cedrus deodara* (Roxb.) G. Donf., and *Abies pindrow* Royle. Since Azad Kashmir is known as a major seismological disturbed area of Pakistan, emphasis is given on landslides, earthquake other past disturbance events and their effects on annual growth rings of pine tree species of this area. A total of 325 cores from 180 trees were sampled from different parts of Azad Kashmir close to and on fault line area. Among them *Abies pindrow* and *Cedrus deodara* produced cross match-able ringwidth series. Group of missing/double rings and abrupt growth change was recorded in various wood samples with a clear wound scars showing some sort of past disturbance. This preliminary study revealed that among five pine tree species, two species showed some signs of disturbance of the past. However, further extensive study is required to investigate past earthquake/disturbance and response of these two species in Azad Kashmir area.

Introduction

Pakistan is situated in a very seismically active region, which has experienced many disastrous earthquakes during historical times. The country is prone to earthquakes because it lies in the collision zone of the Indian tectonic plate to the South and the Eurasian plate to the North. The Northern part of Pakistan is a key area for various seismological studies. More than a million earthquakes rattle the world each year. The most recent significant earthquake of magnitude 7.6 struck on the India-Pakistan border in the Kashmir region at 08:50:38 Pakistan Standard Time on October 8, 2005 with the epicenter in the Pakistan-administered region of the Azad Jammu and Kashmir in South Asia. The State of Jammu and Kashmir encompasses a mountainous region in the heart of Asia, with borders touching to both South and Central Asia, surrounded by Pakistan, India, China and Afghanistan. In these areas Azad Kashmir has high potential for landslides and earthquake investigation through tree-rings. It covers an area of 13,300 km square, location is 73.75 longitude and 33.36 latitude in the North-East of Pakistan.

This is a first kind of investigation in our country which deals with Dendroseismology, the sub-branches of Dendrochronology to explore the potential of Pine tree rings to the past disturbance events. Dendrochronology is the science that uses tree rings dated to their exact year of formation to analyze temporal and spatial patterns of various processes (biological, physical, or cultural). Dendrochronology is a rapidly growing field with many sub-disciplines like dendroclimatology, dendroecology, dendroseismology, dendrohydrology etc. Only a limited amount of tree-ring research has been conducted in Pakistan and all of it has been based on conifer species. The starting point was an introductory paper "Dendrochronology and its scope in Pakistan" by Ahmed (1987; 1988; 1989). He also mentioned the problems encountered with tree age estimation. Ahmed & Naqvi (2005) and Khan *et al*., (2008) worked on dendrochronological potential of *Picea smithiana* in Himalayan range of Pakistan and Afghanistan respectively while Ahmed *et al*., (2009a,b) determined the dendroclimatic potential and age/growth rates of many gymnosperm species. Ahmed *et al.*, (2010, 2012) have presented tree-ring chronologies and growth-climate response from Upper Indus Basin of Karakorum Range of Pakistan. Twenty eight chronologies of Conifers from Northern areas of Pakistan are also presented by Ahmed *et al*., (2011). Siddiqui *et al.,* (2013) used modern techniques of dendrochronology for the estimation of age and growth rate conifer species from moist temperate areas of western Himalayan and Hindukush range of Pakistan. However, no work so far, has been carried out to study how Pine tree species of Azad Kashmir and its adjoining areas respond to natural disasters like earthquake, therefore the present study will be the first attempt in this direction.

Tree shaking and damage is reported during earthquake events by Lawson (1908), Fuller (1912), Jepson (1923), Lauderback (1947) and Gongxu (1989). Lyell (1849) suggested that tree ring analysis could provide information about past earthquakes. Jacoby & Ulan (1983), Jacoby *et al.*, (1988, 1992) used tree-ring data to support his conclusion. Cook & Kairiukstis (1990) described various methods of dendrochronology and its applications in the environmental sciences. Application of Dendrochronological techniques to paleo-seismology is described by Jacoby (1997) and Jacoby *et al*., (1999). Studies of D'Arrigo *et al.,* (2003) in Northern North America indicated a spatial variation in tree-rings reflecting cooling due to volcanic events around AD 1640, 1783, 1815 and other years. Solomina (2002) reviewed various problems relating dendrogeomorphology while Bekker (2004) described the effects of tree location, size and age on the tree rings.

