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DENDROCHRONOLOGICAL ANALYSIS OF THE HISTORICAL FORTS LOCATED IN CHITRAL AND GILGIT-BALTISTAN, PAKISTAN

KHALID IMRAN
Department of Forestry and Wildlife Management, University of Haripur, Hattar Road Haripur City, Khyber Pakhtunkhwa, Pakistan. Assistant Silviculturist (Range), Biodiversity Research Division, Pakistan Forest Institute, Peshawar, Pakistan.

SHER SHAH
Institute of Agricultural Sciences and Forestry, University of Swat, District Swat, KP, Pakistan.

ASHFAQ ALI
Department of Forestry, Range and Wildlife Management, Karakoram International University, Gilgit, Gilgit-Baltistan, Pakistan.

ADNAN YOUSAF
Department for Innovation in Biological, Agri-food and Forestry Systems (DIBAF), University of Tuscia, Viterbo, Italy.

MUSTAFA SERT
Department for Innovation in Biological, Agri-food and Forestry Systems (DIBAF), University of Tuscia, Viterbo, Italy.

MEHVISH MAJEED
Technische Universitaet Dresden, Faculty of Environmental Sciences Institute of International Forestry and Forest Products, Germany.

MUHAMMAD AAMAD KHATTAK
Department of Land, Environment, Agriculture and Forestry, University of Padova, Legnaro, Italy.

MAJID HUSSAIN*
Department of Forestry and Wildlife Management, University of Haripur, Hattar Road Haripur City, Khyber Pakhtunkhwa, Pakistan. *Correspondence Email: majid@uoh.edu.pk

Abstract

Many dendroclimatological studies have been carried out on the conifer forests of Pakistan. But dating of the timber used in the historical forts of Pakistan has not been done yet. The study was carried out in northern areas of Pakistan covering the historical forts of Chitral and Gilgit Baltistan with an aim to identify the date of these woods to their exact calendar year. Sampling was done in different forts of Chitral and Gilgit Baltistan using the standard dendroarchaeological protocols. The samples were sanded and prepared for scanning. The images were measured through CoRecorder and data was saved in RWL format. The program calculates the indices of the ring-width series and also identifies false and missing rings. The maximum length of the samples recorded was 253 years whereas the lowest found sample was of 40 years. The chronology developed was up to 217 years (Baltit fort), followed by 196 years (Naghar fort) and 94 years (Altit fort). All these forts were found to best fit in the calendar year Altit (1731-1825), Naghar (1587-1783), and Baltit fort (1892-1675). These findings provide a true description of the history of these forts and demonstrate the use of dendro-chronological analyses in the assessment of cultural resources.

Keywords: Dendrochronology; Historic forts; Tree rings; COFECHA; Chitral; Gilgit Baltistan

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1. INTRODUCTION

Forest landscape has influenced to a great extent by the human evolution especially human cultural development heavily lean on wood usage for construction, tool production and primary source of energy (Tegel *et al.,* 2022; Cook, 2006). The wooden structures such as historical buildings, artefacts, furniture, music instruments and any other object made of wood species are essential in gaining insights into climate and land use change over the time (Tegel *et al.,* 2022).

To investigate such research, dendroarchaeology, a subfield of dendrochronology, used tree-ring data to identify the precise and accurate time length of a pre-historical period during which timber has been processed (Kaennel and Schweingruber, 1995). In addition to precise chronological data, tree-ring dates also contain information on the interrelation between human, climate, and environmental conditions.

The study of dendrochronology consists of two main principal components, dating of earlier events and climatic reconstruction related to the past events. It studies the annual growth variations, which may be influenced by the climatic and biological conditions at the tree site where it grow (Dominguez *et al*., 2015). Over the last 30 years, dendrochronology has become one of the standard dating techniques in archaeology (Haneca *et al*., 2006).

It is the utmost accurate standard dating method; however, it can only be successfully applied to the object, which is made from wood species that produce distinct tree rings of high resolution (Haneca *et al*., 2009).

