A Study On Dendroclimatic Potential Of Chir Pine (*Pinus Roxburghii)* Grown In Bahali District Mansehra Kp Pakistan.

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Abstract
This study is carried out to evaluate the dendro-climatic potential of Chir pine (*Pinus roxburghi*) growing under the moist temperate condition of Bahali forest area of Khyber Pakhtunkhwa. For this purpose, wood material in the form of tree cores was extracted from healthy trees randomly. The cores were prepared for data measurement using standard laboratory procedures. Data regarding Total Ring Width (TRW) were measured with the help Win-Dendro System. The collected data were compiled and analyzed statistically using computer-based software Cofecha and R packages. Results showed that an increase of **309.3 mm** in total annual precipitation and **0.426 C^0** in temperature had happened in this area. This species reflected accepted mean sensitivity value **(0.297)** under these climatic conditions. The climate-growth relationship for **56 years (1965-2021)** revealed that precipitation is acting as a limiting factor for the growth of this species and temperature is playing its optimum role. It was concluded that Chir Pine has tremendous dendro-climatic potential which is an indication that environmental changes had created impression on growth and developmental of the trees in the study area. Further, it is recommended that this species can be used for further research concerning, reconstruction of climatic parameters and other future issues of climate changes, but long-term chronology development is prerequisite.

Keywords: *Dendroclimatic, WinDendro System, Chir pine, Cofecha software, R-packages, Pakistan.*

INTRODUCTION

In Pakistan tree ring research started in 1986 when Ahmed (1987 – 1988) described Dendrochronology and its scope in Pakistan and problem encountered in age estimation of forest trees. Ahmed and Saranzai (1991, 1992) applied Dendro-chronological methods to estimate age and growth rates of various tree species of Himalayan region of Pakistan. They also presented a Dendro-chronological potential of Himalayan trees. Ahmed and Naqvi (2005) presented tree-ring chronologies of *Picea smithiana* from various climatic zones of Himalayan areas of Pakistan. The radial growth of tree is one of the most easily recognized and observed features, highly sensitive to climate and greatly affected by climate (Cao et al., 2018; Fritts, 1976; Zhang et al., 2016). Tree rings provide a wealth of information on tree growth patterns, species behavior, tree age and environmental impact of tree life cycles, as well as possible response to future climate change and forest dynamics (Fritts, 1976; Gaspard et al., 2018). Therefore, more and more studies on tree rings have been carried out in the world in recent years. Among them, one of the most important and critical issues is to identify the comparative growth-climate relationships in different sites or species (Buras et al., 2016). It can provide us with basic information on common and comparative growth trends among different species to predict potential changes in tree composition, spe- cies and growth changes, and to improve our knowledge of forest ecosystem management (Briffa et al., 1999; D'Arrigo et al., 2008; Jacoby and D'Arrigo, 1995). Previous studies on forest dynamics have insufficient understanding of forest growth and sensitivity, adaptation and climate change (Zhou et al., 2016). Tree rings provide a wealth of information on tree growth patterns, species behavior, tree age and environmental impact of tree life cycles, as well as possible response to future climate change and forest dynamics (Fritts, 1976; Gaspard et al., 2018). In addition, the relationship between tree growth and climate may change over time, especially in the past decades (climate warming). Global climate change, especially temperature and pre- cipitation, is not consistent in time (IPCC, 2013). Applications of this field of dendrochronology is widely used in scienceof silviculture, ecology, forestry, seismology, hydrology, climatology and population dynamic studies (Khan *et al*., 2013; Bhuju and Gaire, 2012). Tree radial growth is more sensitive to climate change near the species distributional boundaries than the suitable area for its growth, such as intermediate altitude or latitude (Malanson, G.P Complex 2001).

Dendroclimatology, as a traditional and valid method, has widely been used to detect the long-term growth-climate relationship, and to further evaluate the impact of future climate change on tree ring growth and forest dynamics. In

this study, we aimed at exploring key climate factors influencing radial growth of *Pinus roxburghi* at District Mansehra KP Pakistan.

