APPLICATION OF TREE RINGS IN EARTHQUAKE STUDIES IN PAKISTAN

Tasveer Zahra Bokhari[1], Zaheer-ud-Din Khan[2], Moin-ud-Din Ahmed[3], Nasrullah Khan[3] and Nadeem Ullah[2]

[1] *Botany Division IP&AB, Bahauddin Zakariya University, Multan, Pakistan*
[2] *Botany Department, GC University, Lahore, Pakistan*
[3] *Laboratory of Dendrochronology and Plant Ecology, Department of Botany, FUUAST, Gulshan-e-Iqbal Campus, Karachi, Pakistan*

ABSTRACT

The present study reports the dendroseismological potential of pine tree species including *Pinus wallichiana, Picea smithiana, Abies pindrow, Pinus roxburghii, Cedrus deodara.* A total of 261 cores from 213 trees were sampled from different areas of Azad Jammu and Kashmir. These samples were processed following the standard dendrochronological techniques described by Stockes & Smiley (1965). The preliminary results revealed that these tree samples exhibit great age and show sensitivity to the environment. These are preliminary results which would be helpful to determine the dendroseismological potential of these trees and sites of the study area.

Keywords: *Pinus wallichiana, Picea smithiana, Abies pindrow, Pinus roxburghii, Cedrus deodara,* Dendroseismological potential, dendrochronological techniques

INTRODUCTION

Pakistan is situated in a very seismically active region, which has experienced many disastrous earthquakes during historical times. An earthquake is a tremor of the earth's surface usually triggered by the release of underground stress along fault lines (http://www.answers.com/topic/earthquake). This release causes movement in masses of rocks and result in shock waves. In spite of extensive research and sophisticated equipment, it is impossible to predict an earthquake, although experts can estimate the likelihood of an earthquake occurring in a particular region. More than a million earthquakes rattle the world each year (http://www.weatherwizkids.com /weather-earthquake.htm.).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 disputed territory of Kashmir in South Asia. The epicenter was located about 95 kilometres to the Northeast of Islamabad. Shocks were felt over a radius of some 300-400 kilometers in Northwest India, Northern Pakistan and Afghanistan (Anonymous 2007).

Pakistan 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. In these areas Azad Kashmir has high potential for earthquake. The area is located between 73º.7 longitude, 33 º.36′ latitude and lies in the north east of Pakistan. It covers an area of 13,300 km square and has an estimated population of three million people.

The Azad Kashmir earthquake of 2005 was a major seismological disturbance. It registered 7.6 on Richter scale making it a major earthquake similar in intensity to the 1935 Quetta earthquake and comparable overseas to the 2001 Gujarat Earthquake, and the 1906 San Francisco earthquake (Anonymous 2007).

In the present investigation an attempt has been made to find out the growth rate, age, and sensitivity primarily and than use this information for natural (earthquake and landslides) and un-natural (anthropogenic disturbances) events.

Since Azad Kashmir is known as a major disaster area (earthquake) of Pakistan, so we are giving more emphasis on earthquake events and their effects on annual growth rings of Pine tree species. This is a first kind of investigation in our country in which we are dealing with Dendroseismology and Dendroecology, the sub-branches of Dendrochronology. It is anticipated that the results would describe the potential of Pine tree species for past disturbance events and its dynamics in Azad Kashmir and its adjoining areas.

MATERIALS AND METHODS

Tree wood samples of different Pine species from the study area were collected using modern dendrochronological techniques. Map of wood collection sites and major earthquake zones of study area are shown in Fig.1. Then these samples were prepared and mounted in the laboratory for analysis and cross-dated under the

microscope. These wood samples were measured by using computer compatible Velmex Measuring system. Construction of master chronologies for each suitable tree species would be done by using COFECHA (Holmes, 1994). These ring width measurements will be then subjected to DPL (ARSTAN) (Cook, 1985; Holmes, 1994) computer program.

REVIEW OF LITERATURE

There has been extensive geological research throughout Pakistan in order to identify the areas that are at greatest risk to future events. One development has been a map created by the Pakistan Meteorological Department where the country is divided into 4 zones based on expected ground acceleration. The areas surrounding Quetta, along the Makran coast and parts of the NWFP, along the Afghan border fall in Zone 4. The rest of the NWFP lies in Zone 3, with the exception of Southern parts of this province, which lie in Zone 2. The remaining parts of the Pakistani coast upto Karachi also lies in Zone 3. The remaining parts of the country lie in Zone 2. The major cities of Peshawar, Rawalpindi and Islamabad are situated in this zone. But despite this, strong earthquakes from the North or from neighbouring Afghanistan regularly rattle them. The upper Westernmost part of Balochistan and region along the border with India lie in Zone 1. This zone also includes Lahore where there was serious damage caused by the 1905 Kangra earthquake in neighbouring India (Anonymous 2007).

