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Mehdi Khosrow-Pour
Information Resources Management Association, USA

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Methodology of Climate Change Impact Assessment on Forests

Mostafa Jafari
Regional Institute of Forest and Rangelands (RIFR), Iran

INTRODUCTION

Climate change is one of the main challenging issues in various countries (Jafari, 2013b) in current century. Climate change and climate variability and Global Warming and its' effects on natural resources, plants, animal and in general on human life are among subjects that received attention of scientists and politicians in recent years. Climate change challenges need to be considered in various dimensions (Jafari, 2013c). To both understand the present climate and to predict future climate change, it is necessary to have both theory and empirical observation. Any study of climate change involves the construction (or reconstruction) of time series of climate data. How these climate data vary across time provides a measure (either quantitative or qualitative) of climate change. Types of climate data include temperature, precipitation (rainfall), wind, humidity, evapotranspiration, pressure and solar irradiance (aric, 2008). Climate change assessments and evaluation should be done by using recorded observation data as well as prepared and provided proxy data (Jafari, 2010). Plant ecophysiological study has very important role to recognize climate changes (Jafari, 2007). Trees and also woods can be used as archive of past events. Climate change will strongly affect water resources, plant communities and wildlife in the arid and semi-arid regions (FAO, 2009). Water, environment humidity and temperature are main factors of plant growth. Majority of plant and forest ecosystems on the earth are formed under these two main factors. Whatever amount of humidity and required water are available and also favorable temperature for plant growth cause plant community reach higher plants and trees and forest ecosystems would develop. In fact plants are important climate indicators. Trees are not an exception. Plants, especially, trees are sensitive to their environmental changes, and tree-ring width is one of the reliable proxies of ambient environmental conditions. Climate and environmental changes affect natural ecosystems as well as planted forests (Kiaee and Jafari, 2014). Investigation of quantity and quality of these growths could help to consider past climatic conditions. Measuring and recording tree rings' widths and its' densities of early woods and late woods can provide valuable data resources to produce time series and consider its correlation with climate factors in the same time periods (Figure 1).

Seasonal changes in temperate climatic region effect on tree rings widths periodically. In spring and summer time plants grow better than unpleasant seasons like fall and winter. The outermost layer of a tree is composed of bark. Bark itself is composed of two tissues: an innermost layer of live phloem, and an outer layer of periderm (the bark 'proper'), which has an outermost layer of waterproofing cork (phellum) which protects the wood to some degree from insects, etc (Figure 2). The cork has its own cambium (phellogen) between the phloem and cork layer. Only the outermost layer of a tree is alive (essentially only the phellogen, phloem, cambium, and maturing xylem of the current year's growth). Consequently, the majority of the trunk does not require gaseous exchange. The bark is punctuated by lenticels, a sort of giant stoma, which allows the thin outermost living layers of the trunk to 'breathe' (Anonymous, 2008a),

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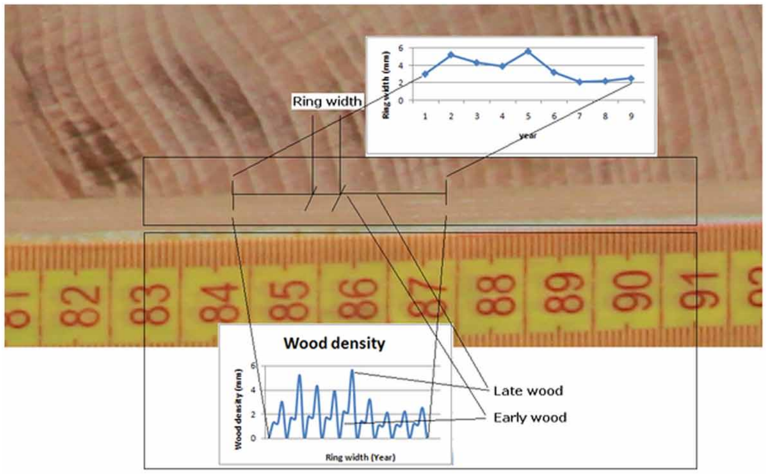
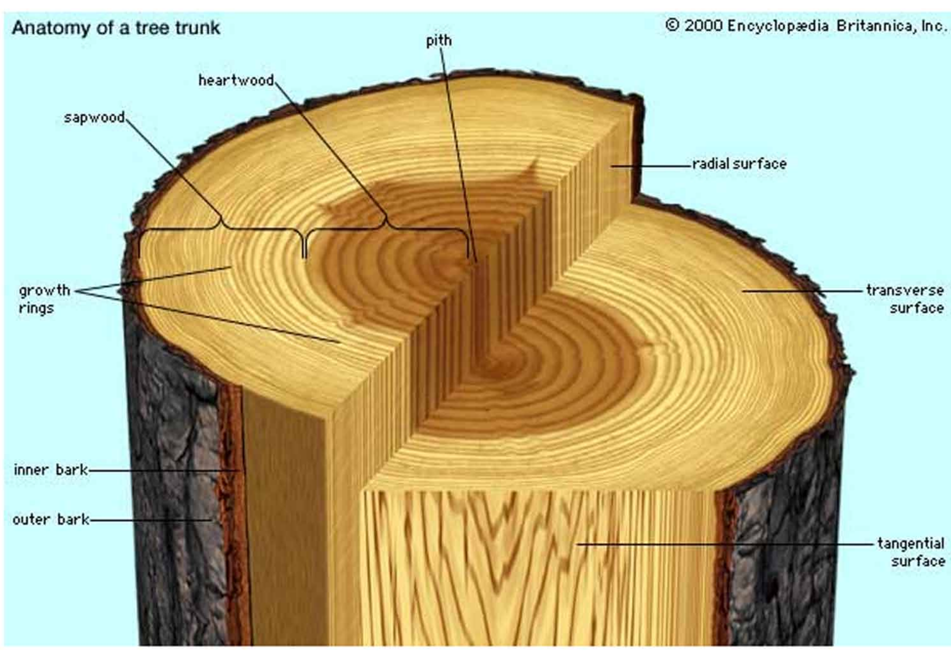
Figure 1. Tree ring width and densities, Fagus orientalis (beech tree), Mazandaran province mid-elevation forest (MA II F3)
(Author, 2010)



