Research Article

Unveiling the Dendroclimatic Potential of Blue Pine (*Pinus wallichiana*) Growing in Shangla, Khyber Pakhtunkhwa

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Abstract | Dendroclimatic potential of coniferous trees reflects their ability to serve as a valuable tool for understanding the past climatic conditions and predicting future trends of the region. Blue pine (Pinus wallichiana) with well-defined annual growth rings offers a reliable record of previous circumstances of environment . The objective of current study was to evaluate its dendroclimatic potential under Shangla's wet temperate climate in Khyber Pakhtunkhwa . In order to conduct study, wood samples in the form of cores were taken from the district of Swat's Shahpur and Liliani Forest areas. Using standard laboratory techniques, the collected cores were processed and measured for tree ring width. Cofecha and R packages, two computer - based programs , were used to statistically evaluate the data. The findings indicated that there was a notable rise in yearly precipitation between 1921 and 2021, which had a substantial impact on the species ' growth . Furthermore , precipitation was discovered to be a limiting factor for this species' growth. From the results, it was concluded that blue pine growing under the prevailing climatic conditions of Shangla has good potential for dendroclimatic studies and could be helpful for scientists and researchers to forecast regional and global climate change by reconstructing past climatic factors.

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Introduction

Dendrochronology is the science of examining tree growth using annual tree rings, while dendroclimatology is the study of the link between tree growth and climatic changes (Lukman, 2013). A tree's growth rate is susceptible to both natural and man-made events, thus the year's conditions will either be beneficial or unfavorable for the tree's growth, causing the ring width to vary from year to year over the course of the tree's lifetime (Nabeshima *et al*., 2010). In most parts of the world, this pattern of broad and narrow growth rings can be used as an indication to track environmental activities (Harley, 2013). It is uncommon, yet, how distinct species and locations react to varied climate conditions (Roman and Wiens, 2020). Any tree species can be used in tree ring research depending on its ring width properties, such as sensitivity, the capacity to match narrow and wide rings together, and correlation within or between tree samples (Khan *et al*., 2018).

Coniferous trees with long lifespans and well-defined annual growth rings are considered reliable tool for understanding past climatic conditions and predicting future trends of a region (Izworska *et al*., 2023). In the region, dendroclimatic potential of Himalayan Fir (*Abies pindrow)* has been evaluated by Rauf *et al.* (2022) and Amir *et al.* (2022); of Himalayan Spruce (*Picea smithiana)* by Ullah *et al.* (2022) and Shah *et al.* (2019); of Blue pine by Bukhari *et al.* (2019) and Asad *et al.* (2017). Shangla is one of the district of Pakistan in KP (Khyber Pakhtunkhwa). The headquarter of the district is situated in Alpurai. With 28 union councils, the district has a total size of 1,586 square kilometers. Shangla district has a total population of 757,810. The district is located between 72.33§ and 73.01° East Longitude and 33.08° to 34.31° North Latitude. Shangla is bordered by the districts of Kohistan to the north, Battagram and Kala Dhaka (Black Mountain of Hazara) to the east, Swat to the west, and Buner to the south. Small valleys sandwiched between hillocks and encircled by towering mountains blanketed in woods make up the Shangla district. With dense, open coniferous forests made up primarily of Abies pindrow, Cedrus deodara, Pinus wallichiana, and Picea smithiana, trees, the region is located at a significant elevation above sea level. 5900 to 12000 feet above sea level is the district's overall elevation (KPK, 2022).

For dendroclimatological research, the blue pine growing in the Swat Valley's Shangla has not yet been investigated. Thus, the objectives of the current study is to determine the suitability of this species for this purpose, collect data on the changes in climate over the past 100 years, and determine the relationship between the growth of Kail (*Pinus wallichiana*) and climate, which is grown in moist temperate climates in these regions.

