SIGNIFICANCE OF INTRA ANNUAL FLUCTUATIONS IN SOME SELECTED CONIFERS FROM A DRY TEMPERATE AREA (KALAM FOREST DIVISION), KHYBER PAKHTUNKHWA, PAKISTAN: A DENDROCHRONOLOGICAL ASSESSMENT

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Abstract. Dendrochronological potential of some gymnosperms was determined by dividing a study site into 9 stands. 76 samples of *Abies pindrow* with maximum age of 698 years having 149.3 cm diameter, 23 samples of *Taxus baccata* with maximum age of 479 years having 137.2 cm diameter, 4 samples of *Pinus roxburghii* with maximum age of 218 years having 19.2 inches diameter and 2 samples of *Cedrus deodara* were obtained. All species were crossdated successfully by Skeleton Plot Model. Among them, mean growth of *A. pindrow* was 0.05-0.27 cm per year while for *T. baccata* it was 0.15-0.24 cm per year. Moreover, regression analysis between age and dbh was (y = 0.0847x + 4.0756), (R^2 = 0.921) in 3rd stand and (y = 11.108x-41.174), (R^2 = 0.8424) in 2nd stand of *A. pindrow* and *T. baccata* respectively. The maximum value observed was in the 3rd stand of *T. baccata* species which showed better correlation as compared to the rest of the stands. Strong correlation was also observed between TRW and difference of earlywood and latewood cell mass in all species. *A. pindrow* showed maximum value as (y = 1.1397x + 0.1873), (R^2 = 0.9972).
Keywords: *skeleton plot, Abies pindrow, Cedrus deodara, Pinus roxburghii, Taxus baccata*

Introduction

Dendrochronology, “the study of tree time,” is a multidisciplinary science that dates annual tree rings to their exact year formation to investigate prehistorical, historical and modern events (Palmer et al., 2011; Cook and Kairiukstis, 2010). It is applied in various subfields like climatology, ecology, forestry, fire history, geology, hydrology, volcanology and many other disciplines (Nash, 2002). Trees are intimately bound to environment as they record natural (temperature and precipitation) or unnatural (human induced) events or processes which can be seen in varying patterns of tree ring widths (Ali et al., 2021). Year to year climate variation induces variability in volume of wood that the tree produces in most geographic regions. When environmental conditions become favorable, trees respond by creating large volume of wood and produce less volume of wood in other years when conditions are unfavorable for growth (Sun et al., 2016; Panyushkina, 2011). Coniferous forests are important natural resources to sustain life in tropical, subtropical and temperate regions throughout the globe as they have economic and ecological importance. Among them, Kalam Forest Division (dry temperate area) is also geographically vulnerable to climate change due to environmental and some anthropogenic activities. The study was conducted in Kalam Forest division with objective to determine dendrochronological potential (age and

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growth rate studies) and to develop tree ring chronologies of conifers by SPM (Skeleton Plot Model) Method (Speer, 2010) (*Fig. 1*).

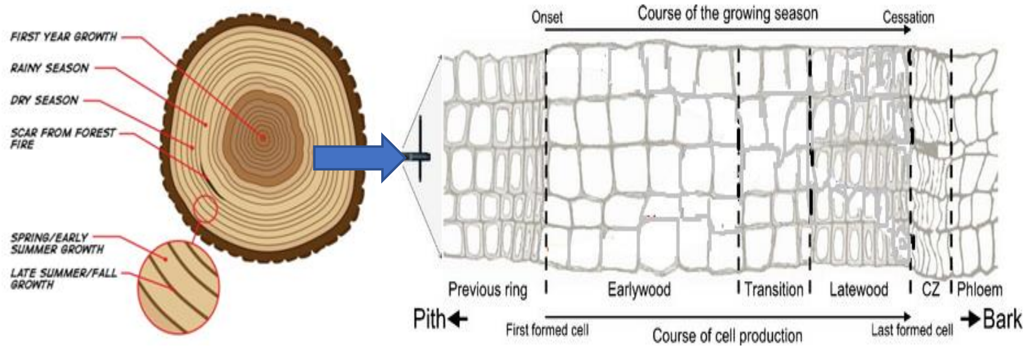

Figure 1. *Annual ring fluctuations (earlywood and latewood) and anthropogenic behavior*

Chronology development by skeleton plot model

Skeleton Plot Model is one of most appropriate and extensively used method by dendrochronologists to crossdate the tree samples which is the "procedure of matching ring width variations." Skeleton Plot, "Plot of vertical bars in which bar length is inversely related to tree ring width, is used to identify the double or false rings which occurs if seasonal growth is interrupted by severe climatic conditions, diseases or other agents and is later resumed a second growth layer, visible and added in during one growth season (Copenheaver et al., 2006). Such additional layer is false ring, which is simply a band of latewood cells between latewood part of previous ring and early wood part of next ring (Nash, 2002). As temperate trees (conifers) develop rings yearly so, patterns of tree ring widths are matched and compared in similar and dissimilar geologic regions (Vasconcellos et al., 2019; Speer, 2010).

Pakistan is more vulnerable to climate change due to environmental factors changing forest types (Bajwa et al., 2015) inducing health problems (Gosling et al., 2009), as well as reducing the oxygen levels in the sea (Shaffer et al., 2009). These changes are not uniform throughout globe and vary with change in regional temperature and precipitation so, dendrochronology helps to examine the past climate as well as to predict future climate by annual rings of trees (Shah et al., 2019). Many researchers have been engaged and are working in above mentioned areas. Muhammad et al. (2021) determined age and growth rate of pines. Ahmed and Naqvi (2005), Khan et al. (2008), Ahmed et al. (2009) determined dendrochronological potential of some gymnosperms from Swat, Dir, Chitral, Mansehra and Azad Kashmir, Pakistan. Khan (2011) determined dendrochronological potential of *C. deodara* and *Pinus gerardiana*. Wahab (2011) also estimated age and growth rates of conifers from Dir, Pakistan. Khan et al. (2013) developed tree ring chronologies and used in forest management, past climate investigation, wildfire and other hydrological aspects. The objectives of study were: (1) to estimate age and growth rate of selected conifers (*A. pindrow*, *T. baccata*, *P. roxburghii* and *C. deodara*); (2) to determine relationships, if any, between diameter/age, diameter/growth rate and between seasonal parts of annual rings of trees; (3) to determine correlation between different parameters to model meaningful relationships in form of regression analysis; (4) to develop Skeleton Plot Model of all

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samples, composite skeleton plot of climatically sensitive trees and their matching with master skeleton plots and raising their master chronologies.