Growths of the vascular cambium tissue produce wood as secondary xylem production. Sapwood is xylem that conveys water and dissolved minerals from the roots to the rest of the tree. The darker heartwood is older xylem that has been infiltrated by gums and resins and has lost its ability to conduct water. Each growth layer is distinguished by early wood (springwood), composed of large thin-walled cells produced during the spring when water is usually abundant, and the denser latewood (summerwood), and composed of small cells with thick walls. Growth rings vary in

Figure 2. Anatomy of a tree trunk
(Encyclopedia Britannica, 2000)



width as a result of differing climatic conditions; in temperate climates, a ring is equivalent to one year's growth. Certain conducting cells form rays that carry water and dissolved substances radially across the xylem. Bark comprises the tissues outside the vascular cambium, including secondary phloem (which transports food made in the leaves to the rest of the tree), cork-producing cells (cork cambium), and cork cells. The outer bark, composed of dead tissue, protects the inner region from injury, disease, and desiccation (Encyclopedia Britannica, 2006). A big trunk of a harvested tree can be use as an archive of data and may provide its life long time series (Figure 3)(Jafari, 2010).

Main objectives of dendrochronology are: a) Put the present in perspective of the past, b) Better understand current environmental processes and conditions, and c) Improve understanding of possible environmental issues of the future. To meet these objectives, the exact year of formation of each growth ring must be known: a) Merely counting rings doesn't ensure accurate dating, and b) Crossdating, also known as pattern matching, ensures accurate dating (Sheppard, 2013).

BACKGROUND

Dendrochronology is an accepted and reliable method in considering climate change impact on forest ecosystem through study tree ring widths (Jafari, 2015). The cambium of the trees growing in temperate zones becomes dormant in the falls and reactivates each spring. This leads to annual rings and the vessels produced in the spring are often larger than in the fall; the large vessels allow for rapid sap movement in the spring, whereas the narrow vessels minimize the risk of cavitations under dry conditions in late summer. This leads to a ring-porous pattern in the wood as opposed to the diffuse porous pattern where vessels are more even in size. As trees age the vessels in the center of the stem become air-filled and cease to carry water; they still function for support and storage of waste products, some of which are colored; this is the heartwood in contrast to the sapwood which carries water and is confined to the outer few annual rings (The Ohio State University, 2013).

Recording temperature and using thermometers have only been widely used since around 1850. Thus, the instrumental record for earlier

Figure 3. Hyrcanian forest research site, an old trunk of Fagus orientalis L. (Asalem, Guilan province forest)
(Jafari, 2010)

times is quite poor and full of gaps. Essentially nothing is available in the way of quantitative measurements of weather conditions for the time before 1800 A.D. To reconstruct climate change, therefore, we need to use indirect indicators. One source of information is historical records: logs, dairies, lists on when the wine harvest began, reports on when the ice first broke up in a northern river, or when the cherry trees first blossomed. In some cases, such reports go back hundreds of years, although rarely in unbroken sequence. Logs and dairies are treasured finds; they do not exist for most regions of the planet (Anonymous, 2008b).

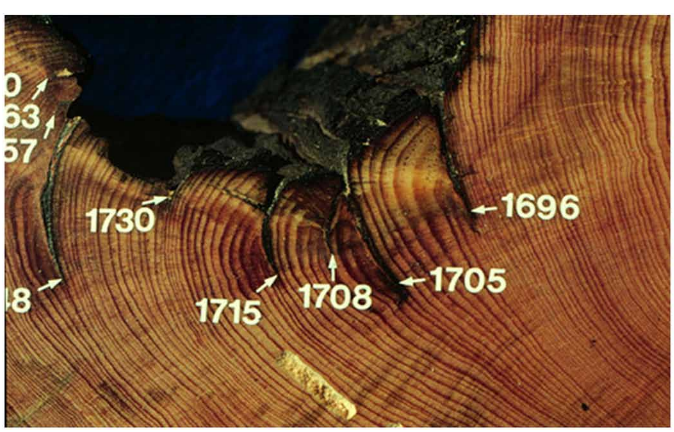
Climate factors data can be measured by direct observation in different meteorological station (like climatology and synoptic stations) or can be recorded by different instrument in different locations and with different time intervals. This information is more or less confidential for judgments on the past events, and good tools for the future projections.

Applications of Dendrochronology

As definition point of view, the word dendrochronology is compose of: dendro (using trees, or more specifically the growth rings of trees), chrono (time, or more specifically events in past time), and logy (the study of). Applications in dendrochronology include: ecology (insect outbreaks, forest stand structure, past fires) (Jafari, 2012a), climatology (past droughts or cold periods), geology (past earthquakes, volcanic eruptions), and anthropology (past construction, habitation, and abandonment of societies) (Sheppard, 2013). Also some new terms provided (Jafari, 2013a) for related applications such as, dendro-productivity (Jafari & Khoranke, 2013), dendro-genetic (Jafari *et al.,* 2012b), dendro-medical (Jafari, 2014a).

In region where the seasons provide clear seasonal climate difference, trees develop annual rings of different properties depending on weather, rain, temperature, soil pH, plant nutrition, CO_2 concentration, etc. in different years. These variations are used in dendroclimatology to infer past climate variations. Annual rings width of old trees wood sample is valuable data source as a live archive document for past climate changes, if year of growth and cross dating be well recognized. In case of sample from standing live trees, growth year is identifiable. But in case of wood samples, which could be found in archeological sites, recognizing growth year by producing skeleton graph and cross dating is necessary. Wood samples could show the years of past events like fire, drought or flood in growing site of sample tree. Fire-scarred ponderosa pine (*Pinus ponderosa*) from Ashenfelder Basin, Laramie Peak, Wyoming, (Figure 4). Low to moderate intensity fires that burned through a forest may injure or scar surviving trees, leaving a clear record of their passage. (Swetnam and Baisan, 2002)

Figure 4. Fires may injure or scar surviving trees (Swetnam and Baisan, 2002)



Proxy Data and Climate Change

Climatologists who study past – or paleo – climates (Paleo-climatologists) use the term "proxy" to describe a way that climate change is recorded in nature, within geological materials such as ocean or lake sediments, tree-rings, coral growth-bands, ice-cores, and cave deposits.