Materials and Methods

Study site

For carrying out this study, moist temperate forest areas of Shangla Forest Division i.e. Shahpur and Liliani were selected. Field data regarding geographic and topographic parameters were collected as given in Table 1.

Sampling method

Research material in the form of tree cores (20-30) from each study site were extracted from the old, healthy and damaged-free trees using Completing Randomized Design (CRD) method. Freshly extracted cores were stored in core holders.

Table 1: *Shangla forest area, Swat site characteristics.*

Name of site	Latitude	Longitude	Aspect	% Slope	Elevation (ft)
Shapur	34.96	72.76	North	15-45	4200-5000
Liliani	35.25	72.75	North-East	7-20	6000-7000

Laboratory work

After being allowed to air dry, the core samples were put on hardwood core holders and sanded to provide a flat surface. Every core was scrutinized using a microscope with varying power, and a visual cross-matching were determined among the cores (Stock,1996). This process makes it possible to identify missing, duplicate, or fake rings from ring-width series. At this point, ten cores were discarded. The latest Win Dendro System was used to measure the cores that demonstrated good cross-matching to the closest 0.001mm (Campbell *et al*., 2011; WinDendro, 2014).

Statistical analysis

The Cofecha program was then used to cross-check each core's measurement series for potential dating errors (Grissino-Mayer, 2001). The program dplR of the R package was then used to compile the cross-dated series into a site chronology (Bunn *et al*., 2022). Through single detrending with the program's spline settings, the age-related growth effects were eliminated. Subsequent modeling was done using the Standard chronologies from the output, for identical reasons. Using the point Res software of the R packages, the pointer and event years of each research site chronology were established in order to increase the trustworthiness of the derived chronologies (Van den Maaten *et al*., 2015).

The computer-based application treeclim from the R package was used to calculate the Correlation function Analyses (CFA), which gave more insight into the relationship between the development of trees and climate (Cristian, 2015). The 12-month window from October of the previous year to the end of the current growing season (September) was chosen since it is generally believed that the time of tree growth in the area begins around March and ends at the end of September. An analysis that looked into the contribution over the previous four years of growth was included (Ahmad *et al*., 2010).

Results and Discussion

Climatic data analysis

The consequences of climatic changes on the tree growth characteristics of Kail (*Pinus wallichiana*) growing in this area were studied using climate data of Shangla that was gathered from the Climate Research Unit (CRU). The grid size of this data was 0.5 X 0.5 degree (50 km x 50 km). Figure 1 illustrates how the climate diagram for mean temperature and precipitation was created for the time period of 1921–2021. The climate diagram showed that the two hottest months were June and July, with mean temperatures of 24.68 and 24.553 degree Celsius, respectively, and means rainfall of 159.61mm and 68.43636mm, respectively. At 4.36 ˚C for the minimum mean temperature and 84.51 mm for the mean monthly rainfall, January was found to be the coldest month.

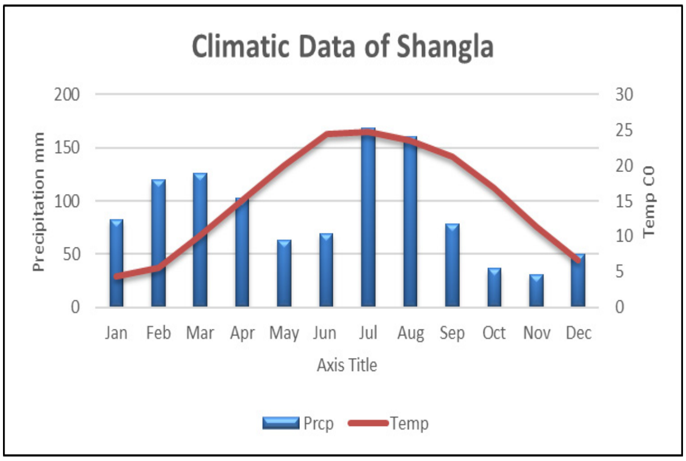

Figure 1: *Shangla meteorological data's Climatogram for the Years 1921–2021.*

In 2015, the highest recorded annual rainfall of 1727.7 mm and the highest recorded annual mean temperature of 15.380˚C were recorded. For the period under study, an increase in total annual precipitation of 272mm was found to be significant ($r=0.4$; $p<0.001$), whereas a rise in temperature of 0.47 ˚C ($r=0.30$; $p>0.03$) was not.

