burden placed on forests by instituting recycling programs and by using alternative materials like plastics in place of wood. In business, companies have begun to use wood products that come only from certified renewable forests that are carefully managed to ensure that they are cut in a sustainable way. Alternative methods of agriculture, such as agroforestry and permaculture, promote the use of trees and the diversification of crops to reduce the stress placed on forests by large-scale agriculture. Protecting forests by creating parks and reserves is another strategy to keep forest resources intact. For those areas that are already devastated, great efforts are being made to re-plant once-forested lands with native species.

Other efforts are aimed at changing our ideas about the value of forests. Economists are now trying to calculate the true value of the forest as an ecosystem and the benefits it gives as a whole, not only the value of cut logs. This reevaluation will help us make more informed choices about how we use forest land. All of these efforts have helped reduce the burden on the forests, but cutting continues unsustainably. Without the cooperation of all humans to create alternative strategies to deforestation, it will continue with terrible results for the health of our planet. See also Biome; Coniferous Forests; Deciduous Forests; Desertification; Ecosystem; Forestry; Human Impacts; Rain Forests.

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Bibliography


Dendrochronology

Trees and other woody plants grow by covering themselves with a new layer of tissue every year. When seen in a horizontal section, such wood layers appear as concentric tree rings, familiar to anyone who has looked at a tree stump. Because tree growth is influenced by the environment, tree rings are then natural archives of past environmental conditions. For instance, trees grow less when climate conditions are less favorable, producing narrower rings. The study of past changes recorded by wood growth is called dendrochronology.

Besides determining tree age, dendrochronological information has been used in four major fields of scientific research:

• reconstruction of climatic factors that control average wood growth from year to year (such as precipitation, temperature, air pressure, drought severity, sunshine)

precipitation rainfall
Southern yellow pine tree rings, natural archives of past environmental conditions.

- dating of abrupt events that leave permanent scars in the wood (fire, volcanic eruptions, earthquakes, insect defoliations, and hurricanes, for example)
- dating of archaeological wood (such as the pueblos of the American Southwest, churches, bridges, and paintings in Europe)
- the calibration of the radiocarbon time scale over the Holocene epoch, covering the last ten thousand years.

The application of tree-ring dating to archaeology is indeed closely linked to the development of dendrochronology as a modern science, a process that began in the early 1900s at the University of Arizona under the direction of Andrew Ellicott Douglass, an astronomer who first established and demonstrated the principles of tree-ring dating.

Most tree-ring samples consist of pencil-shaped cores drilled from the lower stem, allowing an estimate of wood growth without cutting the tree down. So-called increment borers used for coring allow for nondestructive sampling because they leave only a 5 millimeter-wide hole, and such small injury can be readily managed by a healthy tree. (As an analogy, extracting
an increment core is likely to affect a mature tree’s vigor as much as drawing a blood sample is likely to affect an adult animal’s health.

**Dating and Cross-Dating**

Tree-ring dating is the assignment of calendar years to each wood growth ring. This requires more than simply counting visible rings, because not every growth layer is always present or clearly noticeable, especially in very old trees. When only one or two trunk radii are available per tree, the chance of dating errors is greater than when examining entire cross-sections. To ensure dating accuracy, ring patterns from many different trees of the same species and location are matched with one another. This allows the creation of a master chronology for this location. This cross-dating exercise, which is similar in principle to matching fingerprints or deoxyribonucleic acid (DNA) sequences, is first done visually under a binocular microscope using 10 to 30 power magnification. Once a tree-ring sample has been properly surfaced, that magnification is high enough to distinguish individual wood cells. After measuring the thickness of each ring, cross-dating can be verified using specialized numerical procedures. While numerical cross-dating is based on alternating patterns of narrow and wide rings, visual cross-dating can incorporate other anatomical elements as well, such as the proportion and color of earlywood and latewood within individual rings.

Cross-dating has found other important applications in dendrochronology. Once a (master) tree-ring chronology is established, a wood sample from the same species and area can be accurately dated by matching its ring-width patterns against the master. This procedure is commonly used in archaeological and historical investigations to date wood material, artifacts, and structures. In addition, as wood samples from older living trees are cross-matched against those from historic and prehistoric times, the length of the master chronology can also be extended farther back in time, a process that has allowed the development of tree-ring chronologies for the last ten thousand years, over the entire Holocene epoch.

The final tree-ring chronology is derived from the combination of all tree-ring samples into a single, average time series, which summarizes short- and long-term historical patterns for that species and site. Tree growth varies on multiple time scales, from interannual to interdecadal, and various numerical methods have been proposed to preserve (or discard) this information in the final tree-ring chronology. Such methods are grouped under the term standardization in the dendrochronological literature, and they are intended to minimize changes in growth rate that are not common to all trees. For climatological reconstruction, the final tree-ring chronology is statistically calibrated against instrumental records of climate, such as precipitation and temperature, to identify the main climatic signals present in the tree-ring record. The relationship between tree growth and climate is then extrapolated back into the past, and climatic changes are estimated from the tree-ring chronology itself. Because of the long life of many tree species, dendrochronological records tell of climate conditions occurring each year over hundreds, sometime thousands, of years, whereas instrumental weather records are commonly limited to the last decades, and seldom exceed one hundred years.

Tree-ring chronologies have been developed from a number of species in all continents where trees exist. In the western United States, most tree-ring records are derived from conifers, because they are very common, reach
old ages, and, as softwoods, they are easier to sample than hardwoods. However, not all trees are equally suitable for dendrochronological studies. In temperate, high-latitude and high-elevation climates, wood growth is usually constrained to the warm season, and tree rings are easily recognizable. Cross-dating is easier when year-to-year variability of tree growth is higher, because this causes a greater number and degree of pattern differences in tree-ring series. When ring widths are less variable, common, climatically influenced patterns are more difficult to discern. Site conditions are therefore very important in dendrochronological studies because they affect tree-ring variability, which is an expression of the sensitivity of tree growth to climate. Other factors being the same, trees growing in difficult environments—on steep, rocky slopes, at the latitudinal or altitudinal edge of their natural range—attain greater age, grow more slowly, and show higher year-to-year changes than trees of the same species found in more mesic sites, on flat terrain, and/or deeper soils.

To date, tree-ring studies of tropical trees have been limited by the fact that wood growth layers are not visually identifiable, especially in species found at low elevations. Anatomical features and the lack of pronounced seasons allow wood growth in tropical lowlands to occur throughout or erratically during the year, making the identification of synchronous growth patterns among trees a difficult task. Even outside the tropics it is not always possible to reliably cross-date tree-ring patterns among individuals of the same species and site. A notable example is the world’s tallest tree, the California coast redwood (Sequoia sempervirens), whose rings are not uniform around the stem. This causes different radii from the same tree to include a widely different number of rings, which prevents the development of a reliable tree-ring chronology. Such ring discontinuities are species specific and apparently unrelated to climate. see also: Forestry; Palynology; Record-Holding Plants; Trees; Wood Anatomy.

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Bibliography


Nicolas-Théodore de Saussure was one of the early founders of plant physiology. He introduced new and rigorous experimental methods to the study of plants, and his work helped to improve the science of botany.