TREE-RING RESEARCH IN FINLAND

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Studies on variation in the width of tree-rings and on its causes were initiated in Finland by Laitakari (16) in his "Studies on the effect of weather conditions on the height and diameter growth of Scotch pine." His material comprised 322 pine trees from southern Finland and the width of all annual rings was measured. The age of the trees was about 100 years. In order to find out the relationship between height growth and climatic factors the annual shoots of 360 young pines were measured, as far back as possible. Laitakari discovered, as Hesselman (4, 5) did previously in Sweden, that height and diameter growth are different in their relation to climatic factors. The annual height growth depends distinctly on the temperature of the late summer of the preceding year. The width of the annual ring, on the other hand, is dependent, according to Laitakari, on the spring temperature of the current year. Between precipitation and tree growth no correlation could be found.

Laitakari studied also, following the example of Douglass in America, whether any periodicity could be found in the variation of tree growth. According to him, an 11-year cycle exists and the maxima and, minima of diameter growth coincide with the maxima and minima of the sunspot cycles.

Boman's (1) paper, "Studies on the variations of the radial growth of pine", published in Finnish, treated mainly of cycles of different length in the growth of Scotch pine. His material, 230 trees, originated from all parts of Finland and the oldest trees were over 300 years. Boman reported several cycles and he tried to determine their length and amplitude. According to Boman, the lengths of the cycles are 7, 11, 21, 35, and 70 years, and probably there exists even a cycle of 105 years. The causes of these cycles were not discussed.

After the above-mentioned preliminary investigations the Finnish tree-ring research has proceeded along two main lines. Foresters have been interested in the relation of tree growth to different climatic factors, and in the practical significance of growth variations (Mikola). Plant geographers, on the other hand, have studied the recent fluctuation of climate and its effect on vegetation, e.g. on the diameter growth of trees (Hustich). Besides watching diameter growth, the variations of height growth, needle length, flowering, and reproduction have been studied, as well as their relationship to climatic factors. Dendrochronological dating has not been practiced in Finland.

The studies of Laitakari and Boman have shown considerable variation occurring in the growth of pine. Furthermore, it was apparent that, in order to determine the magnitude and practical significance of growth variation, an extensive research material would be required. Because practical growth estimates are always based on a measurement of the total radial growth of several (5 or 10) years, the results depend greatly on eventual favorable or unfavorable periods preceding the year of measuring. Thus, for instance, the effect of thinning cannot be studied by comparing only the width of annual rings before and after thinning, unless the growth fluctuation in unthinned stands is known at the time. The first nation-wide forest survey was performed in Finland in 1922-1923. The preceding years seemed to be exceptionally favorable for the growth of pine and thus the reported annual increment of pine was probably too high. The second national forest survey was carried out in 1936-1938. In order to eliminate the effect of climatic fluctuation when comparing the results of the first and second survey, a large material was collected in the second survey. This material comprised annual ring analyses of 1757 pines and 884 spruces from all parts of Finland. The samples were taken with the increment borer at breast height.

Because of war-time difficulties, this vast material was given to the Swedish Forest Research Institute, where Eklund (2) performed its final treatment and published a paper called "An experiment to estimate numerically the effect of climate on the radial growth of pine and spruce in the two Finnish national forest surveys" (in Swedish). The same material or parts of it has been used as a starting point in several later tree-ring investigations. Eklund studied only the 50-year period of 1887-1936 and calculated for each year a so-called annual ring index, separately for pine and spruce and for South and North Finland.

According to Eklund (2) and Ilvessalo (15), during the 10 years' period preceding the first national forest survey the diameter growth of pine was on a considerably higher level than before the second survey. Regarding spruce the available material is much smaller; the result, however, shows that the growth of spruce was during the second survey lower in North Finland but higher in South Finland than during the first survey (Table 1). Because fluctuation in the general level of growth is so large, a new material was also collected in the third national forest survey in 1951-53, in order to correct the measured growth to normal climate. The results have not yet been published.

Table 1. The average diameter growth of Scotch pine and Norway spruce during the 10-year periods preceding the first (1922-1923) and second (1936-1938) national forest surveys (normal level = 100).

	Pine		*Spruce*	
	1st survey	*2nd survey*	*1st survey*	*2nd survey*
South Finland	109.0	94.9	97.2	98.6
North Finland	106.8	97.2	106.2	98.6

Mikola (17), when studying growth variations, used partly the same basic material as Ilvessalo and Eklund. To supplement it, in 1942-43, 755 trees were sampled, part of them in Soviet Carelia, and an additional 3200 sample trees in 1945-46. Thus his material exceeded 6500 trees, of which 2000 were spruce and 4500 pine; and more than 700,000 individual rings were measured accurately to 0.01 mm. Based on this large material, annual ring indices were calculated for pine and spruce and also for different parts of Finland. Most series go back to 1800 or 1750; some of them are even longer. Later on, Nyyssönen (20) gathered new material and built up an index-series that agrees with the indices by Mikola conspicuously well.

Mikola (17) has also tested in his material the occurrence of cycles reported by Ording (21) in Norway. Most distinct seemed to be the 23-year cycle, but cycles of 11, 17, and 35 years, too, could be traced in the growth of pine. In the growth of spruce the cycles were more obscure, and the cycle of 11 years could not be found at all.

In recent Finnish research little attention is paid to the eventual cycles in growth fluctuation. On the other hand, the effect of climatic changes on tree growth as well as on other phenomena in fauna and vegetation, especially along the northern timber-line, has been the subject of several investigations.