The development of tree ring chronology

Table 2 displays a summary of the COFECHA analysis. There are variations in the chronology ranging from 55 to 101 years. The range of correlation with master chronology is 0.325 to 0.613, with an average value of 0.494. Following filtration, the auto correlation drastically decreased from 0.614 to -0.030. There were no double or missing rings found. Table 2 further demonstrates that 20 of the 30 wood samples, or cores, were chosen. Studying a species dendro-climatic potential for a specific study site can be done with a mean sensitivity of 0.279, a sophisticated value that is accepted globally (Speer, 2010; Zheng *et al*., 2019).

Table 2: *Tree ring chronology from Shangla Forest Area using Cofecha statistics.*

Seq	Series	Interval	No. Years	No. Segmt	No. Flags	Corr with Master	Unfiltered Mean msmt	Unfiltered Max msmt	Unfiltered Std dev	Unfiltered Auto corr	Unfiltered Mean sens	Filtered Max value	Filtered Std dev	Filtered Auto corr	AR ()
1	AWS44	1921 2021	101	3	0	.613	2.64	8.22	1.314	.676	.306	2.62	.391	-.043	2
2	AWS54	1935 2021	87	3	0	.416	2.52	5.50	1.226	.529	.345	2.67	.521	-.058	1
3	AWS23	1954 2021	68	2	0	.443	2.73	5.27	1.182	.789	.258	2.55	.488	-.037	1
4	AWS20	1956 2021	66	2	0	.604	3.09	5.50	.955	.656	.202	2.53	.399	-.037	1
5	AWS49	1957 2021	65	2	0	.495	2.92	5.07	1.021	.780	.207	2.61	.451	-.015	1
6	AWS09	1957 2021	65	2	0	.475	3.03	6.97	1.476	.688	.352	2.44	.435	-.009	1
7	AWS55	1962 2021	60	2	0	.511	2.96	5.50	1.182	.650	.297	2.30	.345	-.018	1
8	AWS47	1962 2021	60	2	0	.531	3.14	6.24	1.074	.583	.238	2.45	.365	-.010	1
9	AWS57	1964 2021	58	2	0	.491	3.18	6.55	1.040	.613	.245	2.45	.510	-.087	1
10	AWS36	1965 2021	57	2	0	.532	3.37	6.17	.844	.609	.180	2.53	.485	-.074	2
11	KFS11	1931 2020	90	3	1	.445	2.28	4.57	1.080	.671	.358	2.53	.414	-.077	2
12	KFS25	1943 2020	78	3	0	.515	2.20	5.73	1.004	.569	.309	2.71	.399	.007	1
13	KFS7	1944 2020	77	3	1	.445	2.68	7.02	1.286	.746	.264	2.62	.484	-.021	1
14	KFS18	1944 2020	77	3	1	.385	2.51	5.32	1.054	.412	.344	2.65	.516	.029	1
15	KFS32	1950 2020	71	2	1	.325	2.10	4.47	.850	.506	.305	2.71	.464	-.109	1
16	KFS1	1951 2020	70	2	0	.508	2.91	5.12	.773	.685	.179	2.58	.407	-.027	1
17	KFS30	1951 2020	70	2	0	.612	2.50	4.91	.850	.585	.240	2.67	.440	-.049	1
18	KFS10	1956 2020	65	2	0	.636	2.53	4.52	.824	.663	.210	2.56	.545	.024	1
19	KFS8	1961 2020	60	2	0	.509	3.69	6.00	1.218	.366	.334	2.54	.554	.014	1
20	KFS15	1966 2020	55	2	0	.406	3.88	6.03	1.195	.462	.316	2.33	.373	.011	2
Total or mean:			1400	46	4	.494	2.79	8.22	1.079	.614	.279	2.71	.449	-.030	

