# Dendrochronological Study on *Cedrus Deodar* in Kumrat Valley, Hindukush Range of Pakistan. Evaluation of Tree Age Estimation Based on Increment Cores

Ikram UL Haq[1], Ahmad Hussain[2],Muhammad Naqash[3], Sajad[4],

[1]Forestry and wiildlife, Management,Faculty of Forestry and wildlife management, University of Haripur KPK

[2]Professor, Faculty of Forestry and wildlife management,University of Haripur KPK,

[3] Forestry and wiildlife Management,Faculty of Forestry and wildlife management, University of Haripur KPK

[4] Forest Management, Faculty of Forestry,Universitas Gadjah Mada,Yogyakarta, 55281

*Email :ahmad.hussain@uoh.edu.pk

## ABSTRACT

The present study of dendrochronology on *Cedrus deodar* was carried out in Kumrat Valley, Hindukush range of Pakistan. For the study of tree-ring analysis,72 trees of *Cedrus deodar* were randomly selected as a sample. Tree volume is estimated by measuring tree height (m), diameter (cm) at mid-point (DMP) and at breast height (DBH) and crown covers (m2). Increment cores were collected from each sample tree at diameter at breast point and studied in the laboratory to determine the exact age, total growth, mean annual increment of *Cedrus deodar* Regression models were used to expose the impacts of tree age on total growth and mean annual increment. It was found that the total increment is 2.75cm at 10 years and31.25 cm at the age of 60 years .The value of $R^2$ (0.9928) while the mean annual increment at 10 years is 0.075 cm and 0.012 cm at 60 years. The value of R2 (0.6810) for total increment. It shows a dependable trend of tree age with total and mean annual increment by increased with age. Illegal cutting and logging were done at minimal age. In the study area consideration of age is important of *Cedrus deodar* for economics purposes in the silviculture system to fix rotation age because of its light demander and slow gowning species. To increase forest area by natural regeneration to control illegal activities.

KEYWORDS:dendrochronology, tree age, total increment, mean annual increment



## Introduction

The word “Dendrochronology” is derived from three Greeks words “*Dendro*” means “tree” “*Cronos*” means “time” and “logos” mean “studies” or “discussion”. Dendrochronology also means “tree ring analysis” is the science which is uses for tree rings to calculate the exact age of a tree species(Heuret, Caraglio, Sabatier, Barthélémy, & Nicolini, 2016). Trees develop a ring annually which varies in thickness and in density due to a number of reasons. In all conifers, tree rings are visible and wider but in broad leaves, tree rings are close, dense and are not clearly visible due to its compactness(Fichtler, 2017).The absence of clearly identifiable annual growth rings in broad-leaved tree species made it difficult for cutting rotation and forest management in comparison to clear and visible growth rings of conifers tree species (Zhao et al., 2019). Development of annual rings in trees is highly affected by a number of ecological factors i.e. precipitation, temperature, latitude, altitude and even by the species type (Ols, Girardin, Hofgaard, Bergeron, & Drobyshev, 2018).Study of tree-ring analysis is also an important and effective tool which is widely applied in ecological studies for determining exact ages of tree species(Locosselli et al., 2019), which can be potentially used to study both temporal and spatial pattern of climatic factors of a region (Andreeva, Kurochkin, Syromyatina, & Chistyakov, 2019).

Tree-ring analysis relates to the counting of rings(Metsaranta, 2020). These rings determine the age of the tree and other valuable parameters such as stored information onpast conditions. It is most commonly used in both old and modern sciences (Borges Silva, Teixeira, Alves, Elias, & Silva, 2017). It is also considered as a tool for archaeology, climatology (to know about the past and future climatic condition), as an art of history, forest, and biology (Nechita, Eggertsson, Badea, & Popa, 2018). Recently it has a broad range of applications such as global climate change, the carbon cycle, canopy process declines and many others (Fujii, Marsoem, & Fujiwara, 1998; van der Sleen, Zuidema, & Pons, 2017). In the field of forest inventory, the knowledge of stand age is a core component. Tree ring data has been widely used in forest inventory programs (DeRose, Shaw, & Long, 2017). Standage is an important variable that is mostly measured from the counting of tree rings (DeRose et al., 2017; Jensen, Boll, Thysen, & Pathak, 2000). The natural forest in Pakistan is under great pressure in term of illegal cutting and for domestic use; due to increase in population Land use change and moderation of peoples to uplands having adverse impact on the management of forest, improper management due to increase in population and lack of scientific forest management and practices making the condition more worse and forest degradation through agricultural expansion and other land uses is one of the major causes of greenhouse gas emission (Ahmad & Nizami, 2015).