MATERIALS AND METHODS

Study Area Map of Bahali District Mansehra

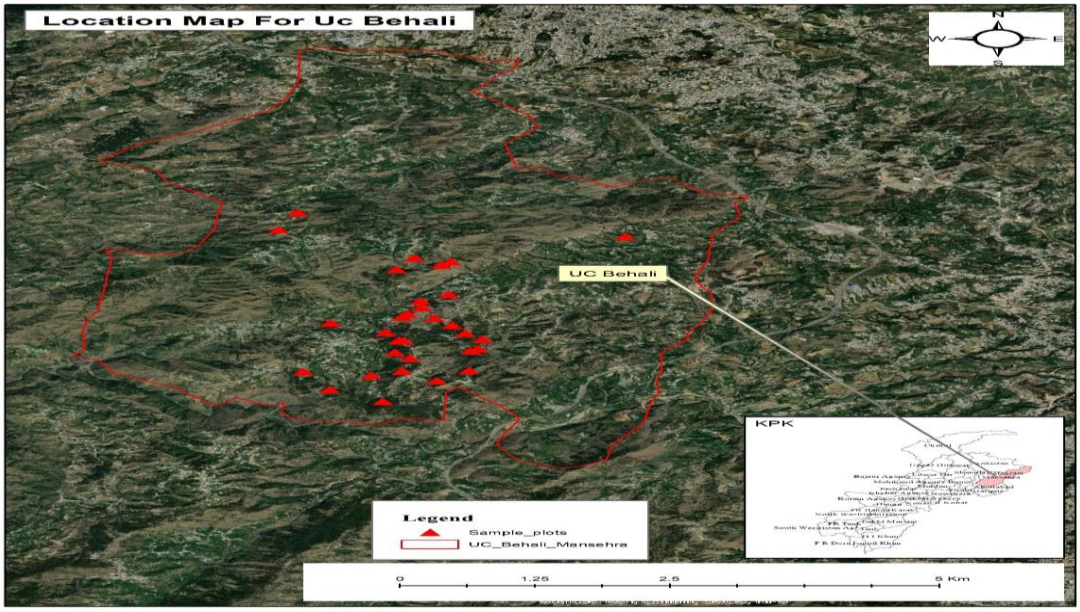

Figure 1 *Study Area Map of Bahali District Mansehra*

Table *1 Site characteristics of Pinus roxburghi at UC-Bahali Forest Area of District Mansehra*

Site Name	Latitude	Longitude	Aspect	Slop %	Elevation (ft.)
Bahali Mansehra KP	34.15	73.10	North	10-58	2500-4500

1 Climate data

Climate parameters including annual mean temperature and precipitation over time scale 1965-2021 from international climatic data source i.e. Climatic Research Unit (CRU) was collected and utilized (Harris, 2020 for tree growth-climate relationship and assessment of impact of climate change for the studied period.

2 Study Area Selection In study area the trees are selected randomly from different area of the union council, in order to maintain spacing, tree morphology, tree population size and density. The tree structure, crop density, altitude deference, aspect, and slope factor is also recorded to obtain better results.

3 Tree Selection Those trees were selected from the study area which is free from any defects (Fire damage, Knots, any other physical injuries), easy in extraction of cores, and accessible to take data.

4 Tree Diameter From the selected tree, diameter is taken with the help of Dia-tape at breast height..

5 Core Extraction With the help of a Pressler increment borer, core are removed from the chosen tree at breast height, at uphill side. Normally two cores are extracted for dendro-chronological study, but in case, it is difficult to extract core from both side due to slope factor. The extracted core is then put in paper core tube for further study, and to keep safe from drying, breaking and damaged.

6 Tree Coordinate The geo-graphic location of selected tree is recorded with the help of GPS, for the purpose to make point map, location of tree, and geographical distribution of study area.

7 Tree Topographical Feature Sunto-Clinometer is used to measure the slope of the chosen tree. In hilly areas, slope is a crucial factor because trees on steep slopes grow under stress from soil erosion, a lack of water, and a lack of nutrients. Elevation of selected tree is recorded with the help of GPS.