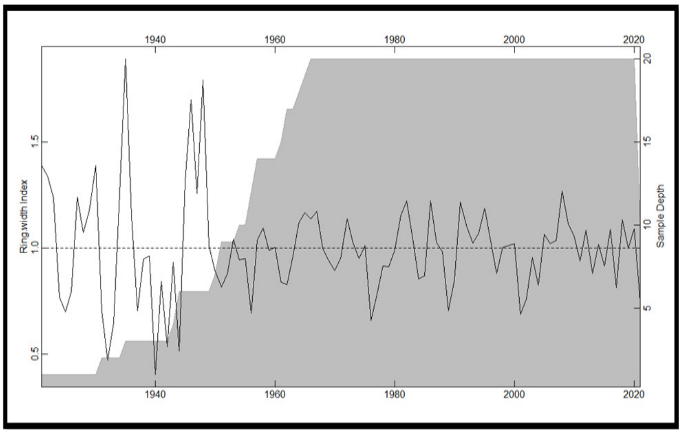

Figure 2: *The Shangla forest area, Swat, regional tree ring width chronology from 1921 to 2021. The sample depth is shown by the gray region.*

Following the detrending and standardization processes, a Pinus wallichiana tree ring width chronology was created, as shown in Figure 2. From 1921 to 2021, a period of 101 years, was covered by the chronology. The trend line indicated that the ring width decreased from 1968 to 1971, 1976 to 1980, 1984 to 1985, 1988 to 1990, 2001 to 2004 and increased from 1966 to 1967, 1972 to 1973, 1981 to 1982, 1986, 1991, 2008 to 2009, and 2018. Growth began to drop in 2020 and continued until 2021. Figure 3 shows that for this research site, a positive pointer year was noted in 1930 and a negative pointer year was determined in 1932.

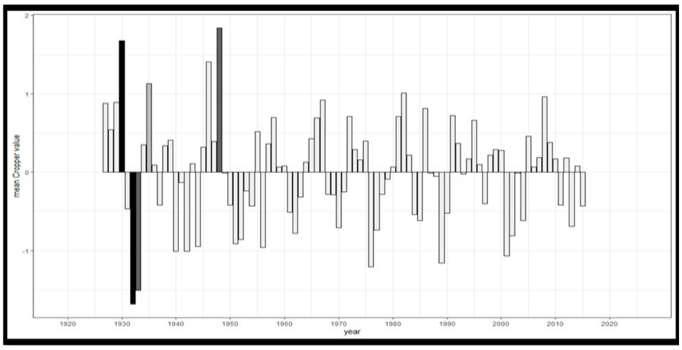

Figure 3: *Blue pine growing in Shangla, KPK, from 1921 to 2021: Positive and negative pointer and event years.*

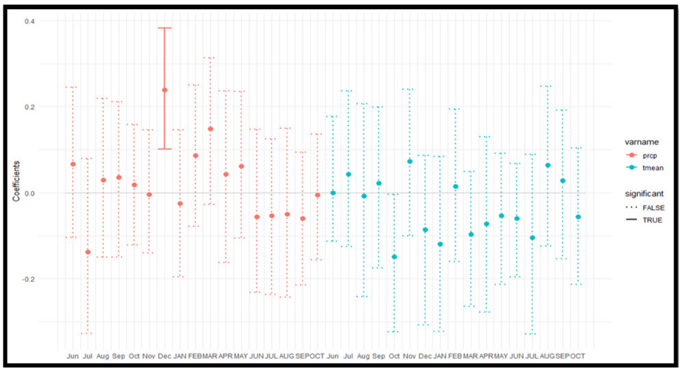

Figure 4: *Analysis of correlation function for Kail at Shangla; correlation coefficient (r) between monthly meteorological variable and TRW for the current year (capital letters) and the previous year (lower case). Stick bars represent statistically significant associations (p<0.05) (Sohar et al., 2017). The common era (1921-2021) was used to compute correlations between June of the year before tree-ring growth and October of the current growth year (Ahmed et al., 2010).*