For a proxy to be useful, it must first be established that the proxy (i.e. tree-ring width, stable isotope composition of ice, sediment composition) is in fact sensitive to changes in temperature (or some other environmental parameter). This phase of research is known as calibration of the proxy. Perhaps the most frequently used temperature proxy is the relative abundance of microfossils in sediments. That microfossils bear witness to temperature was recognized early in the history of oceanography.

Measuring and recording of tree-ring width is another reliable source of proxy of ambient environmental conditions. When a tree grows at high elevation, near the tree limit, its growth is limited by temperature, and the thickness of its growth rings contains clues about whether the growing season was warm or cold. An equation can then be written relating the changes in ring width to temperature change. Similarly, if the growth is limited by water (say, in a warm semi-arid setting) the ring width can be used to calculate changes in rainfall. Climate proxies have been utilized to provide a semi-quantitative record of average temperature in the Northern Hemisphere back to 1000 A.D (Anonymous, 2008b).

To provide paleo proxy data paleo- climatologists gather proxy data from natural recorders of climate variability such as tree rings, ice cores, fossil pollen, ocean sediments, corals and historical data. By analyzing records taken from these and other proxy sources, scientists can extend our understanding of climate far beyond the 100+ year instrumental record.

Principle sources of the major types of proxy climatic data for palaeoclimatic reconstructions can be categorized as following groups (Jafari, 2010): Glaciological (Ice Cores), Oxygen isotopes, Physical properties, Trace element & micro-particle concentrations

- **Geological:** A. Sediments, 1. Marine (ocean sediment cores), i) Organic sediments (plank-tonic & benthic fossils), Oxygen isotopes, Faunal & floral abundances, Morphological variations, ii) Inorganic sediments: Mineralogical composition & surface texture, Distribution of terrigenous material (provided by river erosion), Ice-rafted debris.
- **Geochemistry:** 2. Terrestrial, Periglacial features, Glacial deposits & erosion features, Glacio-eustatic features (shorelines and sea level changes), Aeolian deposits (sand dunes), Lacustrine deposits/varves (related to the lakes), B. Sedimentary Rocks, Facies analysis, Fossil/microfossil analysis, Mineral analysis Isotope geochemistry.
- **Biological:** Tree rings (width, density, isotope analysis), Pollen (species, abundances), Insects.
- **Historical:** Meteorological records, Parameteorological records (environmental indicators), Phenological records (biological indicators).

Proxy material differs according to its: a) its spatial coverage; b) the period to which it pertains; and c) its ability to resolve events accurately in time (Bradley, 1985). Some proxy records, for example ocean floor sediments, reveal information about long periods of climatic change and evolution, with a low-frequency resolution. Others, such as tree rings are useful only during the last 10,000 years at most, but offer a high frequency (annual) resolution. The choice of proxy record (as with the choice of instrumental record) very much depends on what physical mechanism is under review. As noted, climate responds to different forcing mechanisms over different time scales, and proxy materials will contain necessary climatic information on these to a greater or lesser extent, depending on the three factors mentioned (aric, 2008).

Natural Archives

Growth conditions can be recorded in tree rings. A wide ring could be define as plenty of warm days and sufficient water, a narrow ring means nasty conditions, either a short growing seasons because summer was late in coming (up on the mountain), or a severe water shortage (in the foothills, in areas where water is limiting). The mixture of conditions recorded (time of snow-melt, intensity of winter rain, temperature in June, etc.) depends on what a given tree cares about in terms of growth. Hence, a tree is a "reporter," and the same is true for all other organisms recording climate change. What a scientist can extract from tree rings depends on how many properties of a ring can be measured (width, density of early wood, density and width of wood grown late in the season), how clever the statistical methods are, and how well the items of interest (say, spring temperature or annual rainfall) are correlated with the properties measured. For instance, special measurements can be made on the isotope chemistry of the wood. This kind of information can yield insights on the composition of the rainfall (from oxygen isotopes) and on the rate of photosynthesis (from carbon isotopes) (Anonymous, 2008b).

While tree growth is influenced by climatic conditions, patterns in tree-ring widths, density, and isotopic composition reflect variations in climate. In temperate regions where there is a distinct growing season, trees generally produce one ring a year, and thus record the climatic conditions of each year. Trees can grow to be hundreds to thousands of years old and can contain annually-resolved records of climate for centuries to millennia.

Tree Rings Measurement Instruments

Outcome from dendrochronological research studies played an important role in the early days of radiocarbon dating. Tree rings provided truly known-age material needed to check the accuracy of the carbon 14 dating method. During the late 1950s, several scientists (notably the Dutchman Hessel de Vries) were able to confirm the discrepancy between radiocarbon ages and calendar ages through results gathered from carbon dating rings of trees. The tree rings were dated through dendrochronology.

Even now, tree rings are still used to calibrate radiocarbon determinations. Libraries of tree rings of different calendar ages are now available to provide records extending back over the last 11,000 years. The trees often used as references are the bristlecone pine (*Pinus aristata*) found in the USA and waterlogged Oak (*Quercus* sp.) in Ireland and Germany. Radiocarbon dating laboratories have been known to use data from other species of trees (BETA, 2013).

Borer core samples submitted to the laboratory are registered, followed by preparation of optimal surfaces for analysis across several growth radii of the tree. Subsequently, tree-ring series are measured manually (Figure 5) and registered and or using specially designed measuring devices (Lintab and Aniol) connected to computers (Figure 6), screens and printers. The soft wares used for data storage, cross-correlation and statistical analyses are CATRAS and ITRDBLIB. Samples subject to wood anatomical determination are analyzed with light microscopy and compared against the laboratory's extensive reference collection of European woody plants (Hammarlund, 2013). Major Equipment in the Biogeography/ Dendrochronology Laboratory currently houses one Velmex Measuring Machine connected to a

Stereozoom Microscope on a boom stand and a microcomputer analysis system. The lab equipment also includes: - incremento borers, - stereozoom microscopes, - belt sanders (4X24”), - desktop and labtop computers, - GPS units, Stihl Chain saw Stihl 046 with a 24” bar, Hand saws, - Hood, - cruiser packs, - Soil Sampling probes, - Munsell Charts, - Measuring tapes, - map tubes, - Paper straws, Poplar core mounts, skeleton plot paper (Indiana State University, 2013).