The medicinal and economic value of *Cedrus deodar*, wood isuseful in urinary disorder, rheumatism, respiratory disorder, piles, kidney stone problem, flatulence fever, and also used for snake bite as an antidote, while bark is useful for dysentery, diarrhea, and fever. From the root extracted oil is useful for ulcer and skin disease of camel and goat.The bark is astringent, useful in fever, diarrhea, and dysentery. Oil is diaphoretic, useful in skin diseases and for an ulcer(Pharma, Sharma, Prashar, & Arora, 2018). Oil extracted from the root is used for skin diseases of goats and camels. The wood quality of *Cedrus deodar* is good, excellent and durable which is used for construction and furniture purposes. (Manzone, 2016).Tree ring analysis in Pakistan is in the phase of development and different research has been carried out on the tree age, rate of growth and to correlate tree rings with environmental variables in the moist and dry temperate region mainly on coniferous species (Zafar et al., 2016).Researchers in Pakistan had worked in various parts of the country to document the dendrochronology of coniferous trees but very little work regarding the use of tree ring in sustainable forest management was documented (Asad, Zhu, Zhang, et al., 2017). The science of tree ring-ring analysis or dendrochronology is considered a key tool for archaeology, climatology (to know about the past and future climatic condition), as an art of history, forestry, and biology (Fuchs, Stevens, & Fulé, 2019).In Pakistan as far as there is only limited amounted of research has been carried out on tree ring analysis and all has been done it on conifers tree species (Iqbal, Siddiqui, Khan, & Wahab, 2017)Iqbal et al. (2017)mentioned the problems encountered with tree age estimation.

The tree-ring research in Pakistan is in the initial stage of development and generally dealt with Gymnosperm species. Study on tree ring analysis and its scopes the starting point was an introductory paper "Dendrochronology and its scope in Pakistan" by M. Ahmed in 1987, during a science conference atthe University of Peshawar(Iqbal, 2017). In his paper, M. Ahmed presentedgrowth rate and age of few angiosperm tree speciesand planted pines and defined problems comes into the age estimate of a tree species. Tree ring analysis study on *Abies pindrow* and *Cedrus deodar* from moist temperate forest while *Pinus gerardiana* and *Picea smithiana* from dry temperate forest areas of the Himalayan range of Pakistan were successfully cross dated by. Due to lack of facilities, collected samples were taken university of Auckland, New Zealand, for the correct estimation of chronologies. A. Khan et al.,extensive fieldwork was carried out for tree ring analysis study in moist and dry temperate forest areas of Himalayan range of Pakistan and presented the growth rate and age of different tree species(Khan, Ahmed, Khan, & Faheem Siddiqui, 2018). (Hussain et al., 2018)dendrochronological techniques used for to evaluate the dynamics of *Cedrus deodar a*from Hindukush and Himalayan Ranges, covering its distributional limit. The knowledge of tree rings analysis can be effectively used for the determination of past, current and future growth that can also be used for ecological and forest dynamic information(Asad, Zhu, Liang, et al., 2017). The age of a tree species is an important factor for yield regulation from forests and as well as increment determination. The age can be used in developing growth models and yield table development. Therefore, the current work was designed to bridge the gap in proper forest management(Miranda, Guedes, Rosa, & Schöngart, 2018).



