Research Article

Assessment of Climate Sensitivity of Himalayan Fir (*Abies pindrow*) Grown in Ayubia National Park, Khyber Pakhtunkhwa, Pakistan

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Abstract | In this research study time series of 270-year (1750 -2020CE) was used to assess climatic sensitivity of the Blue Pine (*Abies pindrow*) one of the dominant species in the moist temperate forest of Ayubia National Park (ANP), Khyber Pakhtunkhwa. The study revealed that the species is climate and drought sensitive with dendrochronological potential. It was hypothesized that *A. pindrow* is sensitive to climate change and records the variations in climatic factors. The past studies revealed the reliable dendrochronological potential and climate vulnerability of the species but the results were based on short samples. This study was aimed at exploring the climatic sensitivity of *A. pindrow* grown in ANP with sufficient sample strength. We assessed dendrochronological potential, climatic sensitivity by establishing climate-growth relationship and mean annual diameter-age relationship. Forty-four trees were sampled out of which only twenty-five cores were used in the final chronology whereas nineteen samples were found problematic thus omitted from the final master chronology CDend ro & CooRecorder 9, Cofecha, ARSTAN and SPSS were used for data analysis, quality confirmation of time series, chronology construction and climate-growth relationship. Species is climate sensitive and showed dendrochronological potential; however, species is somehow responsive to the endogenous and biological factors as well. Strong and significant relationship was found between diameter and age. Time series revealed a drought period spanned between 1760-1950 CE; however, beyond 1950 CE uptrend in growth which remain constant upto the years 2000 CE. Species may be used to study climatic variations and reconstruction of the past climate and predictions of future changes.

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Introduction

Exceptional changes happening in the climate; continuity of change may transform the earth, and this transformation may threaten the system that may sustain the life on earth (Hardy, 2003). Unpredictable weather patterns are caused by climate change over the globe (Hegerl, 2007; Lipczynska-Kochany, 2018; Change, 2018). Climate change is a natural process, but natural climate regimes have been altered by anthropogenic greenhouse gas emissions (IPCC, 2013). Worldwide the poleward range shifts of various genera and ecosystems are being observed. The population at the range margins may be used to evaluate the response of the plant species toward the changing environment (Hampe and Petit, 2005). Global warming is the major reason for extreme weather happenings (Cramer *et al*., 2014) i.e., extreme hurricanes, famines, rainstorms and variations in the seasonal schedule, i.e., early flowering in the plants (Settele *et al*., 2015). The earth's surface temperature is expected to rise to 1.5-2.0 Celsius by the end of the 21st century (IPCC, 2014). According to the studies of climate change, if the temperature reaches the expected level, almost 20-30% of plant and animal species may become extinct (IPCC, 2014).

Pakistan is vulnerable to climate change; meanwhile, resource exhaustion, urbanization, and industrial progress are limiting sustainability and ecological progress in most of Asian countries, including Pakistan (Chan *et al*., 2018; Shaffril *et al*., 2018). Insufficient infrastructure and adaptive capability (IPCC, 2013), lack of motivation, regulations, environmental education, consumer and government's behavior toward climate change are hitting Pakistan severely (Hussain *et al*., 2018).

Forests are being affected by global warming, floods, droughts and land sliding in Pakistan (Abas *et al*., 2017). The agriculture sector is expected to be in danger because of unpredictable weather and precipitation patterns, regular floods and famines, high temp: and deforestation (Olsen, 2009). Economic and social development sectors must be adapted to climate change (Lin and Ahmad, 2017).

Determination of the recent climatic variations is possible with the help of annual tree ring records that are the archives of past climatic events (Martinelli, 2004; Gebrekirstos *et al*., 2011). Dendrochronology is a method of dating a tree ring to the specific year the ring was developed (Coulthard *et al*., 2013). Response of plants towards the dominant climate of the area is recorded in tree rings; this tree's response provides the base for dendroclimatology (Hughes *et al*., 1982). Dendroclimatology provides signals for global warming and helps in determination of the sensitivity of climate (Hughes, 2002).