Study site

Kalam Forest Division is geographically known as Swat Kohistan (*Fig. 2*), an independent Forest Division from last 5 decades as it was a part of Swat Forest Division in previous times. It consists of two tehsils known as Kalam and Behrain and covers an area about 3182.9272 km^2. The site is climatically very sensitive as it lies in dry temperate zone, too much cold at high elevations causes migration of people to bottom of valley to fulfil their needs and survival. Here temperature and precipitation varies with altitude and appears in form of rain and snow. Rain falls from December to May as its average record is 492 mm and annual record is 423.56 cm (Iqbal, 2014).

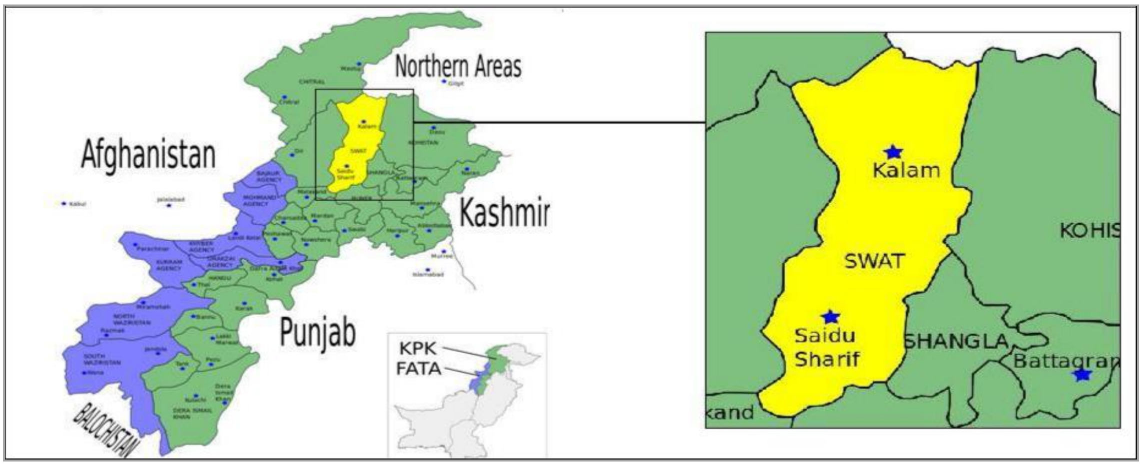

***Figure 2.** Divisional boundaries of Kalam Forest Division*

Materials and methods

Sample collection, processing and measurement

Four conifer species were targeted for sample collection namely *A. pindrow*, *T. baccata*, *P. roxburghii* and *C. deodara* (*Fig. 3*). Subjective sampling was performed in the field and those individual trees were selected that were present on high and low elevation sites, steep slopes and well drained soils because they could possess the tree rings significantly sensitive to regional climate and cross dating could be performed successfully (Ahmed, 2014). Cores were obtained from healthy, rigid and unbranched trees by Swedish increment borers at height as 1.3 m or 4.3 ft. A total of 105 cores were obtained from 51 different trees in 2019. The cores were preserved in plastic straws to maintain alignment of cores. The ends of straws were covered with paper tape and holes created in trees were refilled by wax to protect them from any fungal or pathogen disease (Wahab et al., 2008). The diameter at breast height (dbh) of each tree was measured by dbh measuring tape (Hart and Grissino-Mayer, 2008). Later on, cores were mounted on wooden frames with glue and were allowed to dry. Sander machine fitted with different grades of sand papers (80, 100, 120, 150, 180, 320 and 400 grit, depending upon particular species) was used to make smooth and fine surface of cores. It was proceeded until suitable polished surface was achieved after varnish coat (Phipps,

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1985). Velmex measuring system (TA4021H1) having connection with computer installed with J2X software was used. All samples were measured one by one with respect to earlywood, latewood and total ring width (Volney and Mallet, 1992; Yamaguchi, 1991). All samples were crossdated successfully by skeleton plot method and further statistical analysis was performed.

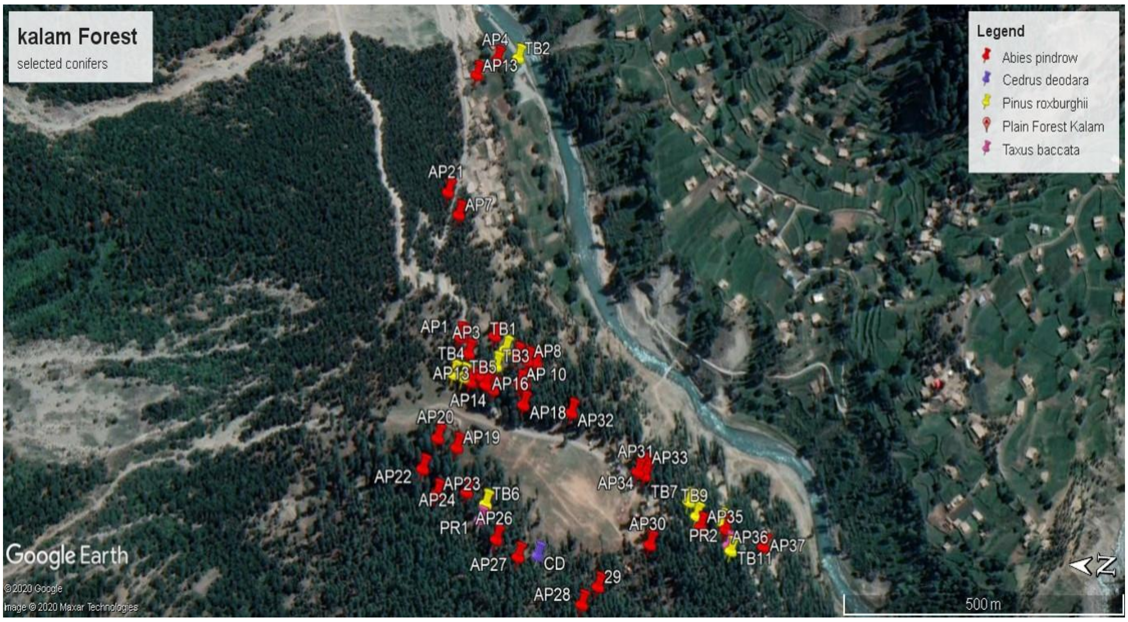

Figure 3. *GPS points of selected conifers location in Kalam Forest Division KP, Pakistan*

Results

Dendrochronological potential of above-mentioned species was determined by dividing study site into different stands and their relationships were determined by different parameters.

Age and growth rate determination

Age of all trees was estimated from nine stands of study site as shown in *Table 1*. The oldest tree was *A. pindrow* with 698 years age and 149.3 cm diameter. The youngest tree was 63 years of age with 73.15 cm diameter. An age of 479 years with 137.2 cm diameter was recorded in *T. baccata* as maximum age in this particular species while youngest was 113 years old having 45.72 cm diameter. In case of *P. roxburghii*, the maximum and minimum age was estimated as 218 years and 68 years with 48.76 cm, 67.05 cm diameter respectively. *C. deodara* was found to be minimal as regional climate and other topographic features of site were found to be unfavorable for this particular species.