8 Preparation of Sample for Microscopic Study

The cores were measured after being glued onto wooden and sanded with sandpaper (60, 80 and 120 grit) until a glossy surface was obtained. Then, with a low-power microscope, the ring width growth patterns within and between trees were compared, i.e. exact cross-dated calendar years were assigned. Stocks and Smiley's techniques are used in the process.

The latest and most advanced Win-Dendro System was used to measure the ring width and other parameters. Sequences from each core were then cross-checked with the reference core for possible alignment errors using Cofecha software. (Holmes 1983; Grissino-Mayer, 2001). The cross-checked data series were then compiled into site histories using the dplR program in the R package. Single de-trending with the Friedman variable-span smoother in the programme options was used to remove the age-related growth effects. The effects and correlation between tree growth and climate were evaluated using the "treeclim" R packages (Zang, 2015).

RESULTS AND DISCUSSION

Climatic Data Analysis

Climatic data of District Mansehra was collected from Climate Research Unit (CRU), having a grid size of 0.5 X 0.5 degree (50 km x 50 km) and was used to study the impacts of climate changes on the tree growth parameters of *Pinus roxburghii* grown in this Study area.

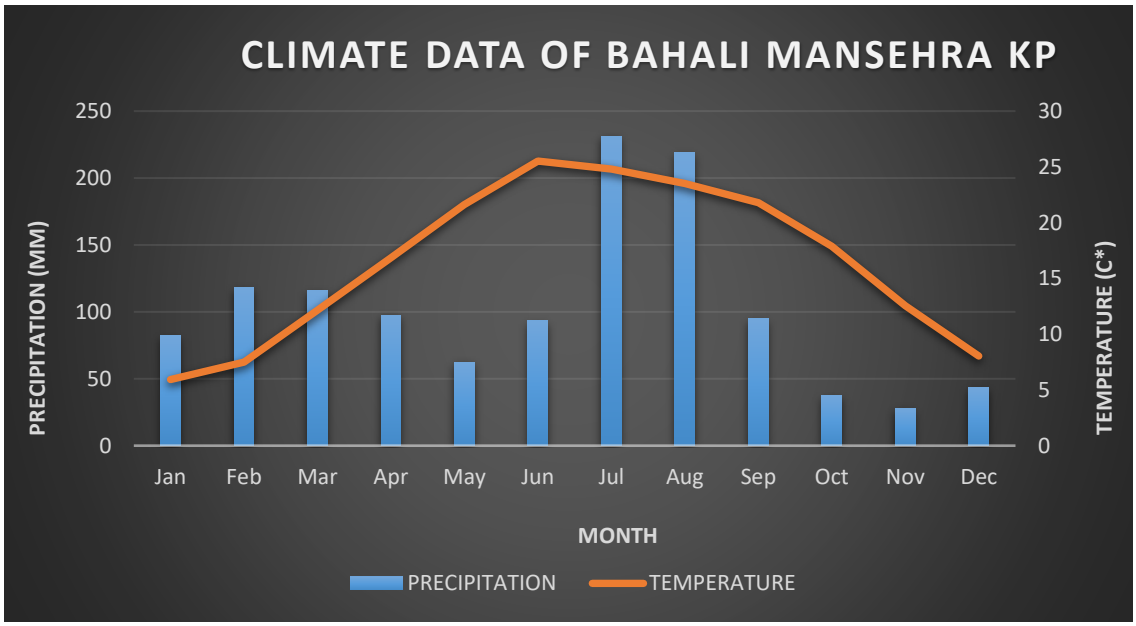

Figure 2 *Monthly variation in mean annual precipitation (bars) and mean annual temperature (line) at UC-Bahali District Mansehra calculated over the period 1965-2021*