Pakistan has limited timber resources, and forest cover is below the desired level. Thus, it is necessary to assess the climatic sensitivity of the species grown in Pakistan to determine their adaptability with possible drastic changes to preserve the biodiversity in future.

This study aims at exploring the climatic sensitivity of *Abies pindrow* in Ayubia National Park; because this is a dominant species along with *Pinus wallichiana* in the Ayubia National Park (Afza *et al*., 2018). The following objectives were addressed in the study: (i) assessment of the dendrochronological potential of the species. (ii) assessment of climatic sensitivity of the species. (iii) Evaluation of the species MAD-AGE relationship.

Materials and Methods

The study area, Ayubia National Park, is located in KP, Pakistan, geographically lies within the lower Himalayas at 1450 m to 3033 m (Ahmad and Afza, 2014). The Park area fall under wet temperate forest (Champion *et al*., 1965) due to receiving monsoon rainfall (Calkins *et al*., 1975; Latif, 1976). The Park falls in the moist temperate forest region in the lower Himalaya (Bukhari *et al*., 2012).

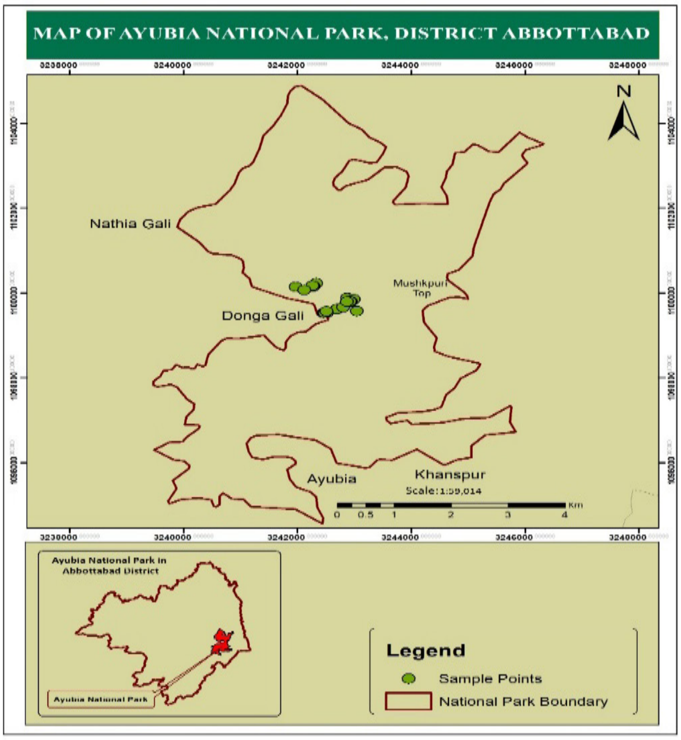

Figure 1: *Map of study area (Ayubia National Park) showing sample points.*

Himalayan fir (*Abies pindrow*) is a large evergreen tree with a straight stem; grown in pure and associated with Spruce, Deodar, Blue pine and Oak forests (Pearson and Brown, 1932). It is grown in the Himalayas, including Pakistan, i.e., at high elevation in Azad Kashmir, Murree hills, Hazara, Swat and Chitral (Sheikh, 1993). Growth rings are clear and delineated (Pearson and Brown, 1932).

For this study, 44 *Abies pindrow* trees were sampled from the site (Figure 1) and cores were collected. After drying, all the cores were successively sandpapered to gain the shine, finish and clarity of annual rings. The sandpapers used different grit sizes from coarse to fine, i.e., 80, 100, 120, 220 and 320. Cores with best ring visibility were scanned at the HP LaserJet Pro MFP M26 nw at 1200 DPI. Images were analyzed using tree measuring software CDendro & CooRecorder 9 to measure the annual rings (Waszake *et al*., 2021).