Growth rate of all trees was also determined from this dry temperate area as shown in respective table. The maximum and minimum growth rate of *A. pindrow* was 0.48 cm/year and 0.05 cm/year. It was maximum as 0.06 cm/year in case of *T. baccata* while minimum was 0.12 cm/year. *P. roxburghii* also showed maximum and minimum growth rate as 0.15 cm/year and 0.10 cm/year respectively. Overall, *T. baccata* was found to be denser in study site and its growth rate was also recorded as maximum as 0.66 cm/year.

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Table 1. *Age and growth rate studies of conifers*

Species	Earlywood (mm)		Latewood (mm)		Age (years)		Mean growth (mm)		Growth rate (cm/year)	
	Max.	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**
A. pindrow	4.7	0.55	0.53	0.13	698	63	0.16	0.02	0.48	0.05
T. baccata	6.5	1.22	0.71	0.14	479	113	0.24	0.06	0.66	0.12
P. roxburghii	1.45	1	0.24	0.14	218	68	0.05	0.04	0.15	0.10

Seasonal dynamics

Tree ring width (TRW) and its parts (earlywood and latewood) were also measured (*Fig. 1*). The maximum TRW measurement was 4.86 mm and 0.69 mm as minimum in case of *A. pindrow*. The early and latewood part was 4.70 mm, 0.53 mm and 0.53 mm, 0.13 mm respectively. In case of *T. baccata,* TRW was 6.64 mm and 1.37 mm as maximum and minimum. The early and latewood part was 6.5 mm, 1.2 mm and 0.71 mm, 0.41 mm respectively *P. roxburghii* showed TRW value as 1.66 mm and 1.11 mm and early latewood parts were 1.45 mm, 1.00 mm and 0.24 mm, 0.14 mm wide respectively.

Correlations between dbh/age, dbh/growth rate, TRW and difference of earlywood, latewood cell mass

Correlations of all species were determined (*Table 2*). Diameter at breast height (dbh) of *A. pindrow* showed positive significant correlation with age (*Fig. 4a*) while it was positive/negative correlated with growth rate (*Fig. 4b*). *T. baccata* showed positive correlation between dbh and age (*Fig. 5a*) and negative between dbh and growth rate (*Fig. 5b*) and it was found to be highly negative in *P. roxburghii* trees (*Fig. 6a, b*). Moreover, the correlation was also observed between tree ring width and difference of early, latewood cell mass. It was observed highly positive in all selected species gymnosperms (*Figs. 4c, 5c, 6c*). The maximum value was observed in 5th stand of *A. pindrow* (*Fig. 4c*).

Table 2. *Correlation and regression analysis between dbh/age, dbh/growth rate and TRW/early & latewood cell mass*

Species	Parameter	Correlation (R^2)	Regression
A. pindrow	Dbh/age	0.921	y = 0.0847x + 4.0756
	Dbh/growth rate	0.4126	y = -339.62x + 84.091
	TRW/Difference of earlywood and latewood cell mass	0.9972	y = 1.1397x + 0.1873
T. baccata	Dbh/age	0.8424	y = 11.108x-41.174
	Dbh/growth rate	0.4055	y = -134.69x + 55.873
	TRW/Difference of earlywood and latewood cell mass	0.9646	y = 0.9417x + 0.8654
P. roxburghii	Dbh/age	0.6296	y = -11.806x + 414.67
	Dbh/growth rate	0.0909	y = -130.91x + 29.018
	TRW/Difference of earlywood and latewood cell mass	0.8943	y = 1.1081x + 0.285