It is evident from the climate diagram of study area that June and July were the hottest month with maximum mean temperature of 25.51 ^{0}C and 24.81 ^{0}C respectively along with mean rainfall of 93.34 mm and 231.26 mm accordingly, while January was recorded as the coldest month with minimum mean temperature of 5.92 ^{0}C and mean monthly rainfall of 82.16 mm. The maximum total annual rainfall of 1890.4 mm was measured during 2015, with annual mean temperature of 16.5 ^{0}C. A non- increase of 0.426 C^0($r=0.26$; $p>0.008$) and a significant ($r=0.4$; $p<0.001$) increase of 309.3 mm in total annual precipitation was calculated for this studied period 1965-2021

Relationship between Study site and Chronology Development

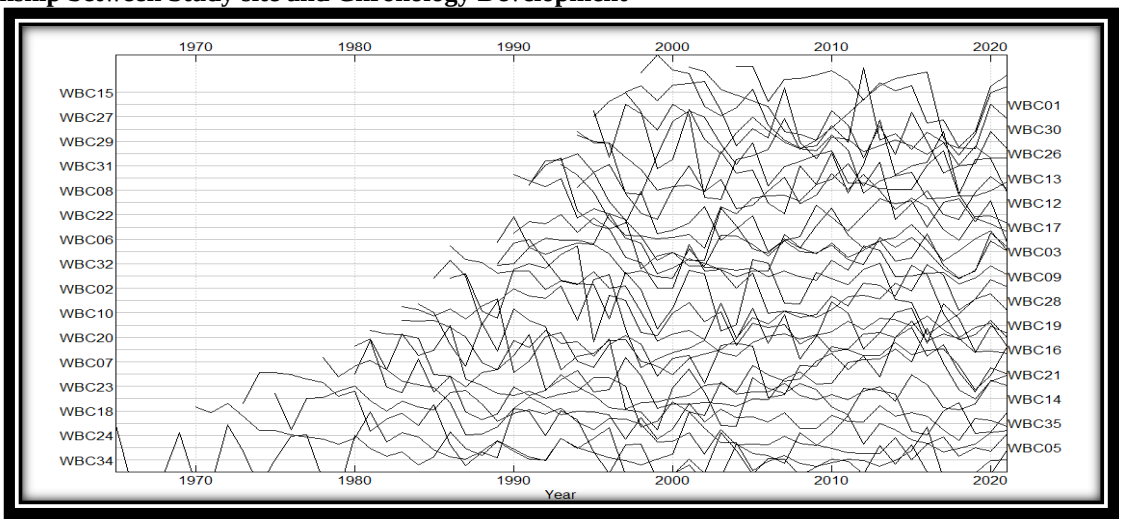

Figure 3 *Relationship between Study site and Chronology Development*

Figure 3 Spaghetti plot shows the chronology of **15 tree cores** with time-span of (1965-2021) showed that the results of Chir Pine tree ring chronology developed through Computer Based Programs Cofecha and dplR of R package.

Table 2 *Result of Quality Control Program Cofecha*

Time Span	No. of Years	Inter-series correlation	Mean measurement of all tree ring width (mm)	Mean sensitivity	Auto-correlation
1965-2021	**56**	**0.347**	**4.71**	**0.297**	**0.605**

The **Table 2** shows the results of quality control program Cofecha obtained from **15 cores** after visually cross-dating. The mean value of inter-series of all cores showed a satisfactory correlation with master chronology. The value of auto-correlation among all thirty-one tree cores ring represented a normal effect on growth from the previous year. The higher value of mean sensitivity showed that climatic factors are strongly influencing the growth of trees in these areas.
The tree ring width chronology developed after de-trending and standardization procedure. Autoregressive Standardization (ARSTAN) program was designed to remove the non-climatic factors from the tree-rings features. After standardization, tree-ring widths are converted to tree ring indices and four chronologies are developed i.e. (Raw, Residual, Standard and Arstan). Residual Chronology (without autocorrelation) has stronger climatic signal and statistically more robust than standard chronology, therefore this chronology was used for climate-growth modeling.