## Methods and Materials

### Study Site

The present study was carried out in out in Kumrat Valley, Hindukush range of Khyber Pakhtunkhwa Pakistan. The valley is located at 35. 15° N latitude and 71. 22° E longitude at an elevation of 1371 meters above the sea level. The soil of the study site was shallow and acidic in nature and the major rocks of the valley include diorite, schist, and granite (Atta Ullah et.al). The mean annual precipitation ranges from 750 mm to 1000mm.The annual temperature ranges from 0.7 to 30 oC. The value of soil PH (power of hydrogen) is in the range of 6.5 to 7.5 while the total organic matter in the soil was present while the total nitrogen in the soil is (Irshad 2009).

### Sample cores collection and measurements

In the present study trees of *Cedrus deodar* were randomly selected for collection of sample cores being a sample tree. There were 72 sample cores were collected by using Swedish Pressler borer. The diameter of each sample tree was measured at two points at diameter at breast height (DBH) for the calculation of cylindrical volume and diameter at mid-point (DMP) for the calculation of actual volume. For the measurement of diameter at mid-point, we climb to the tree and recorded the diameter by using caliper and diameter tape.Total tree height was measured by three different tools it depended on tree condition, by climbing and using staff-rodwhen the tree was with a low height. If the tree were on a steep slope with more height, thenwere used Annie's level. Crown cover was measured of each sample tree from four different sides by using measuring tape through the following formula: $Crown\,coverm^{\wedge}2 = \pi r^{\wedge}2$.For further observation tree cores were collected at diameter breast height point (DBH) from each sample tree through Swedish Pressler borer and were labeled. Tree diameter, height and crown cover were written on the label. The cores were brought to the laboratory for further analysis. The analysis includes calculating the age of each sample by counting the annual rings. Tree total growth was measured from the length of each collected core.The annual diameter growth (cm) was also calculated using the following formula:

$$\mathrm{ADG} = \frac{\mathrm{TDG}}{Tree\ Age}$$

Whereas:

ADG: Annual Diameter Growth (cm)

TDG: Total Diameter Growth (cm)

Similarly,the mean annual increment (MAI) was measured from the relation of tree total volume ($m^3$) and tree age (years):

$$\mathrm{MAI} = \frac{\mathrm{TG}}{Tree\ Age}$$

Whereas:

MAI: Mean Annual Increment (cm)

TG: Total Growth (cm)



**Statistical dataanalysis**

For data analysis, the following software wasused: MS EXCEL, PAST, and Sigma Plot. The data were arranged in Excel sheets. The univariate statistics were carried out in PAST software. The figures and graphs were developed in Sigma Plot. Regression models were also used in Sigma Plot.

## Results and Discussion

**Tree agerelation and total growth or total increment**

In the present study, we calculate the total growth of *Cedrus deodar trees*. The average total growth was 18.89 cm at age of 36.70 years, the maximum total growth was 32.50 cm recorded at the age of 60 years while the minimum was 2.75 cm recorded at the age of 10 years shows in Table 1. For the relation, we used the regression polynomial cubic equation shown in Figure no: 01 and the value of $R^2$ is 0.9928 which shows the positive relation.

The result of the present study about the total increment (total growth) can be compared with age. When the age of the tree increases so the annual growth and total growth will be also increased with standard deviation and the coefficient of variance is given in Table 2.

Tree age relation with a total increment (total growth in cm) shown in Table 1. Age of trees increases with total growth (or total increment) from at age of 10 years to 60 years.

The relationship of tree age with increment. minimum increment at the age of 10 years while the maximum total increment at the age of 60 years. Table 2 shows the value of median, standard deviation, standard error, variance and coefficient variance.

whenthe age of trees increases with an increasing total rate of growth or increment. At the age of 10 years,the total increment is 2.75 cm while at the age of 60 years 32.50 cm are shown in Figure 1. It showsa positive relationship between tree age with increment by using the regression model in the sigma plot.

