Secciones extraidas del libro:
Tree Rings, Basic and Applications of Dendrochronology
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I Origin of the materials

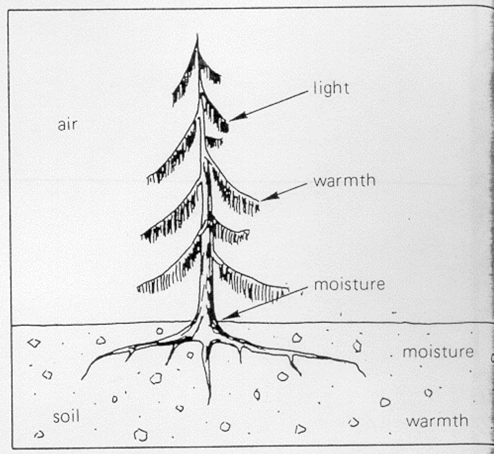
Massive pine (*Pinus sylvestris*) with birches growing beneath, near the tree-line in the east of Scotland. The maximum density in the annual rings of the three-hundred year-old trees reflects to a great extent the summer temperature.

The tree as integrator

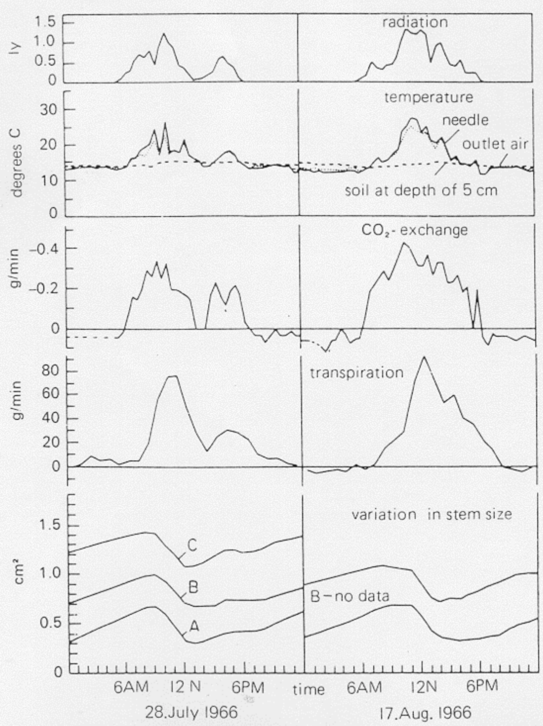
A tree is a stationary living thing. Its crown, trunk and roots are capable of reacting to environmental factors; some parts of the tree receive signals from the surroundings while others react to them. The long-lived *Pinus longaeva* integrates these ever-changing stimuli over 5000 years, the short-lived *Populus alba* only 50. This ability to integrate is reflected in many different kinds of tree characteristics, such as geographical distribution, tree crown and tree rings. In the course of evolution plants have developed on every site, being best adapted to the particular conditions obtaining there.

Reaction time

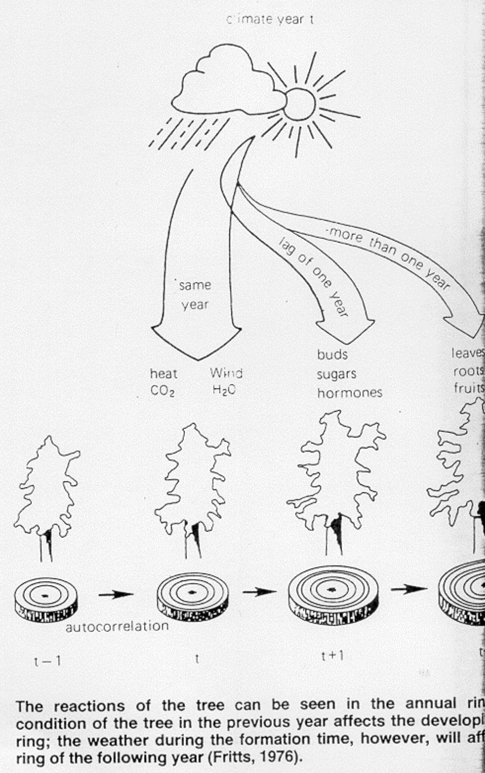
Measurements of environmental conditions and their effects on trees have shown that a tree responds to changes immediately, i.e., within a few minutes of the event. Such extremely short-term individual adjustments are scarcely reflected in the tree rings. The sum of all these slight changes, however, is expressed in a very complex way in the annual ring, which reflects events both in the current growth year and in the past.



A tree is an integrator. It reacts to environmental factors.



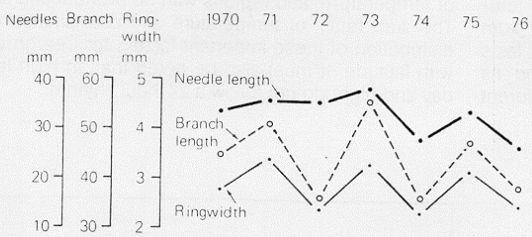
The reactions of trees are measurable. With the help of appropriate equipment it can be shown that gas exchange, transpiration and growth of the trunk are all related to precipitation, temperature and other environmental factors (Fritts, 1976).



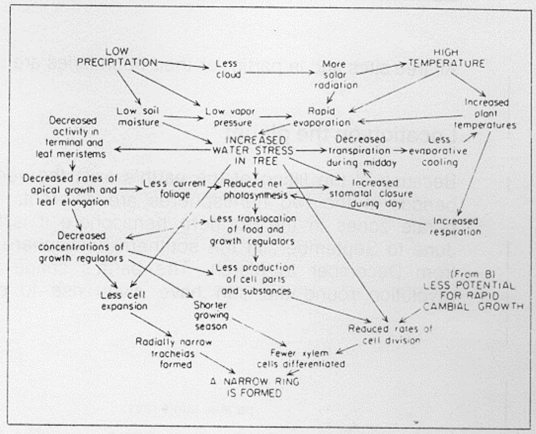
The reactions of the tree can be seen in the annual rin[g]; condition of the tree in the previous year affects the developi[ng] ring; the weather during the formation time, however, will aff[ect] ring of the following year (Fritts, 1976).

Transformation into structure

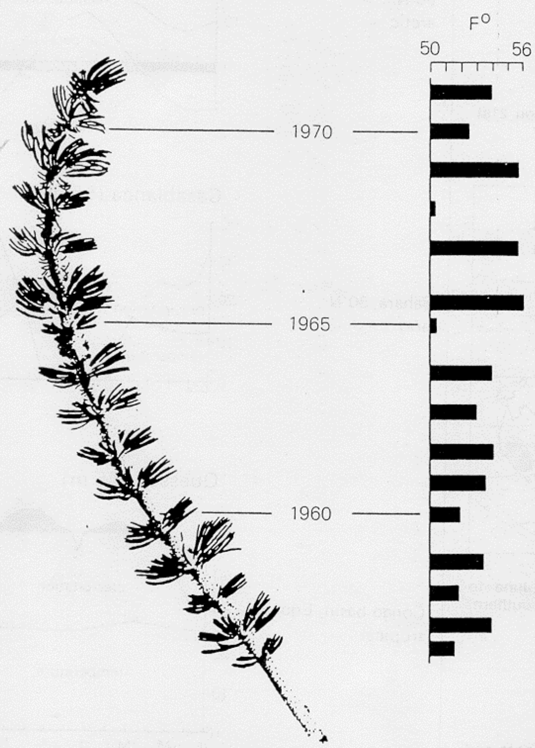
Most of the activities of a tree i.e. its physiological processes, are manifested in its structure. A physiological process initiated by a change in the environment eventually becomes directly measurable as a growth change, or evident in the variation of such features as length of shoots and needles, tree ring width, cell size or cell wall thickness.



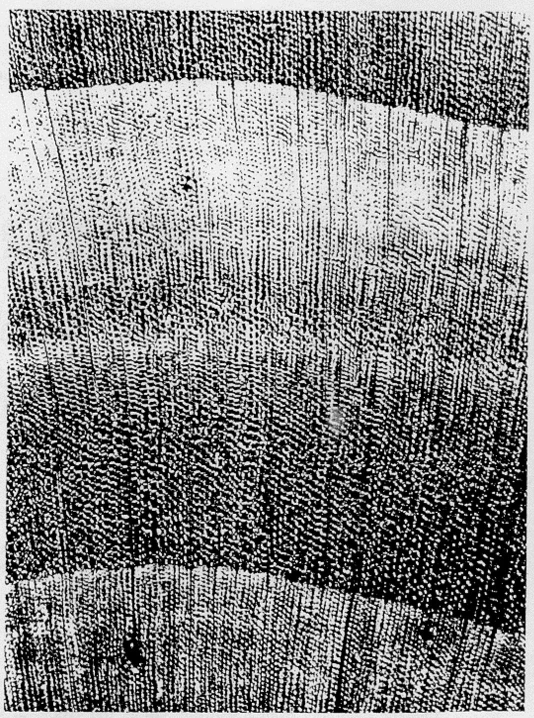
Relationship between tree-ring width in twigs, length of shoots and needles in Douglas Firs. The same environmental factors seem to affect these three growth characteristics in the same way (Shane and Harper, 1979).



The reaction mechanisms in trees are very complicated. Chain reactions are set up between the influencing environmental factors and the parts of the tree which react to these influences. The diagram here gives only a glimpse of the whole (Fritts, 1976).



Relationship between needle length of a Bristlecone Pine on a site on the tree-line in California and summer temperatures. In a cold summer (1965) short needles are formed, in a warm one (1966) long ones (LaMarche, 1974).



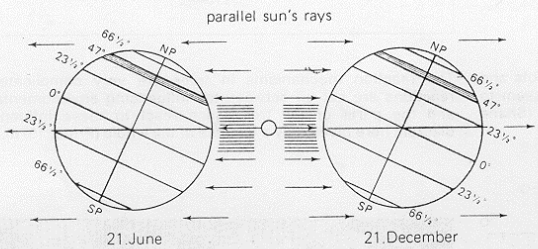
Differing cell sizes and cell wall thickness reflect frequent changes in the environment. Spruce shoot 40 : 1 Cross section.