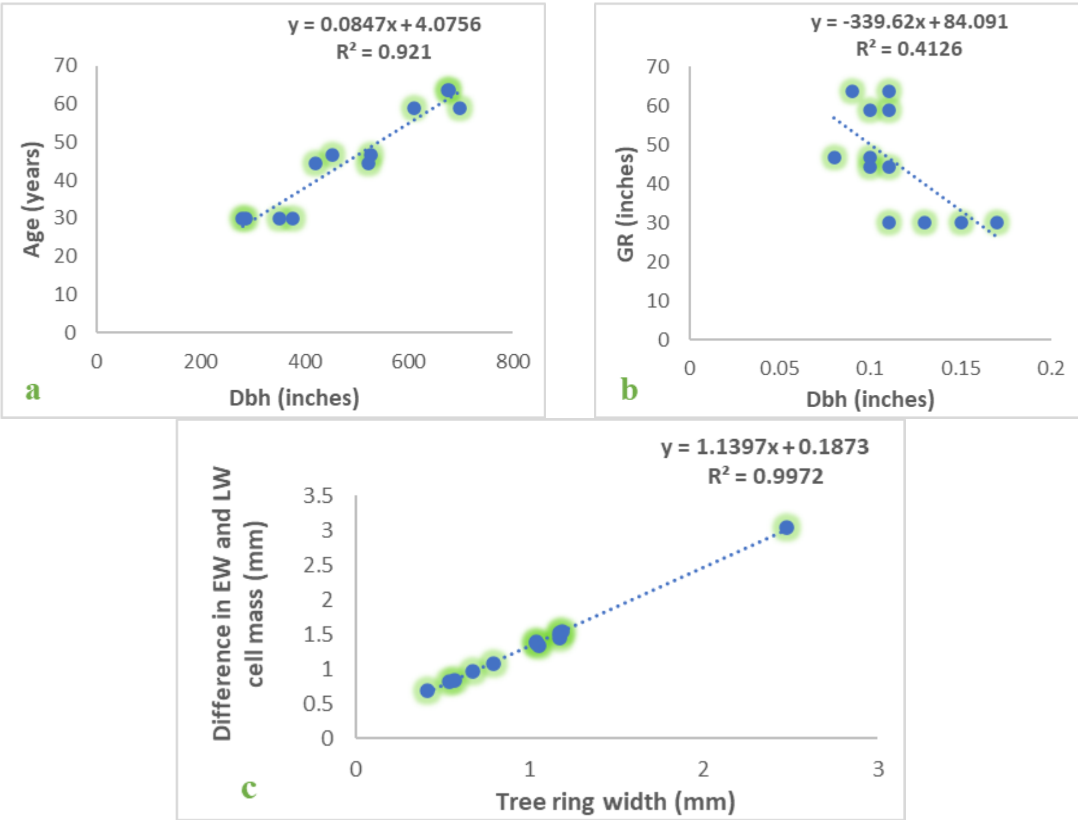

Figure 4. *Correlation studies of A. pindrow*

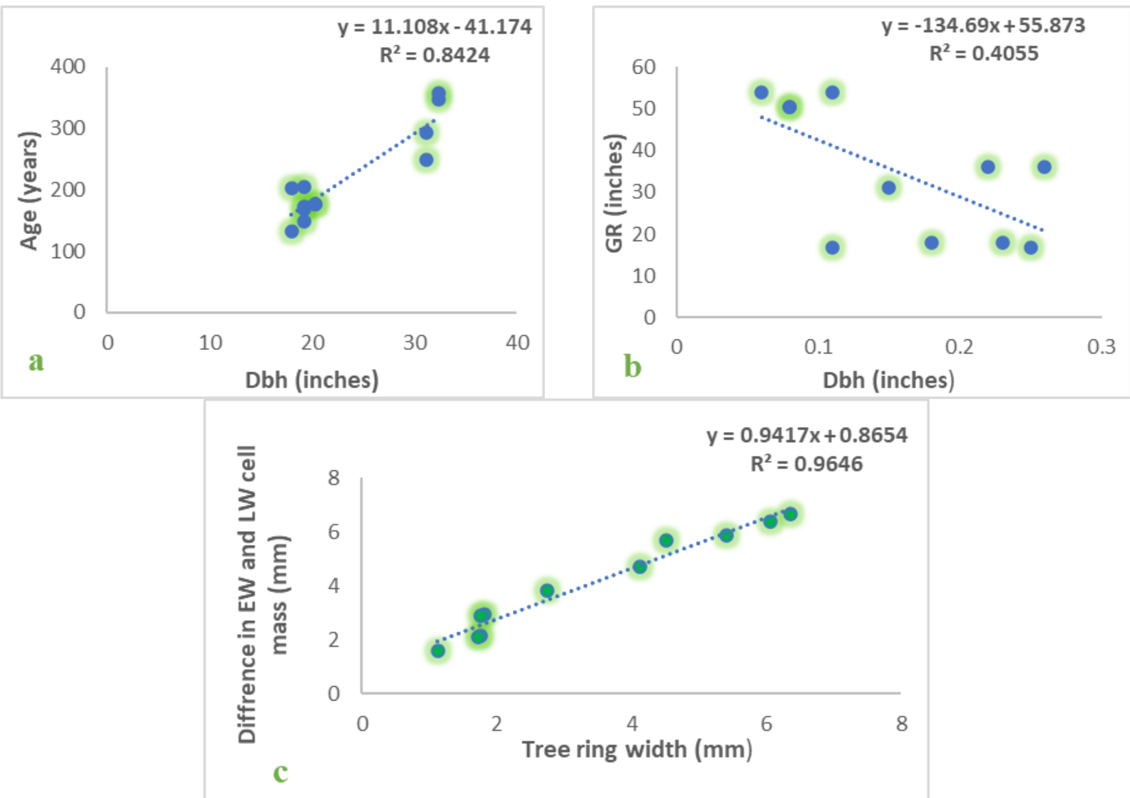

Figure 5. *Correlation studies of T. baccata*

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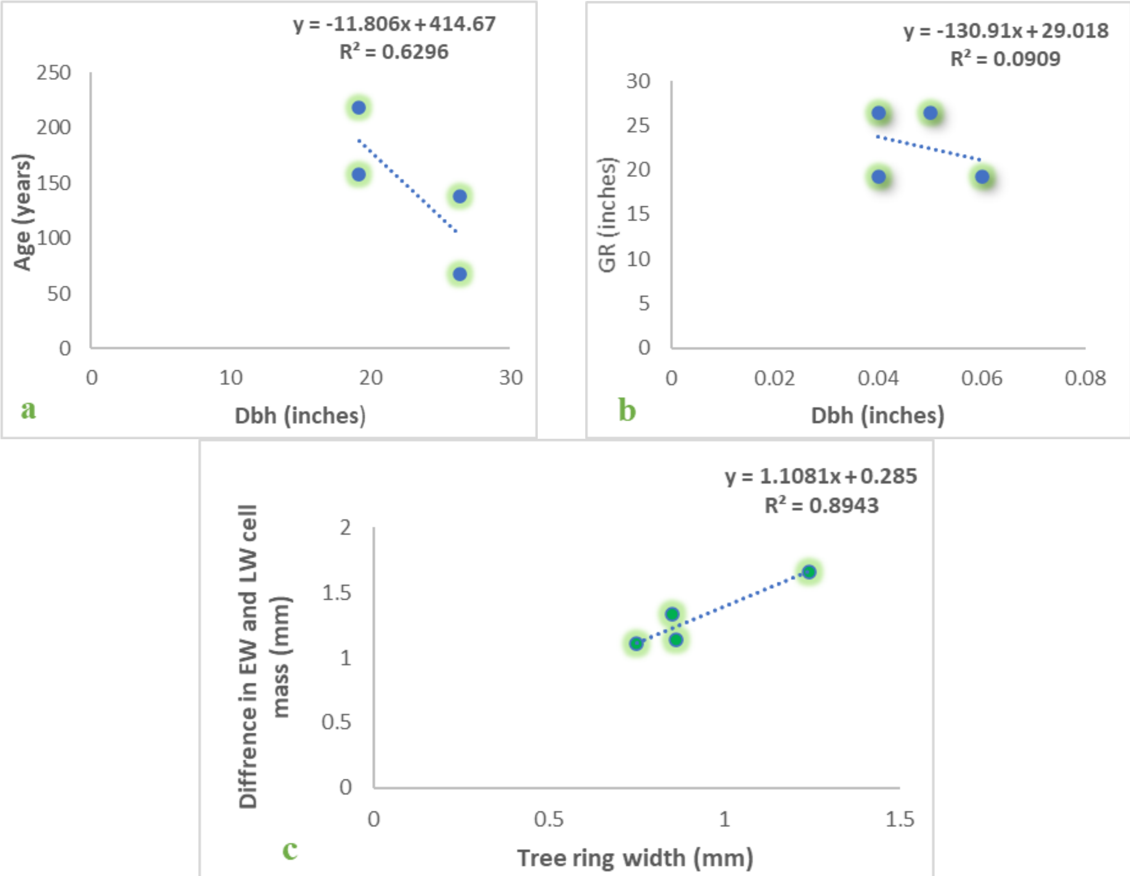

Figure 6. *Correlation studies of P. roxburghii*

Skeleton plot model

The fundamental principle of dendrochronology is crossdating which is simply crossmatching of tree ring width patterns among the species of similar and dissimilar geologic regions. It was applied to all trees either they showed complacent or sensitive growth patterns (*Table 3*). It was best represented by sensitive trees (*Fig. 7*) as they produced rings yearly or seasonally and responded well to climate fluctuations by creating larger and smaller rings while complacent trees produced rings of similar widths, as their growth was not affected by seasonal climate fluctuations. The samples showed sensitivity as they obtained from high and low elevation sites, steep slopes and well drained soils while others showed complacent nature as they were obtained from poor drained soils and near bank of river (Swat River, Pakistan).