Cofecha and ARSTAN were used to cross-date and standardize the time series. Cross dating is a technique to analyze and check the accuracy of pattern fluctuation, and standardization is a process to remove the growth trend, age and non-climatic variation (Cook, 1985). All samples were cross dated (Stokes and Smiley, 1968); cofecha was used to verify cross-dating (Holmes, 1983; Grissino-Mayer, 2001), 19 out of 44 series were found problematic thus removed. After cross dating each ring was assigned a calendar year and final chronology of *A. pindrow* consisting 25 series was developed. ARSTAN was used to standardize the TRW data (Cook, 1985). Each cross dated series was standardized by fitting the hugershoff growth curve with the help of dependent smoothing spline (Melvin et al., 2007); after standardization, the standardized series were combined for developing a signal-free chronology by applying bi-weight robust mean to curtail the impact of outliers (Cook, 1985; Cook and Kairiukstis, 1990). Four chronologies, i.e., Raw, Standard and Arstan and residual chronologies, were developed using ARSTAN. In this study, the residual chronology was used for establishing a correlation with climatic factors. To develop a chronology minimum of 12 trees must be sampled and cross dated (Schweingruber, 1988); thus, 25 samples were cross dated to develop robust chronology.

Descriptive statistics as interseries correlation was measured to gauge the strength of cross-dating for a site, mean sensitivity values to check the sensitivity that requires a value above 0.30, which represents the sensitive measurement with high standard deviation and low autocorrelation (Grissino-Mayer, 2001), correlation coefficients, GLK and t-values were calculated to validate the cross-dating, EPS and Rbar to ensure the common signal strength. The important criteria utilized to scale a successful cross - dating were Gleichläufigkeit (GLK) and Student 's t-test. The recommended Student 's ttest cutoff is t-value1.96, and GLK values of 70 (von Platen and Eker, 2008) were used.

Results and Discussion

The results showed in the Tables 1 and 2 were compiled using cofecha, ARSTAN and CDendro and CooRecorder 9 programs. Cubic smoothing spline 50% wavelength cutoff for filtering was used; segments examined at 50 years lagged successively by 25 years. Correlation was applied, and a critical correlation 99% confidence level was set for 0.3281 which is a default spline rigidity of 32 years. Using the default spline rigidity of 32 years, with 50% frequency response at a wavelength of 32 years; this is the wavelength where calculated interseries correlations and standard deviation in standardized series were found highest. This 32-years response period rather like a window of years used in calculating a moving mean. Environmental signals that contribute in the formation of common annual ring patterns may be removed if more flexible spline of a shorter length is used. Whereas, less flexible spline would not be able to omit of low-frequency trend that may cause a chronology to hold unwanted signals i.e., competition and anthropogenic disturbances and these signals may mask cross dating. Table 1 shows the dating series ranges from CE 1750 to 2020, and 271 years longmaster chronology was developed. Previous studies also revealed the long chronologies of the species in the area i.e., 117 (1870-1987), 237 (1750-1987), 500 (Astore 1505-2005), 327 (1678-2005) have been reported by Ahmed (1989) and Ahmed *et al*. (2010); moreover 500 (1505 AD-2005 AD) years long chronology have been developed by Ahmed *et al*. (2010) in Astore. Total 2340 annual rings were checked, and dated rest were found missing thus omitted. The average age of *Abies pindrow* was calculated up to 94 years ranging between 41-271 years (Table 1). Series intercorrelation was found reliable and above the critical level. Series intercorrelation was found low 0.366; hardly above the critical level. However, Ahmed *et al*. (2010) reported comparatively higher series intercorrelation in the species grown in Ayubia but little lower than the Astore (Dry temperate) but the sample size was not mentioned to compare with our study. A study conducted in Indus Kohistan by Khan *et al.* (2018) reported comparatively high series intercorrelation with only 20 samples. Mean sensitivity, gauges the inter annual variability of ring series that is related to the growth speed and considered as a tool for establishing capacity of the species to record variations in climate (Esper and Gärtner, 2001) was found 0.253; the value that falls in the medium category (Grissino-Mayer, 2001). The previous studies have revealed the mean sensitivity of the species is in between the range of 0.203 to 0.25 (Ahmed, 1989; Palmer *et al.*, 2011). Hughes *et al.* (1982) says high sensitivity is not necessary for determination of strong climatic signals in species.