The most vulnerable parts of Pakistan are parts of Balochistan province in and around Quetta stretching to the Afghan border and Western parts of Balochistan, which include the Makran coast till the Iranian border. These regions could expect to have maximum peak ground acceleration (PGA) ranging between 0.24g to 0.4g. Parts of Northern Punjab could expect a maximum PGA ranging between 0.24g to 0.32g. Similar values of PGA could be expected in Northern sections of the North-West Frontier Province (N.W.F.P.) and around Karachi, in Sindh Province. Maximum PGA values for the rest of the country do not fall below 0.8g. These values steadily decrease towards the Indian border. The region with the lowest maximum PGA is a region between Khangarh and Fort Abbas, along the borderline with India (Anonymous 2007).

In order to develop an accurate assessment of the risk of future earthquakes, the history of past earthquakes is needed in as much detail as possible. Written records can only help us to go back to a limited time period. The use of tree-rings can tell us when past events happened beyond any written records. This is a new approach and developed countries are using it to investigate past earthquakes with Dendroseismology. Tree-ring studies have started in Pakistan to explore forest dynamics, climatology and hydrology. But unfortunately, there has been no research in the field of Dendroseismology so far. Therefore bearing these points in mind, the present study is designed to investigate the potential of Pine tree rings for past earthquake investigation in Azad Kashmir, Pakistan.

TREE RING RESEARCH IN PAKISTAN

Tree-ring research has been conducted in Pakistan and that generally relates to the conifer species. The starting point was an introductory paper "Dendrochronology and its scope in Pakistan" by Ahmed (1987). Ahmed (1988) also mentioned the problems encountered with tree age estimation. Subsequent papers presented standardized *Abies pindrow* tree-ring chronologies from moist temperate region of the country (Ahmed, 1989) and focus on population dynamics of *Juniperus excelsa* and *Pinus gerardiana* in dry temperate areas (Ahmed *et al*. 1990a, 1990b & 1991). Ahmed and Sarangzai (1991 & 1992) and Ahmed *et al*. (2009b) estimated age and growth rates of various conifer species. An important work by Treydte *et al*. (2006) led to the reconstruction of millennial precipitation based on tree-ring oxygen-isotope concentrations. Systematic tree-ring investigations started from 2005 by Ahmed and Naqvi (2005). Khan *et al*. (2008) worked on dendrochronological potential of *Picea smithiana* from Afghanistan while Ahmed *et al*. (2009a) determined the dendroclimatic potential of the same species. 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. Though no work has been published in Pakistan but a number of investigations were carried out in different parts of the world. 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 and Ulan (1983) used tree-ring data to support his conclusion of substantial seaward shifting of shoreline after around 1900. Jacoby *et al.* (1988) examined growth rings of trees near the San Andreas Fault to date precisely the second most recent event and to estimate its fault rupture length. Jacoby *et al.* (1992) reported tree-ring correlation between pre-historic landslides and abrupt tectonic events in Seattle, Washington. Application of Dendrochronological techniques to paleoseismology is described by Jacoby (1997). Jacoby *et al.* (1999) postulated that Laki eruption of 1783, the unusual, frosted tree ring, recorded data, oral historic of famine and death are all

intercorrelated. Studies of D'Arrigo *et al* (2003) in Northern North America indicated a spatial variation in tree-ring reflecting cooling due to atmospheric circulation patterns induced by volcanic events around AD 1640, 1783, 1815 and other years. Further back in time, historical records, augmented by tree ring and ice core evidence from Western Europe and North America, suggested that three of the largest eruptions in the last two millennia occurred around AD 536, 934 and 1258. Solomina (2002) reviewed various problems relating dendro-geomorphological and geochronological informations to continuous time series. He also emphasized the importance of research in dendrohydrology, dendrovolcanology, Dendroseismology and mass movement. Bekker (2004) described the effects of tree location, size and age on the response of tree rings to the Hebgen lake earthquake, which occurred along a normal fault in the Gallatin National Forest in Southwestern Montana, USA.

Table1. Earthquake Sites information for different pine tree species of Azad Jammu & Kashmir. Pakistan.