In Pakistan, the application of dendrochronology to examine the ancient objects/buildings/forts is rare. Many dendroclimatological research has been carried out in Pakistan from last two decades on different conifer species like *Abies pindrow*, *Cedrus deodaraa*, *Picea smithiana*, *Pinus gerardiana* and *Pinus wallichiana* (Muhammad et al., 2021; Iqbal et al., 2020; Ahmed *et al.,* 2010). But dating of the timber used in the historical forts of Pakistan has not been done yet, it is a first attempt to understand tree ring growth with changing climate on the historical sites and to define the kind of wood specie being use in the structure of these forts.

It is accompanying a dendroarchaeological study which will also allow us to reconstruct the past climate from ancient architectures of these forts from Chitral and Gilgit Baltistan cities in Pakistan. The main objectives of the study are (1) To identify the wood species used in the traditional architecture of the forts and (2) An attempt to reconstruct the past climate conditions using tree ring chronology from woody structure of these forts.

2. METHODS

2.1 Description of study sites

The study was carried out in selected forts of district Chitral of Khyber Pakhtunkhwa province and Gilgit-Baltistan province of Pakistan. The district of Chitral lies between 35°-37°N and 70°-72° in the far northwest of Pakistan and is one of the country's most remote

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and isolated regions. In terms of historical knowledge, archaeological and historical interpretations of this region are extremely limited, and false narrative tends to play an equivalent role in providing the premise for a story of historical events and previous human activity here and even today (Ali *et al*., 2013).

District Chitral is bounded on the west by the Afghan provinces of Badakhshan and on the north by the Wakhan corridor, on the west by the Pakistan province of Gilgit-Baltistan, and on the south and southeast by the Swat and Dir valleys. Chitral is divided into two parts: Lower Chitral and Upper Chitral. Lower Chitral is made up of hilly areas, whereas Upper Chitral is mostly flat. Coniferous forests can be found in Lower Chitral, while the Upper Chitral and inward valley floors are notably treeless. Elevations range from 1070 to 7708 meters and creating many local climatic and vegetation zones. In the district Chitral, the world's fifth highest mountain peak (Tirichmir) stands at 7690 meters. A total of four forts were selected from Chitral including: Mastuj, Drasun, Chitral and Naghar fort.

The newly recognized province Gilgit Baltistan located in the Northern Areas of Pakistan, comprising of districts i.e., Gilgit, Ghizer, Skardu, Diamer, Ghanche and Astor. It is located between 35°-37° N and 72°-75° E and shares a border with China's Xingiang province. It is the point where the three foremost parts of Asia, namely Central Asia, Southern Asia, and Southeast Asia, converge. (Abbas *et al*., 2014). It expands from the Hindukush in the north and in the east to the Karakorum, with the Western Himalaya in the south while the Pamirs in the far north. With elevations ranging from 1000 to 8750 meters above sea level and with land surrounded by immense mountains, snowcapped peaks, and slender valleys.

The alpine scrub zone, which is located at the topmost reaches of the entire region, adopted to snow pressure, and is one of the four ecological zones in the northern areas. The Betula, Juniper, Salix, Bebris, Lonicera, Vibernum, Ephedra, and Anthopogon Ribes are found in the sub–Alpine forest zone in almost all upper reaches of Gilgit Baltistan's mountains and valleys (Zain, 2010). *Cedrus deodara* forest can be found in the upper Muskin, Nagar, Astore valley, Naltar and Haramosh, while *Pinus wallichiana,* and *Picea smithiana* in the montane temperate forest zone. The capris, spinosa, Artemisia, pistacha, Dodonia, Saccharum, Daphneoloodes and Rosa muschata are seen in bulk. A total of four forts were selected from Gilgit Baltistan including: Altit, Baltit, Shigar and Khalpu fort. Altit and Baltit are located in Karimabad Hunza, Shigar is located district shigar, while Khaplu is located in ghanche district.