Table 1: *COFECHA results summary and mean annual diameter and age correlation.*

Number of dated series	**25**
Timespan of master dating series	1750-2020 CE
Master series	271 years
Total rings in all series	2349
Total dated rings checked	2340
Series intercorrelation	0.366
Average mean sensitivity	0.253
Mean length of series	94
MAD-age correlation	r = 0.631

An increase in mean annual diameter (MAD) was found between 0.89 mm/year to 3.91 mm/year, with an average growth of 1.94 mm/year (Table 2). The annual growth rate was found little higher than the reported in previous studies in Ayubia (Ahmed *et al.*, 2010) and Indus Kohistan (Khan *et al.*, 2018) as well. Mean annual diameter and age correlation was found significant and positive (r = 0.631) (Figure 2).

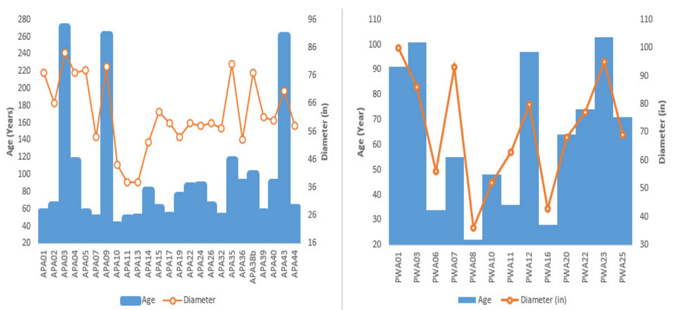

Figure 2: *Age and mean annual diameter increment.*

Autocorrelation, an intrinsic nature of annual rings, determines the endogenous and impact of biological regulators on the growth of the species. Though the low values of autocorrelation are required (Grissino-Mayer, 2001) but here found quite high up to 0.706 (Table 2); showing the high influence of endogenous and other factors on the growth in comparison to climate. Ahmed (1989), Ahmed *et al.* (2009) also reported high autocorrelation value up to 0.771 in *Abies pindrow* grown in moist temperate forest. Competition between spp. and size may cause high autocorrelation (Ahmed and Ogden,1985); moreover, holding leaves for a long period may be the reason of high autocorrelation (Ahmed, 1989).

Table 2 shows , the standard deviation was calculated upto 0.872 in raw chronology, whereas high values of standard deviation are desirable in the detrended series as the SD in detrended series shows that the variation is high in the series indices. These high values of SD in detrended series reveals the high sensitivity of the species to the environmental changes (Grissino-Mayer, 2001). The results revealed high values of SD in detrended series up to 0.506 (Table 2) showing the higher sensitivity of the species toward the climatic changes. However, Ahmed (1989), Ahmed *et al.* (2009) recorded low standard deviation in indices in the same area. Ahmed *et al.* (2010) reported low detrended SD from Ayubia and Astore.

Table 2: *Summary of COFECHA results and descriptive statistics of master chronology.*

Unfiltered				Filtered			
Mean msmt	**Max msmt**	**Std dev**	**Auto corr.**	**Mean sens**	**Max value**	**Std dev.**	**Auto corr.**
1.94	10.44	0.872	0.706	0.253	3.04	0.506	-0.017

Table 3 shows that mean correlation was calculated up to 0.47 between all samples; besides this, GLK value was found up to 0.79 above the accepted threshold of 0.70 and mean *t-value* 3.35 was found above the recommended threshold of ≥1.96 at $p \leq 0.05$. Correlation coefficients, GLK and t-value (Table 3) shows the chronology is robust and reliable. Besides this, the Expresses Population Signal (EPS) and Rbar were measured with the help of ARSTAN. Mean EPS and Rbar were calculated 0.716 and 0.343 (Table 3), respectively; EPS and Rbar both are below the accepted threshold EPS≥0.85 and Rbar≥0.5 (Wigley *et al.*, 1984). Low EPS and Rbar values reveal a lack of common signal in the chronology. Therefore, to develop a robust chronology, the samples may still be increased to represent the site reliably.