The study area includes Sudhan Gali, Chakothi, Chikar, Kail, Pir Chinasi, Keran, Muzaffarabad and Sharda. We have sampled specifically those areas which were closed to the fault line. The present study was aimed to know the dendrochronological potential of Pine species of Azad Kashmir and how they respond to natural (earthquake and landslides) and un-natural (anthropogenic disturbances) events? It is hoped that this study would open a new door and would determine a new direction of research in this field of seismology in Pakistan.

Materials and Methods

Eight sites were sampled for the collection of cores from various Pine species. Approximately 325 cores from 180 trees were obtained. Samples were taken from those individual trees which were located near fault line and were sound and free from severe competition from neighbours. At least two cores (uphill and downhill) per tree were taken using a hand operated Swedish Increment Borer. GPS was also used to record the elevation, locations and aspect of sampling sites. Coring procedure, handling in field, sample preparation and cross-dating were followed by Stokes & Smiley (1968) and Ahmed (1984). The cores were subjected to visual cross-dating under a stereoscopic microscope to locate any missing and false (double) rings. Years of abrupt growth, extremely narrow/wide ring, sign of injury and sudden change in ring sequence are also recorded and properly dated. After the visual cross-matching under the microscope, rings of each core were measured on computer-compatible measuring machine (Velmex) using program COFECHA (Holmes *et al*., 1986) to check quality of ring width characteristic and cross-dating. The radial uniformity of the tree, and the ring-width pattern of the site, was checked by cross-matching the cores from the same tree and with different trees. Good crossmatching was achieved on a few sites and missing and false rings were identified in their correct sequence. But in some stands crossdating was extremely poor and ring sequences within or among trees could not be crossmatched. In such trees ageing was based on a simple ring count, with extrapolation for any missing portions of the total radius. Tree-ring series were standardized by using another computer program ARSTAN. Standardization changes the ring widths into dimensionless indices, removes age-growth trends and permits the raw data to be averaged into a single index chronology for each site (Fritts, 1976).

Results and Discussion

Details of sampling sites are given in Table 1, while location of Azad Jammu and Kashmir, fault lines and study sites are shown in Fig. 1. A few cross-sections of *Abies pindrow* and *Cedrus deodara* are shown in Fig. 2(a-d). Cross-section of *Abies pindrow* is showing abrupt growth, extremely narrow/wide ring, sign of injury and sudden change in ring sequence due to various possible landslides in these areas. In Fig. 2(b), cross-section of *Abies pindrow* is showing damage due to landslide in 1996 at Sudhan Gali & bark from both of the sides is trying to cover the wound. Fig. 2(b) there is also wound scar due to landslide hit in 1909. There is also merging of rings in cross section of this species showing sign of extreme environment. Group of missing/double rings and abrupt growth change was recorded in cross-section of *Cedrus deodara* with a clear wound scars showing landslide hit in 1908-1909 at Kail Fig. 2(a). Cross section of *Cedrus deodara* also shows a pattern of wide and narrow rings in late 1980s and 1930s. It is clear from Fig. 2(c), that during the period of 1987-1995 the rings were very wide while in 1970-1980 the rings were very narrow. This sort of ring width pattern shows various natural and anthropogenic disturbances affecting growth of these species. The results revealed that among five pine tree species, two species showed some signs of disturbance in the past. *Abies pindrow* provide 309 and 85 years of chronology from Sudhan Gali & Pir Chinasi while using *Cedrus deodara* 221 and 118 years of chronologies were obtained from Kail and Keran respectively. In each chronology sample size is considerably short to cover maximum chronology length. Many narrow rings were found in same calendar year in cores of many trees, showing good cross-matching. The core samples of *Abies pindrow* and *Cedrus deodara* were also cross-matched with the cross-sections of both of these species. In the whole time span, years of slow radial growth (narrow rings) and rapid radial growth (wide rings) are presented in Table 2. It showed that the samples collected from landslide area were highly disturbed due to various past events and can be further used to analyze various environmental and anthropogenic disturbances. Data about various past disturbance events like earthquakes, landslide and fire were also taken from local people of these areas. The difference of occurrence of these events was about five to ten years. But still we can go back in time to date these past events by the help of dendroseismological techniques, however more samples with more annual growth rings are required.