Discs or Borer Core Samples

The stem cross section is the best way to have a good surface on which to observe tree ring series. These discs can be sometimes obtain in co-operation with foresters when timbering is programmed. In most of the cases, cross dating and then measurements of ring-width as well as densitometry analysis are performed with small cores 4mm in diameter extracted from the tree by an increment borer. In order to avoid dissymmetry in radial tree-growth measurement 2 or 3 cores are extracted on each tree. Consequently, on each sampling site 20 to 45 cores are collected and brought back to the laboratory. Precise cares have to be taken in coring, particularly when densitometry analysis will be performed. The most important is the position of the borer on the trunk. In order to obtain lately an observation surface the most perfectly perpendicular to the long axis of tracheids and fibers, the borer has to be also positioned perpendicularly to trunk axis (TGTC, 2008).

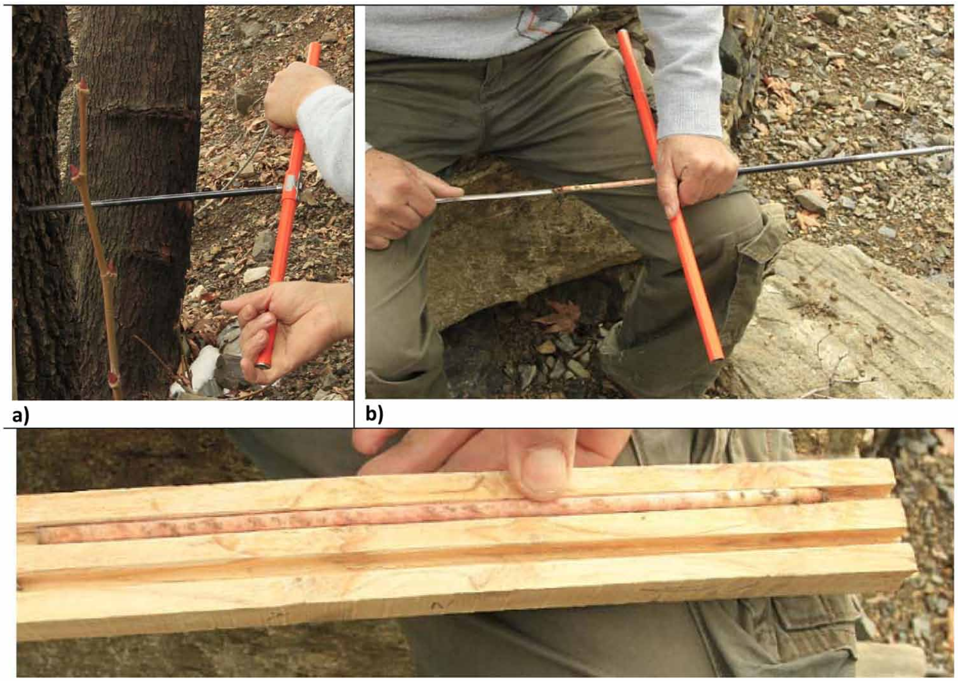
In case which disc of harvested trunk is not available (Figure 7) or it is not possible to take disc, core sampling is an alternative. There are different types of drill instrument for this purpose (Figure 8). Increment borers are instruments that take a small cylindrical core from trees and allow determination if radial growth or age of the tree (Figure 8c). The borer consists of three parts (Figure 8): the case or handle, the borer bit, and the extractor. Increment borers come in various sizes, from 4 inches (101.6 mm) to 30 inches (762 mm) length or more. The ones which are in usual

Figure 5. Measuring disc sample tree ring widths in the Golestan research centre lab. using manual measurements
(Author, 2010)

Figure 6. Measuring core sample tree ring widths in the dendrochronology lab. using computer equipped machine
(Author, 2012)

Figure 7. Big trunk disc sample taken during harvesting process
(Author 2010)

Figure 8. Wood sample by increment borer: a) Using borer in the trunk, b) Extracting core sample from borer, c) sample in wooden holder
(Eng Khoshnevis, photos by the author, 2012)



use are in the 8-18 inch range (457.2 -203.2 mm). Smaller borers are used for small trees or where only recent growth is needed from larger trees (Figure 8a, b, and c, Figure 9).

In the field sampling experiment, when the cores remove from the borer, for the safety, it is needed to lay them into an increment core holder that has been pre-glued. Tightly wind the glued cores with cotton string (Figure 10) so as to apply pressure during the drying process (McCarthy, 2008).

Immediate observation of rings on cores extracted from the borer is rarely possible, and moreover rings width measurement quite impossible. Good observation and measurement need a perfect transverse section. After a correct reorientation of the core as the piece of wood was in the trunk, such a section is obtained either by refreshing with a razor blade or polishing the surface selected in order to obtain a plane surface allowing to access to the cell structure (TGTC, 2008).

Measured Data Analysis

A great number of laboratories in different part of the world have been established to study on wood and climate changes. Palaeo-climate changes are on the target of the most of these institutes. The International Tree-Ring Data Bank is maintained by the NOAA Paleoclimatology Program and World Data Center for Paleoclimatology. The Data Bank includes raw ring width or wood density measurements, and site chronologies (growth indices for a site). Tree-ring measurement series from other parameters are welcome as well. Reconstructed climate parameters, including North American Drought, are also available for some areas. Over 2000 sites on six continents are included (WDC, 2008). The objective of the measuring ring widths would be to develop tree-ring records of climate over the past several centuries, to understand inter-annual to century scale variability in climate. This study will improve the capability of understanding environmental variability and key features of the

Figure 9. Borer samples in wooden holder
(Author, 2014)

Figure 10. Borer sample and sample holder in the field
(Author, 2012)

regional environment, e.g. persistence of drought, reliability of stream flow (Hughes & Touchan, 1997). Analyzing data by using software by accuracy of 0.01 mm (Robinson & Evans 1980) or more accurate up to 0.001 mm.

