THE STATUS OF TREE-RING ANALYSIS IN PAKISTAN

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Abstract

Dendrochronology is a rapidly growing, multidimensional, multidisciplinary and applied science in developed world. It was initiated around 1986 in Pakistan, however systematic studies started from 2005. Handfull results are published using dendrochronological techniques in the country during this period. This paper present a brief review of investigations carried out in Pakistan by overseas and national researchers.

Dendrochronological work in Pakistan

The tree-ring research in Pakistan is in initial stage of development and generally dealt with gymnospermic species. The starting point was an introductory paper "Dendrochronology and its scope in Pakistan" by Ahmed (1987), during a science conference in Peshawar University. He mentioned suitable tree species and the sites of northern areas of Pakistan where Dendrochronological studies can be carried out. During various field trips along with his research students of the Department of Botany, University of Balochistan, they collected hundreds of cores from different gymnospermic tree species. Ahmed (1988a,b) presented age and growth rates of a few planted pine and angiosperm trees and described problems encountered in age estimate of tree species. *Abies pindrow* from moist while *Picea smithiana* from dry temperate areas of Himalayan range of Pakistan were successfully cross dated by him. Due to lack of facilities in Pakistan, Ahmed took these samples to the Department of Botany, University of Auckland, New Zealand and the first dated. *Abies pindrow* chronologies (1750 to 1987 AD) with 22 to 41% variance (shown by ANOVA; due to climate) were (Ahmad, 1989) presented. After a long period of 16 years *Picea smithiana* dated (1422-1987AD) chronologies with 17 to 33 variance were presented by Ahmed and Naqvi (2005).

Due to unavailability of measurement and analytical facilities in Pakistan, Ahmed *et al.* (1989; 1990a; 1990b; 1991) used Dendrochronological technique to explore population dynamics of *Junipers excelsa* seedling, juniper trees in Rodhmallazi, Ziarat and *Pinus gerardiana* forest at Zhob District of dry temperate areas of Balochistan. Ahmed and Sarangzai (1991) carried out extensive field work in dry to moist temperate areas of Himalayan range of Pakistan, presented age and growth rates of different species from different areas. Ahmed and Sarangzai (1992) also explored Drochronological potential of some gymnospermic and angiospermic tree species of Himalayan areas of Pakistan. Tree species included *i.e. Juniperus excelsa, Pinus roxburghii, Pinus wallichiana, Pinus gerardiana, Cedrus deodara, Abies pindrow, Pistacia khinjuk* and *Olea furruginea.* Besides growth rates, various ring-width and stem characteristics of tree species that were problematic with regard to cross-dating procedure were discussed.

The first international publication related to the climate potential from the tree-rings viewpoint was published by Esper *et al.* (1995) based on *Juniperus excelsa* from northern areas of Pakistan. The same species was subsequently used to determine long-term tree-ring variations (Esper, 2000). Esper, (2001) analyzed 429 trees from northwest Karakorum in Pakistan and classified some regional pointer years. These years are valid for western central Asia. 1300 years climatic year history from western central Asia from tree-rings was also described by Esper *et al.* (2002). The collection site was from lower to upper timber line in the northwest Karakorum of Pakistan. The results provided a comprehensive reconstruction reflecting temperature fluctuations. Ultimately Treydte *et al.* (2006) were able to reconstruct millennial precipitation based on tree-ring oxygen-isotope analysis.

In the year 2005, Moinuddin Ahmed was able to establish a first "Laboratory of Dendrochronology and Plant Ecology" in the Department of Botany, Federal Urdu University of Arts, Science and Technology, Gulshan-e-Iqbal Campus, Karachi. The turning point was the approval of a grant of Rs. 4.7 million to carry out research to examine the Dendrochronological potential of pine tree species of northern areas of Pakistan. In the year 2007, another funding (Rs. 3.7 million) was approved by the same institution "Higher Education Commission of Pakistan" to Moinuddin Ahmed for Dendroclimatological investigations in the same area. Ahmed extended Dendrochronological research to University of Balochistan, Quetta, GC University Lahore and Bahauddin Zakarya University, Multan where Dendrochronology was introduced as a subject in B.Sc, M.Sc and higher levels of formal education.