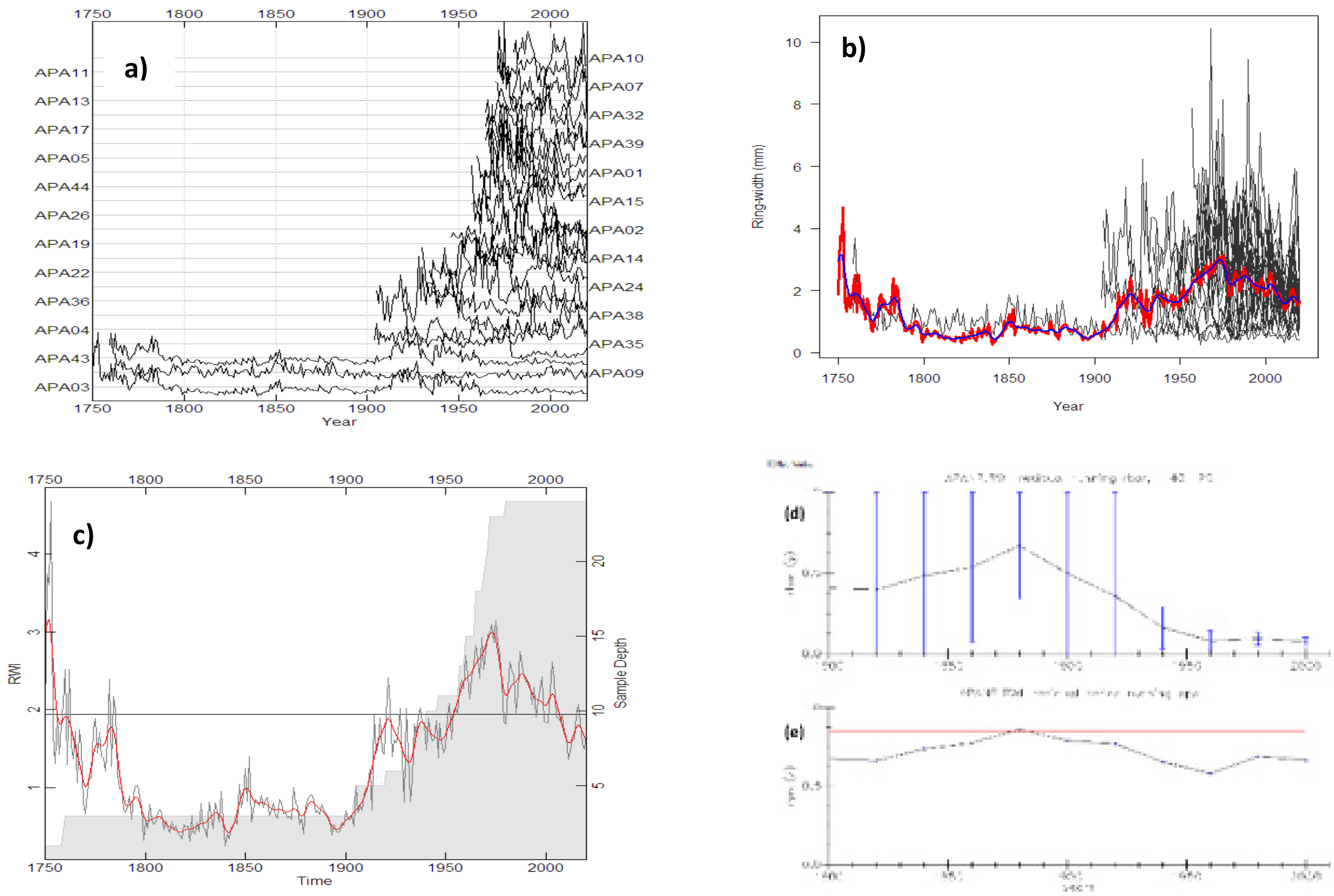

Figure 3: *(a) Spaghetti plots of all series (b) TRW measurement with mean (c) Chronology: horizontal black line shows mean growth; red line shows the spline; gray area shows the sample depth (d) Rbar (e) EPS: black line shows the running EPS and Rbar and horizontal red line shows accepted EPS threshold of ≥0.85 (Wigley et al., 1984).*

Table 3: *Statistical parameters of TRW/TRI (mean EPS and Rbar (detrended).*

Mean GLK	t- value	Correlation coefficients	EPS	Rbar
0.79	3.21	0.47	0.343 (Res)	0.716 (Res)

The chronology reveals in the Figure 3c the growth in the species is gradually increasing between the year 1890-1900 AD and this trend of fast growth is constant up to the years 1960-1970 AD. However, after the year somewhere between 1973-1976 the growth line falls back toward the horizontal line of mean and it is evident that after AD 2000 the growth rate of the species is slowing down and falls below the mean growth rate 1.94 mm. This decrease in the growth rate may be the result of the over age of the species or the change in climatic events i.e., high temperature and change in pattern of rainfall.

Conclusions and Recommendations

Abies pindrow grown in ANP w as found with reasonable dendrochronological potential and sensitive to climatic factors. However, the species is highly influenced by the endogenous and biological factors. The species has recorded high climatic and environmental variability information in the growth rings and may be used for future dendroclimatic studies subject to large sample size. The study revealed fast growth in the species in the beginning of 20 th century; this trend shows better and suitable growth conditions. Species found drought sensitive; beyond 1760 CE species revealed a drought season spanned over a period up 1950 CE. However, after 1950 CE this trend seemed to be over and again after 2000 CE sign of drought era is evident. Species may be used to study climatic variations and reconstruction of the past climate and predictions of future climatic changes which may help in sustainable forest management.