Statistical Analysis of the Climate Factors

Tree- rings can provide continuous yearly paleoclimatic records for regions or periods of time with no instrumental climate data. However, different species respond to different climate parameters with, for example, some sensitive to moisture and others to temperature. For example four common species which grow in Northern Ireland and their suitability for climate reconstruction are beech, oak, ash and Scots pine. Beech and ash are the most sensitive to climate, with tree-ring widths more strongly Influenced by precipitation and soil moisture in early summer than by temperature or sunshine. Oak is also sensitive to summer rainfall, where as Scots pine is sensitive to maximum temperature and the soil temperature. The moisture-related parameters, rainfall and the Palmer Drought Severity Index (PDSI), and to a lesser extent, maximum and mean temperatures, can be reconstructed. Reconstructions of climate parameters with tree-rings as proxies may be relatively stable for some seasons such as May–July. The combinations of species are more successful in reconstructing climate than single species (GarcÍa-Suárez *et al*., 2009). The development of dendrochronological time series in order to analyze climate-growth relationships usually involves first a rigorous selection of trees and then the computation of the mean tree-growth measurement series. A change in the perspective, passing from an analysis of climate-growth relationships that typically focuses on the mean response of a species to investigating the whole range of individual responses among sample trees (Carrer, 2011).

Crossdating

Primary faze of crossdating work, under a good dissecting microscope, begins by counting backwards from the first known year behind the bark. Using a fine mechanical pencil, place a single dot on each decadal ring (e.g., 2010, 2000, 1990, etc.), place two dots on each 50-year ring (2010, 1960, 1910, etc.), and three dots on each century ring (2010, 1910, 1810, etc.). At this stage, these marks are just temporary year assignments. The actual years will be confirmed after skeleton plotting (McCarthy, 2008).

Using a mm graph paper is first step to draft skeleton plots.The decades are labeled on the x-axis and a vertical line is drawn on a y-scale composed of 10 units. Any ring that is smaller than its neighbor rings (± 3 on either side) gets a line drawn on the paper. If the ring is very small, the line may be 10 units. If the ring is half as small as its predecessor you might code it as a 5, etc. (rings that are coded less than a 5 are rarely useful in crossdating). This is a bit counterintuitive because the longer the line, the smaller the ring. According to the provided skeleton graphs, cross-dating among different samples comparing with control sample would be possible. It is also possible to recognize different years of various samples from different sources for cross-dating.

A more precise method of dating volcanic deposits of recent age is to identify anomalous growth patterns among the annual rings of trees growing at the time the deposits were emplaced. Trees that were injured but not killed by tephra or lahars may show a sequence of narrow rings beginning at the time of impact. “Cross-dating,” the matching of ring-width variation patterns in one tree with corresponding ring patterns in another, should be used to ensure that dating errors are not introduced by missing rings.

Missing rings can often identified by drawing narrow rings in cross-dating progress. Control tree shows 23 annual rings between the 1472 and

1495 narrow rings (Figure 11), while the tree in the We (Mount St. Helens) tephra-fall zone shows only 20 rings. The series of missing and narrow rings starting with the 1482 ring were caused by tree injury during fallout of layer we. Because of possible missing rings, dates of past volcanic events cannot be determined unequivocally by counting back to a series of narrow rings (Brantley *et al.,* 1986).

Since, the same set of environmental factors influence tree growth throughout a region, the patterns of ring characteristics, such as ring widths, are often common from tree to tree. These patterns can be matched between trees in a process called crossdating (Figure 12), which is used to assign exact calendar year dates to each individual ring (The University of Arizona, 2013). The chronology provides two main types of information:

1. The chronology can be used as a tool for dating events that caused tree death or a marked change in the appearance of a ring or set of rings. The death date can be used to date the tree cutting involved in the construction of wooden dwellings. Scars can record the timing of events such as fire, flood, avalanche, or other geomorphologic events, while sequences of suppressed or larger rings record events such as insect infestation, effects of pollution, or changes in forest dynamics.
2. The chronology is an average of coherent variations in growth from a number of trees. It enhances the common pattern of variation or "signal" -usually related to climate- while the non-common variance or "noise" is dampened. Chronologies from trees that are sensitive to climate can be used to reconstruct past variations in seasonal temperature, precipitation, drought, stream flow, and other climate-related variables (The University of Arizona, 2013).

Figure 11. Tree-ring cross-dating
(Brantley et al., 1986)

