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.


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 (Velmax) 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.
Table 1. Ecological characteristics of sampling sites of Azad Kashmir.

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


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

<table>
<thead>
<tr>
<th>Species name (Year)</th>
<th>Site name</th>
<th>Narrow rings</th>
<th>Wide rings</th>
</tr>
</thead>
</table>
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>
<thead>
<tr>
<th>Species/ Sampling sites</th>
<th>1Mean msmt.</th>
<th>2Std dev.</th>
<th>3Max value</th>
<th>4Mean sens.</th>
<th>5Corr.with master</th>
<th>6Auto corr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cedrus deodara Kail</td>
<td>2.00</td>
<td>0.981</td>
<td>12.20</td>
<td>0.205</td>
<td>0.162</td>
<td>-0.015</td>
</tr>
<tr>
<td>2. Cedrus deodara Keran</td>
<td>2.53</td>
<td>1.380</td>
<td>8.61</td>
<td>0.240</td>
<td>-0.043</td>
<td>-0.013</td>
</tr>
<tr>
<td>3. Abies pindrow Sudhan Gali</td>
<td>1.89</td>
<td>1.261</td>
<td>13.74</td>
<td>0.299</td>
<td>0.250</td>
<td>-0.015</td>
</tr>
<tr>
<td>4. Abies pindrow Pir Chinsa</td>
<td>3.58</td>
<td>1.474</td>
<td>9.62</td>
<td>0.249</td>
<td>0.282</td>
<td>0.025</td>
</tr>
</tbody>
</table>

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

Fig. 2(d). C.S. of Abies pindrow showing Wound Scar. 2. Merging of the rings.
A. Cedrus deodara (Kerau)

B. Abies pindrow (Sudhan Gali)
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.
References


(Received for publication 27 February 2012)