Among five pine tree species, *Abies pindrow* and *Cedrus deodara* produced cross match-able ringwidth series. Results of cross-dating of *Abies pindrow* and *Cedrus deodara* using COFECHA program are given in Table 3. Average correlation among these cores was low which may be increased after removing of short cores with negative correlation values. Amount of autocorrelation ranged for 0.705 and 0.838 in these chronologies, while mean sensitivity values were ranging from 0.205 to 0.299. In each chronologies COFECHA show various places of abnormal growth. The narrow and wide ring years were sorted out in both the species from each site. This is the first attempt to analyze the growth-disturbance relationship; therefore, only raw and standard chronologies were used to see the impact of various past disturbance events on these pine tree species. Raw ringwidth chronologies before and after standardization of these two species are shown in Fig. 3(A-D), we fitted negative exponential curve to check growth trends of these species. It is shown that growth is continuously decreasing after 1980 till early 2000 in both of these species. On the other hand, there is also a positive growth trend before and after 1960 till early 1970s in both of these species. It is anticipated that these areas may show sign of various anthropogenic disturbances. After 2005, a major earthquake event, most of the fallen, damaged or bended trees has been removed by the people to construct their houses. Therefore, it was very difficult to find those samples.

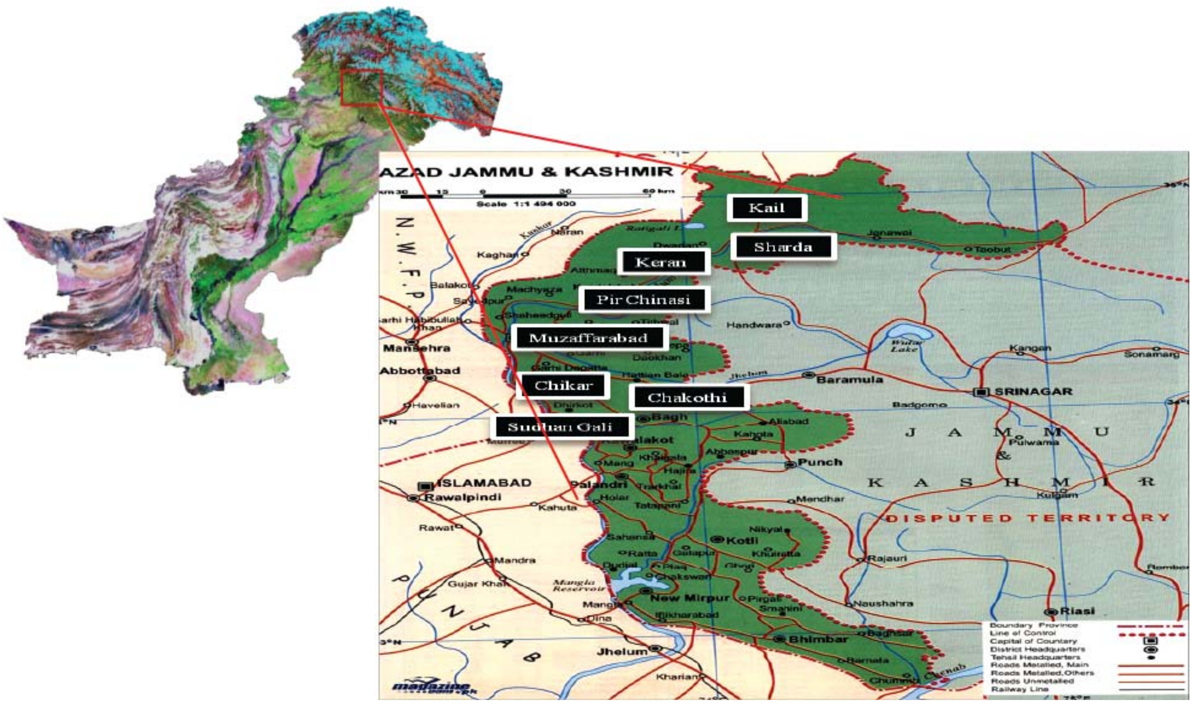


Fig. 1. Map of Azad Kashmir indicating Study area and main earthquake sites/ fault lines.

Table 1. Ecological characteristics of sampling sites of Azad Kashmir.