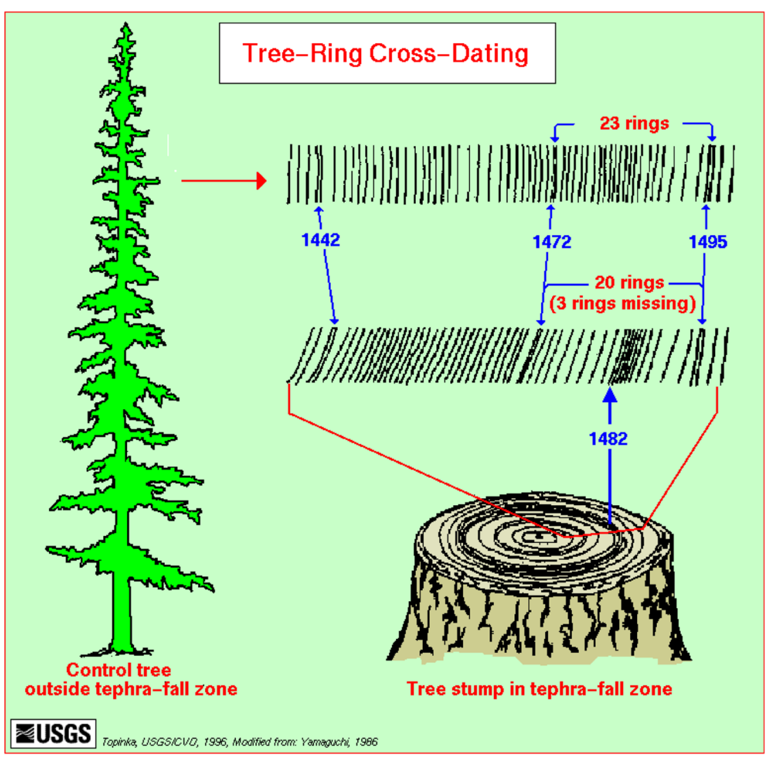
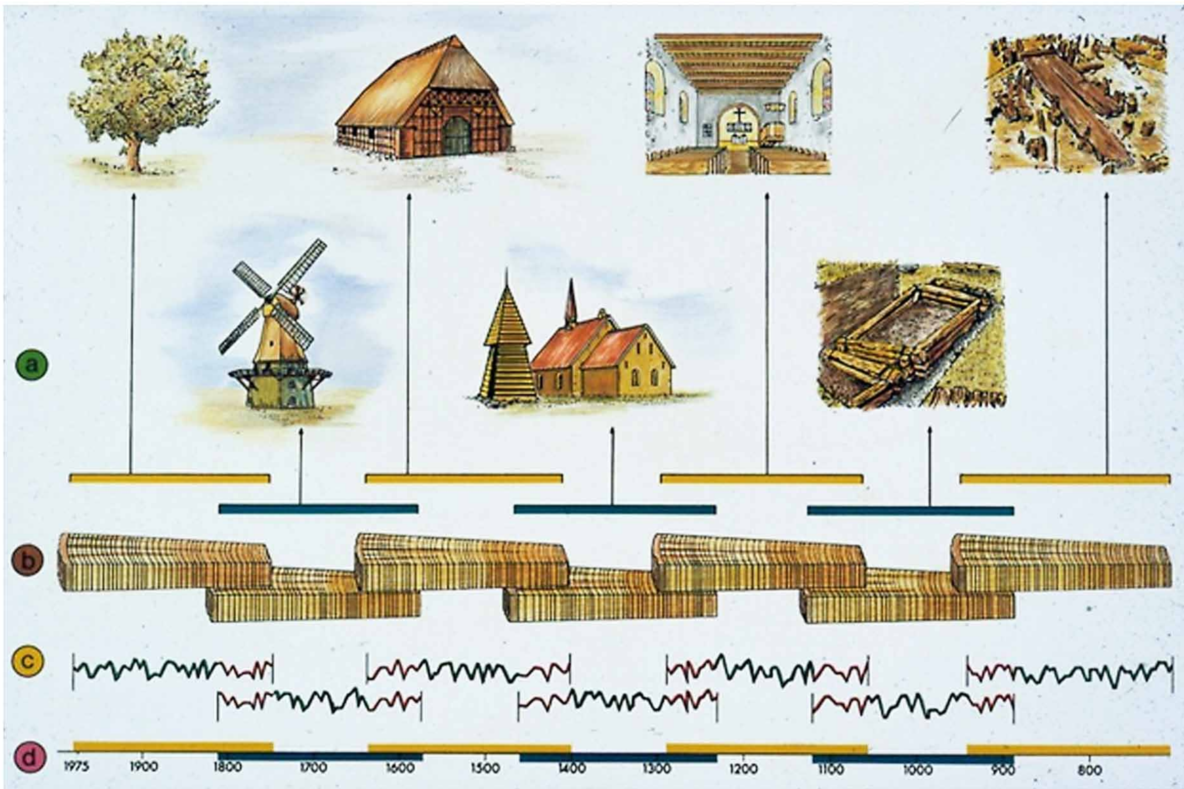


Figure 12. Cross-dating according to the annual ring growth of different samples from live standing trees to old or new wood samples, Illustration showing an example of time series crossdating
(Adapted from Dendrologisches Labor Hamburg, 2015, http://www.scinexx.de/dossier-detail-186-7.html)

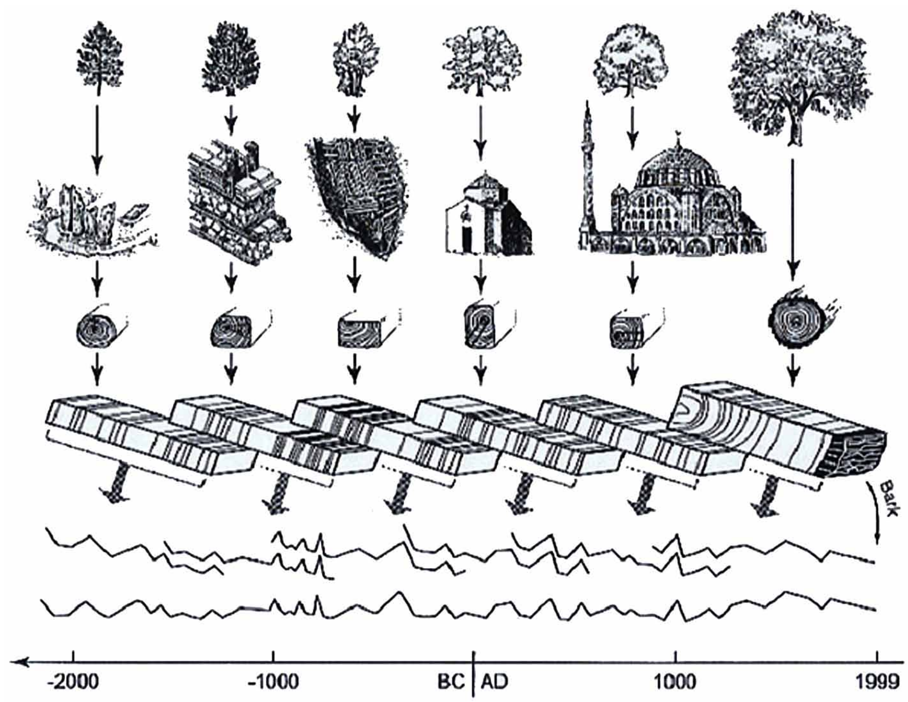


The techniques of dendrochronological study were used to date a spruce coffin board from Pukatawagan Bay, Manitoba received from Manitoba Historical Resources. The sample contained 74 annual rings, although the outermost 16 rings were rotten and not measured. The ring width series from the coffin board was matched against records from living spruce growing near South Indian Lake. Crossdating shows that the coffin board was cut in 1878. The board also contains a ring containing poorly developed latewood (a 'light' ring) in 1817 that is found commonly in spruce records across northern Manitoba (Figure 12)(Scott & Nielsen, 2002).

Using different wood materials of different periods, by cross-dating of the samples comparing with control one, it would be possible to record and estimate changes from present time back to the ancient area (Figure 13).

Dr. Andrew E. Douglass, an astronomer, developed dendrochronology about 1913. Douglass used a bridging method to create his chronology. First he studied recently cut trees whose dates he knew. This initial step was critical because by knowing the cut date, Douglass knew when each tree added its last growth ring. This, in turn, let him determine the year each tree started growing. The calculation was straightforward: count the dark rings inward and subtract that number from the year the tree was cut. As Douglass matched and recorded ring patterns from trees of different ages, he confirmed that their patterns overlapped during the years the trees simultaneously lived (The University of North Carolina, 2013).