Main Location	**Species**	**No. of cores** **Trees** **Cores**	**Status**
Pirchanasi	*Pinus wallichiana*	**20**	**1 0**
	Picea smithiana	**3**	**1 2**
	Abies pindrow	**13**	**1 2**
	Pinus wallichiana	**4**	**1 0**
Chakoti	*Pinus roxburghii*	**19 22**	**1 0**
Keran (Nelum)	*Cedrus deodara*	**11 13**	**1 2**
	Pinus wallichiana	**8 10**	**1 0**
	Pinus roxburghii	**3 3**	**1 0**
Kail	*Cedrus deodara*	**42**	**1 2**
Chakar	*Pinus wallichiana*	**19**	**1 0**
Sudan Gali	*Pinus wallichiana*	**36**	**1 0**
	Abies pindrow	**35**	**1 2**

1, Mounted; 2, Cross dated (suitable); 0, Not crossmatchable

OVERVIEW OF PRESENT RESEARCH

The details of sampling sites with their geographical coordinates, tree sampled and their status and suitability are depicted in Table 1. Brief description of major earthquakes in Pakistan is given in Table2. This study incorporates several different species within pine genera including *Cedrus deodara*, *Pinus wallichiana*, *Abies pindrow*, *Picea smithiana* and *Pinus roxburghii*. A total of 261 cores from 213 trees were obtained. Out of which 24 cores of *Pinus wallichiana*, 3 of *Picea smithiana*, and 13 from *Abies pindrow* were obtained from Pirchanasi area. Maximum number of cores samples was obtained from Kail of *Cedrus deodara* while *Pinus wallichiana* and *Abies pindrow* shows the maximum number of samples from Sudan Gali sampling site. Annual rings of the pine tree species were checked, which show that pine tree species of the study area have distinct annual ring growth and exhibit great age. Moreover these species have heartwood type, ring very distinct, delineated by pronounced band of darker late wood. Sap wood is nearly white to yellowish. Heartwood appears in shades of yellow brownish in colours and gives resinous odor. The rays are fine but not visible to naked eyes. The nature of Pine ring formation

makes this type of wood an excellent choice for dendrochronological research because it has clear ring boundaries and rarely produces false or locally absent rings. Similar results were also reported by Ahmed *et al*, (1988), Ahmed *et al* (2005), Ahmed *et al* (2008), Khan *et al*, (2008) and Wahab *et al*, (2008) from Hindukush and Himalayan region of Pakistan. The preliminary results show that the dbh of *Cedrus deodara* ranged between 51 to 170 dbh cm which exhibited 126 and 450 rings respectively. The average growth rate was recorded 9.5 years/cm. *Pinus roxburghii* diameter was ranged between 28 to 66 dbh cm which have 53 to 93 years old respectively. Similarly *Pinus wallichiana* ranged between 22 to 98 dbh cm with complacent rings (2 rings/ cm). *Abies pindrow* and *Picea smithiana* was rare species and its dbh was range between 50 to 140 dbh cm. These two species show almost similar (6 to 8 rings/year) growth rate and age.

Some published data of the same species were presented by Ahmed *et al*, (1988), Ahmed *et al*, (2005), Ahmed *et al*, (2008), Khan *et al*, (2008) , Wahab *et al*, (2008) and Ahmed *et al*, (2010) which show that the present findings are within the range of results presented by these workers.

Based on above tree ring characteristics of different species and present preliminary results it is concluded that *Cedrus deodara*, *Abies pindrow* and *Picea smithiana* attain great diameter and age while the rest of species are fast growing in addition, these three species show distinct cross-matchable annual rings, hence suitable for dendrochronological investigation i.e. dendroseismology, therefore characteristics may show abrupt changes in growth by an earthquake event, Present study aim to address this point. However, it is suggested that more extensive sampling should be carried out to increase the sample size in order to better understand the species potential for further study.

Table 2. Brief description of major earthquakes in Pakistan.

Year	Location	Magnitude	Comments
893-894 A.D.	Debal (Lower Sindh)	7.5	Nearly 1,50,000 people were killed
2 May 1668	Near Shahbundar (Lower Sindh)	7.6	-
16 June 1819	Allahbund (Indo-Pak border region)	7.5	About 3200 people were killed
26 September 1827	Near Lahore	-	1000 people killed
24 January 1852	Near Kahan (Balochistan)	-	250-350 people killed
1865	Near Kahan (Balochistan)	-	Several buildings were destroyed
1883	Jhalawan	-	-
1889	Jhalawan	-	-
20 December 1892	Near Chaman, Afghanistan	6.8	-
20 October 1909	Between Loralai and Sibi (Balochistan)	7.0	More than 100 people were killed
1 February 1929	Between Buner and Hazara	-	-
30 May 1935	Quetta (Balochistan)	8.1	30,000 people were killed and the city of Quetta was devastated
28 December 1974	Northern areas of Pakistan	6.2	5,300 were killed with approximately 17,000 injured
1975	Swat	-	About 4,000 people were killed
8 October 2005	NWFP and Azad Kashmir	7.8	87,000 people were killed