Table 3. *Tree ring matching patterns (chronology development) between samples of same trees through ***SPM method*

Sample codes	Tree life span	Matching pattern		No. of matched years	GPS coordinates
		Narrow ring years	Wide ring years		
		A. pindrow			
AP1 and AP1’	1929-2019AD	1998, 1999	----	2	N:35.51123 E:72.60368
AP2 and AP2’	1888-2019AD	1905-1927, 1933-1945, 1947-1974, 1995-1998, 2010-2019	----	78	N:35.51118 E:72.60368

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AP3 and AP3’	1926-2019AD	1967, 1978, 1984, 1985, 1991-1993, 2000, 2010, 2011	----	10	N:35.51107 E:72.60342
AP4 and AP4’	1926-2019AD	1967, 1968, 1982, 1983, 1992, 2001-2003, 2013, 2018, 2019	----	11	N:35.51095 E:72.60850
AP7 and AP7’	1933-2019AD	1946, 1964, 1996, 1997, 2009, 2010	1977-1986	16	N:35.51068 E:72.60374
AP11 and AP11’	1817-2019AD	1931-1934, 1985-1989, 1994, 2018, 2019	----	12	N:35.51031 E:72.60343
AP12 and AP12’	1897-2019AD	1936-1938, 1981-1983, 1989, 2001-2003, 2005-2008, 2010-2019	----	24	N:35.51080 E:72.60860
AP13 and AP13’	1819-2019AD	1944, 1953-1961, 2015, 2018, 2019	----	13	N:35.51014 E:72.60337
AP14 and AP14’	1846-2019AD	1903, 1904, 1937, 1938, 1943-1946, 1951-1974, 2007-2014, 2019	1900, 1901, 1983-1993, 1998-2003	59	N:35.51000 E:72.60334
AP15 and AP15’	1830-2019AD	1915-1924, 1936-1945, 1968-1973, 1995-1997	1948, 2005-2007	33	N:35.51024 E:72.60297
AP16 and AP16’	1857-2019AD	1879-1882, 1889, 1900, 1907-1912, 1958-1965, 1973-1987, 1990-1993	1946, 1947, 2005-2009	46	N:35.51020 E:72.60298
AP17 and AP17’	1879-2019AD	1926-1945, 1973-1977, 1979-1985, 1999, 2000, 2011-2019	----	43	N:35.51016 E:72.60300
AP18 and AP18’	1930-2019AD	1983, 1984, 1986, 1989-1991, 2001-2005, 2018, 2019	1982, 1995-1999	19	N:35.51127 E:72.60818
AP21 and AP21’	1922-2019AD	1959-1963, 1975-1977, 1982, 1983, 1998-2001, 2010-2012, 2016-2019	----	21	N:35.51101 E:72.60296
AP22 and AP22’	1942-2019AD	1983, 1998-2000, 2016-2019	----	8	N:35.51086 E:72.60307
AP23 and AP23’	1897-2019AD	1940-1947, 1952-1954, 1982, 1983, 1987-1989, 2001-2019	----	35	N:35.51077 E:72.60293
AP24 and AP24’	1910-2019AD	1948, 1949, 1975, 1980, 1998, 2018, 2019	----	7	N:35.51065 E:72.60280
AP25 and AP25’	1900-2019AD	1940, 1947, 1984, 1967-1973, 1999, 2011, 2018, 2019	----	14	N:35.51016 E:72.60265
AP26 and AP26’	1859-2019AD	1926-1931, 1933, 1938-1942, 1944-1947, 1949, 2001, 2009-2015, 2018, 2019	1911-1924	41	N:35.51115 E:72.60189
AP27 and AP27’	1929-2019AD	2001	----	1	N:35.51145 E:72.80202
AP28 and AP28’	1859-2019AD	1904, 1970, 1975, 1981-1986, 1996, 2002-2007, 2010-2019	1936, 1937, 1998-2001	32	N:35.51158 E:72.80608
AP29 and AP29’	1879-2019AD	1975, 1976, 2012-2019	----	10	N:35.51164 E:72.60152
AP30 and AP30’	1801-2019AD	1820-1828, 1857-1865, 1872-1876, 1929-1931, 1945-1951, 1960, 1961, 1964-1966, 1996-1999, 2002-2005, 2009-2019	1897-1903, 1936, 1910-1914	70	N:35.51140 E:72.60114
AP31 and AP31’	1872-2019AD	1911, 1915, 1916, 1943-1953, 1959-1999	2005-2014	65	N:35.51095 E:72.60119
AP32 and AP32’	1679-2019AD	1729-1755	1760-1767, 1783-1835, 1837-2019	271	N:35.51064 E:72.60100
AP35 and AP35’	1775-2019AD	1838-1840, 1844-1852, 1856-1870, 1881-1900, 1906-1910, 1913-1956, 1958, 1961, 1962, 1965, 1973, 1974, 1976-1978, 1981-1992, 1996-2004, 2018, 2019		128	N:35.51045 E:72.60047
AP36 and AP36’	1806-2019AD	1977-2004, 2007, 1881-1890, 1898-1951, 1969-1974, 2018, 2019	1953-1967	115	N:35.51010 E:72.60021
AP38 and AP38’	1834-2019AD	1907-1913, 1915, 1927-1930, 1932-1945, 1948-1953, 1964, 1965, 1974-1977, 2002-2019	----	56	N:35.50907 E:72.59952
AP39 and AP39’	1802-2019AD	1930-1950, 1983-2019, 1964-1973	1908-1918	89	N:35.50883 E:72.59981