Figure 13. The bridging method, cross-dating of annual rings from present live tree to the past wood samples, for establishing a tree-ring sequence
(Kuniholm, 2001)



FUTURE RESEARCH DIRECTIONS

Enhance and improvement of measuring methods on climate change issues in different sector is a crucial and important needs. Dendrochronology study method has several different applications. It is crucial to used dendrochronological method in medical field. Some question need to be considered and if possible answered. How medical needs could link with dendrochronological experiences? What kind of element may be detected on tree rings? How people could benefit of the results? What are the best analysis methods? By using this method we will be able to extend our work in medicine science areas and speed up medical approach with lower cost and economical saving (Jafari, 2014a).

CONCLUSION

The AFOLU sector (AR5, IPCC, WGIII, Chapter 11) is responsible for just under a quarter (~10–12 $GtCO_2eq/yr$) of anthropogenic GHG emissions mainly from deforestation and agricultural emissions from livestock, soil and nutrient management (robust evidence; high agreement) (Smith *et. al*., 2014).

Climate change impact will cause changes in biomass production in natural ecosystems. It is a need to consider the vulnerability of Net Primary production (NPP) in forest ecosystem (Jafari, 2014b).

Climate change issue is an important subject in current century. In all possible ways we need to cope with this phenomenon to enhance our understanding knowledge. Dendrochronology as an able and certified study method could be implying in a wide range of applications.

REFERENCES

Anonymous. (2008a). *Plant Growth, in Science*. Retrieved from http://www.steve.gb.com/images/science/wood_layers.jpg

Anonymous. (2008b). *Climate Change, Past and Future, Calspace Courses*. Retrieved from http://earthguide.ucsd.edu/virtualmuseum/climatechange1/cc1syllabus.shtml

aric. (2008). *Global Climate Change Student Guide*. Author.

BETA. (2013). *Beta Analytic, Radiocarbon Dating*. Retrieved from http://www.radiocarbon.com/tree-ring-calibration.htm

Bradley, R. S. (1985). *Quaternary Palaeoclimatology: Methods of Palaeoclimatic Reconstruction*. London: Unwin Hyman.

Brantley, S., Yamaguchi, D., Cameron, K., & Pringle, P. (1986). Tree-Ring Dating of Volcanic Deposits. *Earthquakes and Volcanoes*, *18*(5), 184–194.

Carrer, M. (2011). Individualistic and Time-Varying Tree-Ring Growth to Climate Sensitivity. *PLoS ONE*, *6*(7), e22813. doi:10.1371/journal.pone.0022813 PMID:21829523

FAO. (2009). *Guidelines for good forestry and range practices in arid and semi-arid zones of the Near East*. Cairo: FAO Regional Office for the Near East.

García-Suárez, A.M., Butler, C.J., & Baillie, M.G.L. (2009). Climate signal in tree-ring chronologies in a temperate climate: A multi-species approach. *Dendrochronologia, 27*, 183–198. doi:10.1016/j.dendro.2009.05.003

Hammarlund, D. (2013). *Equipment and sample handling*. Retrieved from http://www.geol.lu.se/dendro/en/equipment.htm

Hughes, M., & Touchan, R. (1997). *Preparation for Collaborative Work on Past Climate in Jordan*. Science Storm, A world of wonder. Retrieved from http://www.sciencestorm.com/

Indiana State University. (2013). *Dendrochronology Lab, Indiana State University*. Retrieved from http://dendrolab.indstate.edu/equip_fac.htm

Jafari, M. (2007). *Review on needfulness for plant ecophysiological study and investigation on climate change's effects on forest, rangeland and desert ecosystems*. Presented at Workshop, Climate Change in South-Eastern European Countries: Causes, Impacts, Solutions, Orangerie, Burggarten, Graz, Austria. Retrieved from http://www.intecol.net/pages/002_personal.php?mode=list&table=blog&tb_kind=Research&id=mjafari&vvt=aa&bidx=27531

Jafari, M. (2010). Climate Change Impacts on Iranian Ecosystems with review on Climate Change Study Methods (Pub. No. 421). RIFR.

Jafari, M. (2012a). A new approach to dendroecological studies: Climate change impact on forest' wood production in Astara (Gilan). *Iranian Journal of Wood and Paper Science Research*, *27*(4), 690–706.

Jafari, M. (2013a). *New method on dendrochronology study in forest ecosystems; two new approaches: Dendro-productivity and Dendrogenetic.* Paper ID: 1076-ADA2013. Presented in The 3rd International Conference of Asian Dendrochronology Association (ADA2013), Climate Change and tree Rings, Tehran, Iran. Retrieved from http://ada2013.ut.ac.ir/paper?manu=7148

Jafari, M. (2013b). Integration of forestry and rangeland management institutions in the Islamic Republic of Iran. In *Challenges in adopting an integrated approach to managing forest and rangelands in the Near East Region, Part II, Country studies* (pp. 37–67). Cairo: FAO.

Jafari, M. (2013c, July-December). Challenges in Climate Change and Environmental Crisis: Impacts of Aviation Industry on Human. *Urban and Natural Environments in International Journal of Space Technology Management and Innovation*, *3*(2), 24–46.

Jafari, M. (2014a). *Dendro-Medical as New Approach on Dendrochronological Study method.* Presented in the 9th International Conference on Dendrochronology, as Poster No. PO086, Ref. 1590, ThemeZ01, Melbourne, Australia.

Jafari, M. (2014b). Change and vulnerability of Net Primary Production (NPP) in Iranian forest, rangeland and desert ecosystems impacted by climate change. *Iranian Journal of Range and Desert Research, 21*(1), 139-153.

Jafari, M. (2015). Dendrochronology and Climate Change. In *Encyclopedia of Information Science and Technology* (3rd ed., pp. 2917–2930). IGI Global.

Jafari, M. & Khorankeh S. (2013). Impact of climate and environmental changes on forest ecosystem's productivity (case study: Galugah). *Iranian Journal of Forest and Poplar Research, 21*(1), 166-183.