**Tree age relation with mean annual increment (MAI)**

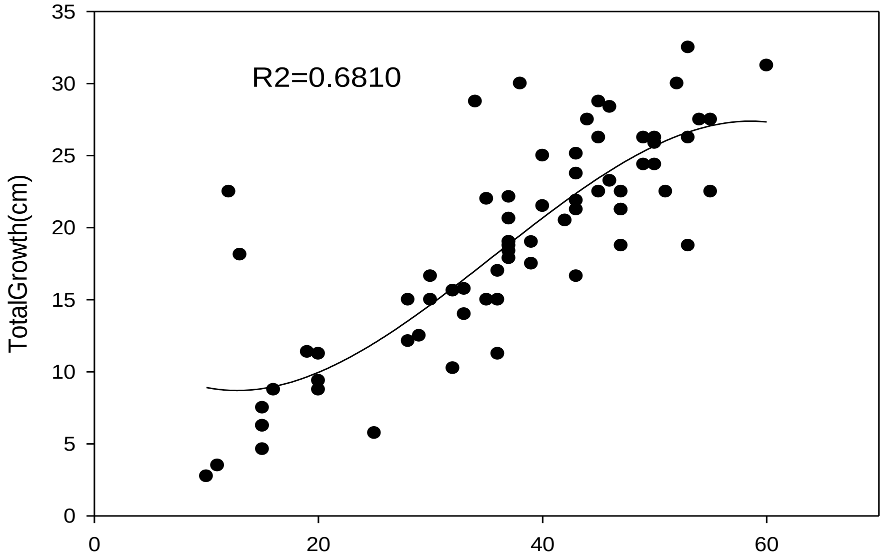
In the present study, we determined the age of tree *Cedrus deodar* and its ranges from 10 to 60 years in *Cedrus deodar* sparse type of vegetation the average mean annual increment (MAI) was 0.02482 52 cm at age of 36.87 years shows in Table 4. The minimum mean annual increment was 0.012 cm at the age of 60 years and while the maximum mean annual increment (MAI) was 0.0.755 cm recorded at the age of 10 years are shown inTable 3. In order to understand the relationship, we were used the regression polynomial cubic equation shows in figure no: 02 and the value of $R^2$ is 0.9928 which shows the positive impact of age on mean annual increments.

Minimum mean annual increment is 0.012 cm at age of 10 years while the maximum mean annual increment is 0.0755 cm at age of 60 years while total mean annual increment of all sample cores of trees is 1.7396 and the average mean annual increment is 0.02482 cm at age of 36.87 years shows in Table 4.The result of the present study about the mean annual increment (MAI) compared with age when the age of trees increases so the mean annual increments also increase with a coefficient of variance and the standard deviation is given in Table 3.

Table 3shows the tree age relation with mean annual increment (cm). The mean annual increment at the age of 10 years is 0.075 cm while at the age of 60 years 0.0125 cm. Mean annual increment at 10 age of 10 years more as compared to the age of 60 years.

Showsthe relationship of tree age with mean annual increment. The minimum mean annual increment at the age of 10 years is 0.0125 cm while the maximum mean annual increment at the age of 60 years is 0.075 cm. It means that in the early stage of tree growth mean annual increment is more than the later stage of tree growth. The value of calculated median, standard deviation, standard error, variance and coefficient variance are shown in Table 4 above.