Khan *et al.* (2008) presented first dated chronology (1663 - 2006AD) of *Picea smithiana* from Afghanistan,

close to the border of Dir District of Pakistan. Cores were highly correlated, showing similar climatic signals; therefore they suggested that this species has high Dendroclimatic value.

Ahmed *et al.* (2009a) investigated the same species from Chera and Nalter from Himalayan area and presented 600 years (1400-2006AD) chronologies which were highly correlated (r=0.65-0.73). They also obtained first growth-climate response, using response function analysis. Though both sites fall under dry temperate area, Chara site was drier due to the absence of snow covered peak unlike Nalter, therefore only extreme climatic affects were common in both response function diagrams.

Based on previously mentioned projects and publications, applied Dendrochronological research was initiated by Ahmed in June, 2008, in collaboration with Dr. Edward Cook, Tree ring Laboratory, Lamont-Doherty Earth Observatory, Columbia University, New York and Dr. Jonathan Palmer, Director of Gondwana Tree ring Laboratory, New Zealand. This team submitted a joint project to Higher Education Commission of Pakistan and United State Science and Technology Cooperation namely "Upper Indus river flow reconstruction using tree-ring implications for agriculture and hydroelectricity". Dr. Connie Woodhouse of Tree-Ring Laboratory, University of Arizona, Tucson Arizona, USA, also participated with this team. These investigations produced a number of research papers.

Ahmed *et al* (2009b) estimated age and growth rates of six gymnospermic tree species from 39 different sites of Dir, Chitral, Swat, Abbotabad, Mansehra, Azad Kashmir and Northern area, suggesting suitability of these species in Dendrochronological investigation. Ahmed *et al.* (2010a) explored Dendrochronological potential of gymnospermic tree species of Pakistan. Using *Cedrus deodara, Juniperus excelsa, Pinus gerardiana* and *Picea smithiana,* Ahmed *et al.* (2010b) presented dated (212 to 486 years) chronologies from Upper Indus Basin. The main purpose of such study was to explore Dendrohydrological potential of these species. Statistical analysis showed that these chronologies had a high potential of river flow reconstruction.

Zafar *et al.* (2010) established *Picea smithiana* dated (about 500 years) chronologies from Haramosh and Bagrot with significant correlation (r = 0.74 to 0.85) correlation. Dated (1300-2000AD) chronologies of *Pinus wallichiana* from Astore and *Pinus gerardiana* (1400-2000AD) from Kalash with their growth-climate response were investigated by Ahmed *et al.* (2010c). Site conditions were similar to Chera and Nalter (Ahmed *et al.* 2009a) whereas Astore is similar to Nalter and Kalash site is similar to Chera. Therefore, difference in growth climate response is understandable. However, both response function diagrams showed extreme climatic signals. Kalash showed 40% while Astore explained 22% variance due to climate.