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AP40 and AP40'	1815-2019AD	1977, 1980-1982, 2012, 2013	1977	7	N:35.50805 E:72.80054
AP41 and AP41'	1833-2019AD	1946-1950, 1960, 1975, 1976, 1984-1989, 1987, 1993-2000, 2012-2014	----	26	N:35.50829 E:72.60169
AP42 and AP42'	1898-2019AD	1934-1939	----	6	N:35.50940 E:72.60258
AP43 and AP43'	1944-2019AD	1992-1999	----	8	N:35.50817 E:72.60177
AP44 and AP44'	1903-2019AD	1925-1949, 1956-1962, 1977-2005	1976	62	N:35.50818 E:72.60164
AP48 and AP48'	1891-2019AD	1988-1994, 2008-2019	----	19	N:35.50685 E:72.60086
AP50 and AP50'	1876-2019AD	2019-1990, 1933, 1932	----	32	N:35.50980 E:72.60096
T. baccata					
TB5	1953-2019AD	----	----	---	N:35.51085 E:72.60382
TB6 and TB6'	1918-2019AD	1978, 1979	----	2	N:35.51063 E:72.60875
TB8 and TB8'	1985-2019 AD	----	2016-2013, 2009, 2001, 2000, 1999, 1998	9	N:35.51050 E:72.60353
TB9 and TB9'	1950-2019AD	2018, 2019	----	2	N:35.51061 E:72.60857
TB10 and TB10'	1932-2019AD	1960, 1961, 1963, 1964, 2018, 2019	1954, 1992, 1993	9	N:35.51063 E:72.60325
TB19 and TB19'	1966-2019AD	1998-2000, 2018, 2019	1993	6	N:35.51128 E:72.60306
TB20 and TB20'	1953-2019AD	1997, 2018, 2019	----	3	N:35.51113 E:72.60306
TB33 and TB33'	1903-2019AD	2019-1996, 1998, 1987	----	24	N:35.51113 E:72.60303
TB45 and TB45'	1894-2019AD	1951, 1971-1982, 1989-1995, 2008-2011, 2016-2019	----	28	N:35.51065 E:72.60102
TB46 and TB46'	1899-2019AD	1972, 1973, 1979, 1980, 1996-2000	2006-2008	12	N:35.51065 E:72.60102
TB47 and TB47'	1859-2019AD	1904-1909, 1932-1934, 1960-1966	1998-2019	38	N:35.50746 E:72.60127
TB49 and TB49'	1874-2019AD	1938-1940, 1956, 1992, 1993, 1997, 1998, 2004-2008, 2010-2019	1970	24	N:35.50734 E:72.60123
P. roxburghii					
PR34 and PR34'	1814-2019AD	1827, 1828, 1918-1923, 1929, 1932-1939, 1940, 1942, 1943, 1992, 1993, 1998-2000, 2007, 2008, 2018, 2019	1887-1906	49	N:35.51072 E:72.60047
PR51 and PR51'	1877-2019AD	1985-1988, 2004-2019	1995-1998	24	N:35.50680 E:72.60061
C. deodara					
CD37and CD37'	1783-2019AD	1860-1864, 1905, 1932-1936, 1945-1947, 1949, 1951-1954, 1959-1960, 1970-1988, 1998-2010, 2013-2019	----	60	N:35.50980 E:72.60024

After crossdating all the core samples, composite skeleton plots of the most sensitive trees were made between two cores of each individual tree which highlighted the most sensitive years of growth. These plots were matched with the master skeleton plot and master chronology was developed as shown in *Figure 7a-h*.

Composite skeleton plots, master skeleton plots and master chronologies of sensitive trees were presented in *Figure 7*.

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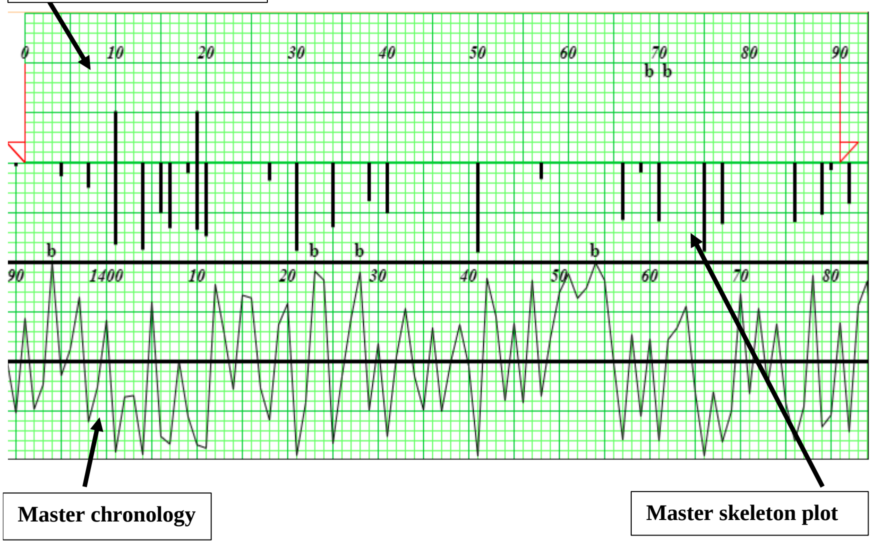
AP1 & AP3 (1931-2019 AD)

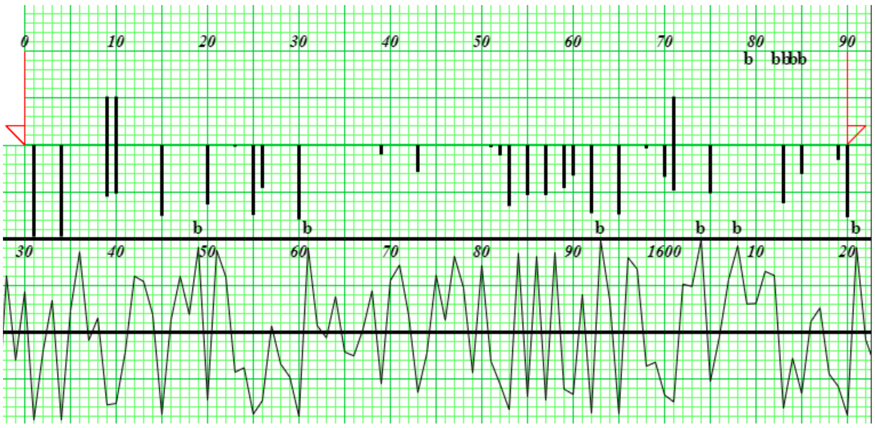
**1948, *1950, 2000, 2009.



a

AP4 & AP7 (1928-2019 AD)

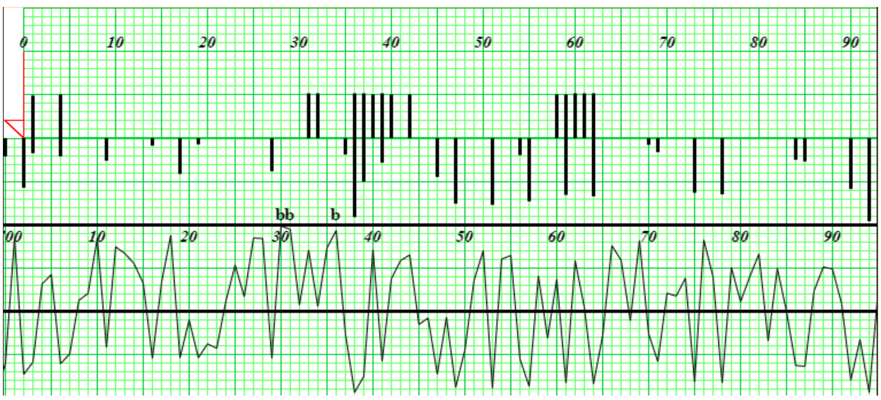
*1934-1937, *1940, 1948, 2010, 2009



b

AP12 & AP13' (1897-2019 AD)