Climate-growth relationship

Figure 4 show the correlation function analysis (CFA) of Pinus wallichiana tree ring width from Shangla and climate conditions. In this area, it is clear that December precipitation from the previous year is a strong predictor of blue pine tree development. This indicates that if there was more precipitation available in the previous year, broader ring formation may occur in the current growth year. Conversely, the temperature in December of the previous year had a negative but non-significant coefficient value, indicating that low temperatures are not conducive to the growth of this species. According to Figure 04, precipitation during the growth season (January to March) has a beneficial impact on the growth of this species because there is enough water available for photosynthesis to occur. This beneficial impact was observed through May of this year. Precipitation had a consistent negative (non-significant) influence from June to October. Regarding temperature, no discernible impact was observed throughout the preceding year or the current growth phase of this species. August and September temperatures, however, appeared to have a slight favourable impact on the growth.

The dendroclimatic potential of a tree species depends on its tree ring characteristics like correlation with master chronology, average width of tree ring, mean sensitivity, standard deviation (SD), 1st order auto-correlation coefficient, and sample depth (Fritts and Shatz,1975; Ahmed *et al.*, 2010). Cofecha statistics showed that the tree ring chronologies scored an acceptable value of correlation with the master chronology and may be used for the study of climate-growth relationship (Wigley *et al.*, 1984). The possible reason is good cross-dating of these tree ring series that generated a higher value of correlation and the outcomes align with the fresults of Asad *et al.* (2017) who evaluated the dendroclimatic podential of Bluepine growing in the Karokuram forest areas. Both biotic and abiotic environmental conditions have an impact on tree growth. Two of the most influential abiotic variables are generally thought to be precipitation and temperature (Toledo *et al.*, 2011). Determining the climate changes that have occurred in the area is crucial to examining the effects of climate change on the flora and fauna of a study site. The statistical analysis of climatic data for the both study sites revealed a prominent increase in annual precipitation. It is commonly considered that precipitation played a vital role and serve as an impediment and limiting factor for the growth and development of trees under moist conditions (Ullah et al., 2022). The temperature along with a suitable supply of water during the growth period are prerequisites for the normal growth of tree species (Pallardy, 2010). Shangla is in Khyber Pakhtunkhwa's damp temperate zone, and it's generally believed that precipitation is a factor that restricts tree growth and the results we obtained in this study are in accordance with previous findings of Bajwa *et al.* (2015) and Bukhary *et al.*, (2019).

Conclusions and Recommendations

The Kail tree exhibits promising potential for dendroclimatic research and could be regarded as a sensitive species in the context of reconstructing precipitation in Shangla forest regions, according to the findings. Throughout the past 100 years, this region has experienced a non-significant increase in mean annual temperature and a major increase in annual precipitation, both of which have had a substantial impact on the growth and proliferation of this species.

It was also discovered that during the Kail growth period in this area, precipitation is serving as a limiting factor.

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Novelty Statement

This study offers never-before-seen insights into the relationship between climate and tree growth in this location by examining the dendroclimatic potential of Blue pine (*Pinus wallichiana*) in Shangla, Khyber Pakhtunkhwa.

Author's Contribution

Tanvir Hussain: Collected tree core samples, measured data, wrote the findings as a manuscript/ research article for publication. Additionally, served as a corresponding author.
Zahid Rauf: Supported in statistical analysis.
Mansoor Ali Khan: Contributed in samples drying/ seasoning, plagiarism and grammatical mistakes removal.
Khalid Hussin: Supported in data collection and compilation.

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

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