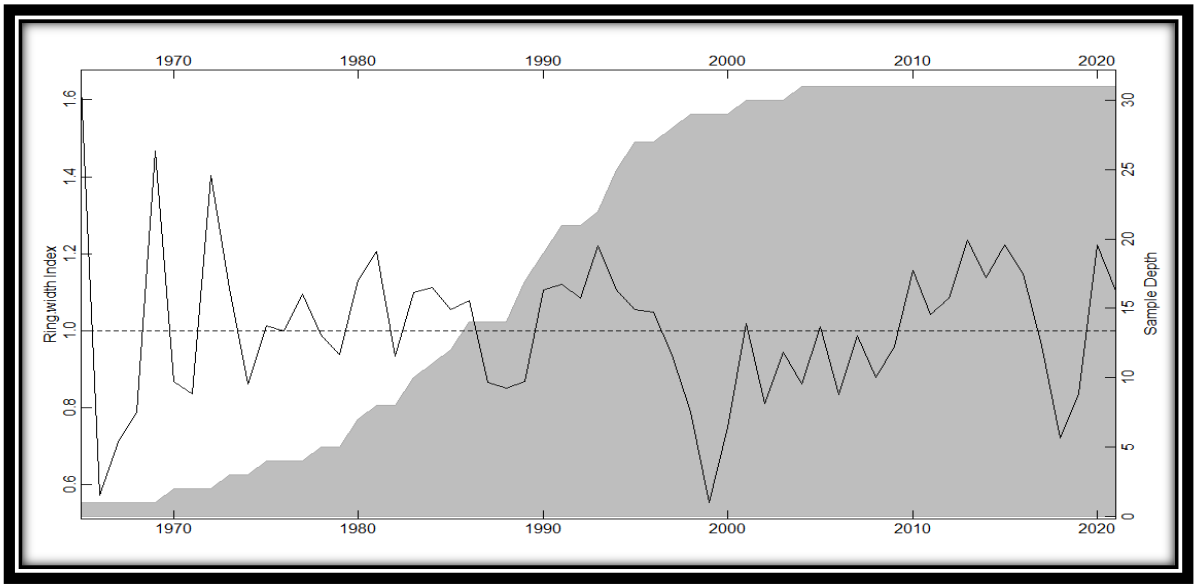

Figure 4 *shows the regional tree ring width chronology for Chir Pine from 1965-2021 for study area. The gray area represents the sample depth.*

Figure 4 shows the trend line of an increase of ring width from 1988 to 1994, and a decrease from 1995 till the drought season of 1998 then no prominent evidence of increase found up to 2009. From 2010 to 2014 an upward increase was again seen but after that a decreasing trend occurs up to 2018 and again drought season was observed in 2018 after that a rapid rise in growth trend was found till 2021.