Tree sites on the earth

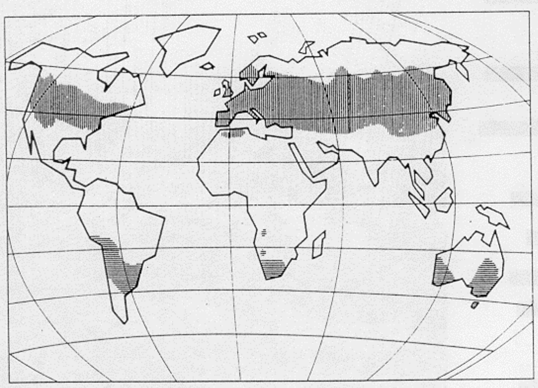
All tree sites and in particular their boundaries are influenced by their position on the earth. Important factors are:

Location on the planet

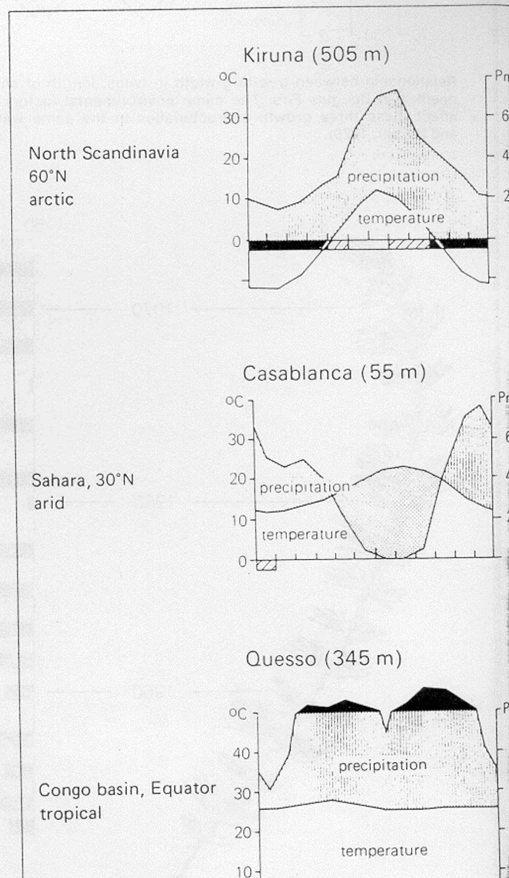
Because of the tilting of the earth's axis, the vegetation periods in the two hemispheres are different; in temperate zones in the northern hemisphere it lasts from June to September; in the southern hemisphere it lasts from December to March. The earth's shape and its revolution round the sun have given rise to different climatic zones; there are regions hostile to trees, region with seasonal changes due to differences in precipitatio or temperature, and regions with no pronounced seasons The sum totals of temperature and precipitation and th distribution of these important factors for tree growth va with latitude. It must also be noted that, in high latitude day and night do not follow a 24-hour rhythm.



Movement of the earth round the sun, side view. Position on 21st June and 21st December.



Beginning of the wheat harvest in both hemispheres; June to September in the northern, November to January in the southern. Tree rings are formed in these months (Heyer, 1977).

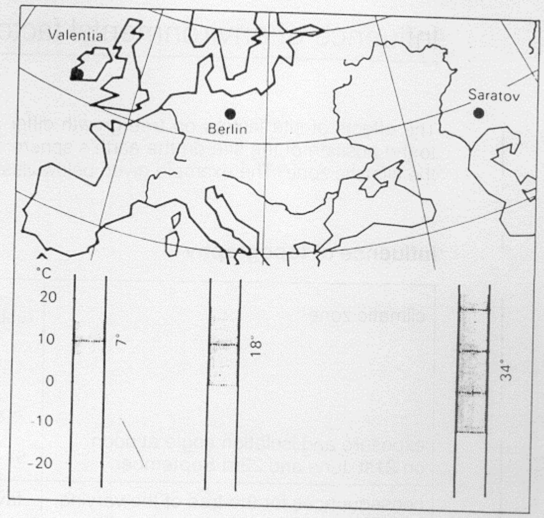


Climatic diagrams from the Arctic circle, the Tropic of Cancer and the Equator (Lieth and Walter, 1967), For explanation see p. 20.

Bär, 1977; Walter and Lieth, 1967; Strahler, 1975; Walter, 1964/68; Weltfors

Location on the continent

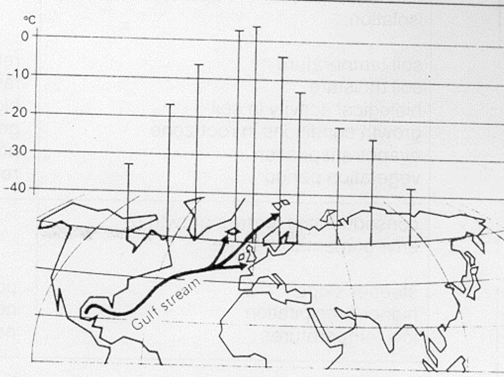
The distribution of tree sites over the land—water mosaic is mainly influenced by regional climatic conditions. The extent to which the climate is continental or oceanic has a very great effect on tree growth.



Temperature amplitudes between January and July in three different climatic zones at the same latitude (Bär, 1977).

Location in relation to ocean currents

Warm and cold ocean currents play an important part in the arrangement of vegetation belts and determine the northern timber line to a great extent.

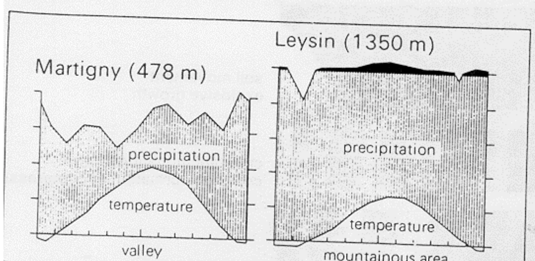


Average January temperature at latitude 60°N. The temperature is low over the continent but high in the region of the Gulf Stream (Bär, 1977).

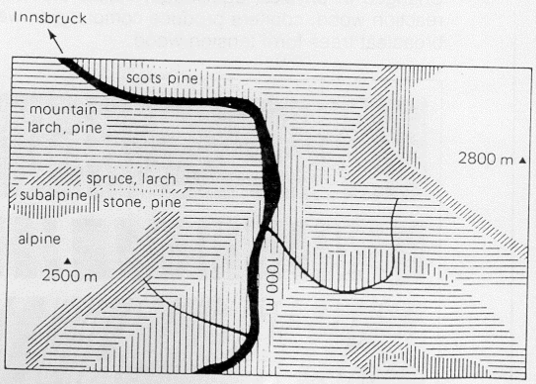
Elevation

The effects of altitude vary greatly with geographical position. This is particularly noticeable in timber line regions, where usually a single factor determines the presence or absence of fairly large perennial plants, so that the principle of limiting factors is most clearly seen.

As an integrator of weather, vegetation is capable — as long as man does not interfere too much — of reproducing all climatic zones faithfully. Maps showing the distribution of various species of trees indicate the differences between the contours clearly. An example is shown below; the vegetation changes with decreasing temperature and increasing precipitation and characteristic vegetation belts are formed at each level.



Climatic diagrams from low and high altitude within a uniform climatic area. Valais, Switzerland (Lieth and Walter, 1967).

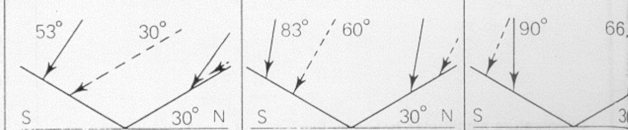


Map of the vegetation of the Tyrol, a dry alpine valley (Schiechtl, 1973).

Influence of environmental factors on tree sites

The effects of site factors on tree growth differ according to the position of the site on the earth's sphere and within the climatic zone. The example given below illustrates this variation and the inter-correlation of the many fa involved. Two further examples show the effects of logical substrate and light relations.

Influence of topography

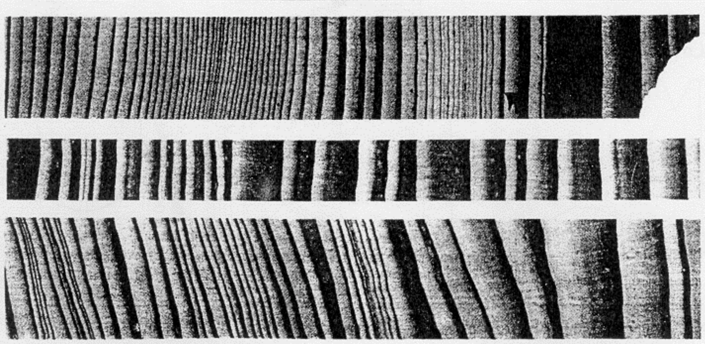
climatic zone	subpolar 60° N		semi–arid 30° N		tropical 0°	
exposure and isolation angle at noon on 21st June and 23rd September.						
consequences for the tree of the varying isolation:	favorable	too cold	too warm	favorable	no differen	
soil temperature	rel. high	rel. low	too high	normal	normal	
soil moisture	favorable	too high	too low	favorable	favorable	too hi
biological activity in soil	high	low	low	high	high	
growth conditions in root zone	good	poor	poor	good	good	
evapotranspiration	normal	too low	too high	normal	normal	
vegetation period	rel. long	too short	too short	rel. long	all-year	
consequences for tree growth of environmental changes:						
steeper slope	positive	negative	negative	positive	neutral	
higher precipitation	negative	negative	positive	positive	negative	
low temperatures	negative	negative	positive	positive	neutral	

The influence of topography on soils with normal drainage and on tree growth in different climatic zones.

Influence of mechanical movement

Changes in physical equilibrium initiate the formation of reaction wood; conifers produce compression wood while broadleaf trees form tension wood.