Jafari, M., Maghsudloo, M. K., Khanjani Shiraz, B., Karimidoost, A., & Hemmati, A. (2012b). New approach in dendro-genetic method for identification of beech tree variability. *Iranian Journal of Rangelands and Forests Plant Breeding and Genetic Research*, *20*(2), 284–294.

Kiaee, M., & Jafari, M. (2014). Investigation and consideration of forest tree reaction to climate and environmental changes (Case study: Lavizan forest park). *Journal of Plant Research*, *27*(1), 130–141.

Kuniholm, P. I. (2001). *Dendrochronology and Other Applications of Tree-ring Studies in Archaeology. In The Handbook of Archaeological Sciences*. London: John Wiley & Sons, Ltd.

McCarthy, B. C. (2008). *Introduction to Dendrochronology, Lab procedures*. Retrieved from http://www.plantbio.ohiou.edu/dendro/

RMTRR. (2008). *Rocky Mountain Tree-Ring Research (RMTRR).* Retrieved from http://www.rmtrr.org/gallery.html

Robinson, W. J., & Evans, R. (1980). A microcomputer-based tree-ring measuring system. *Tree-Ring Bulletin*, *40*, 59–64.

Schweingruber, F. H. (1988). *Tree Rings: Basics and Applications of Dendrochronology*. Dordrecht: Reidel; doi:10.1007/978-94-009-1273-1

Scott, St. G., & Nielsen, E. (2002). Dendrochronological analysis of a coffin board recovered from Pukatawagan, Bay, Manitoba. Terrain Sciences Division, Geological Survey of Canada and Manitoba Geological Survey, Manitoba Industry, Trade and Mines.

Sheppard, P. R. (2013). *Crossdating Tree Rings.* Laboratory of Tree-Ring Research, The University of Arizona. Retrieved from http://www.ltrr.arizona.edu/skeletonplot/applications.htm

Smith, P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E. A., & Tubiello, F. et al. (2014). Agriculture, Forestry and Other Land Use (AFOLU). In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Swetnam Thomas, W., & Christopher, H. B. (2002). Fire Regimes in Sierran Mixed-Conifer Forests. In Sierra Nature Notes, (vol. 2). Laboratory of Tree-Ring Research, The University of Arizona.

TGTC. (2008). *Tree growth and the tree-site complex*. TGTC.

The Ohio State University. (2013). *Woody plants*. Department of Horticulture & Crop Science, The Ohio State University. Retrieved from http://www.hcs.ohio-state.edu/hcs300/anat2.htm, http://hcs.osu.edu/

The University of Arizona. (2013). *Paleo Slide Set: Tree Rings: Ancient Chronicles of Environmental Change*. Laboratory of Tree-Ring Research, The University of Arizona.

The University of North Carolina. (2013). *Tree-Ring Dating, Lesson 2.4*. Research Laboratories of Archeology. The University of North Carolina at Chapel Hill. Retrieved from http://rla.unc.edu/lessons/Lesson/L204/L204.htm

WDC. (2008). *The World Data Center for Paleoclimatology Mirror Site (WDC).* Retrieved from http://wdc.obs-mip.fr/treering.html

ADDITIONAL READING

Barnola, J. M., Raynaud, D., Korotkevich, Y. S., & Lorius, C. (1987). Vostok ice core provides 160,000 year record of atmospheric CO_2. *Nature*, *329*(6138), 408–414. doi:10.1038/329408a0

Bergthorsson, P. (1969). An estimate of drift ice and temperature in Iceland in 1000 years. *Jökull*, *19*, 94–101.

Briffa, K. R., & Schweingruber, F. H. (1992). Recent dendroclimatic evidence of northern and central European summer temperatures. In: Climate Since A.D.1500. Routledge, London, pp. 366-392. COHMAP Members, 1988. Climatic change of the last 18,000 years: Observations and model simulations. *Science*, *241*, 1043–1052.

Davis, M. B. (1963). On the theory of pollen analysis. *American Journal of Science*, *261*(10), 899–912. doi:10.2475/ajs.261.10.897

Emmanuel, W. R., Shugart, H. H., & Stevenson, M. P. (1985). Climate change and the broad-scale distribution of terrestrial ecosystem complexes. *Climatic Change*, *7*(1), 29–43. doi:10.1007/BF00139439

Fritts, H. C. (1971). Dendroclimatology and dendroecology. *Quaternary Research*, *1*(4), 419–449. doi:10.1016/0033-5894(71)90057-3

Fritts, H. C. (1976). *Tree rings and climate* (pp. 80–96). London: Academic Press.

Schweingruber, F. H., Fritts, H. C., Bräker, O. U., Drew, L. G., & Schär, E. (1978). The X-ray technique as applied to dendroclimatology. *Tree Ring Bull.*, *38*, 61–91.

KEY TERMS AND DEFINITIONS

AFOLU: Agriculture, Forestry and Other Land Use (AFOLU), main players on emission reduction and mitigation aspect of climate change, chapter 11, WGIII, IPCC AR5 2014.

Climate Change: Global Warming, climate change and climate variability are a definition of deviation of climatic factors from its normal trends mainly impacted by human activities. Global Warming and its' effects on natural resources, plants, animal and in general on human life are among subjects that received attention of scientists and politicians in recent years.

Dendrochronology: Dendrochronology was developed about 1913, and is a (climate change) method to study tree ring widths in terms of time. The word dendrochronology is compose of: dendro (using trees, or more specifically the growth rings of trees), chrono (time, or more specifically events in past time), and logy (the study of). Dendrochronology as an able and certified study method could be implying in a wide range of applications.

Proxy Data: Climate change assessments and evaluation should be done by using recorded observation data as well as prepared and provided proxy data. Paleoclimatologists (climatologists who study past – or paleo – climates) use the term "proxy" to describe a way that climate change is recorded in nature, within geological materials such as ocean or lake sediments, tree-rings, coral growth-bands, ice-cores, and cave deposits.

Tree Rings: Trees growing in temperate climatic region are under seasonal changes. In spring and summer time plants grow better than unpleasant seasons like fall and winter. Each growth layer is distinguished by early wood (springwood), composed of large thin-walled cells produced during the spring when water is usually abundant, and the denser latewood (summerwood), and composed of small cells with thick walls.