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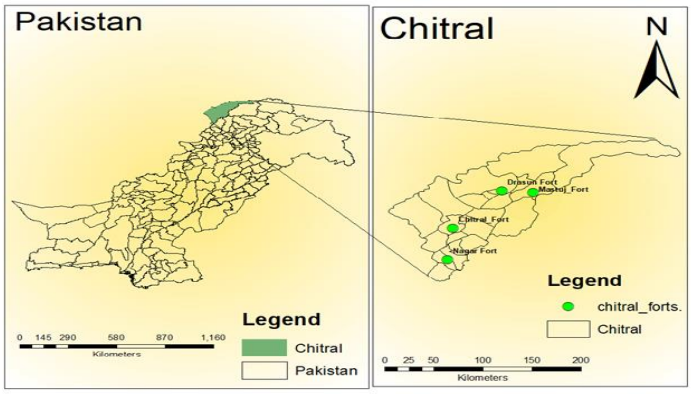

Figure 1: Chitral Fort Map

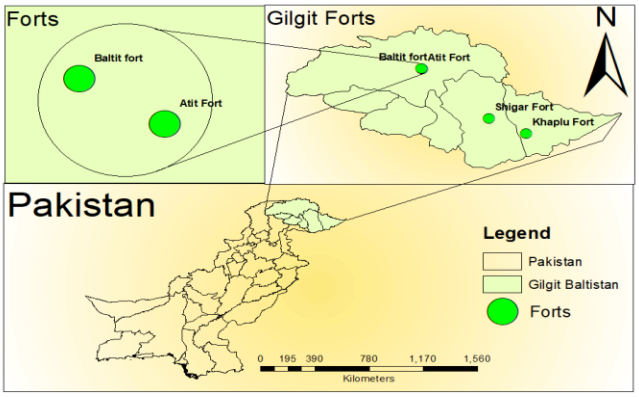

Figure 2: Gilgit Baltistan Fort Map

2.2. Methodology

The study was conducted in the different historically forts of District Chitral and Gilgit Baltistan of the northern areas of Pakistan. In Chitral, different forts like Chitral, Naghar, Mastuj, and Drasan Fort, while Alit, Baltit, Khaplu, and Shigar fort were the study sites from Gilgit Baltistan. Permission was obtained from local administration and Agha Khan Trust (who are responsible for the care of historical forts in Gilgit Baltistan) to carry out data collection from the aforementioned forts. Maximum samples of wooden discs and tree ring cores were taken from different wooden frames of these forts (Figure 3) (Figure 4). During sampling, standard dendroarchaeological protocols were applied and samples were taken from such angle that there is minimum damage to the wooden structure of these forts. A total of 25 samples were taken from Altit and Baltit forts and only those samples were allowed for taking samples which were removed from these forts during renovation of these forts in the past. But were not allowed to sample the Khaplu and Shigar forts due to ownership of the local peoples. Owners of the forts located in Chitral were found cooperative and total of 32 samples were taken from Naghar, Chitral, Drasan, and Mastuj fort. The very limited number of samples collected because of structure remains was being replaced by the new wood to support the structures/building.

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Increment cores were stored in drinking straws and transported to the laboratory for further laboratory work. Cores are small and fragile, so it is necessary to mount them before any surfacing work. The cores were glued to wooden holders and sequentially sanded using progressively finer grit sandpapers (80-600 grit). Wooden discs collected from the forts were individually sanded using Rikon disc sander to clearly make all individual rings growth visible (Pourtahmasi *et al*., 2011) (Figure 5), which later used for dendrochronological analysis. The prepared sanded discs were scanned with high EPSON A3 Photo scanner at 600 dpi to make ring boundaries clearly visible for measurement (Figure 6). The images were then saved in the JPEG format, which is compatible with Co-Recorder software (Electronik, 2007).

2.3. Data analysis

Subsequently the first objective of our study was to conclude the wood species used in the traditional building of forts, anatomical investigation was carried out. For this purposes, microscopic slides showing wood in its cross, tangential, and radial section were prepared. Then the slides will be observed under a biological microscope in transmitted light. JPEG images were processed consequently, the tree rings of respectively sample were measured through CDendro software (Malik and Sukumar, 2021) and saved as “pos” file, which are compatible with TSAP-Win software. With help of TSAP-Win software data analysis were carried out for dating the samples to the exact calendar year (Rinn, 2011). Individual ring series cross-dated and also measured the accuracy of ring data from samples using computer program COFECHA, Inspection by COFECHA added a degree of self-confidence that tree ring samples had been cross-dated appropriately and measured precisely (Holmes, 1983). ARSTAN program was used to remove the false rings (Moussa et al., 2020). Different packages of the R like dplR (dendrochronology program library in R) and Treeclim helped to represent the relationship between the tree ring width series and different climatic variables (Shah et al., 2020). ORIGIN Pro used for graphically representation of data.