S. No.	Sites	Lat. (N)	Long. (E)	Elev. (m)	Asp.	No. of samples taken
1.	Sudhan Gali	34˚ 22	70˚ 28	2500	N	100
2.	Chakothi	34˚ 11	73˚ 88	2114	NE	45
3.	Chikar	34˚ 08	73˚ 40	1609	NW	25
4.	Kail	34˚ 49	74˚ 21	2743	SW	40
5.	Pir Chinasi	34˚ 22	73˚ 32	2900	N	42
6.	Keran	34˚ 22	73˚ 79	1997	NE	27
7.	Muzaffarabad	34˚ 22	73˚ 28	833	NE	26
8.	Sharda	34˚ 46	74˚ 09	2134	N	10

Lat. = Latitude, Long. = Longitude, Elev. = Elevation, Asp. = Aspect

Table 2. List of narrow and wide rings in *Abies pindrow* and *Cedrus deodara* from different sampling sites of Azad Kashmir.

Species name	Site name	Narrow rings	Wide rings
Abies pindrow (1940-2008)	Pir Chinasi	1999, 1993, 1992, 1990, 1988, 1987-80, 1977-76, 1974-69, 1966, 1962-60, 1955, 1953-1940	2008-2000, 1998-94, 1991-89, 1979-78, 1975, 1968-63, 1959-54, 1944-41
Abies pindrow (1890-2008)	Sudhan Gali	2007-05, 2001-84, 1979-77, 1958-57, 1953-46, 1942-35, 1933-26, 1922-18, 1909-07, 1905, 1902-1894	2004-02, 1983,-80, 1976-59, 1956-54, 1945-43, 1934, 1925-23, 1917-10, 1910, 1906-03, 1893-90
Cedrus deodara (1820-2008)	Kail	2007-1993, 1991-79, 1975, 1973, 1971-1948, 1946-45, 1919-1856, 1839-38, 1834-26	1992, 1978-76, 1974, 1972, 1947, 1944-20, 1855-40, 1837-35, 1833, 1825-20
Cedrus deodara (1912-2008)	Keran	2006, 2004, 1997-79, 1977, 1975-1973, 1971, 1967-66, 1957-55, 1946-45, 1942, 1939-37, 1928-22, 1919-18	2007, 2005, 2003-98, 1978, 1976, 1972, 1970-68, 1965-58, 1954-47, 1941-40, 1936-29, 1921-20, 1917-1912

On the basis of this preliminary investigation, it may be suggested that sign of landslides and rock damage can be properly dated from the wood cross-section. However it may also be recognize in core samples. Ring may respond both way (suppression or release) and *Cedrus deodara* chronology (1820-2008) shows some sudden suppression and release in the year (1860-1920). These are the prominent earthquakes in Azad Kashmir. These tree rings response may be due to earthquake. In addition present chronologies are not large enough (220 years) to detect past earthquakes. Therefore more samples with more annual growth rings (atleast 300 to 400 years) are required.

Table 3. Summary of Cofecha statistics of different sites.

Species/ Sampling sites	[1]Mean msmt.	[2]Std dev.	[3]Max value	[4]Mean sens.	[5]Corr.with master	[6]Auto corr.
1. *Cedrus deodara* Kail	2.00	0.981	12.20	0.205	0.162	-0.015
2. *Cedrus deodara* Keran	2.53	1.380	8.61	0.240	-0.043	-0.013
3. *Abies pindrow* Sudhan Gali	1.89	1.261	13.74	0.299	0.250	-0.015
4. *Abies pindrow* Pir Chinasi	3.58	1.474	9.62	0.249	0.282	0.025

Note: 1 = Mean ring width measurement, 2 = Standard deviation, 3 = Maximum value, 4 = Mean sensitivity, 5 = Correlation with master chronology, 6 = Autocorrelation

Fig. 2(a). C.S of *Cedrus deodara* showing 1. Uncountable (Indistinct) narrow rings. 2. Lobote growth. 3. Merging of the wide rings. 4. Wound mark. 5. and 6. Double / False rings.