An extensive survey was conducted to obtain cores from 52 sites including sub alpine to moist, dry temperate and sub tropical areas of Pakistan. The main purpose of this sampling was to locate suitable sites and sensitive tree species which could be used for applied Dendrochronological research in Pakistan. *Abies pindrow* was used for Dendroclimatic investigation from Ayubia, moist temperate site and from Astore, dry temperate site of Himalayan areas of Pakistan by Ahmed *et al.* (2010d). Despite of their origin from two different climatic zones, good cross-dating was achieved between two sites. Variance due to climate was 15 to 20%. Both sites were similar on the basis of available moisture. Bokhari *et al.* (2010) described the application of tree rings in earthquake, landslide, rock fall investigation in Pakistan. Sarangzai and Ahmed (2011) described Dendrochronological potential of *Juniperus excelsa* from 30 locations of juniper track of Balochistan, presenting age and growth rate data. Application of tree ring research in Pakistan was presented by Palmer *et al.* (2011). They asserted that various sub-branches of Dendrochronology may be used in Pakistan *i.e.* Dendroecology, Dendroclimatology, Dendrohydrology, Dendroarcheology, dendroseismology and dendroglaciology. Research on these branches will be highly beneficial for the country. Dendrochronological potential of *Juniperus excelsa* from dry temperate area of Balochistan was discussed by Sarangzai *et al.* (2012a). They reported the presence of false rings, missing rings, and wedge out lack of ring pattern consistency, lobate growth and acentric stem in this species. Wahab (2011) used dendrochronological technique on pine species of Dir, describing growth climate response of *Cedrus deodara* and *Picea smithiana* from 5 different places while Khan (2011) did similar investigation in Chitral valley using *Cedrus deodara* and *Pinus gerardiana*. Siddiqui (2011) carried out extensive sampling throughout moist temperate areas of Pakistan describing dynamics of pine tree species using tree-ring approach. Nazim (2011) and Nazim *et al,* (2013) applied Dendrochronological technique to estimate age and growth rate of *Aviccenia marina* (mangrove) without much success. Ahmed *et al.* (2011) used Dendrochronological techniques to evaluate dynamics of *Cedrus deodara* from Hindukush and Himalayan Range, covering its distributional limit. Similarly, Sarangzai *et al.* (2012b) used tree-rings to explore dynamics of *Juniperus excelsa* forest in Balochistan.

Ahmed *et al.* (2011) carried out an extensive survey, presented a network of 28 chronologies and explored growth climate response of various gymnospermic tree species to obtain potential of these species for advanced tree ring investigations. Fifteen of the sites \were new while the remaining 13 (all *Juniperus excelsa* M. Bieb.) were reported earlier. Several tree species attaining ages of around 700 years *i.e. Cedrus deodara* (D.Don) G. Don, *Pinus gerardiana* Wall. Ex D.Don, *Pinus wallichiana* A.B. Jacks and *Picea smithiana* (Wall.) Boiss. But the juniper was the oldest with some trees greater than 1000 years. Correlation between the site chronologies declined with increasing separation distance. This was consistently seen both between site of the same species

and between sites composed of different species. This led to a situation where a much stronger correlation occurred between two different species growing at the same site than between sites of the same species but separated by as little as 0.5km. Such results highlight the obvious strong elevation gradient present in the mountainous region. They also lend support to the practice of multi-species combination for better spatial and temporal coverage. The best prospects for this appear to be *Cedrus deodara* and *Pinus gerardiana* and are consistent with studies from neighboring India. A general climate correlation pattern from all species was evident that started with a strong negative relationship to temperature in the previous October, then turned towards positive during winter, before again becoming significantly negative by the current May, no evidence of a summer (June-September) monsoon signal was seen in the rainfall correlation functions.

Ahmed *et al.* (2012a) included 4 pine species *i.e. Picea smithiana, Cedrus deodara*, *Pinus gerardiana* and *Juniperus excelsa* in seven catchments of the Indus River of Karakorum Range. The purpose of this study was to evaluate Dendrochronological and Dendroclimatological potential of these species. However, the strongest climatic signal was seen in *Pinus gerardiana*. Dendroclimatic and Dendrohydrological response of *Picea smithiana* and *Juniperus excelsa* from Gilgit were explored by Ahmed *et al.* (2013).

During this period Ahmed and coworkers kept hunting new sensitive sites, producing new chronologies *i.e.* Akber (2013) found a new sensitive site of *Pinus wallichiana* producing dated chronology (1730-2010AD) from Ganji valley of Skardu District. Growth climate response of this tree was also discussed. Similarly, Hussain (2013) included another new sensitive site (Stak valley) for *Picea smithiana* (1680-2009AD) from Central Karakorum National Park (CKNP) of Gilgit Baltistan area. Growth climate response of this species was also evaluated. An independent study outside Indus Basin was conducted by Khan *et al.* (2013) using *Cedrus deodara* from Chitral, Hindukush range of Pakistan. It was shown that spring precipitation (March-May) is a critical limiting factor for tree growth.