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Novelty Statement

The novelty of our research lies in investigating the impact of climate change on the growth and survival of Himalayan Fir *(Abies pindrow)* in Ayubia National Park, Khyber Pakhtunkhwa, Pakistan, contributing to an understanding of the species' resilience in a changing environment.

Author's Contribution

Khalid Hussain: Concept and design, data collection and research, data analysis, writing the first manuscript, literature review, data presentation, collaboration and communication, editing and revisions, and final approval.
Tanvir Hussain: Data analysis, literature review and suggestion, and proofreading.
Nowsherwan Zarif: Compilation and tabulation of data, data analysis, literature review, proofreading, and revisions.
Zahid Rauf: Provision of software for data analysis, literature review, tabulation of data, and proofreading.

Conflict of interest
The authors have declared no conflict of interest.

References

Abas, N., Kalair, A., Khan, N. and Kalair, A.R., 2017. Review of GHG emissions in Pakistan compared to SAARC countries. Renewable Sustain. Energy Rev., 80: 990-1016. https://doi.org/10.1016/j.rser.2017.04.022

Afza, R., Ahmad, H., Saqib, Z., Marwat, K.B. and Khan, J., 2018. Spatial analysis of vascular flora of Ayubia National Park, KPK, Pakistan: A classical example of moist temperate Himalaya. Pak. J. Bot., 50(4): 1499-1508.

Ahmad, H. and Afza, R., 2014. Nesting places of Koklass and Kalij Pheasants, associated plants and habitat losses in Western Himalayas. In: North America Congress for Conservation Biology (NACCB), Missoula city, USA.

Ahmed, M. and Ogden, J., 1985. Modern New Zealand tree-ring chronologies III. Agathis australis (Salisb.)-Kauri.