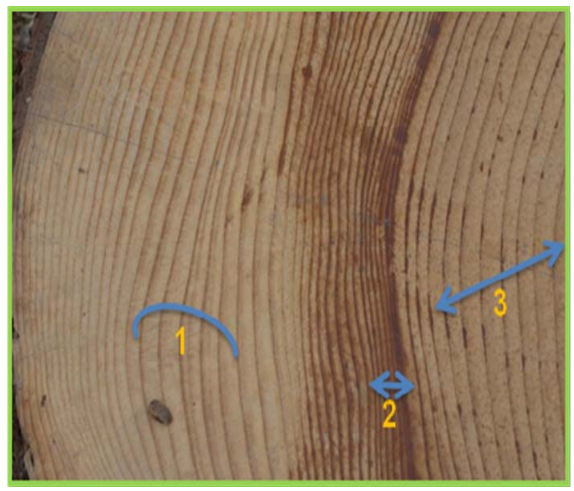
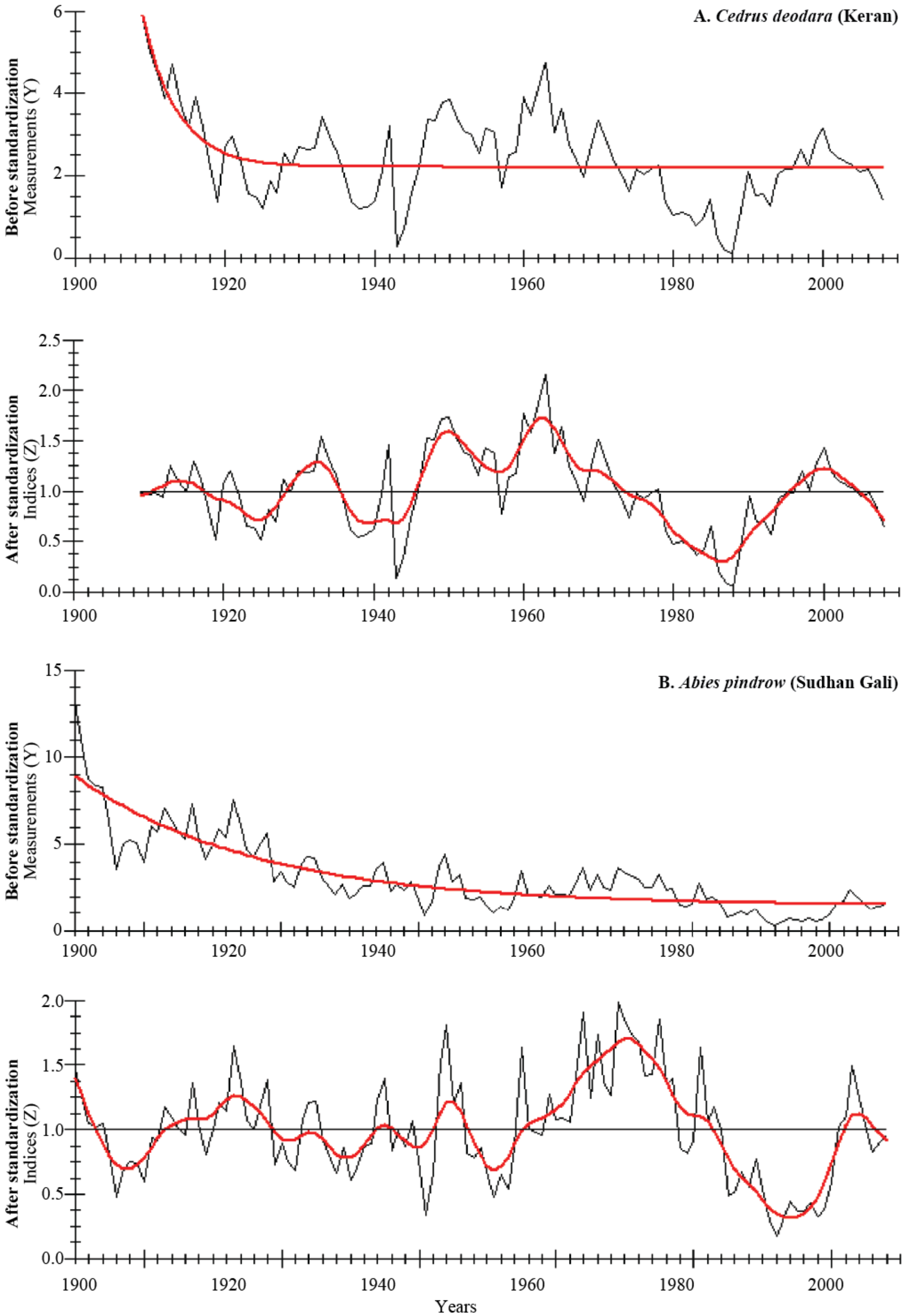


Fig. 2(c). C.S. of *Cedrus deodara* showing Lobote growth. 2. Narrow rings. 3. Complacent rings.

Fig. 2(b). C.S of *Abies pindrow* showing the damage due to landslide, bark from the both sides trying to cover or overlap the wound. (Scale 4″ x 6″).