Ahmed *et al.* (2012) and Cook *et al.* (2013) presented past five centuries (557 years) of Upper Indus River flow (outcome of 2008 joint project) from tree rings, a milestone in water planning in Pakistan. This river discharge reconstruction provides the basis for comparing past, present, and future hydrologic changes, which will be crucial for detection and attribution of hydroclimate change in the Upper Indus Basin. The following findings were derived on the basis of this study.

1. On the basis of available gauge record water planning is not possible.
2- Long term (1452-2008) reconstruction mean (3545 m^3s^{-1}) should be used as the best estimate of expected May September discharge.
3- 1962 to 2008 gauged mean was 3674 m^3s^{-1}.
4- 1962 to 1987 mean was 3470 m^3s^{-1}
5- 1988 to 2008 mean was 3926 m^3s^{-1}
6- 1684-1700 mean was 3904 m^3s^{-1}.
7- 1572-1683 mean was 3377 m^3s^{-1} (showing dry condition).
8- 1637-1663 mean was 3271 m^3s^{-1} (drought).
9- Water flow like 3377 and 3271 m^3s^{-1} in future may seriously reduce Pakistan capacity of irrigation and hydroelectricity power generation.
10- Variability of water flow is a common feature of Indus River.
11- Observed cooling trend at Upper Indus Basin.
12- Higher (3926 m^3s^{-1}) discharge is not due to glacial melt.
13- Karakorum glaciers are not retreating.

Table 1. Summary of tree-ring analysis in Pakistan.

Name of Species	Site	Elev. (m)	SAMS	CHRO AD	RCF	Reference
Abies pindrow	Murree	2166	5/10	1840-1987	-	Ahmed (1989)
	Ayubia	2616	5/10	1750-1987	-	
	Ayubia	2436	5/10	1870-1987	-	
Picea smithiana	Nalter	3350	14/24	1422-1987	-	Ahmed, Naqvi (2005)
	Rama	3100	6/10	1780-1987	-	
	Matiltan	2350	5/8	1800-1987	-	
	Miandum	2300	3/6	1770-1987	-	
	Aghanis	2300/3500	12/24	1663-2006	-	Khan *et al.* (2008)
	Chera	3100	18 cores	1400-2000	√	Ahmed *et al.* (2009)
	Nalter	3400	30 cores	1400-2000	√	
Abies pindrow	Astore	3450	40 cores	1505-2005	√	Ahmed *et al* (2010a)
	Ayubia	2500	12 cores	1678-2005	√	
	Haramosh	3296	20 cores	1467-2009	√	Zafar *et al.* (2010b)