Figure 3: Scanned and Measured sample

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3. RESULTS

3.1. Species identification

Wooden samples collected from historical forts in Gilgit Baltistan and Chitral bring about in the identification of five different species of Conifer and Broad leave. The identified species from Gilgit Baltistan forts are: *Cedrus deodara, Picea smithiana, Populus nigra, Juniper excelsa,* while identified species from Chitral forts are: *Cedrus deodara, Picea smithiana, Populus ciliata*. Total number of collected samples was 57, in which most of the samples was *Cedrus deodara* 32 followed by *Picea smithiana with 05, Populus nigra* with 06*, Juniper excelsa* with 01 and *Populus ciliate* with 13 as shown in the (Table 1).

Table 1: Wood identification of samples collected in Gilgit Baltistan and Chitral forts

S/No	Sampled species	Baltit	Altit	Naghar	Chitral	Drasan	Mastuj
01	*Cedrus deodara*	**06**	**07**	**10**	**08**		
02	*Picea smithiana*	**03**	**02**			**01**	
03	*Populus nigra*	**04**	**02**				
05	*Juniper excelsa*		**01**				
05	*Populus ciliate*					**07**	**06**

3.2. Gilgit Baltistan forts

The data collected from Gilgit Baltistan from different forts such as Altit fort and Baltit fort. Results of each fort are as follow. Both Baltit and Altit forts were near to each other and located in Karimabad, Hunza.

3.3. Baltit Fort

Baltit fort located in the town of Karimabad, which is positioned in a broad green valley beyond the foremost gorges of the lower Hunza Valley; close to the border with China. The Fort has prolonged with its increasing prominence over the centuries and been modified to changing needs and function. Total of 13 samples were taken for consideration. Deodar and spruce were the main species found in the wooden structure (frames) of these forts. The oldest sample length was 253 years while the lowest was 44 years (Table 2).

Table 2: Baltit fort samples

Site/fort	Collected samples					
Baltit	**Total samples**	***Cedrus deodara***	***Picea smithiana***	***Populous nigra***	**Largest age**	**Lowest age**
	13	06	03	04	253	44

3.4 Statistics of COFECHA from Baltit Fort

Total of 13 wooden discs collected from the wooden frames of the fort. The COFECHA Statistics Result showed that only six wooden discs was able for cross dating and the chronology shows that the time span for these discs collected from the fort was 214 years. Figure also shows the Ring Width Length (RWL) Baltit fort samples against year. Mean

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sensitivity found was 0.121, the standard deviation found for these samples was 0.426, the signal to noise ratio was 0.512 and series inter correlation was 0.532 as shown in (Table 3).

Table 3: Statistics of COFECHA for Baltit Fort

Wooden Discs	**06**
Time span	**214**
Mean Sensitivity	**0.121**
Standard Deviation	**0.426**
Signal to Noise Ratio	**0.512**
Series inter correlation	**0.532**

3.5. Altit Fort

The fort located in the town of Karimabad, close to the border with China. Total of 12 samples were taken for consideration. Deodar and spruce were the main species found in the wooden structure (frames) of these forts. The oldest sample length was 220 years while the lowest was 54 years (Table 4).

Table 4: Altit fort samples

Site/fort	**Collected samples**						
Altit	**Total sample**	***Cedrus deodara***	***Picea smithiana***	***Juniper excelsa***	***Populus nigra***	**largest age**	**Lowest age**
	12	07	*02*	*01*	*02*	220	54

3.5. Statistics of COFECHA for Altit Fort

Total of 13 wooden discs collected from the wooden frames of the fort. The COFECHA Statistics Results for total of seven wooden discus showed the Chronology time span for these discs collected from the fort was 94 years. Figure also shows the Ring Width Length (RWL) against year. Mean sensitivity found was 0.163, the standard deviation found for these samples was 0.488, the signal to noise ratio was 0.512 and interseries correlation was 0.521 as shown in (Table 5).