1957-1961, 1976, 1978, 1983, 1987, 1988, 2015, 2018.



c

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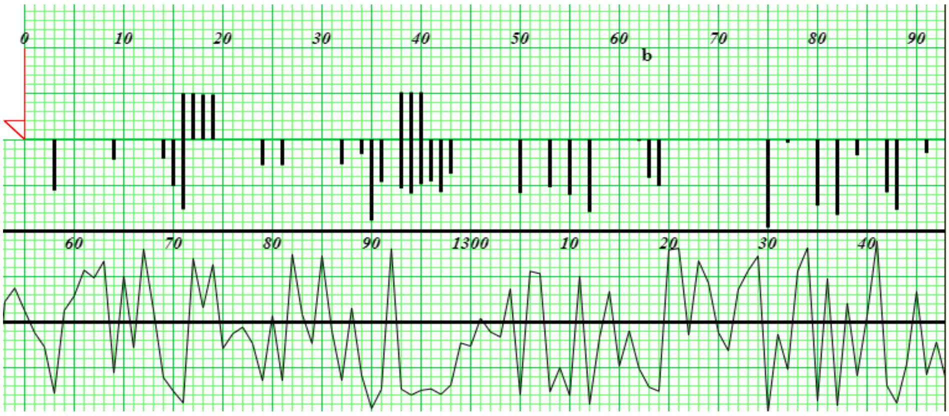
AP15 &AP18' (1887-2019 AD)

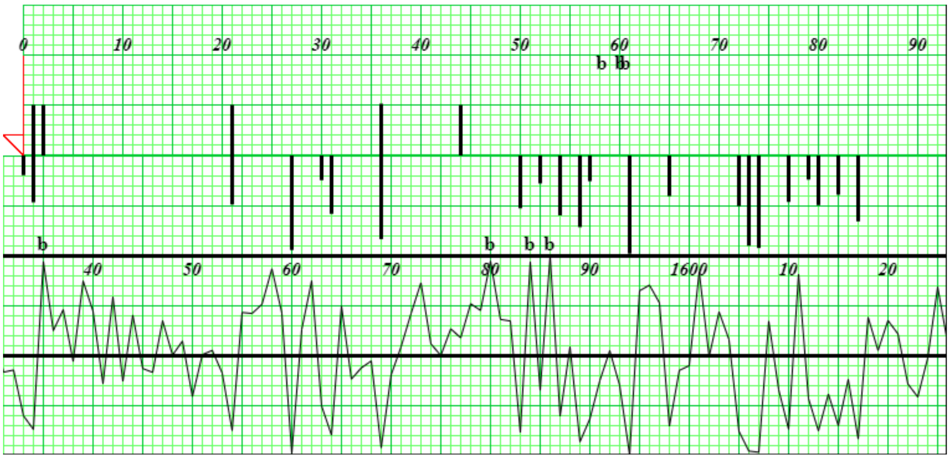
*1956, 1979-1981, 2000-2003.



d

AP22 & AP24 (1911-2019 AD)

*(1958, 1959, 1961), 1975, 1983, 1998, 2017, 2018.



e

AP27 & AP42' (1898-2019 AD)

*1967, 2001.

f

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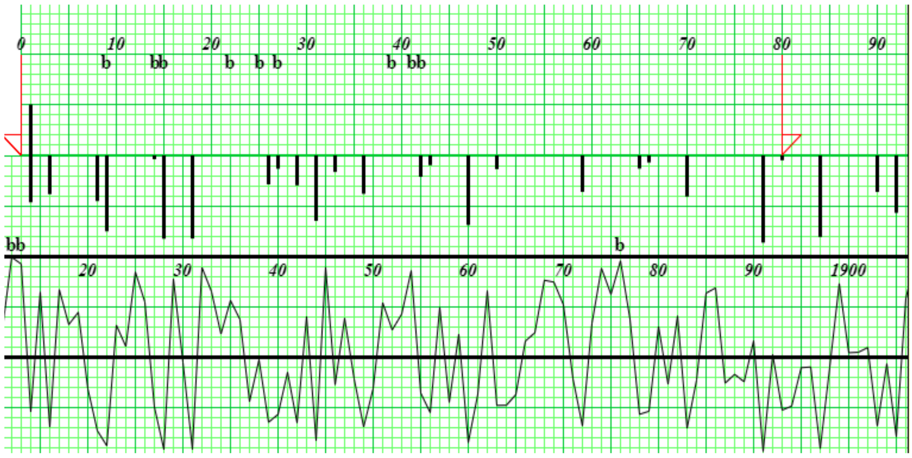
TB5 & TB9 (1963-2019 AD)

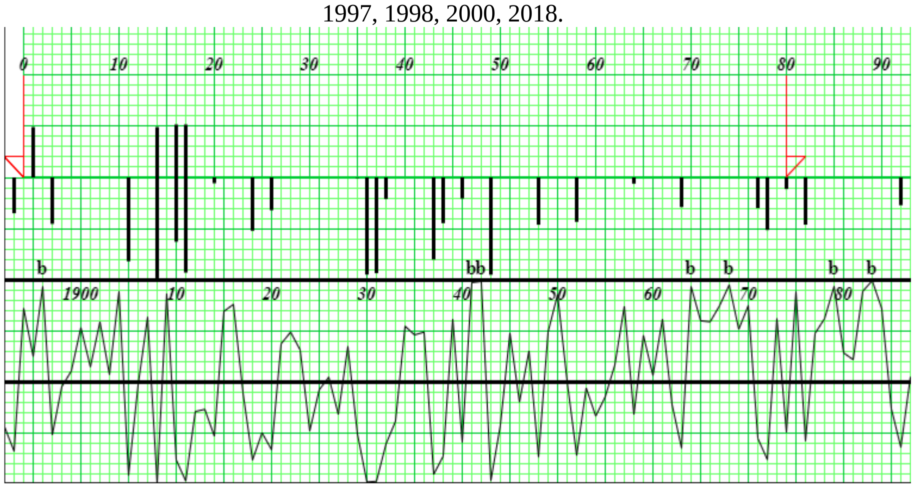
** (1977, 1978, 1980, 1992, 1994, 1997, 2004, 2005, 2010), 2018.



g

TB19’ & TB20 (1953-2019 AD)

1997, 1998, 2000, 2018.



h

***Figure 7.** (a-h) Most sensitive growth years of trees, representation through composite skeleton plot and their matching with master skeleton plot and master chronology*

Discussion

Conifers population increases with increase in forest resources and particular species have wide range of distribution. The nature of any forest is determined by interaction of many physical and biological factors resulted in species distribution in particular geographical region depending upon resource requirements in tolerant sites where it makes necessity for survival (Glatzel, 2009; Shaheen et al., 2015). Thus, present study focuses on age and growth rate determination and intra annual fluctuations between different species by graphical representation. In this way, chronology was prepared by Skeleton Plot Model after identification of climate sensitive years in selected species (Sheppard, 2002).