Name of Species	Site	Elev. (m)	SAMS	CHRO AD	RCF	Reference
Picea smithiana	Bagrot	3130	20 cores	1480-2009	√	Ahmed *et al.* (2013)
Pinus wallichiana	Astore	3550	40 cores	1317-2005	√	Ahmed *et al.* (2010c)
Pinus gerardiana	Kalash	2650	12 cores	1403-2006	√	
Cedrus deodara	Tangir	2320	22 cores	1661-2008	√	Ahmed *et al.* (2010d) Chronologies only
Juniperus excelsa	Babusar/	3200	10 cores	1690-2007	√	
	Chaprot	3130	10 cores	1670-2008	√	
Pinus gerardiana	Chaprot/	2850	20 cores	1797-2008	√	Ahmed *et al.* (2012) Growth/climate response
	Cgbak	2650	20 cores	1738-2007	√	
Pinus smithiana	Jutial	3250	26 cores	1523-2008	√	
Picea smithiana	Kargah	2989	12 cores	1680-2008	√	
Cedrus deodara	Suleman Baiky		16/33	1513-2006	√	Wahab (2011)*
			15/29	1511-2006	√	
			11/19	1353-2006	√	
Picea smithiana	GajorKali		8/12	1790-2006	√	
	Benshaki		12/18	1810-2006	√	
Abies pindrow	Rama	3450	17/28	1505-2005	√	
Abies pindrow	Ayubia	2550	7/13	1678-2005	√	
Cedrus deodara	Kalash	2590	10/19	1411-2006	√	Khan (2011)*
Cedrus deodara	Gol Nati	3030	16/27	1539-2006	√	Ahmed *et al.* (2011)
Cedrus deodara	Islam Baikey	2660	31/62	1511-2006	√	
Cedrus deodara	Mushfar	2860	15/30	1296-2007	√	
Cedrus deodara	Ziarat	2900	17/23	1467-2005	√	Khan (2011)*
Picea smithiana	Chera	3100	10/18	1394-2005	√	
Picea smithiana	Nalter	3400	22/35	1387-2005	√	
Pinus gerardiana	Kalash	2590	11/20	1403-2006	√	
Pinus gerardiana	Gol NP	3030	11/21	1260-2006	√	
Pinus gerardiana	Joti	2670	15/28	1559-2007	√	
Pinus gerardiana	Mushkin	2640	9/18	1362-2007	√	
Pinus wallichiana	Rama	3450	25/44	1317-2005	√	
Pinus wallichiana	Mushkin	2750	6/12	1730-2007	√	
Avicennia marina	Sindh coast	Zero	40/80	NIL	×	Nazim (2011)* Nazim *et al.* (2013)
Juniperus excelsa	Nalter	1614-2009	20/40	1614-2009	√	Ahmed *et al.* (2013)
Cedrus deodara	Kalash	2283	10/19	1411-2006	√	Khan *et al.* (2013)
	Chitral	2331	16/26	1537-2006	√	
	Ziarat	2900	16/23	1472-2006	√	
River Indus flow reconstruction	Upper Indus	18 from above mentioned sites		550 years	√	Cook *et al.* (2013)
Drought Reconstruction of Gilgit, Hunza valley	Gilgit Hunza	7 new chronologies		550 years	√	Zafar (2013) *
Picea smithiana	Gauji	3400	12/23	1730-2010	√	Akber (2013) *
Picea smithiana	Stak	3200	22cores	1670-2010	√	Hussain (2013)*

Note: Elev. = Elevation; SAMS = Sample size Tree / core; CHRO = Chronology span; RCF = - Chronology only

√ = Correlation or response function analysis were carried out; *=Thesis x = No cross-dating; Esper *et al* (2005, 2011), Esper (1999, 2000) and Treydte (2006) data not shown in this table.

These findings are extremely important and to give additional support to the above mentioned findings and opinions it is suggested that this reconstruction record should be extended at least up to one thousand years.

Recently, Ahmed and his team has completed another applied project with the financial support of Higher Education Commission of Pakistan. The purpose of this research was to reconstruct drought years of Gilgit and Hunza valleys of northern areas of Pakistan. Zafar (2013) and Ahmed *et al*, (2014) obtained cores of *Picea smithiana, Juniperus excelsa* and *Pinus gerardiana* from 11 different locations of these valleys.

Picea smithiana was used to reconstruct mean March-June (Spring) temperature back to 1523AD. The calibration model explained about 38% of variance in temperature. Calibration and verification tests were highly significant at the 95% confidence level. The reconstruction exhibited a strong positive correlation with the instrumental data and was characterized by annual to multiyear variations of cool and warm periods. The 19th century experienced a prolonged warmth period over a centennial scale with the highest temperature in the 1850-1870's. The coldest 20 year period was 1880-1910. The consistency observed on decadal scale among present reconstructions, April-May construction (Kashmir) of Hughes (1992, 1994) and April-May construction of western Himalaya (Yadav *et al*. 1997) in India indicated the potential for reconstruction of regional-scale climatic change. The "Little Ice Age (LIA)" was also observed from present reconstruction which matched with the reported cooling period of NASA. However it was felt that sample size should be increased and reconstruction should be extended further back in time to obtain better climatic picture. This should increase our knowledge to elucidate climatic variation of the past.