To satisfy its need to grow vertically a tree quickly to stimuli such as wind or earth movemen reaction can be particularly clearly seen in the root c

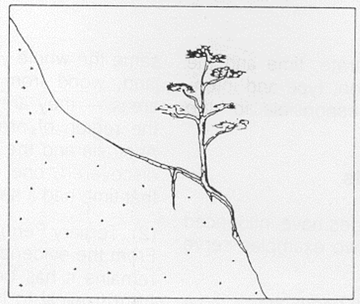


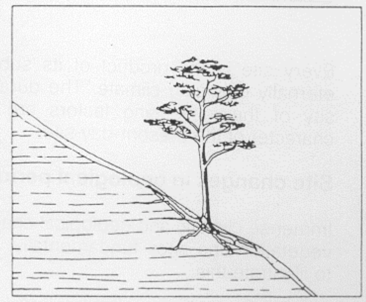
soil movement
explosive growth

constant influence of wind
continual formation of compression

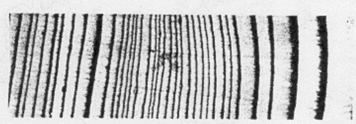
root collar; abruptly changing ring w

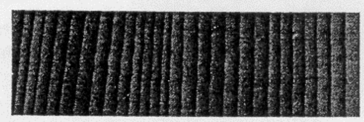
Influence of geological substrate





substrate	hard rock, acid to basic e.g. granite, limestone	soft stone, basic to acid, e.g. marl
soil	ranker, rendzina	brown earth
weatherability	low	high
penetrability	low	high
nutrient supply	poor	good
drainage	good	good to limited
water supply	very weather-dependent	good over long periods; soil acts as reservoir.
tree growth	good to poor	usually good
tree-ring pattern	sensitive	complacent

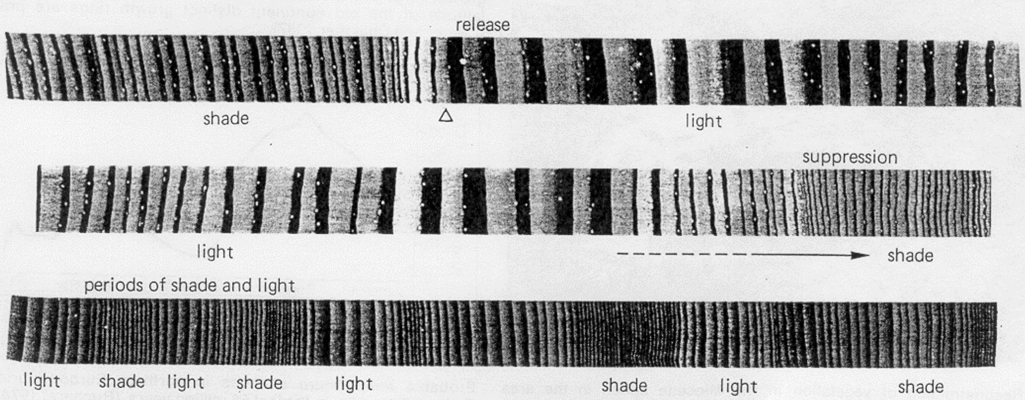




Infuence of geological substrate on tree growth in temperature zones

Influence of light

The vitality of a tree is substantially determined by the supply of light during the vegetation period. A tree growing beneath a dense canopy receives only poor illumination, which reduces photosynthesis and thereby cambial activity, so that narrow tree rings are formed. If the tree is released after such a period of suppression, it is instantly in a position to perform better.



Reactions of tree and cambium to changes in light conditions

Every site is the product of its substrate, time and the eternally changing climate. The duration, type and intensity of the influencing factors are responsible for the character of the present-day site.

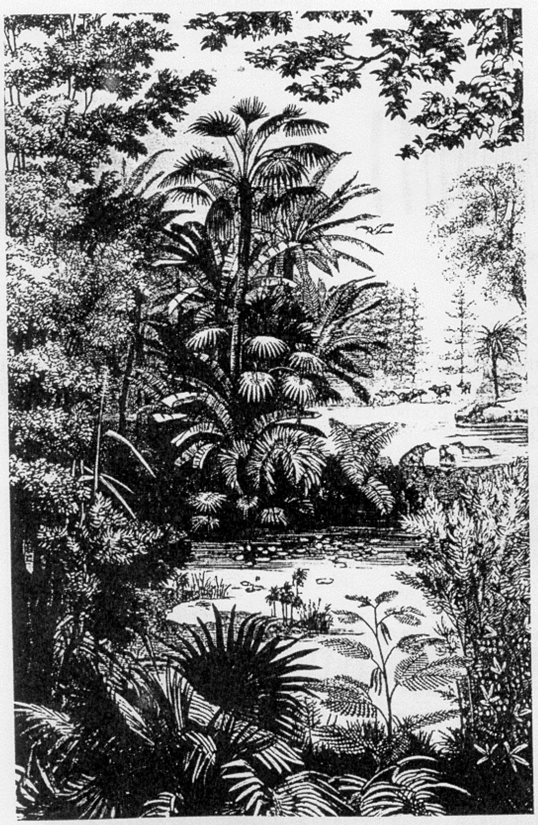
Site changes in geological periods

Immense climatic and geological changes have influenced vegetation and sites fundamentally. Two examples serve to illustrate this:

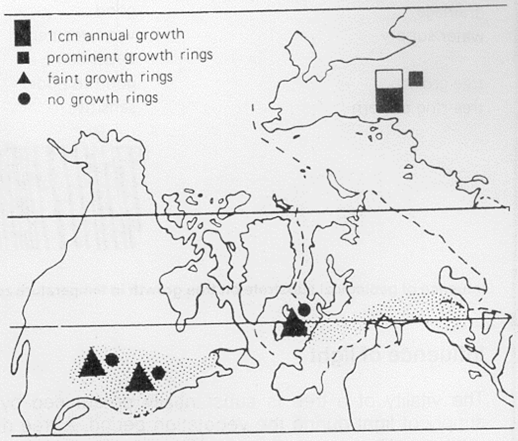
(1) Palaeozoic Era — about 300 million years ago.
At the end of the Palaeozoic era the present-day continents formed a large, practically complete landmass. In the charred, silicified tree trunks from the Carboniferous swamps in the north of the continent hardly any annual rings are to be found. The climate may have been the same the whole year through. In the south in Gondwanaland, wood from the same period shows clear growth areas — they are perhaps annual rings. Moreover, as in the region of present-day South America, South Africa, Australia and the Antarctic traces of glaciation have been discovered, one must assume that the polar regions of that time had a seasonal climate.

(2) Tertiary Period — about 70 to 5 million years ago.
From the evidence provided by fossilized plant and animal remains it has been clear for a long time that a change from tropical to temperate climate occurred in Europe in the Tertiary Period. But only after the discovery of the outer layers of micro-organisms in ocean-boring samples was it possible to plot the temperature course for the whole time period.

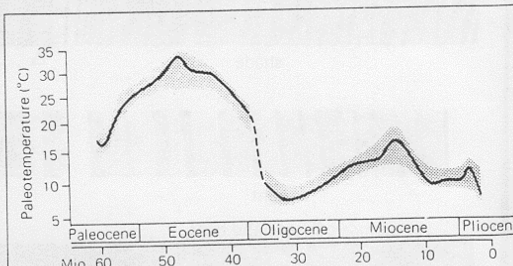
Conifer tree trunks from the Tertiary Era (miocene) in central Europe have tree rings.



Reconstruction of vegetation in the Miocene epoch in the area around Lausanne, Switzerland. In areas where oak forests and vines grow today, palms, laurels and acacias grew 15 million years ago (Heer, 1865).



In the mid Carboniferous period (approx. 320 my BP) most of the carbonised trees grew in tropical swamps (shaded area) and growth rings are therefore absent. In woods growing in northern latitude of the old continent distinct growth rings are present. (Creber and Chaloner 1987).

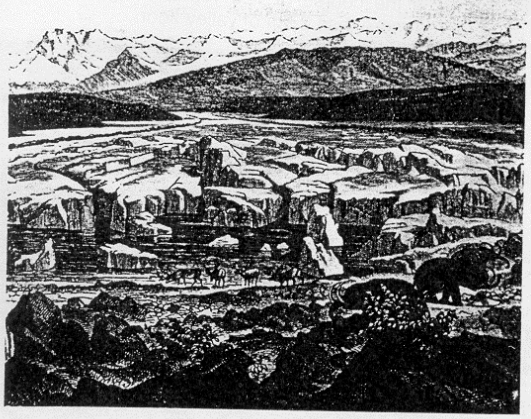


Probable temperature changes in northern Europe during the Tertiary Period i.e. in the last 65 million years. (Bucharat 1978)

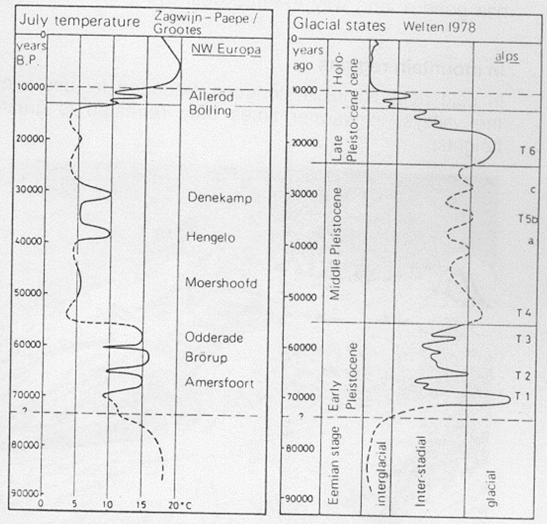
Creber and Chaloner, 198

Site changes in prehistoric times

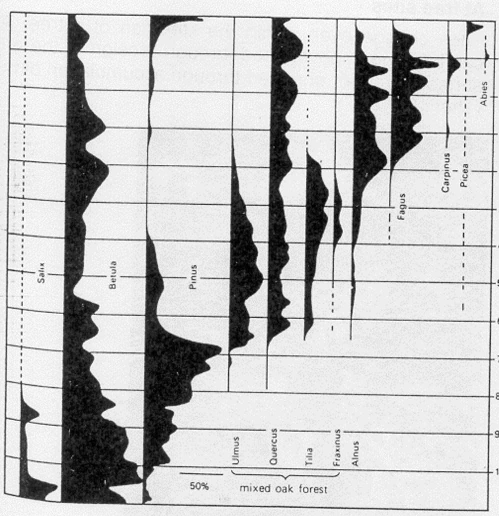
During the Ice Age prehistoric man experienced drastic changes in climate, ecology and flora. The *Homo erectus* of the early Quaternary Period in Europe was familiar with magnolias, sequoias and Sciadopitys and hemlock. *Homo neanderthalensis*, on the other hand, lived in tundra with creeping willow and dwarf birches. *Homo sapiens* in central Europe saw the arrival one after another of our present-day forest trees.