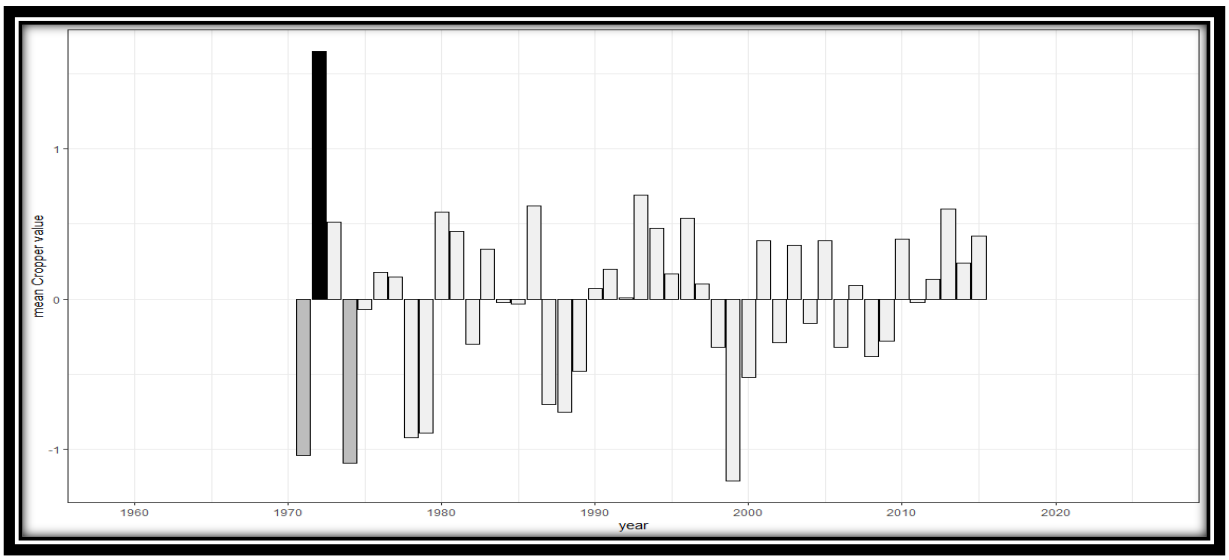

Figure 5 *Positive and negative pointer and event years from 1961-2021 of Pinus roxburghi growing in Mansehra KP.*

Figure 5 shows the **Pointer year** of this area may be considered the year **1972**, where a prominent increase in ring width can be seen. Event years i.e. **1971** and **1974** where remarkable decrease in growth can be observed. Event years are the years with remarkable increase or decrease in growth whereas the term pointer years refers to years with remarkable growth responses at the stand level(Schweingruber, Eckstein et al. 1990).

Climate-growth relationship of Chir Pine

In order to see the impact of climate change on the growth of *Pinus roxburghi*, climate-growth relationship was developed between the climatic factors and tree ring width by response function analysis using "treeclim" R package.

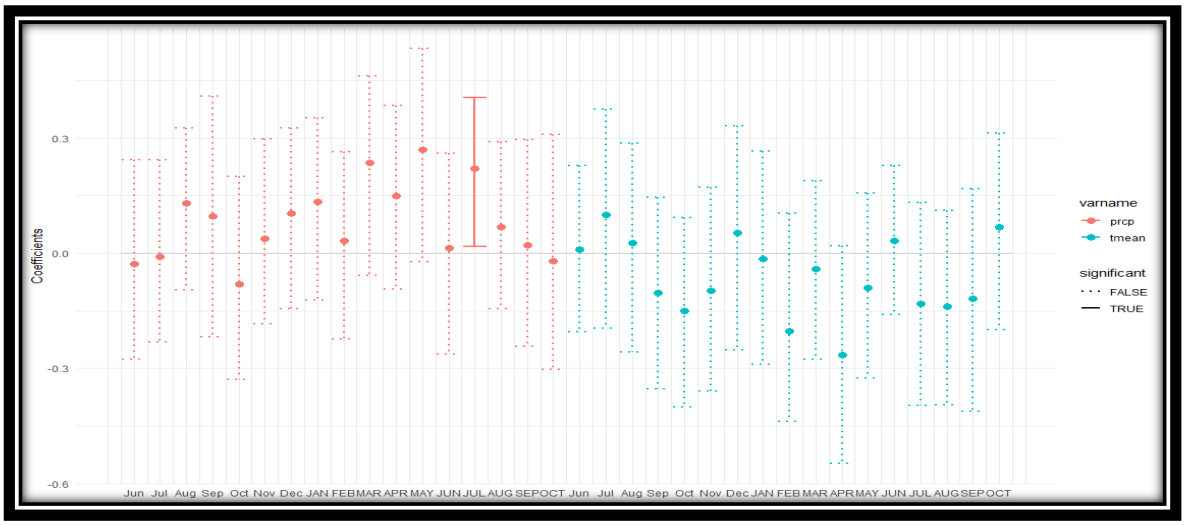

Figure 6 *Shows the Correlation matrix between tree ring-width and monthly mean temperature and mean annual Precipitation of Chir Pine at District Mansehra in the period 1965-2021. Statistically significant relationships (p<0.001) are indicated by stick bar.*

Figure 6: shows correlation matrix between tree ring-width of Chir Pine and monthly mean temperature and monthly total precipitation.