Dendrochronological work in Pakistan is being carried out (Table 1) by various workers of Fed. Urdu University, Balochistan University, Bahauddin Zakarya University, Swat University and Malakand University. Up to now a network of chronologies and their growth climate-responses have been disclosed, beside reconstruction work. Many chronologies have short span of duration. Many chronologies produced have poor sample size.

Therefore, next step should be to obtain samples from older and dead trees to extend chronologies in past and increase satisfactory and adequate sample size. In addition, *Juniperus excelsa* and *Pinus gerardiana* forests of Balochistan which has received little attention in the past may be useful sites and prove to be important addition to the tree-ring network. In Zhob District in the Tukhat-e-Sulaman Range, pure forest of *Pinus gerardiana* has large size of alive and standing dead trees on which long-term climatic reconstruction work can be undertaken.

Tree-ring research may be extended into forestry, earthquake, glacial and archeological investigations, which will be useful for the country. There is a bright future and higher potentiality of dendrochronological investigations in Pakistan.

References

Ahmed, M. (1987). Dendrochronology and its scope in Pakistan. Proceeding. In, Modern trends of Plant Science Research in Pakistan. Botany Department, University of Peshawar, Pakistan 35-38.

Ahmed, M. (1988a). Problems encountered in age estimation of forest tree species. *Pakistan Journal of Botany* 20(1): 143-145.

Ahmed, M., (1988b). Population structure of some planted tree species in Quetta. *Journal of Pure and Applied Sciences* 7(1): 25-29.

Ahmed, M. (1989). Tree-ring chronologies of *Abies pindrow* (Royle) Spach. from Himalayan regions of Pakistan. *Pakistan Journal of Botany* 21(2): 347-354.

Ahmed, M., Ahmed, I. and Anjum, P.I. (1989). A study of natural regeneration of *Juniperus excels* M. Bieb. in Balochistan, Pakistan. *Pak. J. Bot*. 21(1): 118-127.

Ahmed, M., Ashfaq, M., Amjad, M. and Saeed, M. (1991). Vegetation structure and dynamics of *Pinus gerardiana* forests in Balochistan, Pakistan. *Journal of Vegetation Science* 2: 119-124.

Ahmed, M., Cook, E.R., Palmer, J. and Zafar, M.U. (2012) Upper Indus River flow reconstruction using tree-rings implication for agriculture and forestry. Report submitted to HEC, Islamabad.

Ahmed, M., Elahi, E. and Wang, E.L.M. (1990a). Present state of Juniper in Rodhmallazi Forest of Balochistan, Pakistan. *Pakistan Journal of Forestry* July, 227-236.

Ahmed, M., Khan, N. and Wahab, M. (2010a). Climate response function analysis of *Abies pindrow* (Royle) Spach. Preliminary results. *Pak. J. Bot*. 42(1): 165-171.

Ahmed, M., Khan, Z. and Zafar, U.M. (2014). Drought Reconstruction of Gilgit and Hunza Valleys. Report submitted to Higher Education Commission, Govt. of Pakistan.

Ahmed, M., Khan, N., Wahab, M., Zafar, U. and Palmer, J. (2012a). Climate / growth correlation of tree species in the Indus Basin of Karakorum Range, North Pakistan. *IAWA Journal* 33(1): 51-61.

Ahmed, M., Palmer, J., N, Khan., Wahab, M., Fenwick, P., Esper, J. and Cook ER. (2011). The dendroclimatic potential of conifers from northern Pakistan. *Dendrochronologia* 29(2): 77-88.

Ahmed, M. and Naqvi, S.H. (2005). Tree-ring chronology of *Picea smithiana* (Wall.) Boiss, and its quantitative vegetation description from Himalayan region of Pakistan. *Pakistan Journal of Botany* 37(3): 697-707.

Ahmed, M. and Sarangzai, A.M. (1991). Dendrochronological approach to estimate age and growth rate of various species from Himalayan region of Pakistan. *Pakistan Journal of Botany* 23(1): 78-89.