Table 5: Statistics of COFECHA for Altit Fort

Wooden Discs	**07**
Time span	94
Mean Sensitivity	0.163
Standard Deviation	0.488
Signal to Noise Ratio	0.512
Series inter correlation	0.521

3.6. Chitral forts

The forts sampled in the Chitral was Naghar, Chitral, Drasan, and Mastuj forts. Naghar and Chitral forts were in lower Chitral district, while Drasan and Mastuj were in upper

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Chitral district. Results of each fort are as follow. From Chitral site only Naghar fort samples were able to be cross dated.

3.7. Naghar Fort

Nagar Fort, at Nagar is situated near Chitral Valley north of Pakistan, Nagar is a village situated in lower Chitral. Surrounded by water from three sides, it is accessible through a suspension bridge that prevails the charm of the Fort. Total of 10 samples were taken for consideration. Deodar was the only species found in the wooden structure (frames) of these forts. The oldest sample length was 217 years while the lowest was 40 years (Table 6).

Table 6: Naghar fort samples

Site/fort	**Collected samples**			
Naghar	**Total samples**	***Cedrus deodara***	**Largest age**	**Lowest age**
	10	10	217	40

3.8 Statistics of COFECHA for Naghar Fort

Total of 10 wooden discs collected from the wooden frames of the Naghar fort. The COFECHA Statistics Results shows that the samples were acceptable for chronology development and the chronology found that the time span for these discs collected from Naghar was 196 years. Figure also shows the Ring Width Length (RWL) against year. Mean sensitivity found was 0.130, the standard deviation found for these samples was 0.324, the signal to noise ratio was 0.451 and inter series correlation was 0.582 as shown in (Table 7).

Table 7: Statistics of COFECHA for Naghar Fort

Wooden Discs	**10**
Time span	196
Mean Sensitivity	0.130
Standard Deviation	0.324
Signal to Noise Ratio	0.451
Series inter correlation	0.582

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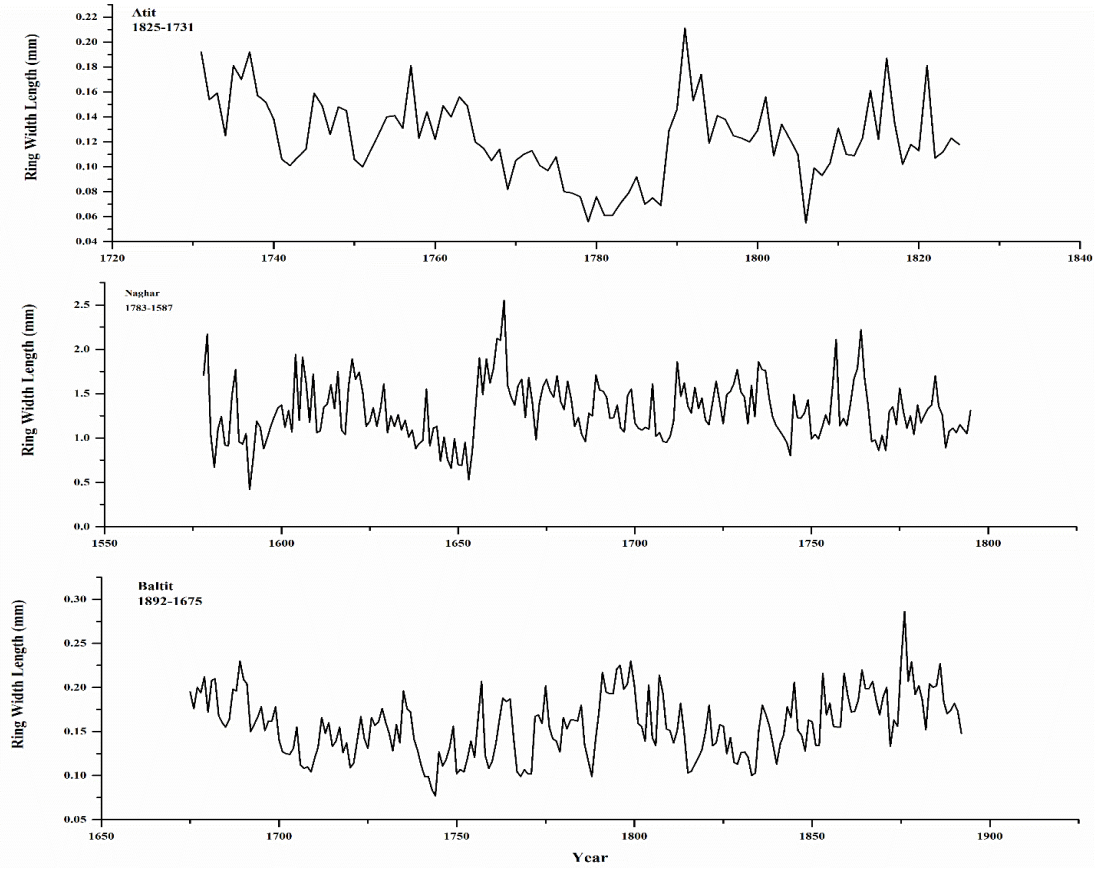