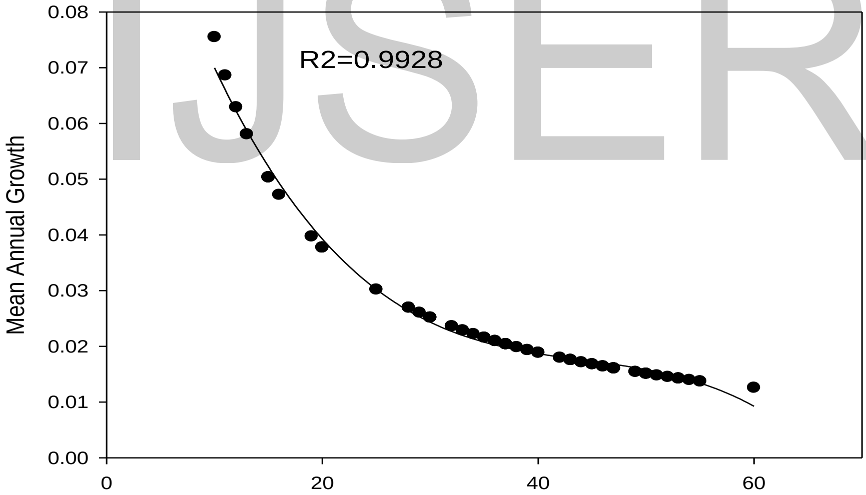
The relationship betweenthe age of trees with a rate of mean annual increment. It shows that in the early stage of the tree growth rate of mean annual increment is increases with increases in age but in later stage mean annual increment growth rate will be decreased. At the age of 10 years mean annual increment is 0.075 cm while at the age of 60 years 0.0125 cm are shown in Figure 2. It showsa positive relation in between tree age with increment by using the regression model in the Sigma Plot.




Age(years)Equation: Polynomial, Cubic
f=y0+a*x+b*x^2+c*x^3 R2=0.6810,y0=13.8309,a=-0.8687,b=0.0415,c=-0.0004

Figure 1. The relation between tree age and total growth






Age(years )Equation: Polynomial, Cubic
f=y0+a*x+b*x^2+c*x^3 R2=0.9928,y0=0.1230,a=-0.0066,b=0.0001.c=-1.0834

Figure 2. Relation of tree age with mean annual growth

**Table 1**. The relation between tree age (years) and total growth (cm)

| Age | T. Growth (CL) | Age | T. Growth (CL) | Age | T. Growth (CL) |
|---|---|---|---|---|---|
| 10 | 2.75 | 34 | 28.75 | 44 | 27.5 |
| 11 | 3.5 | 35 | 15 | 45 | 26.25 |
| 12 | 22.5 | 35 | 22 | 45 | 28.75 |
| 13 | 18.125 | 36 | 15 | 45 | 22.5 |
| 15 | 6.25 | 36 | 17 | 46 | 23.25 |
| 15 | 4.62 | 36 | 11.25 | 46 | 28.37 |
| 15 | 6.25 | 37 | 22.12 | 47 | 21.25 |
| 15 | 7.5 | 37 | 18.75 | 47 | 22.5 |
| 16 | 8.75 | 37 | 17.87 | 47 | 18.75 |
| 19 | 11.375 | 37 | 20.62 | 47 | 21.25 |
| 20 | 11.25 | 37 | 19.01 | 49 | 26.25 |
| 20 | 9.375 | 37 | 18.375 | 50 | 25.875 |
| 20 | 8.75 | 38 | 30 | 50 | 26.25 |
| 25 | 5.75 | 39 | 19 | 50 | 24.37 |
| 28 | 12.12 | 39 | 17.5 | 51 | 22.5 |
| 28 | 15 | 40 | 25 | 52 | 30 |
| 29 | 12.5 | 40 | 21.5 | 53 | 26.25 |
| 30 | 15 | 42 | 20.5 | 53 | 32.5 |
| 30 | 16.625 | 43 | 16.625 | 53 | 18.75 |
| 32 | 15.625 | 43 | 21.875 | 54 | 27.5 |
| 32 | 10.25 | 43 | 25.125 | 55 | 27.5 |
| 33 | 14 | 43 | 23.75 | 55 | 22.5 |
| 33 | 15.75 | 43 | 21.25 | 60 | 32.50 |

Table 2. Statistical analysis of the relationship between tree age and total and annual increment

| | | |
|---|---|---|
| N | 69 | 69 |
| Min | 10 | 2,75 |
| Max | 60 | 32,50 |
| Sum | 2532 | 1303,35 |
| Mean | 36,70 | 18,89 |
| Std. error | 1,54 | 0,89 |
| Variance | 162,92 | 54,49 |
| Stand. dev | 12,76 | 7,38 |
| Median | 37 | 19,01 |
| 25 prcntil | 29,50 | 14,50 |
| 75 prcntil | 46,50 | 24,69 |
| Skewness | -0,51 | -0,36 |
| Kurtosis | -0,60 | -0,62 |
| Geom. mean | 33,84 | 16,93 |
| Coeff. var | 34,78 | 39,08 |