Fig.2(d). C.S. of *Abies pindrow* showing Wound Scar. 2. Merging of the rings.


A. *Cedrus deodara* (Keran)
Before standardization
Measurements (Y)
After standardization
Indices (Z)
B. *Abies pindrow* (Sudhan Gali)
Before standardization
Measurements (Y)
After standardization
Indices (Z)
Years

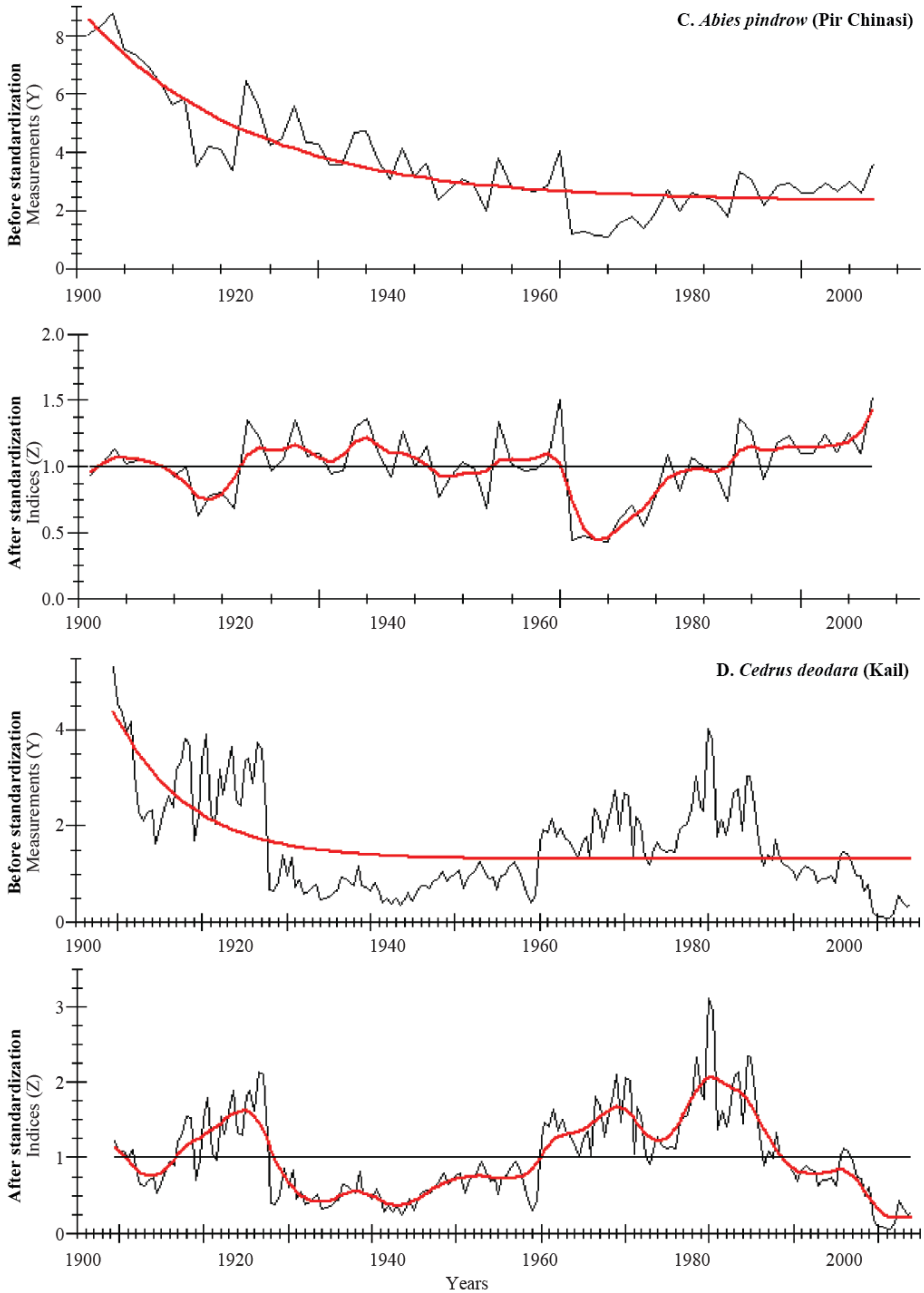


Fig. 3(A-D). Showing raw ring-width chronologies of *Abies pindrow* and *Cedrus deodara* before and after standardization from different sites of Azad Jammu and Kashmir.

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