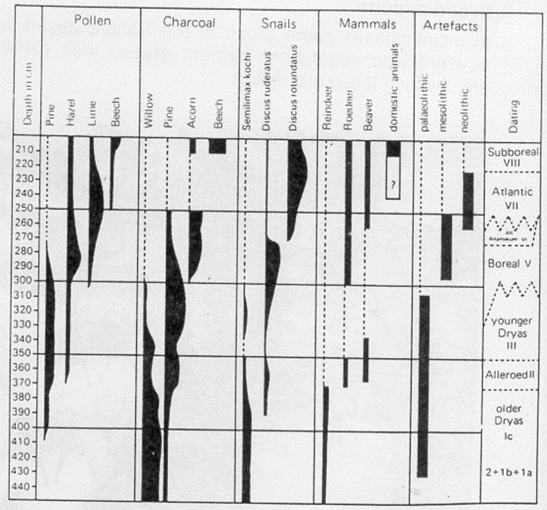
Zürich at the time of the last Ice Age (Heer, 1865).



Possible July temperature curve since the last interglacial time in northern Europe (Grootes, 1977) and the probable glacial stages on the northern boundary of the Alps (Welten, 1978, 1981).



Appearance of main tree genera in northern Europe in the last 12 000 years (Straka, 1970).



Appearance and disappearance of various key fossils in prehistoric caves in the upper Donau valley. The plant, animal and human associations have changed fundamentally in the last 12 000 years (von Koenigswald *et al.*, 1979).

Site changes in historic times

Since the fading-out of the Ice Age, the climate has fluctuated only slightly. In recent times, climatically caused site changes have obviously occurred only in extreme areas. Over the last three millennia man has altered the landscape by clearing forests and in the last fifty years he has gone a long way towards destroying the balance of nature through over-utilisation and pollution.

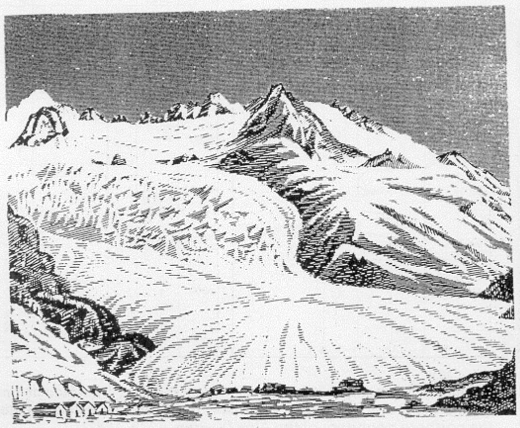
Plant distributions and species combinations are the products of all these changes.

Different species areas have arisen as a result of differing genetic predispositions of individual species and different species combinations on ecologically similar sites.

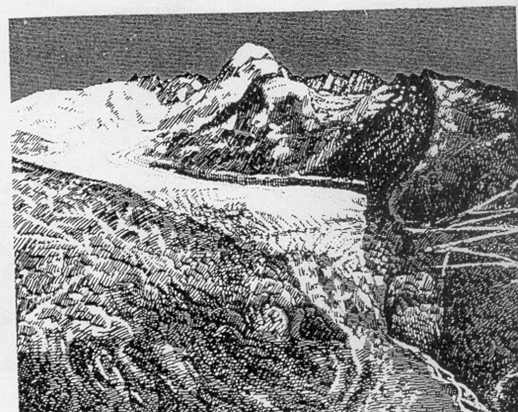
In mountain regions

In cold periods glacier tongues extended far down into the valleys, in warmer times they retreated to greater heights.

The Rhone glacier (Switzerland) in 1850 (left) and 1970 (right). In the course of 120 years, the glacier has surrendered more than 2 km of valley floor.



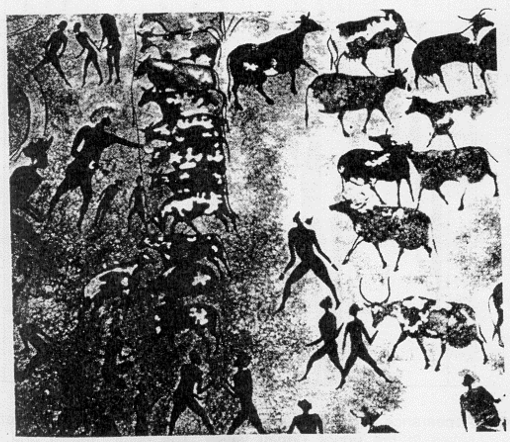
Rhone glacier in 1850



Rhone glacier in 1970

In arid regions

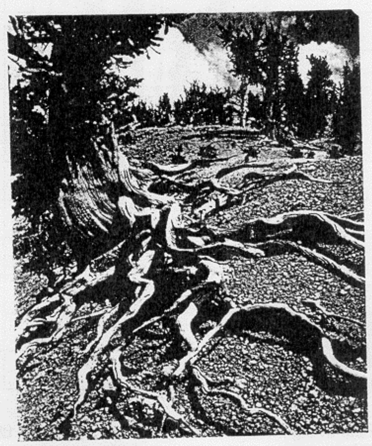
In moist phases some areas of the Sahara desert were covered with vegetation; farmers grazed their cattle on areas which today are desert.



Herd of cattle in a cliff drawing in the present-day desert.

At tree sites

Sites change even within the life-span of a tree. A site can become impoverished through erosion of the organic surface layers or enriched through accumulation of humus (Thenius, 1977).



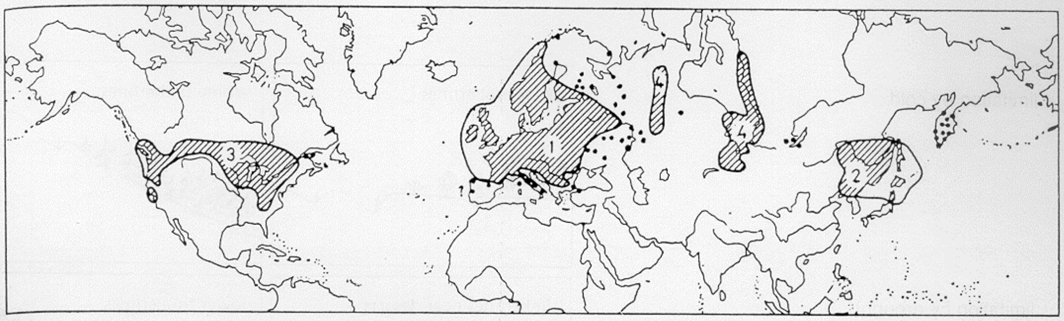
Exposed roots of a 4000-year-old Bristlecone pine. During this time the soil has settled, the site has changed (Muench and Lambert, 1972).

Firbas, 1949/52; Gothan and Weyland, 1973; Heer, 1865; Straka, 19

The product of the changes

In the course of time, several separate species or subspecies have arisen from one basic species through isolation, and become more or less widely distributed. This explains, for instance, why alpine flora under similar ecological conditions form plant communities with the same composition of genera, but with different species.

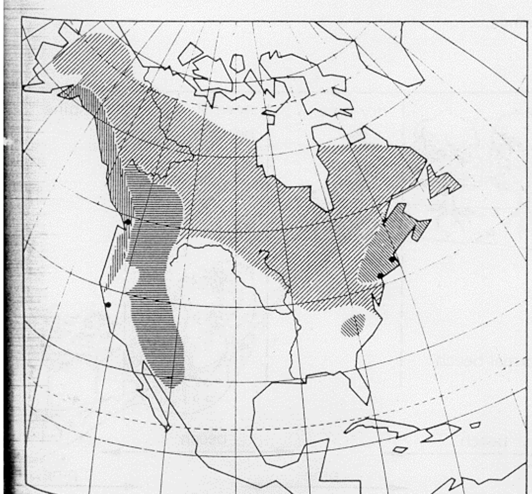
If the species areas are very distant from each other and the different species clearly distinguishable, they were probably isolated at an early stage. If the differences in area and form between two species are only slight, separation probably occurred during the Ice Age.



The widely-separated areas of *Anemone nemorosa* (1), *amurensis* (2), *quinquefolia* (3) and *altaica* (4) indicate early isolation (Straka, 1970).

Atlas and Pyrenees	Southern Europe	South-eastern Europe	Eastern Europe and Asia Minor
mauretanica clusiana salzmannii	laricio italica calabrica	nigra dalmatica gocensis	pallasiana banatica pindica balcanica caramanica fenzlii

The geographical varieties of *Pinus nigra* (Straka, 1970).
These fifteen varieties originated in stands limited to the south in the cold periods, having been separated by fragmentation of the area and subsequently developed in different directions.



Distinctly separated areas of individual species. Within the area of the genus *Picea, P. sitchensis* occurs at low elevations and *P. engelmannii* at greater heights in western North America.
The species area of *P. rubens* in the east is very distinctive (Harlow and Harrar, 1950).