Figure 4: Ring width length of Altit, Naghar and Baltit fort samples

3.9. Regional Chronology development

The chronology was developed with help of COFECHA for Altit, Baltit and Naghar fort. The chronology is based on data derived from *Cedrus deodara* of these forts. A well cross dated chronology intercorrelation is 0.599 and therefore deemed acceptable. Average Mean Sensitivity 0.164 for total Chronology. The chronology shows that the longest series was found to be 333-year-old. (Figure 5) shows that samples from Altit Fort found 94 years best old fit in Calendar year (1825-1731), Baltit fort 217 years old (1892-1675) in Calendar year while Samples from Naghar fort in Chitral, 196 years old found to best fit in Calendar year of (1783-1587). The results shows that the Altit and Baltit fort were renovated in 1832 and 1911 for maintaining, while Naghar fort was initially formed in 1795.

Table 8: Statistics of COFECHA for Regional Chronology

Description	Detail
Longest Series	333 years
Series inter-correlation	0.599
Average Mean Sensitivity	0.164

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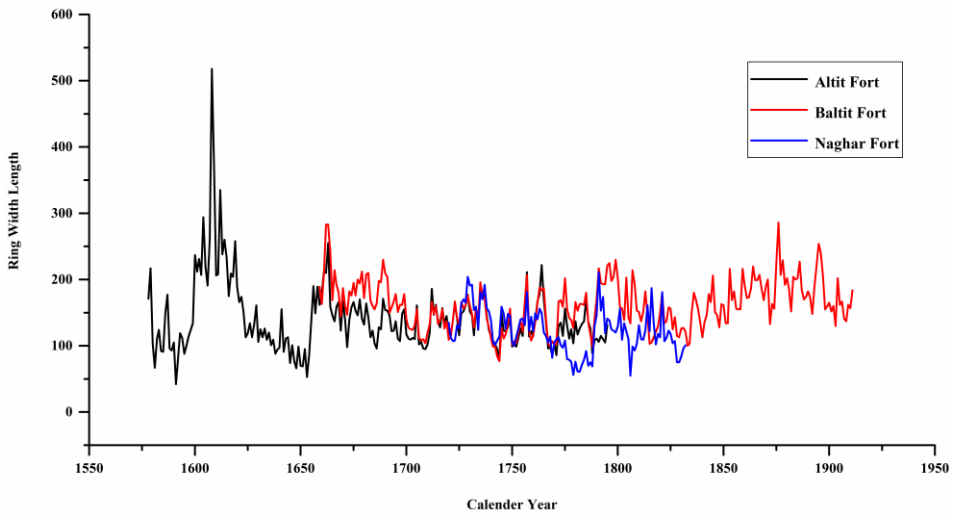

Figure 5: Regional forts Chronology

4. DISCUSSION

Dendrochronological research carried out in Gilgit Baltistan and Chitral to find out the species used in the architecture of these fort, how long before they were made (Time span) and to find out any proxy climate from these fort wooden rings. Subsequently no bark and/or waney edges were preserved in the samples, it was not conceivable to define the exact year at what time the trees were cut. The merely date that can be specified for every element is a initial possible felling date (Gmińska *et al*., 2022).