Table 3. Tree Age (Years) and Mean Annual Increment

| Age (Years) | MAI (cm) | Age (Years) | MAI (cm) | Age (Years) | MAI (cm) |
|---|---|---|---|---|---|
| 10 | 0.0755 | 35 | 0.021571 | 45 | 0.016778 |
| 11 | 0.068636 | 35 | 0.021571 | 45 | 0.016778 |
| 12 | 0.062917 | 36 | 0.020972 | 46 | 0.016413 |
| 13 | 0.058077 | 36 | 0.020972 | 46 | 0.016413 |
| 15 | 0.050333 | 36 | 0.020972 | 47 | 0.016064 |
| 15 | 0.050333 | 37 | 0.020405 | 47 | 0.016064 |
| 15 | 0.050333 | 37 | 0.020405 | 47 | 0.016064 |
| 15 | 0.050333 | 37 | 0.020405 | 47 | 0.016064 |
| 16 | 0.047188 | 37 | 0.020405 | 49 | 0.015408 |
| 19 | 0.039737 | 37 | 0.020405 | 49 | 0.015408 |
| 20 | 0.03775 | 37 | 0.020405 | 50 | 0.0151 |
| 20 | 0.03775 | 38 | 0.019868 | 50 | 0.0151 |
| 20 | 0.03775 | 39 | 0.019359 | 50 | 0.0151 |
| 25 | 0.0302 | 39 | 0.019359 | 51 | 0.014804 |
| 28 | 0.026964 | 40 | 0.018875 | 52 | 0.014519 |
| 28 | 0.026964 | 40 | 0.018875 | 53 | 0.014245 |
| 29 | 0.026034 | 42 | 0.017976 | 53 | 0.014245 |
| 30 | 0.025167 | 43 | 0.017558 | 53 | 0.014245 |
| 30 | 0.025167 | 43 | 0.017558 | 54 | 0.013981 |
| 32 | 0.023594 | 43 | 0.017558 | 55 | 0.013727 |
| 32 | 0.023594 | 43 | 0.017558 | 55 | 0.013727 |
| 33 | 0.022879 | 43 | 0.017558 | 60 | 0.012583 |
| 33 | 0.022879 | 44 | 0.017159 | | |
| 34 | 0.022206 | 45 | 0.016778 | | |

Table 4. The determined statistical value of age with mean annual increment

| | | |
|---|---|---|
| N | 70 | 70 |
| Min | 10 | 0,012583 |
| Max | 60 | 0,0755 |
| Sum | 2581 | 1,739642 |
| Mean | 36,87143 | 0,024852 |
| Std. error | 1,524666 | 0,00169 |
| Variance | 162,7224 | 0,0002 |
| Stand. dev | 12,75627 | 0,01414 |
| Median | 37,5 | 0,020137 |
| 25 prcntil | 29,75 | 0,016064 |
| 75 prcntil | 47 | 0,025384 |
| Skewness | -0,53041 | 1,936551 |
| Kurtosis | -0,58866 | 3,148179 |
| Geom. mean | 34,01552 | 0,022196 |
| Coeff. var | 34,59662 | 56,89585 |

## Conclusions and Recommendations

The result of the present study revealed that from all conifers trees *Cedrus deodar* isthe nationaltree of Pakistan. *Cedrus deodar* is light demander species and growing with the slow rate the rotation age of deodar is long. The present study determined the age of the tree, age is an important factor that impactson total growth, mean annual diameter growth, total and mean annual increment and Basel area is positive. Age is an independent variable, age increases total growth, mean annual diameter growth, total and mean annual increment and Basel area rate will be increased to the age. So, to make Shure increase the planting, seedling, of conifers trees in northern areas of Pakistan and to control on deforestation of conifers trees because it takes more time for its growth. By forestation and reforestation of conifers trees on degraded land and on steep slopes areas to controls soil erosion. Increasing the forest areas with proper management that will give more economical, social and biological benefits to a country like a forest that will provide habitat for wildlife, provide timber, fuelwood, watershed areas provides good quality of water, provides environmental services and other NTFS.