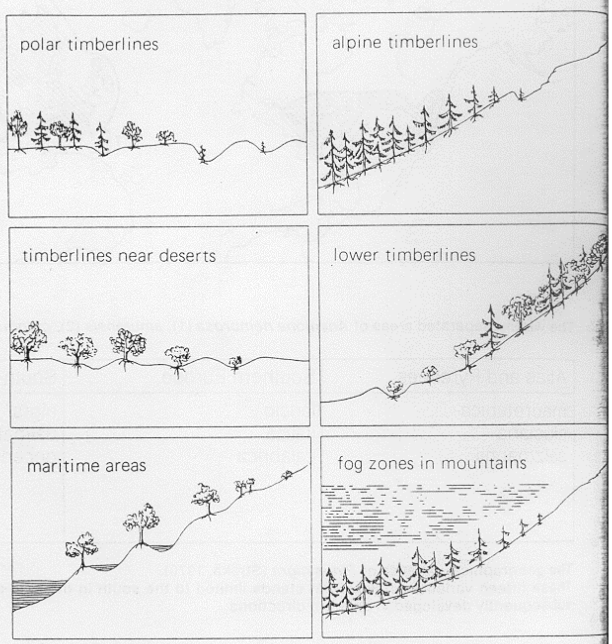
Selection of the sampling site

The selection of sampling sites is a key factor in dendroclimatological research. In order to build up sampling networks containing similar climatic information, it is expedient to choose samples from boundary situations, where growth is limited mainly by one factor, although not from extreme outposts, where the information stored in the tree ring pattern does not reflect the normal weather conditions. It must also be borne in mind that natural boundaries can be considerably displaced by human activities such as animal grazing, felling and fire.

limitation by cold

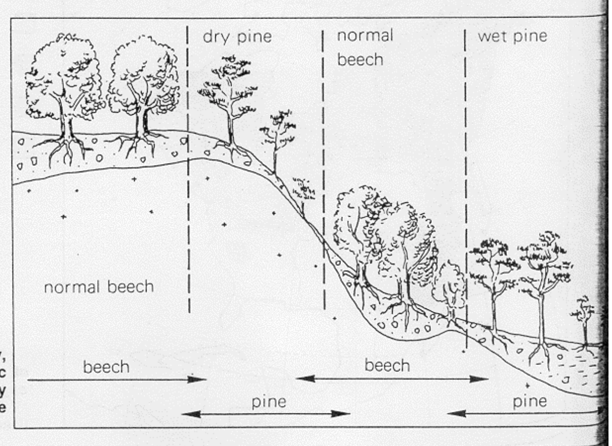
limitation by drought

limitation by moisture



Timberlines.

Ecologically determined limits of distribution



Beech grows well on deep soils with normal permeability, but cannot grow on shallow soils subject to periodic drought or waterlogging. Pine succeeds on ecologically special sites e.g. steep slopes, bogs. On normal sites pine is suppressed by beech.

Annual rings from varying sites within a restricted area of a uniform climatic zone reflect different climatic events. The delimitation of a site, however, is not easy. In every case a sound knowledge of ecology and botany is necessary for the selection of a sampling site on biological grounds. The selection process is as follows:

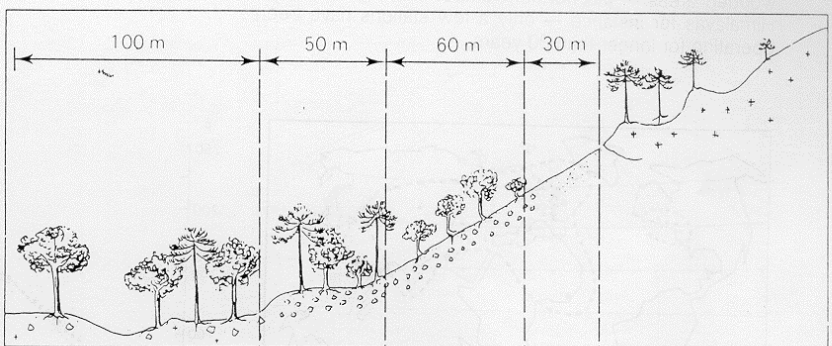
Getting to know the site
Every objective, whether dendroclimatological, ecological or pathological, requires that the researcher obtain a comprehensive knowledge of the site by familiarizing himself with the whole spectrum of conditions in the field.

The following are the foremost criteria:

- variability of the site conditions. Which plant societies are typical?
- evaluation of the probable ecological conditions as shown by indicator plants.
- identification of possibly suitable tree species (age, form, annual ring width, etc.)

Deciding on the sampling site:
The following example from a temperate zone illustrates the selection and delimitation of sites in relation to the research goals.

Selection of trees in relation to the sites.



Geological substrate	recent alluvium volcanic ash and granite	alluvium terrace coarse-grained volcanic ash		volcanic tuff, bedrock
Soil	brown earth and virgin soil	brown earth	rubble over loose ash	virgin soil
Conspicuous indicator plants	grasses and large-leaved plants	grasses	—	dwarf shrubs
Dominant trees	*Nothofagus pumilio Araucaria araucana*	*Nothofagus Araucaria*	*Nothofagus*	*Araucaria araucana*
Tree height	up to 30 m	Araucaria 12—30 m Nothofagus up to 18 m		8—12 m
Disturbances	tree felling, floods in the past	tree felling fire	landslides fire	wind
Choice of species and research objectives	Araucaria and Nothofagus	Araucaria and Nothofagus	—	Araucaria
	hydrology, especially river run-off	dating forest fires regional climatology	—	local climatology

Practical example of site definition for selection of sampling trees in an Araucaria araucana/Nothofagus pumilio region in the southern Andes on the alpine timber line at 1700 m.

Ellenberg, 1978; Küchler, 1966; Meusel, 1965/1978; Walter, 1964/1968.

Measurement of climatic factors at the sampling site

Measurement of ecological factors over decades: the network of meteorological stations

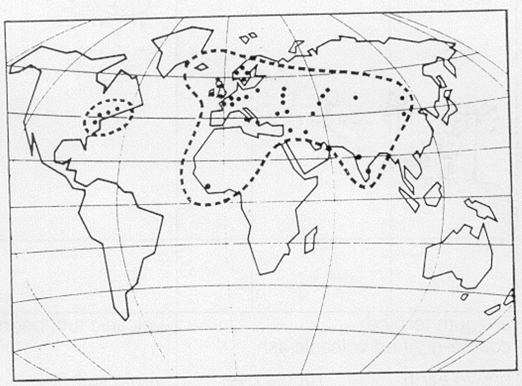
Density of the network

Dendroclimatology needs the long-term records of the meteorological stations in order to relate tree-ring parameters to weather. Biologically, the most important factors are temperature and precipitation. Air pressure does not directly influence tree growth. Comparison of data presents considerable difficulties, particularly when values from all parts of the world have to be compared.

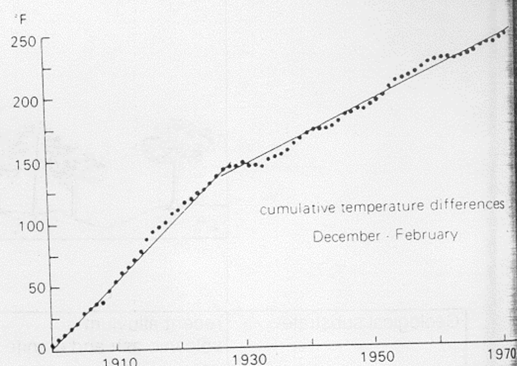
The meteorological stations are not evenly distributed. In highly developed areas of Europe, a dense network has been in existence for over 100 years, but in other densely wooded areas — the northern timber line regions or the Himalayas for instance — only a few stations have been operating for longer than 30 years.

Limitations

The reliability of the data is very variable. The dendro climatologist must check them carefully before using the in the calibration of tree ring data. This process is ve time-consuming. It spans the reconstruction of the histor of the station, the question of calibration of the instru ments, and the comparison of the data series with thos of other stations. Collaboration with meteorologists therefore essential. There are, however, some simple an not very time-consuming methods which allow the den droclimatologist to form an estimate of the homogenei of the data series.



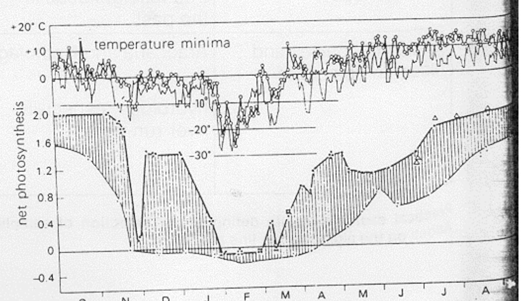
Meteorological stations measuring air pressure around 1850 (Lamb, 1977, Vol. 2).



Cumulative temperature differences as a function of each yea The series is homogeneous when the points form a straight line The kink in the curve shown here may have been due to a re-siting of the station (Fritts, 1976).

Extrapolation of the Data

The official measuring station is seldom in the immediate vicinity of the sampling site. Considerable differences between conditions prevailing at the station and at the site are therefore to be expected.



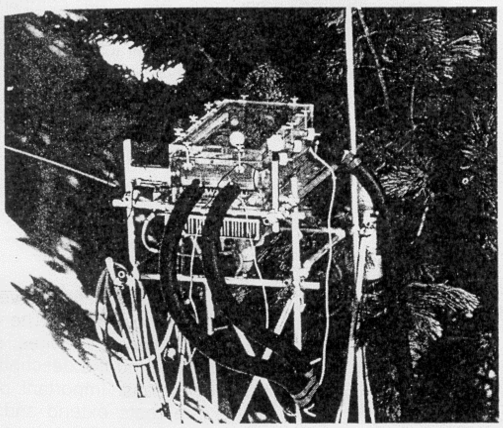
Relation between daily minimum temperature (top) and net photosynthesis at two stations in a dry alpine valley. Upper line: 600 m, valley floor. Lower line: 1900 m, mountainous area (Larcher, 1973).