This was a common belief that conifer species had been used in Chitral and Gilgit Baltistan, but our studies found that *Poplus nigra* found to be the most durable specie for construction in these forts. Spruce (*Piceae smithiana*) and Deodar (*Cedrus deodara*) are few of the wooden species have also been used in some wooden frames of these forts. In Chitral forts, the species which were dominant in the construction of these forts were Deodar (*Cedrus deodara*) and Sufaida (*Populus ciliata*). *Populus ciliata* was found in the construction of dry temperate area of Mastuj and Booni. Populus Ciliata found in the boundary wall of the Mastuj and Drasan fort. Maximum wall timbers were in a very thorough condition with attached connections still powerfully working. Deodar is Himalayan specie and evergreen tree which usually grow in a wide altitudinal gradient (1200-3000 m) (Shah *et al*., 2014) found to be the most dominant specie in forts of Gilgit Baltistan and Chitral. The use of Deodar as a timber for structural elements in these forts is not an exceptional situation. Its essential oils are antimicrobial, insecticidal, molluscicidal, germicidal, anti-tubercular agents which makes it a very durable in building construction (Minocha *et al*., 2021).

Samples from Altit and Baltit forts found to be old a 94 and 217 years old. Samples collected from Naghar fort in Chitral found to be as old as 196 years. Samples from Altit Fort found to be 94 years old found to best fit in Calendar year (1825-1731), Baltit fort

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217 years old (1892-1675) in Calendar year while Samples from Naghar fort in Chitral, 196 years old found to best fit in Calendar year of (1783-1587). The Calendar year shows that wood used in Altit fort and Baltit fort for construction were felled down in 1832 and 1911. The fundamentals of Altit and Baltit forts held to be dated nearby 700 years back, but there had been reconstructs and alterations over the time (Ali, 2011). Due to renovation activities, the broken and damaged samples had been replaced by some steel support and wooden logs. While our results suggested that Naghar fort logs were initially felled in 1795 for construction.

5. CONCLUSION AND RECOMMENDATIONS

The historical forts of Chitral and Gilgit Baltistan famous all over the world. Tourists from all over Pakistan and around the world visit these forts to learn about the history of these areas. There is a lot of information available about the history of these forts but there is no as such evidence of how old these woods are, which has been used in these forts. The data derived from the timber found in these forts became a key component of the Chitral and Gilgit Baltistan chronology. The result of this study found that the species found in the construction of these forts are; Deodar *(Cedrus deodara*), Spruce (*Picea smithiana*), Black popular (*Populus nigra*), *Juniper excelsa,* Sufaida (*Populus ciliata*). Deodar, spruce, black popular and juniper were found in Gilgit Baltistan forts, while Chitral forts species were deodar, spruce and sufaida found used in the different parts of the construction. The chronology developed for Altit, Baltit and Naghar fort shows that the longest series was found to be 333-year-old. Baltit found to be 253-year-old, while Altit found to be 243-year-old and the Naghar fort found 214-year-old. Altit Fort found 243 years old best fit in Calendar year 1832-1590, Baltit fort 253 years old 1911-1659 in Calendar year while Samples from Naghar fort in Chitral, 218 years old found to best fit in Calendar year of 1795-1578. The total chronology length starts from 1911-1578 going up to 433 years back from the current time. The results shows that the Altit and Baltit fort are renovated in 1832 and 1911 to maintain it, while Naghar fort was initially formed in 1795.

Pakistan is place known to many cultures heritage and history. The dendrochronological investigation carried out in the forts of Chitral and Gilgit Baltistan is of supreme importance for the improvement of dendroarchaeological research in Pakistan. As it was the paramount tribute in these forts significantly dated using dendrochronological methods.

These forts are unique historic buildings, but at the moments some of the forts are long gone and many are threatened with collapse like Drasan and Mastuj fort. Conservation of these forts are required to let the tourist to visit and get information on these forts. The additional attention we induce to the object, the easier it become to raise funds for the preservation and fortification of this astonishing heritage.

These forts have the potential for dendrochronological studies for further research to study. To conclude possible directions for forthcoming examinations and the requirement

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to bear systematic research and to mature distinct master chronologies for different local species growing in different climatic conditions of the region.

Need a movement of wakefulness about the potential of this discipline to evaluate culture heritage are still needed.

Given the available resources for historic preservation, as well as the historical research's credibility it is imperious that techniques like dendrochronology should be used to precisely determine the accurate construction history of significantly important buildings.

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Conflicts of Interest (COI): The authors declare no Conflict of Interest.

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