Ahmed, M. and Sarangzai, A.M. (1992). Dendrochronological potential of a few tree species from Himalayan region of Pakistan, a preliminary investigation. *Pakistan J. of Pure and Applied Sciences* 11(2): 65-72.

Ahmed, M., Shaukat, S.S. and Buzdar, A.H. (1990b). Population structure and dynamics of *Juniperus excelsa* in Balochistan, Pakistan. *Journal of Vegetation Science* 1: 271-276.

Ahmed, M., Shaukat, S.S. and Siddiqui, M.F. (2011). A multivariate analysis of the vegetation of *Cedrus deodara* forests in Hindukush and Himalayan range of Pakistan: evaluation the structure and dynamics. *Turk. J. Bot.* 35: 419-438.

Ahmed, M., Wahab, M. and Khan, N. (2009a). Dendroclimatic investigation in Pakistan using *Picea smithiana* (Wall) Boiss. – Preliminary results. *Pakistan Journal of Botany* 41(5): 2427-2435.

Ahmed, M., Wahab, M. and Khan, N. (2010c). Dendrochronological potential of gymnospermic species of Pakistan. *Int. J. Biol. Biotech*. 7(30): 159-174.

Ahmed, M., Wahab, M., Khan, N. and Palmer, J. (2010b). Tree-ring chronologies from Upper Indus Basin of Karakorum Range of Pakistan. *Pakistan Journal of Botany* 42(special): 295-308.

Ahmed, M., Wahab, M., Khan, N., Palmer, J., Nazim, K., Khan, M.U. and Siddiqui, M.F. (2010d). Some preliminary results of climatic studies based on two pine speices of Himalayan area of Pakistan. *Pak. J. Bot.* 42(2): 731-738.

Ahmed, M., Wahab, M., Khan, N., Siddiqui, M.F., Khan, M.U. and Hussain, S.T. (2009b). Age and growth-rates of some gymnosperms in Pakistan - A dendrochronological approach. *Pakistan Journal of Botany* 41(2): 849-860.

Ahmed, M. and Zafar, M.U. (2014). Drought Reconstruction of Gilgit and Hunza valleys. Report submitted to Higher Education Commission of Pakistan.

Ahmed, M., Zafar, M.U., Hussain, A., Akber, M., Wahab, M. and Khan, N. (2013). Dendroclimatic and dendrohydrological response of two tree species from Gilgit valleys. *Pak. J. Bot*. 45(3): 987-992.

Akber, M. (2013). Forest Vegetation and Dendrochronology of Gilgit, Astore and Skardu Districts of Northern areas Gilgit, Baltistan, Pakistan. Ph.D. Thesis, Dept. of Botany, Fed. Urdu University, Karachi.

Bokhari, T.Z., Khan, Z., Ahmed, M., Khan, N. and Ullah, N. (2010). Application of tree-rings in Earthquake studies in Paksitan. *Int. J. Biol. and Biotech* 7(3): 241-247.

Cook, E.R., Palmer, J., Ahmed, M., Woodhouse, C.A., Fenwick, P., Zafar, M.U., Wahab, M. and Khan, N. (2013). Five centuries of Upper Indus River flow from tree-rings. *Journal of Hydrology* 486: 365-375.

Esper, J. (2000). Longterm tree variation in juniperus at the upper timber line in the Karakorum (Pakistan). *The Holocene* 10(2): 253-260.

Esper, J., Bosshard, A., Schweingruber, FH. and Winiger, M. (1995). Tree-rings from the upper timberline in the Karakorum as climatic indicators for the last 1000 years. *Dendrochronologia* 13: 79-88.

Esper, J., Schweingruber F.H., Winiger, M. (2002). 1300 years of climate history for western central Asia inferred from tree-ring. *The Holocene* 12, 267-277.