Geiger, 1961; Lamb, 1977; Larcher, 1973; Tranquillini, 1

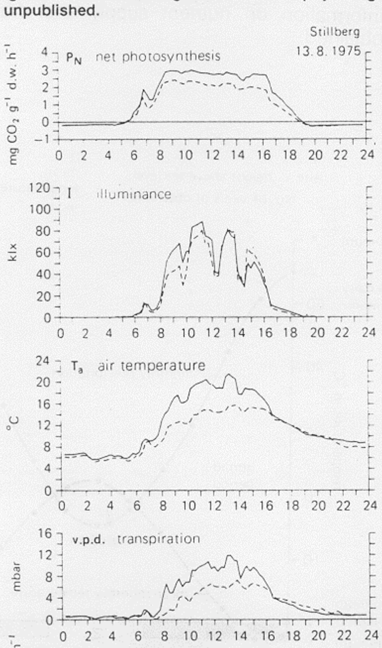
Measurement of ecological factors over periods of a few years: measurements in the stand

Meteorological data series from the stand under investigation provide, without doubt, the best values for comparison with annual ring parameters; tree site and measuring station are in one and the same place. Only in rare cases is it possible to continue the measurements over decades. The physiological reactions of the tree can be measured at the same time as the meteorological factors. Measurements of gas-exchange processes in trees indicate physiological activity. Technical problems limit investigations more or less to small trees. Dendrometers can be used to register fluctuations in trunk thickness, which form one of the expressions of physiological activity.

Ecophysiological measurements

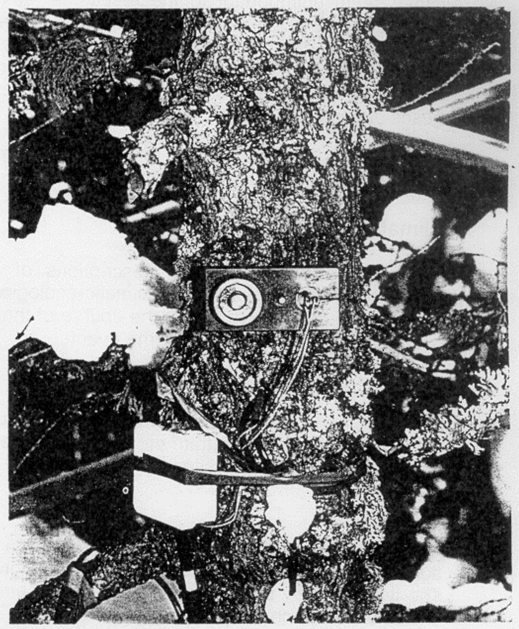


Measuring chamber. Twig of Stone pine (*Pinus cembra*) with measuring chamber for the registration of ecophysiological data. Haesler, unpublished.



Ecophysiological data for one day recorded on a *Pinus mugo* (Haesler, 1982).

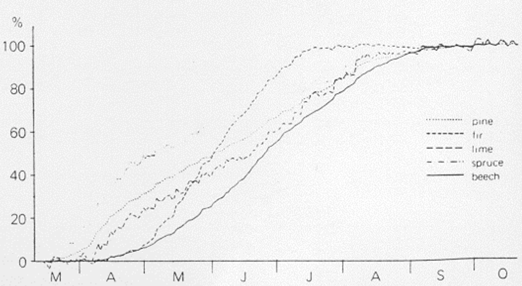
Measurement of cambial activity



Two dendrometers on a conifer trunk.

Top: a needle resting on the bark registers changes in thickness at one point on the trunk.
Bottom: a belt round the stem registers changes in circumference.

Both instruments send impulses to a recording unit (Tranquillini, unpublished).



Daily radial growth of various central European tree species in southern Germany (Mitscherlich, 1970—75).

Dendroclimatological investigations aim basically at obtaining information on two points; climatic changes over large areas and weather conditions in particular localities. In the end, however, the findings from all regions of the earth possessing annual-ring-forming trees must be fitted together like a puzzle and related to each other. For this, site descriptions are of the greatest importance, even if they seem unimportant to the researcher at the time of sampling. Only by comparing the site descriptions is it possible to determine which tree ring-sequences fit together to form a unit. The formulation of regional dendroclimatological objectives seems to me possible only by means of good site descriptions.

There are two basic ways in which a site can described:

— description of site integrators i.e. those elem whose behaviour depends on climate.
— measurement of the main site factors over a gi number of years.

The first method has the advantage that values f widely differing areas can easily be compared. second allows direct comparison with tree-ring gro but usually permits only a poor characterization of the s since the biologically decisive extreme years are registered. Comparison of measurements from diffe regions is, for chronological reasons, simply not possib

Climatic integrators

The site is characterised by descriptions of position, topography, soil, vegetation and climatic-ecological conditions. These parameters reflect the course of the weather over many years, including extreme events.

Location and topography

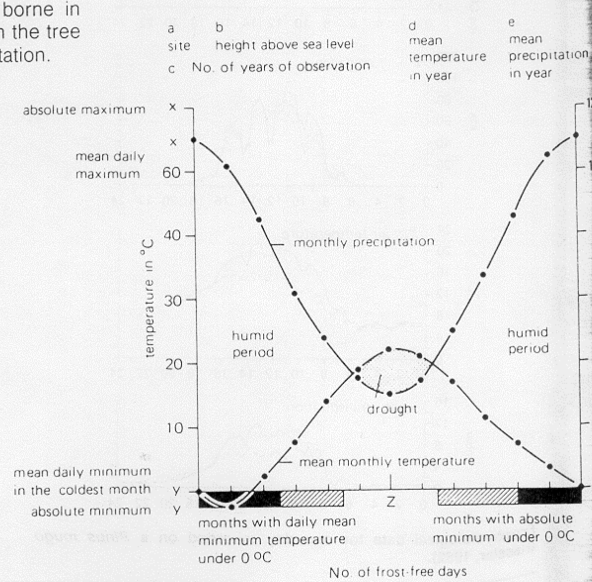
Information on geographical conditions elevation, relation of site to timber line, substrate etc. expresses the regional and local character of the site.

Climate

Climatic diagrams provide in concentrated form the best survey of average conditions obtaining at any given area. The type used by Lieth and Walther is very compact and characterises each area very well. It must be borne in mind that the climate of the sampling site or even the tree stand is not identical with that of the measuring station.

Soil

Soil is an outstanding integrator of climatic and vegetati historic conditions over very long periods. The decod of the stored information however requires extens investigations, as it extends beyond the description of soil profile and rooting conditions. Important points the depth to which the tree roots extend and the p sence of roots of other species. Plants indicative factors important for tree growth must be identified, information on nutrient supply and drainage must obtained.

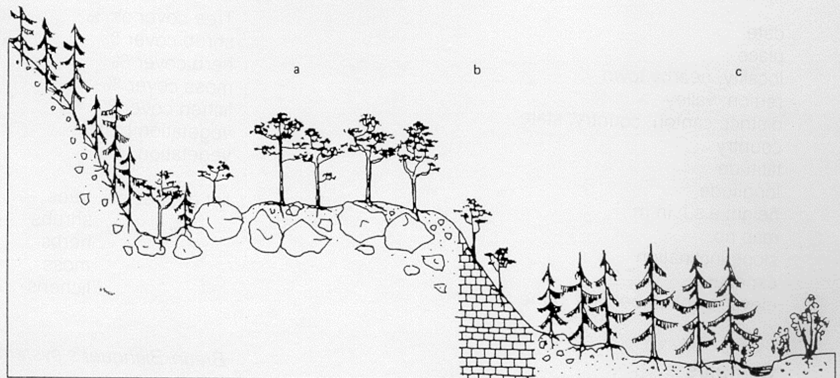


Explanation of a climatic diagram (Walter and Lieth, 1967).

Ellenberg, 1967; Walter and Lieth,

Vegetation

In plant sociology there are several systems for describing and classifying sites. That of Braun—Blanquet has proved very useful for the delimitation of small units, especially in Europe, and dendroclimatological work in temperate zones has shown that it is also well-suited for site characterisation. Equally, it has been found that in many cases simplifications of the system are permissible while in others refinements would be advantageous. The system requires a knowledge of plant species and their significance as ecological indicators, although generally we are far from being able to relate the reactions of trees directly to a few indicator species or species groups.



General characteristics Stand		a	b		c
Geological substrate	limestone debris	limestone boulder debris	limestone bedrock	alluvium terrace	recent alluvium
Soil	Rendzina	Rendzina with thick surface layer of humus	virgin soil	Brown earth	Clay
Drainage	good	very good	very good	good	good to limited
Dominant trees	Picea	Pinus	Pinus	Picea	Picea, Alnus
Conspicuous indicator plants	Cyperaceae Ericaceae	Ericaceae Mosses		Gramineae Alnus	Gramineae and large-leaved herbs
Tree heights	to 20 m	to 18 m	to 8 m	to 25 m	to 30 m
Characterisation of the stand	fairly undisturbed normal stand	ditto	steep bank pine forest extremely dry	pine forest in ground water zone	
Objectives of sampling	regional climatology	ditto	local climate precipitation	hydrology, particularly river run-off	

Picea abies/Pinus sylvestris **forests at 1000 m in the lower alpine regions in the central Alps.**

Common species in a, b, and c	Differentiating species		Stand b	a	c
Picea abies *Pinus sylvestris* *Corylus avellana*	indicating dry conditions	*Carex halleri*	x		
		Limodorum abortivum	x		
Prunus mahaleb *Carex alba* *Erica carnea* *Carex ornithopoda*	indicating moist conditions	*Cornus sanguinea*		x	
		Hylocomium slendens		x	
	indicating wet conditions	*Alnus incana*			x
		Petasites alba			x

Phytosociological division with differentiating species and characterisation with overall species composition.

Site description

A large number of easily recorded features can be used for the characterization of a site and the comparison of different sites. The following list indicates those appropriate.