Ahmed, M., Wahab, M., Khan, N., Siddiqui, M.F., Khan, M. and Hussain, S.T., 2009. Age and growth rates of some gymnosperms of Pakistan: A dendrochronological approach. Pak. J. Bot., 41(2): 849-860.

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

Ahmed, M.H.D., 1989. Tree-ring Chronologies of *Abies pindrow (royle) spach*, from Himalayan region of northern Pakistan. Pak. J. Bot., 21(2): 347-354.

Bukhari, S.S.B., Haider, A. and Laeq, M.T., 2012. Landcover Atlas of Pakistan.

Calkins, J.A., Offield, T.W. and Abdullan, S.K.M., 1975. Geology of the southern Himalaya in Hazara, Pakistan and adjacent areas. https://doi.org/10.3133/pp716C

Champion, S.H., Seth, S.K. and Khattak, G.M., 1965. Forest types of Pakistan.

Chan, F.K.S., Chuah, C.J., Ziegler, A.D., Dąbrowski, M. and Varis, O., 2018. Towards resilient flood risk management for Asian coastal cities: Lessons learned from Hong Kong and Singapore. J. Cleaner Prod., 187: 576-589. https://doi.org/10.1016/j.jclepro.2018.03.217

Change, N.G.C., 2018. Vital signs of the planet. URL: https://climate.nasa.gov/vital-signs/global-temperature/(дата обращения: 25.12. 2019).

Cook, E.R. and Kairiukstis, L.A., 1990. Methods of dendrochronology: Applications in the environmental sciences. Kluwer Academic Publishers, Dordrecht

Cook, E.R., 1985. A time series analysis approach to tree ring standardization (Doctoral dissertation, University of Arizona).

Coulthard, B.L. and Smith, D.J., 2013. Dendrochronology. Elsevier, BC, Canada. pp. 453-458. https://doi.org/10.1016/B978-0-444-53643-3.00355-1

Cramer, W., Yohe, G. and Field, C.B., 2014. Detection and attribution of observed impacts. Cambridge University Press. pp. 979-1037.

Esper, J. and Gärtner, H., 2001. Interpretation of tree-ring chronologies (Interpretation von Jahrringchronologien). Erdkunde, pp. 277-288.