During the first decades of this century the prevailing opinion was that the northern timber-line was receding, due to unfavorable climatic development. This idea was based on the lack of young seedlings in the timber-line region as well as on the occurrence of subfossil pine remnants above the present timber-line. Later on, however, meteorologists showed that the annual mean temperature has been generally increasing in northern Scandinavia. In the 1920's and 1930's plenty of pine seedlings appeared along the Scandinavian timber-line. The studies of Hustich (6, 7, 8, 9, 10, 14) and Mikola (18, 19) showed that the diameter growth of pine increased considerably from 1910 until the 1930's. Hustich used the material of the national forest survey from northernmost Finland, and, to supplement it, he gathered annual ring series of several hundred pines along the timber-line.

According to these northern studies, the diameter growth of trees depends closely on the temperature of the growing season. A clear correlation exists between the diameter growth of pine and the July temperature. Towards the south, the correlation weakens. Mikola (17) confirmed the previous observation made by Ording (21) in Norway, that the diameter growth of pine depends mainly on the temperature of the late season (July) while that of spruce is more dependent on the temperature of early summer (June). Therefore the correlation between index-series of pine and spruce is rather weak. Mikola studied also the effect of climatic conditions on the formation of different components of the annual ring, early and late wood. Thus, variations in the width of early wood are much smaller than in the width of late wood. The late wood is the broader, both absolutely and relatively, the earlier the growth commences in the spring and the higher the temperature is of middle and late summer.

The studies of Hustich and Mikola confirmed the previous results of Hesselman (4) and Laitakari (16) that the height growth of pine depends mainly on the temperature of the preceding summer. Hustich (11) stresses especially the difference that in this respect occurs between humid and arid climates. In an arid climate both height and diameter growth depend on weather conditions of the same year; in a humid and cold climate on conditions of different years.

In Finland no correlation has been found between precipitation and diameter growth of trees. Since in central Europe, however, the growth of trees is evidently proportional to precipitation, the moisture may exert some influence in Finland, too, but its significance is hard to ascertain because the rainfall and the temperature of the growing season are usually more or less inversely proportional. Indeed, when examining tree-ring analyses, it is noticeable that very dry summers have been unfavorable to tree growth on the driest sites, just as very rainy summers on wet peatlands (17). In general, however, growth variations are rather uniform, independently of the site.

In the tree-ring studies of the timber-line region the large variation in the width of the annual rings is of special interest. As Hustich (11) stresses in particular, variation is largest where the growth is determined mainly by one varying factor, as by temperature on the northern timber-line or by moisture in the transitional zones between forest and steppe. When going from the north to the south, the variation gets smaller. To express the extent of variations Hustich (11) uses the variation coefficient that he calls "climatic hazard coefficient", and Mikola (17) has calculated mean sensitivities according to Douglass. The figures below show the average extent of variations in Finland.

	Climatic hazard coefficient (Hustich)	*Mean sensitivity (Mikola)*
Pine		
Northern timber-line	31 %	0.22
North Finland	23 %	0.15
South Finland	18 %	0.12
Spruce		
North Finland	20 %	0.18
South Finland	12 %	0.15

Hustich (9, 11) compared also the variations of agricultural crops in Finland and noticed a parallel development, as when moving in Finland from the north to the south or in America from a maritime to an arid climate.

Climatic variations in pine growth on the polar timber-line are often accentuated by extensive frost injuries, as is demonstrated by Mikola (18). A prolonged growth depression, such as occurred in northern Scandinavia in 1903-1911, may be due to one single year of heavy frosts. Corresponding depression in spruce growth does not exist, and therefore the growth improvement of spruce in 1911-1930 is not so steep as that of pine. Mikola's tree-ring analyses include also growth depressions, both in pine and in spruce, that probably result from damage caused by insects or fungi.

Finland is climatically a rather uniform area without high mountains, and accordingly a close correlation exists between tree-ring index-series from different parts of the country (Table 2). The only exception is the northern timber-line region (between 68° and 70° latitude) where variations are considerably larger than elsewhere. On the other hand, correlation between index-series from different parts of the Scandinavian timber-line, as those by Hustich (8) and Erlandsson (3), is conspicuously high.

Table 2. Correlation coefficients between north Finnish (67°-68° lat.) and more southern annual ring indices in 1887-1936 (Mikola).

	Pine	*Spruce*
67-68°/66-67°	0.93 ± 0.02	0.89 ± 0.03
67-68°/65-66°	0.76 ± 0.06	0.83 ± 0.04
67-68°/64-65°	0.69 ± 0.07	0.76 ± 0.06
67-68°/63-64°	0.58 ± 0.05	0.68 ± 0.07
67-68°/62-63°	0.43 ± 0.11	0.54 ± 0.10
67-68°/60-61.5°	0.36 ± 0.12	0.38 ± 0.12

Going from west to east in northern Europe the change of climate takes place much faster, and tree-ring index-series from the same latitude, e.g. from Finland and Norway, have almost no common features (Table 3).

Table 3. Correlation coefficients between annual ring index-series (1887-1936) of Soviet Carelia and Finland and Norway, after Mikola (17).

	Pine	*Spruce*
Soviet Carelia/East Finland	0.77 ± 0.06	0.86 ± 0.04
- " - /West Finland	0.53 ± 0.10	0.70 ± 0.07
- " - /East Norway	0.22 ± 0.14	−0.23 ± 0.13

Hustich compared Finnish tree-ring analyses to American ones (11) and also gathered new material from eastern Canada (12, 13). The comparison reveals that quite an opposite trend prevailed in 1910-1930 in climatic development in Europe and in America. While a marked growth improvement is characteristic to the Scandinavian timber-line region, a distinct decrease occurred in eastern Canada at the same time.

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