Sampling site

date
place
locality, nearby town
region, valley
district, canton, country, state
country
latitude
longitude
height a.s.l. in m
map no.
slope inclination
exposure
elevation of timber line in the area

Samples

Name of collector
address
tree species
no. of trees sampled
no. of samples

Climate

nearest meteorological station
climatic diagram
average January temperature
average July temperature
average annual temperature
average precipitation in January
average precipitation in July
average yearly precipitation
climatic zone

Sampled tree

height (estimated)
sociological rank: dominant
co-dominant
dominated
suppressed
crown: diameter
foliage normal
foliage scanty
strong — 2/3 of tree branched
medium — 1/2 of tree branched
weak — 1/3 of tree branched

trunk: excellent quality, no faults
excellent, faultless to 20 m
good, faultless to 5—10 m
poor, faults to stem base

Vegetation

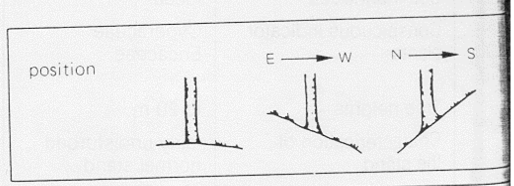
Tree cover as %
shrub cover %
herb cover %
moss cover %
lichen cover %
vegetation belt
vegetation unit

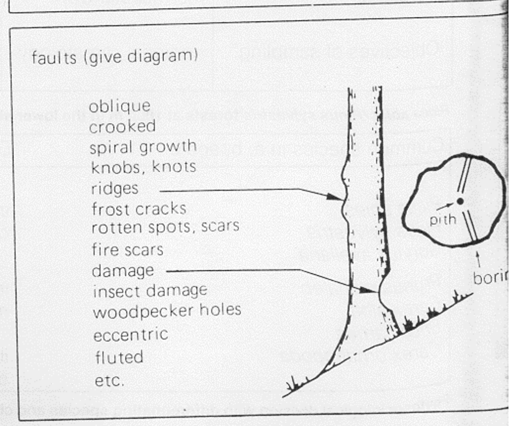
tree height in m
shrub height in m

list of species: trees
shrubs
herbs
moss
lichens

Braun-Blanquet's system of rating species abundance

5 = covering more than 75% of the area
4 = any number of individuals covering 50—75% of the area
3 = any number of individuals covering 25—50% of the area
2 = very numerous, or covering at least 5% of the area
1 = plentiful but of small cover value
+ = sparsely or very sparsely present, cover very small.





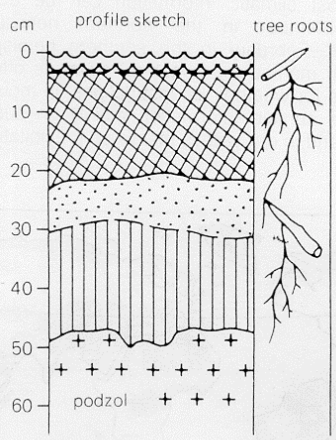
Assmann 1961; Ellenberg 1967; Fritts 1

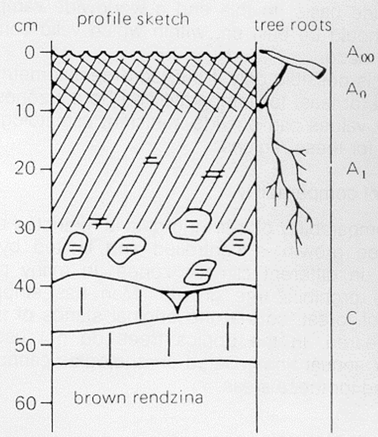
Geological substrate

Rock type
Weathered or unweathered
Weatherability of the rock

Soil

soil profile (Duchaufour 1970)
symbols:





Symbols:

Surface layers:
- organic layer with little decomposition (litter).
- layer of decomposition

Mineral soil:
- humus
- carbonate
- bleached horizon
- loam–clay
- iron enrichment
- rust stains
- bedrock: silicate, carbonate
- horizon boundaries: sharp, diffuse

Assessment of water regime

Precipitation annual
during vegetation period

Interception loss → Interception loss: approx. 20% for closed stands, correspondingly less for more open stands.

Topographically determined inflow
runoff
Ground water level at ... cm
Impervious layer at .... cm

→ Water balance in relation to relief

cupola	inflow only
upper slope	moderate runoff
lower slope	moderate inflow
plateau	inflow = runoff
basin	inflow only

Duchaufour, 1970; FitzPatrick, 1980; Mückenhausen, 1975; Scheffer and Schachtschnabel, 1970.

With living trees

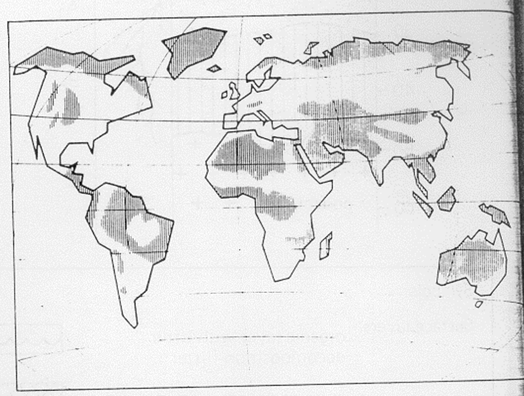
In the absence of meteorological records going back over a long period information on weather conditions in earlier times can be supplied by annual rings. Since weather and climate are global phenomena, the aim of dendroclimatological research is to investigate climatic interplay on a worldwide basis; to this end a worldwide sampling network should be built up, within which valid comparisons can be made.

This is possible only if the radio-densitometric method is used, at least for temperate and boreal zones, as only density values can provide sufficient climatological information for these regions.

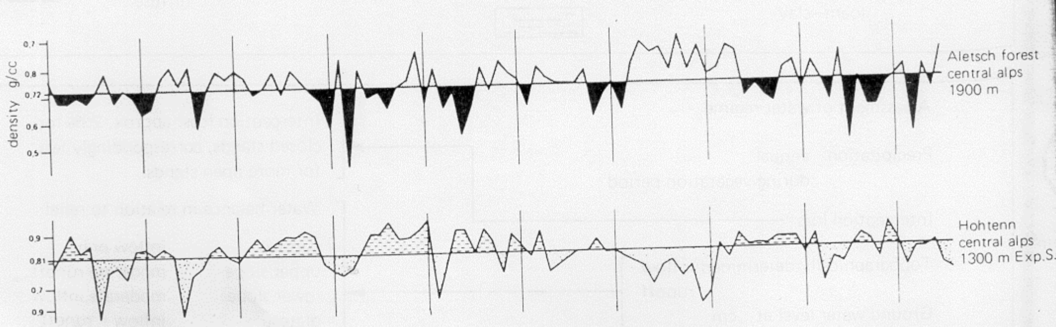
Limits of comparability

The comparability of tree-ring data is restricted by the fact that tree growth is controlled and limited by different factors in different climatic zones. In many places the climate prohibits tree growth. Man has stripped large areas of forest, so that the original stands of trees have disappeared. In the tropics trees do not usually form regular annual rings. Dated chronologies cannot be constructed for these areas.

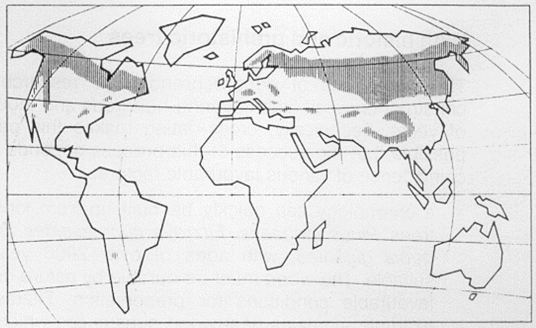
Hardly any information on precipitation can be obtaine from tree rings in arctic regions, as temperature is th limiting factor even on local dry sites. In semi-dese areas, on the other hand, the low precipitation even i deep valleys with a relatively high ground water leve determines tree-ring width and density. The periods fo which most climatic information can be obtained ar June—September in the northern hemisphere an November—February in the southern hemisphere. Re gions with marked topographical divisions offer the bes conditions for weather reconstructions. In mountain area tree rings contain information mainly on summer tem perature and in dry valleys mainly on precipitation.



Areas without forest (arctic and dry deserts) and without trees which form annual rings (tropics).



Maximum density curves for trees growing on the upper timberline (top) and those growing on dry sites in an inner-alpine valley, Valais, Switzerland (Schweingruber *et al.*, 1979).



Forested areas for which summer temperature could be reconstructed.

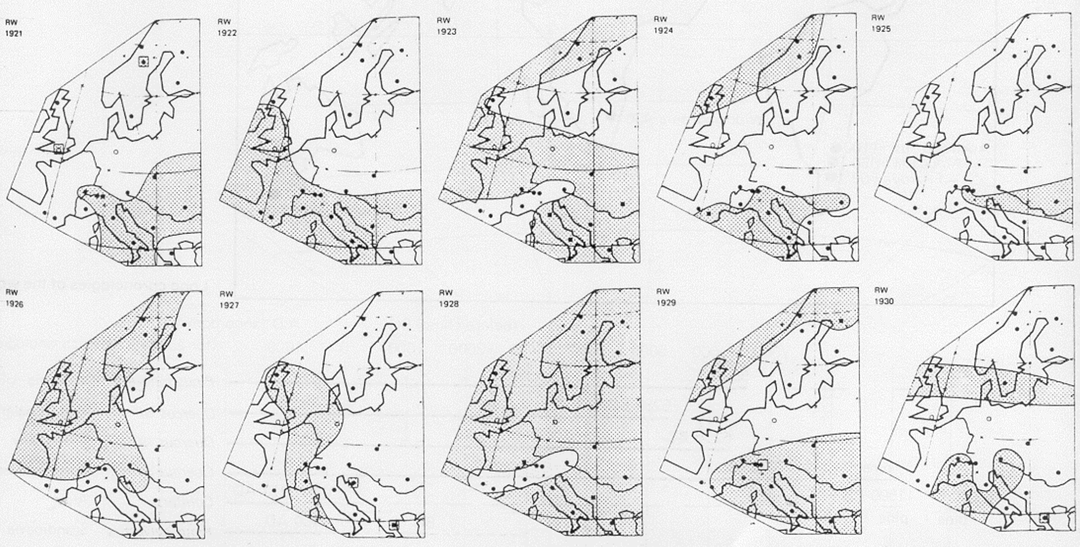
The compromise

The multiplicity of sites and tree reactions theoretically permits the construction of a sampling network with an almost arbitrary amount of climatic information; in practice, however, this is not the case, since the means of research are limited and worldwide dendroclimatological research has only just begun. Consequently, the objectives must be constrained and research is restricted to sites on which the trees are exposed to similar environmental factors. One of the research goals for the northern hemisphere is the reconstruction of summer temperatures. Since the maximum densities of conifers at the northern and subalpine timberline reflect average summer temperatures, they could provide more or less homogeneous climatic information for the last 300–500 years over a wide-meshed sampling network. Such an investigation would also help to define the areas for which data series for historic and prehistoric times could be constructed. See p. 128.