Environmental factors are very important in determining species dominancy at site such as sufficient light, nutrition, moisture and other edapho climate features. So, *A. pindrow* was found to be in large number as edapho climate features favored its growth

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while *T. baccata*, *P. roxburghii, C. deodara* was found to be minimal which may due to some anthropogenic activities like cutting, logging, fire and overgrazing.

Age and growth rate studies

Maximum and minimum age and growth rate of all selected conifers is presented in *Table 1*. Age and growth rate varies with elevation variation, from species to species and even among the similar species of similar sites. Many researchers have been engaged and are investigating dendrochronological potential from Pakistan and around the globe. Ahmed et al. (1990) reported age of *P. wallichiana*, 112 years with 20.5 cm dbh from dry temperate area of Takhtesuleman and moist temperate area like Khanaspur, Ayubia and Murree with different diameters, 58 cm, 65 cm, 58 cm dbh. *A. pindrow* showed an age of 103 years and 105 years with 71.2 and 92 cm dbh respectively from Murree site. An oldest *A. pindrow* was recorded with age of 277 years and 89 cm diameter from Ayubia. *C. deodara* was found to be oldest with age of 533 years and 180 cm dbh from Chitral site. The present study revealed the dominancy of *A. pindrow* with maximum age of 698 years and 149.3 cm diameter from Kalam Forest Division. Some other researchers from other countries determined dendrochronological potential of trees. Mccarthy and Weetman (2006) determined age of *Abies balsames* with 264 years black and white spruce with 264 and 247 years respectively from Canada. Muhammad et al. (2019) determined age of *C. deodara* from Kashmir Point Murree, Pakistan. Moreover, age of *Pondesera* was also determined, 618, 613 and 330 years from different sites of California by Youngblood et al. (2004). In the present study, we determined age of *A. pindrow*, *T. baccata* and *P. roxburghii,* 698 years with 149.3 cm dbh, 479 years with 137.16 cm and 218 years with 48.76 cm dbh respectively. *C. deodara* was found in minimum quantity due to reduced competition among trees and illegal cutting and burning of trees. So, significant positive correlation was observed in age and dbh among different species. Age may increase or decrease with increase of diameter as species lie in different geographical positions. Moreover, it was not observed an effective parameter for age variation as regional climate also favors the growth of conifers after Scipioni et al. (2021) and Ahmed et al. (2011).

Maximum and minimum growth rate of all species is presented in *Table 1*. Growth rate of conifers is also affected by availability of forest resources such as moisture content, favorable temperature and precipitation, adequate nutrients and prevention from natural or unnatural disasters after Ahmed et al. (2012). Among selected species *T. baccata* was found to be with maximum growth rate as environmental factors favored its growth and development. However, growth rate of rest species was also observed reasonable but not responded like *T. baccata.* Siddiqui et al. (2013) observed slow growth rate of *A. pindrow* from moist temperate area. Ahmed and Sarangzai (1992) determined growth rate of *P. wallichiana,* 2.5 cm/years from Murree. Ahmed et al. (2009) also determined as 1.7 cm/years in *P. wallichiana* from Dir. *A. pindrow* and *C. deodara* was observed with faster growth rate from Dir and Naran areas. In present study, *T. baccata* was observed with maximum growth rate, 0.66 cm/year while it was 0.05 and 0.10 cm/year as maximum in *A. pindrow* and *P. roxburghii* respectively.

Correlations study

Many researchers observed significant positive correlation between age and diameter from different sites of world. Ahmed and Sarangzai (1991) obtained such positive correlation in all selected species. However, Ahmed et al. (1990) did not find significant

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relationship between these parameters in *Juniperus excela* from Baluchistan, Pakisan. Moreover, Wahab et al. (2008) did not observe such positive relationship in *Picea smithiana*. Ahmed et al. (2009) did not find such correlation four species i.e., *A. pindrow, P. wallichiana, C. deodara* and *Picea smithiana* but they observed positive relation in *P. roxburghii*. In the present study, *A. pindrow*, *T. baccata* and *C. deodara* showed positive correlation while *P. roxburghii* showed highly negative correlation between age and diameter.

Growth rate was also observed non-significant by various researches. Muhammad et al. (2021) did not observe significant correlation between dbh and growth rate in *C. deodara* from Murree, Pakistan. Wahab et al. (2008) also observed negative relationship between dbh and growth rate in *P. smithiana* from conifers of Afghanistan Forest. *A. pindrow, P. wallichiana* and *C. deodara* also showed highly significant negative correlation between dbh and growth rate by Siddiqui et al., 2013. Ahmed et al. (2012) observed strongest response by rainfall. All selected species showed highly negative correlation between dbh and growth rate in present findings as shown in *Figures 4b, 5b, 6b.*

Conclusion

Kalam Valley, located at the junction of three mountains (Hindukush, Himalaya, and Karakoram), has a special topography, according to the researchers. The alpine peaks in the area vary in elevation from 1900 to 4600 m. Conifers grow taller as a result of edaphoclimate factors such as harsh winters, acidic soil, altitude variation, salts, sand, silt, and organic matter. Briefly to conclude, the study site was densely covered with *A. pindrow* as huge number of this species was observed while *C. deodara* was observed as minimal due to some anthropogenic disturbances. Significant positive correlation was observed between age and diameter in all species except *P. roxburghii* after Ahmed and Sarangzai (1991) while no such significant relationship was observed between diameter and growth rate after Wahab et al. (2008). Moreover, environmental factors mainly temperature, precipitation and rainfall also favored age and growth rate of these conifers and *T. baccata* responded well to these climatic variations as maximum growth rate was recorded in this species after Ahmed et al. (2012). A lot of reasons (deforestation, burning of wood as to fulfil needs of coal, overgrazing, town planning, and frequent forest fires) have placed the study site under biological stress due to *C. deodara* was observed a few in number. The chronology presented in results clearly depicted highly sensitive tree rings which were distinct indications of growth rate variations during development of trees. The developed chronologies signify the sensitivity of conifers of dry temperate study region towards diverse climatic factors and could be analyzed to predict future seasonal climate variations. Some highly recommended steps can be followed to conserve species habitat (natural biodiversity) through traditional practices such as:

- Need of awareness and management of forests to regain their valuable potential regarding to scientific research projects.
- Implementation of Forest rules to avoid from illegal cutting, burning and chopping by providing alternative fuel resources.
- Old age trees of study site such as *A. pindrow, T. baccata,* particularly *C. deodara* (national tree of Pakistan) etc. must be declared as cultural heritage of country.
- Ecotourism must be developed to promote cultural and economic significance by working with international counterparts, to acquire global exposure.

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