Response function analysis of Mansehra to climatic factors i.e., monthly mean temperature and monthly total precipitation showed that precipitation from current year (July) participating significantly in the growth of Chir Pine in the current year. Further it was found that the rainfall during growth period (Jan-March) positively effecting the growth of Chir Pine, this shows that precipitation is acting as a limiting factor in this area for the growth of tree species. These results are in accordance with (Bajwa, (2015) who studied climate change and its impacts on growth of blue pine in Murree forest division, Pakistan.

The increase in temperature of **0.426 C^0** for the study period 1965-2021 is not significantly playing its role in the growth of this species and even found slightly negative effect during the growth period (Jan-Mar). Further, the availability of good amount of rainfall prominently influencing the growth of Chir Pine in this area and temperature is providing optimum conditions for the process of photosynthesis. It is commonly considered that precipitation acting as a limiting factor in the moist temperate region of Khyber Pakhtunkhwa (KP) and the results of this study also confirmed this statement.

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Table 3 *Field data collection (Taking geographical co-ordinates (GPS), and DBH (Dia-tape)*

S.no	Sample	DBH	Direction of Sample Obtained.	Latitude	Longitude
1	A	41cm	SW/Uphill Side.	N34°15′20.9"	E073°10'15"
2	B	44Cm	SW/Uphill Side.	N34°16'19"	E073°10'29"
3	C	45Cm	NW/Uphill Side.	N34°15′34.9"	E073°"10'24"
4	D	58Cm	NW/Uphill Side.	N34°16′15.40"	E073°10'41.9"
5	E	42Cm	SE/Uphill Side.	N34°16'12.8"	E073°10'38.3"
6	F	56Cm	S/Uphill Side.	N34°14'36.81"	E073°9'52.26"
7	G	50Cm	SE/Uphill Side.	N34°16′42.9"	E073°9'41"
8	H	51Cm	SE/Uphill Side.	N34°14'26.69"	E073°9'46.2"
9	I	44Cm	NW/Uphill Side.	N34°16'56.14"	E073°9'49.70"
10	J	49Cm	SE/Uphill Side.	N34°15'43"	E073°10'31.2"
11	K	51Cm	SE/Uphill Side.	N34°15'45"	E073°10'29"
12	L	55Cm	SE/Uphill Side	N34°15'32.8"	E073°10'21.7"
13	M	46Cm	SE/Uphill Side.	N34°15'39.7"	E073°10'29.3"
14	N	62Cm	SW/Uphill Side.	N34°15'20.83"	E073°10'13.86"
15	O	51Cm	N / Uphill Side	N34°15'14"	E073°10'21.2"

Table 4 *Field Data Collection (Taking elevation (GPS), and Slope (Sunto-Clinometer)*

S.No	Sample	Elevation(m)	Aspect	Slope
1	A	1232m	NE	43°
2	B	1250m	NE	46°
3	C	1260m	SE	35°
4	D	1280m	SE	45°
5	E	1252m	NW	48°
6	F	1317m	N	35°
7	G	1318m	NW	51°
8	H	1184m	NW	36°
9	I	1265m	SE	45°
10	J	1222m	NW	40°
11	K	1266m	NW	33°
12	L	1238m	NW	48°
13	M	1224m	NW	28°
14	N	1221m	NW	57°
15	O	1265m	S	59°

CONCLUSIONS

Based on the findings, it is inferred that Chir pine (Pinus roxburghi) is thriving at UC-Bahali under the local climate, has good level for dendro-climatic potential and can be used for further research concerning, reconstruction of climatic parameters and other future issues of climate change, but long-term chronology development is prerequisite. It is also concluded that the effect of temperature was found non-significant, while the effect of precipitation is significantly influencing tree growth. It is also concluded that the availability of precipitation during the growth period coupled with the optimum level of temperature is of critical importance for tree growth of Chir pine in study area. It is also be concluded that those trees of Chir pine is effected from precipitation which is mature. But the effect is also shown in pole crops.