## References

Ahmad, A., & Nizami, S. M. (2015). Carbon stocks of different land uses in the Kumrat valley, Hindu Kush Region of Pakistan. *Journal of Forestry Research*, *26*(1), 57–64. https://doi.org/10.1007/s11676-014-0008-6

Andreeva, M. V., Kurochkin, Y. N., Syromyatina, M. V., & Chistyakov, K. V. (2019). Factors of Spatial and Temporal Variability of Siberian Larch Growth in the

Mountain Regions of Altai, Tuva, and Mongolia. *Russian Journal of Ecology*, *50*(5), 453–459. https://doi.org/10.1134/S1067413619040040

Asad, F., Zhu, H., Liang, E., Ali, M., Hamayun, M., Sigdel, S. R., … Hussain, I. (2017). Climate signal in tree-ring width chronologies of pinus wallichiana from the Karakoram mountains in northern Pakistan. In *Pak. J. Bot* (Vol. 49). Retrieved from http://climexp.knmi.nl

Asad, F., Zhu, H., Zhang, H., Liang, E., Muhammad, S., Farhan, S. Bin, … Esper, J. (2017). Are Karakoram temperatures out of phase compared to hemispheric trends? *Climate Dynamics*, *48*(9–10), 3381–3390. https://doi.org/10.1007/s00382-016-3273-6

Borges Silva, L., Teixeira, A., Alves, M., Elias, R. B., & Silva, L. (2017). Tree age determination in the widespread woody plant invader Pittosporum undulatum. *Forest Ecology and Management*, *400*, 457–467. https://doi.org/10.1016/j.foreco.2017.06.027

DeRose, R. J., Shaw, J. D., & Long, J. N. (2017). Building the Forest Inventory and Analysis Tree-Ring Data Set. *Journal of Forestry*, *115*(4), 283–291. https://doi.org/10.5849/jof.15-097

Fichtler, E. (2017). Dendroclimatology using tropical broad-leaved tree species: a review. *Erdkunde*, *71*(1), 5–22. Retrieved from http://www.jstor.org/stable/44280263

Fuchs, L., Stevens, L. E., & Fulé, P. Z. (2019). Dendrochronological assessment of springs effects on ponderosa pine growth, Arizona, USA. *Forest Ecology and Management*, *435*, 89–96. https://doi.org/10.1016/j.foreco.2018.12.049

Fujii, T., Marsoem, S., & Fujiwara, T. (1998). Annual growth rings in mahogany (Swietenia macrophylla) growing in Java. *IAWA Journal*, *19*, 449--450.

Heuret, P., Caraglio, Y., Sabatier, S.-A., Barthélémy, D., & Nicolini, E.-A. (2016). Retrospective analysis of plant architecture: an extended definition of dendrochronology. *Tropical Ecology and Society Reconciliating Conservation and Sustainable Use of Biodiversity. Program and Abstracts*.

Hussain, A., Ahmed, M., Khan, S. W., Abbas, H., Hussain, A., & Abbas, Q. (2018). *Agroforestry practices in relation to the age and growth rate patterns of picea smithiana using modern techniques of dendrochronolgy from Istak Valley of Central Karakoram National Park (CKNP) Gilgit-Baltistan, Pakistan*. 569–574. https://doi.org/10.21162/PAKJAS/18.7020

Iqbal, J. (2017). *Phytosociology and Dendrochronological investigation of Shangla Pine Forests of Khyber Pakhtunkhwa, Pakistan JAVED IQBAL* (Federal Urdu University of Arts, Science and Technology,). Retrieved from https://pdfs.semanticscholar.org/3c7a/09c4bee165aea1ad5a0b47cd0c9d24dce05c.pdf