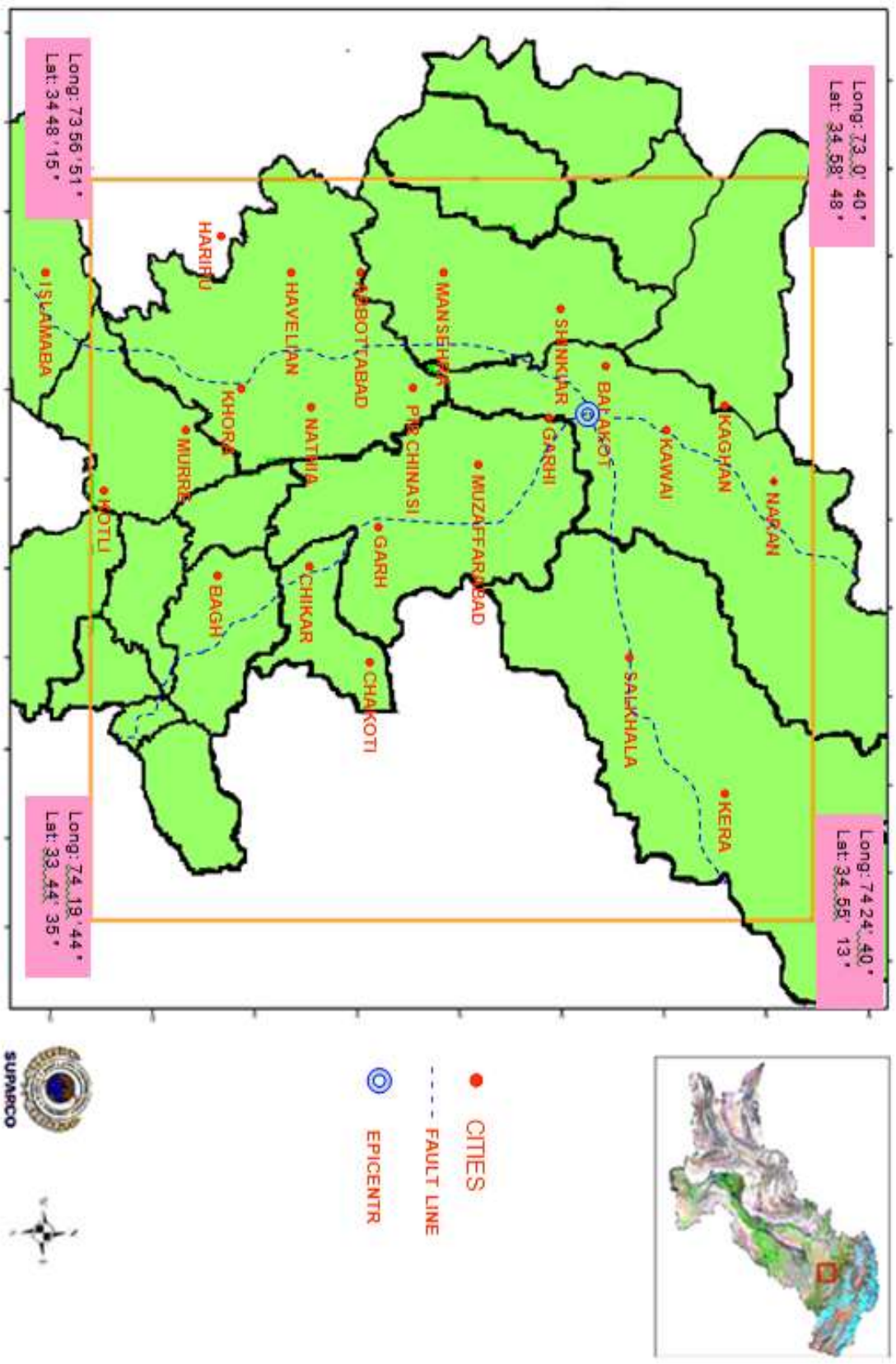

Fig: 1. Map of Study area, showing main earthquake sites/ fault lines in Azad Jammu & Kashmir.

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