It can be also concluded from present research work that Chir Pine has tremendous dendro-chronological potential which is an indication that environmental changes had created impression on growth and developmental of the trees in the study area. More precisely it was also observed that environmental factors like, precipitation, rainfall and moisture content did play vital role in affecting the age and growth rate of the trees in this research site (Bahali District Mansehra KP).

REFERENCES

1. Ahmed, M. (1987). Dendrochronology and its scope in Pakistan. In: *Modern Trends of Plant Science Research in Pakistan*. Botany Department, University of Peshawar, Pakistan 35-38.
2. Ahmed, M. and A.M. Sarangzai (1991). Dendrochronological approach to estimate age and growth rates of various tree species from Himalayan Region of Pakistan. *Pak. J. Bot*., 23(1): 78-89.
3. Ahmed, M and S.H. Naqvi (2005). Tree-ring chronologies of *Picea smithiana* (Wall.) Boiss; and its quantitative Vegetation description from Himalayan ranges of Pakistan. *Pak.J.Bot*., 37(3): 697-707.
4. Cao, J., Zhao, B., Gao, L., Li, J., Li, Z., Zhao, X., 2018. Increasing temperature sensitivity caused by climate warming, evidence from Northeastern China. Dendrochronologia 51, 101–111.
5. Fritts, H.C., 1976. Tree Rings and Climate. Academic Press, Tucson.
6. Zhang, X., Bai, X., Chang, Y., Chen, Z., 2016. Increased sensitivity of Dahurian larch radial growth to summer temperature with the rapid warming in Northeast China. Trees 30, 1799–1806.
7. Gaspard, D.T., Venegas-González, A., Beeckman, H., Tomazello-Filho, M., Ridder, M.D., Ramananantoandro, T., 2018. Tree ring responses to climate variability of xerophytic thickets from south Solara, Madagascar. Dendrochronologia 49, 57–67.
8. Buras, A., Van der Maaten-Theunissen, M., Van der Maaten, E., Ahlgrimm, S., Hermann, P., Simard, S., Heinrich, I., Helle, G., Unterseher, M., Schnittler, M., Eusemann, P., Wilmking, M., 2016. Tuning the voices of a choir: detecting ecological gradients in time-series populations. PLoS One 11, e0158346.
9. Zhou, F., Fang, K., Zhang, F., Dong, Z., Dan, C., 2016. Climate-driven synchronized growth of alpine trees in the southeast Tibetan Plateau. PLoS One 11, e0156126.
10. IPCC, 2013. Climate change: the physical science basis. Contribution of Working 43 (22), 866–871.
11. Malanson, G.P. Complex responses to global climate change at alpine treeline. *Phys. Geogr.* **2001**, *22*, 333–342. Malanson, G.P Complex (2001)
12. Schweingruber, F.H.; Briffa, K.R.; Nogler, P. A tree-ring densitometric transect from Alaska to Labrador.*Int. J. Biometeorol.* **1993**, *37*, 151–169.
13. Briffa, K.R., Jones, P.D., Vogel, R.B., Schweingruber, F.H., Baillie, M.G.L., Shiyatov, S.G., Vaganov, E.A., 1999. European tree rings and climate in the 16th century. Clim. Change 43, 151–168.

14. D'Arrigo, R., Wilson, R., Liepert, B., Cherubini, P., 2008. On the 'Divergence Problem' in northern forests: a review of the tree-ring evidence and possible causes. Glob. Planet. Change 60, 289–305.
15. Jacoby, G.C., D'Arrigo, R.D., 1995. Tree ring width and density evidence of climatic and potential forest change in Alaska. Global Biogeochem. Cycles 9, 227–234.
16. Khan, N., M. Ahmed and S.S. Shaukat (2013). Climatic signal in tree ring chronologies of *Cedrus deodara* from Chitral Hindukush Range ofPakistan. Geochronometria. 40(3):195-207.
17. Bhuju, D.R. and N.P. Gaire (2012). Plantation history andgrowth of old pine stands in Kathmandu valley: A dendrochronologial approach. FJB. 2(2):13- 17.
18. Fritts, H.C. *Tree Rings and Climate*; Academic Press: London, UK, 1976.