In the south-west of North America a sampling network of trees from dry sites on the lower forest limit was studied (Stockton, personal communication). In these areas the width of tree-ring growth was limited by deficiency in precipitation. As the trees on the site were very old, information was provided about precipitation conditions in these arid regions for the last 500 to 700 years.

In Europe a sampling network of conifers from cool, moist sites in summer on northern and subalpine timberlines was studied (Schweingruber, 1985). Cambial activity is limited from several factors which change from year to year. Thus the maps express mainly areas of high and low growth and less climatic information.

A similar network has been established from Russian dendrochronologists over large Russian and Asian regions (Bitvinskas, personal communication).



Distribution of years with abnormal high growth (white areas) and abnormal low ring-width growth (dotted areas) in trees from cool-moist sites near timberline in Europe (Schweingruber, 1987).

Hughes et al. (edit), 1980; Schweingruber, 1987.

With historic and prehistoric trees

The stated aim of dendrochronological research is to construct chronologies covering hundreds and thousands of years. Technically, cross-dating makes this perfectly possible, but the success of this process depends on the coincidence of various favourable factors:

- a chronology can quickly be built up from long-lived trees *Pinus longaeva, Fitzroya cupressoides and Sequoia gigantea*, with ages of over 2000 years are suitable. The wood must be durable by nature or given favourable conditions for preservation. Fitzroya, for example, contains heartwood substances which resist decomposition in a moist-warm climate. Pinus longaeva has decomposition-inhibiting resins and grows in a desert climate in which decomposition scarcely takes place. Oak also possesses decomposition-inhibiting tannins, and fossil stems are often present in sediments with no aeration; decomposition cannot occur under these circumstances.
- the tree ring sequence must contain much climatic information. Trees from sites on ecological boundaries, e.g. arctic or arid timber lines, are more suitable than those from sub-tropical regions.

It is a lucky fluke when all these conditions are fulfilled.

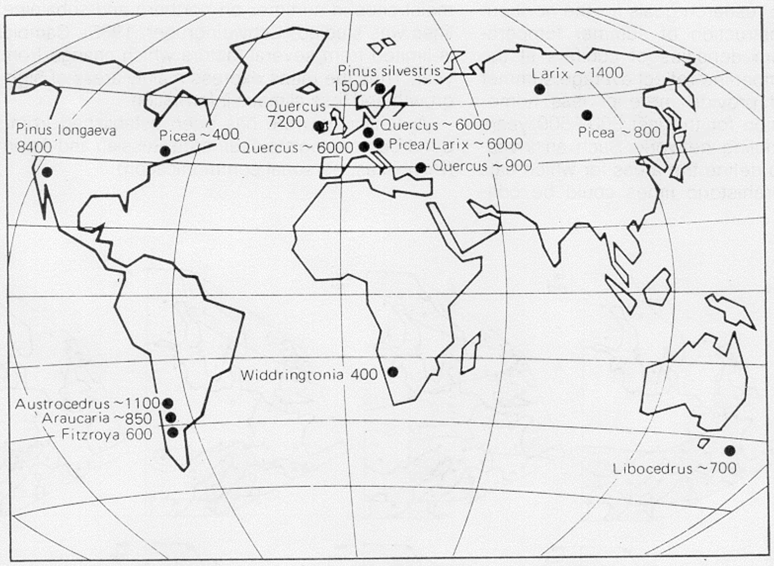
Up to now it has been possible to build an unbrok[e] chronology only with the extremely long-lived *Pin[us] longaeva* and the European oak (*Quercus robur/[*] *petraea*). The Norway spruce and European larch chron[ol]ogies are still floating earlier than 900 A.D.

Each of these chronologies has a particular impo[r]tance:

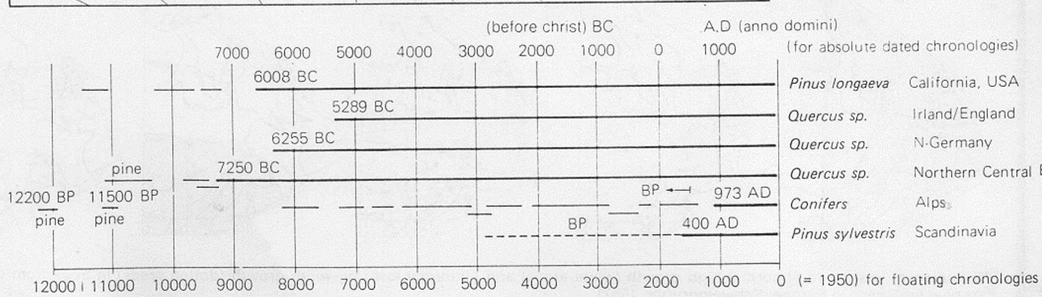
Pinus longaeva served for calibration of the C[14] method.

Quercus sp. The sequences from central Europe pr[o]vided an outline of river and landscape history in this are[a]. Currently, they are being used in the dating of prehisto[ric] lake dwellings in the region of the Alps, and also [for] calibration of the radiocarbon method.

Larix decidua, Picea abies. The material comes fro[m] the alpine timber line and is analysed radiodensitomet[ri]cally. It affords an insight into the annual weather cond[i]tions of the last 8000 years.



Long chronologies of the world.



The longest chronologies (State, 1987).

Characterization of the most important tree species in dendrochronology: Bristlecone pine, oak, larch, spruce

Pinus longaeva D. K. Bailey, Bristlecone Pine

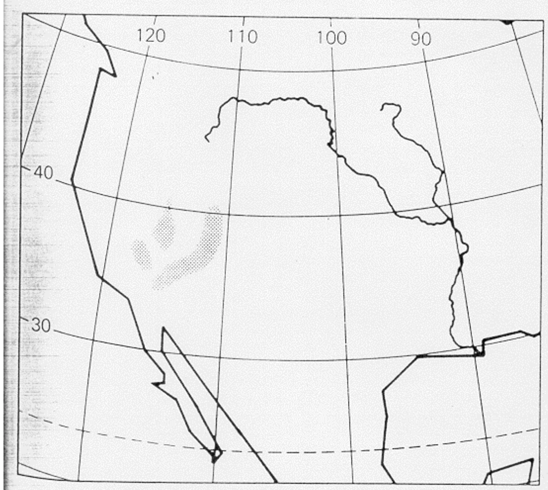
This evergreen conifer is found in continental alpine zones. The average January temperature lies below 0°C, the lowest temperatures around −29°C, with average summer temperatures between 10—15°C. In the rain shadow of the Sierra Nevada precipitation is slight and very variable; for the years 1949—1964, the precipitation for the period December to March lay between 34—250 mm. At any time of year, there may be a whole month without precipitation. The distribution of this species is limited to a few high mountain areas in the south-west of North America. It forms the timber line at 3000—3800 m.

The chronology

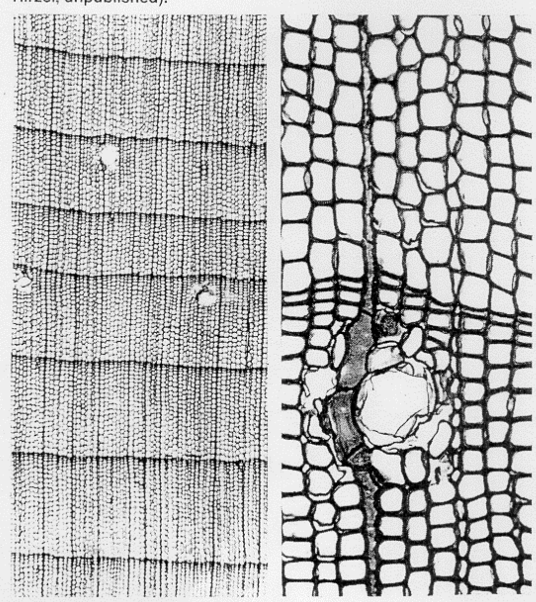
In 1953 E. Schulman discovered "the oldest living things", the more than 4000-year-old bristlecone pines. After Schulman's early death in 1958, W. Ferguson continued his work and constructed a continuous chronology of 8700 years from fossil wood. Synchronizations were made using tree-ring widths.

Fritts, 1969, investigated the ecological conditions in relation to cambial activity of bristlecone pines in the White Mountains over three vegetational periods. The sequence is chiefly important for calibration of the radiocarbon method, since no immediate conclusions about weather can be drawn from this study.

Pinus longaeva. Twigs from good and poor sites, and a cone (R. Hirzel, unpublished).



Geographical distribution of *Pinus longaeva*.



Pinus longaeva, wood, 40× and 100×.
Resin canals and small differences between earlywood and latewood can be clearly seen in this cross-section.

Münch and Lambert, 1972; Schulman, 1958; Ferguson, 1968; Fritts, 1969.