Esper, J., Treydte, K., Gartner, H., Neuwirth, B. (2001). A tree-ring reconstruction of climatic extreme years since AD 1427 for western central Asia. *Palaebotanist* 50: 141-152.

Hughes, M.K. (1992). Dendrochronological evidence from the Western Himalaya. In Bradley RS. Jones PD (ed) Routledge Press: London. *Climate Science* since AD 1500, 415-431.

Hughes, M.K. (1994). Lessons from past global change. *Journal of Korea Forest Energy* 14: 23-34.

Hussain, A. (2013). Phytosociology and Dendrochronological study of Central Karakorum National Park, Northern area, Gilgit-Baltistan, Pakistan. Ph.D Thesis, Dept. of Botany, Fed. Urdu University, Karachi.

Khan, N. (2011). Vegetaion Ecology and Dendrochronology of Chitral. Ph.D Thesis, Dept. of Botany, Fed. Urdu University, Karachi.

Khan, N., Ahmed, M. and Shaukat, S.S. (2013). Climatic signal in tree-rings chronologies of *Cedrus deodara* from Chitral Hindukush Range of Pakistan. *Geochronometer* 40(3): 195-207.

Khan, N., Ahmed, M. and Wahab, M. (2008). Dendrochronological potential of *Picea smithiana* (Wall) Boiss. From Afghanistan. *Pakistan Journal of Botany* 40(3): 1063-1070.

Nazim, K. (2011). Papulation dynamics of mangrove forests from coastal areas of Sindh. Ph.D Thesis, Dept. of Botany, Fed. Urdu University, Karachi.

Nazim, K., Ahmed, M., Shaukat, S.S. and Khan, N. (2013). Age and growth rate estimate of gray mangrove *Avicennia marina* from Pakistan. *Pak. J. Bot.* 45(2): 535-542.

Palmer, J., Ahmed, M. and Khan, Z. (2011). Application of tree-ring research in Pakistan, *FUUAST J. Biology* 1(1): 19-25.

Sarangzai, A.M. and Ahmed, I. (2011). Dendrochronological potential of *Juniperus excelsa* (M.Bieb) from dry temperate forests of Balochistan province, Pakistan. *FUUAST J. Biology* 1(2): 65-70.

Sarangzai, A.M., Ahmed, M., Ahmed, A., Leghari, S.K. and Jan, S.U. (2012a). Juniper forests of Balochistan. *FUUAST J. Biology* 2(1): 63-70.

Sarangzai, A.M., Ahmed, M., Ahmed, A., Tareen, L. and Jan, S.U. (2012b). The ecology and dynamics of *Juniperus excels* forest in Balochistan-Pakistan. *Pak. J. Bot*. 44(5): 1617-1625.

Siddiqui, M.F. (2011). Community structure and dynamics of conifer forests of moist temperate area of Himalayan range of Pakistan. Ph.D Thesis, Dept. of Botany, Fed. Urdu University, Karachi.

Treydte, KS., Schlesr, GH., Helle, G., Frank, DC., Winige, M., Hang, GH. and Esper, J. (2006). The twentieth century was the wettest period in northern Pakistan over the past millennium. *Nature* 440(27): 1179-1182.

Wahab, M. (2011). Population dynamics and dendrochronological potential of pine tree species from District Dir, Ph.D Thesis, Dept. of Botany, Fed. Urdu University, Karachi.

Yadav, R.R., Park, W.K and Bhattacharya, A. (1997). Dendroclimatic reconstruction of April-May temperature fluctuations in the Western Himalaya of India since AD 1698. *Quaternary Research* 48: 187-191.

Zafar, M. U. (2013). Water analysis and climatic history of Gilgit and Hunza valleys (A dendrochronological approach) Ph.D Thesis, Dept. of Botany, Fed. Urdu University, Karachi.

Zafar, M.U., Ahmed, M., Farooq, M.A., Akber, M. and Hussain, A. (2010). Standardized Tree Ring chronologies of *Picea smithiana* from two new sites of northern area Pakistan. *World Applied Science Journal* 11(12): 1531-1536.