https://doi.org/10.3112/erdkunde.2001.03.05
Gebrekirstos, A., Neufeldt, H. and Mitlöhner, R., 2011. Exploring climatic signals in stable isotopes of Sclerocarya birrea tree ring chronologies from the Sahel region in West Africa. Trace Conf. Paper, 9: 143-148.
Grissino-Mayer, H.D., 2001. Evaluating cross dating accuracy: A manual and tutorial for the computer program COFECHA.
Hampe, A. and Petit, R.J., 2005. Conserving biodiversity under climate change: The rear edge matters. Ecol. Let., 8(5): 461-467. https://doi.org/10.1111/j.1461-0248.2005.00739.x
Hardy, J.T., 2003. Climate change: Causes, effects, and solutions. John Wiley and Sons.
Hegerl, G.C., 2007. Understanding and attributing climate change. Climate change 2007: The Physical Science Basis, S. Solomon *et al*., Eds.
Holmes, R.L., 1983. Computer-assisted quality control in tree-ring dating and measurement.
http://www.cybis.se/forfun/dendro/version90/index.htm
https://en.wikipedia.org/wiki/Dendrochronology
Hughes, M.K., 2002. Dendrochronology in climatology the state of the art. Dendrochronologia, 20(1-2): 95-116. https://doi.org/10.1078/1125-7865-00011
Hughes, M.K., Kelly, P.M., Pilcher, J.R. and LaMarche, V.C., 1982. Climate from tree rings. Cambridge Univ. Press, Cambridge. https://doi.org/10.1017/CBO9780511760006
Hussain, M., Liu, G., Yousaf, B., Ahmed, R., Uzma, F., Ali, M.U. and Butt, A.R., 2018. Regional and sectoral assessment on climate-change in Pakistan: social norms and indigenous perceptions on climate-change adaptation and mitigation in relation to global context. J. Cleaner Prod., 200: 791-808. https://doi.org/10.1016/j.jclepro.2018.07.272
IPCC, 2013. Summary for policymakers. Climate change.
IPCC, 2014. 5th AR. Mitigations of climate change.
Khan, A., Ahmed, M., Siddiqui, M.F., Iqbal, J. and Gaire, N.P., 2018. Dendrochronological potential of Abies pindrow Royle from Indus Kohistan, Khyber Pakhtunkhwa (KPK) Pakistan. Pak. J. Bot., 50(1): 365-369.
Latif, M.A., 1976. Stratigraphy and micropaleontology of the Galis group of Hazara, Pakistan. Geol. Bull. Punjab Univ., 13: 1-64.
Lin, B. and Ahmad, I., 2017. Analysis of energy related carbon dioxide emission and reduction potential in Pakistan. J. Cleaner Prod., 143: 278-287. https://doi.org/10.1016/j.jclepro.2016.12.113
Lipczynska-Kochany, E., 2018. Effect of climate change on humic substances and associated impacts on the quality of surface water and groundwater: A review. Sci. Total Environ., 640: 1548-1565. https://doi.org/10.1016/j.scitotenv.2018.05.376
Martinelli, N., 2004. Climate from dendrochronology: Latest developments and results. Glob. Planet. Change, 40(1-2): 129-139. https://doi.org/10.1016/S0921-8181(03)00103-6
Melvin, T.M., Brifa, K.R., Nicolussi, K. and Grabner, M., 2007. Time-varying response smoothing. Dendrochronologia, 25: 65–69. https://doi.org/10.1016/j.dendro.2007.01.004
Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A. and Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature, 403(6772): 853-858. https://doi.org/10.1038/35002501
Olsen, L., 2009. The employment effects of climate change and climate change responses: A role for international labour standards? GURN.
Palmer, J., Ahmed, M. and Khan, Z., 2011. Application of tree-ring research in Pakistan. Fuuast J. Biol., 1(1 June): 19-25.
Pearson, R.S. and Brown, H.P., 1932. Commercial timbers of India: Their distribution, supplies, anatomical structure, physical and mechanical properties and uses. Volumes I and II. Commercial timbers of India: their distribution, supplies, anatomical structure, physical and mechanical properties and uses. Volumes I and II.
Schweingruber, F.H., Bartholin, T., Schaur, E. and Briffa, K.R., 1988. Radio densitometric-dendroclimatological conifer chronologies from Lapland (*Scandinavia*) and the Alps (Switzerland). Boreas, 17(4): 559-566. https://doi.org/10.1111/j.1502-3885.1988.tb00569.x
Settele, J., Scholes, R., Betts, R.A., Bunn, S., Leadley, P., Nepstad, D. and Root, T., 2015. Terrestrial and inland water systems. In climate change 2014 impacts, adaptation and vulnerability: Part A: Global and sectoral aspects. Cambridge University Press. pp. 271-360

Shaffril, H.A.M., Krauss, S.E. and Samsuddin, S.F., 2018. A systematic review on Asian's farmers' adaptation practices towards climate change. Sci. Total Environ., 644: 683-695. https://doi.org/10.1016/j.scitotenv.2018.06.349

Sheikh, M.I., 1993. Trees of Pakistan. Islamabad: Pictorial Printers. Vol. 110

Stokes, M.A. and Smiley, T.L., 1968. An introduction to tree-ring dating. University of Chicago, Reprinted 1996.

Von Platen, C. and Eker, J., 2008. Efficient realization of a cal video decoder on a mobile terminal (position paper). In 2008 IEEE workshop on signal processing systems. IEEE, pp. 176-181. https://doi.org/10.1109/SIPS.2008.4671758

Wigley, T.M., Briffa, K.R. and Jones, P.D., 1984. On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology. J. Appl. Meteorol. Climatol., 23(2): 201-213. https://doi.org/10.1175/1520-0450(1984)023<0201:OTAVOC>2.0.CO;2