Iqbal, J., Siddiqui, M. F., Khan, A., & Wahab, M. (2017). Age and radial growth analysis of conifer tree species from Shangla, Pakistan. *Pakistan Journal of Botany*, *49*, 69–

72. Retrieved from https://www.researchgate.net/publication/317429320

Jensen, A. L., Boll, P. S., Thysen, I., & Pathak, B. K. (2000). Pl@nteInfo® - A web-based system for personalised decision support in crop management. *Computers and Electronics in Agriculture*, *25*(3), 271–293. https://doi.org/10.1016/S0168-1699(99)00074-5

Khan, A., Ahmed, M., Khan, A., & Faheem Siddiqui, M. (2018). Ring width characteristics of 4 pine tree species from highly disturbed areas around Murree, Pakistan. *Pak. J. Bot*, *50*(6), 2331–2337.

Locosselli, G. M., Camargo, E. P. de, Moreira, T. C. L., Todesco, E., Andrade, M. de F., André, C. D. S. de, … Buckeridge, M. S. (2019). The role of air pollution and climate on the growth of urban trees. *Science of the Total Environment*, *666*, 652–661. https://doi.org/10.1016/j.scitotenv.2019.02.291

Manzone, M. (2016). Quality, productivity, energy and costs of woodchip produced by Cedrus deodara plantations: A case study in Italy. *Biomass and Bioenergy*, *92*, 81–87. https://doi.org/10.1016/j.biombioe.2016.06.008

Metsaranta, J. M. (2020). Dendrochronological procedures improve the precision and accuracy of tree and stand age estimates in the western Canadian boreal forest. *Forest Ecology and Management*, *457*. https://doi.org/10.1016/j.foreco.2019.117657

Miranda, Z. P., Guedes, M. C., Rosa, S. A., & Schöngart, J. (2018). Volume increment modeling and subsidies for the management of the tree Mora paraensis (Ducke) Ducke based on the study of growth rings. *Trees - Structure and Function*, *32*(1), 277–286. https://doi.org/10.1007/s00468-017-1630-7

Nechita, C., Eggertsson, O., Badea, O. N., & Popa, I. (2018). A 781-year oak tree-ring chronology for the Middle Ages archaeological dating in Maramureș (Eastern Europe). *Dendrochronologia*, *52*, 105–112. https://doi.org/10.1016/j.dendro.2018.10.006

Ols, C., Girardin, M. P., Hofgaard, A., Bergeron, Y., & Drobyshev, I. (2018). Monitoring Climate Sensitivity Shifts in Tree-Rings of Eastern Boreal North America Using Model-Data Comparison: Shifts in Tree Growth Sensivity to Climate. *Ecosystems*, *21*(5), 1042–1057. https://doi.org/10.1007/s10021-017-0203-3

Pharma, D., Sharma, A., Prashar, B., & Arora, P. (2018). *ISSN 0975-413X CODEN (USA): PCHHAX Cedrus deodara: A Medicinal Herb* (Vol. 10). Retrieved from www.derpharmachemica.com

van der Sleen, P., Zuidema, P. A., & Pons, T. L. (2017). Stable isotopes in tropical tree rings: theory, methods and applications. *Functional Ecology*, *31*(9), 1674–1689. https://doi.org/10.1111/1365-2435.12889

Zafar, M. U., Ahmed, M., Rao, M. P., Buckley, B. M., Khan, N., Wahab, M., & Palmer, J. (2016). Karakorum temperature out of phase with hemispheric trends for the past five centuries. *Climate Dynamics*, *46*(5–6), 1943–1952. https://doi.org/10.1007/s00382-015-2685-z

Zhao, S., Pederson, N., D’Orangeville, L., HilleRisLambers, J., Boose, E., Penone, C., …

Manzanedo, R. D. (2019). The International Tree-Ring Data Bank (ITRDB) revisited: Data availability and global ecological representativity. *Journal of Biogeography*, *46*(2), 355–368. https://doi.org/10.1111/jbi.13488