REGIONALITY IN STAND INCREMENT AND ITS DEPENDENCE ON THE TEMPERATURE FACTOR ON DRAINED SWAMPS

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Preface

One of the authors has earlier treated the subject of regional changes in stand increment (Heikurainen 1959). At that time, however, no closer attention was given to the correlation between climatic factors and regionality in regard to tree growth. As the question concerning the effect of climate on stand increment has recently come more and to the fore (cf. Huikari 1964, Sirén 1963), the authors have felt inclined to bring their contribution to the discussion already carried on and to be carried on in the future.

It is difficult to give a detailed account of the division of labour between the authors, for many phases of the work have been carried out in complete collaboration. Seppälä, however, has planned and performed the statistical treatment of the material, while the primary material has been drawn from Heikurainen's previous investigations.

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The Authors

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1. Introduction

The clarification of the factors regulating the growth of trees is one of the most important tasks in the science of forestry. If the influence of stand treatment is not considered, growth factors are divisible into two groups, climatic and edaphic.

The effect of climate on stand increment can be dealt with in two ways. First, fluctuations in the growth for different years can be examined as a function of climatic factors (e.g. M i k o l a 1950, E k l u n d 1957, S i r é n 1961) and secondly, stand growth under different climatic conditions can be compared for the same period and again examined as a function of climatic factors (e.g. P a t e r s o n 1961). In this work investigational methods of the latter kind have been used.

The aim of this work is to clarify, on the basis of the material published before (H e i k u r a i n e n 1959), the effect of temperature on stand increment, to find out if there is any difference between spruce and pine in this respect, and to study the effect of site quality on the relationship between stand increment and temperature.

This kind of work requires that stand increment under different climatic circumstances be compared on sites as similar as possible from the edaphic point of view. As is well known, the swamp types used in Finland designate site quality within comparatively close limits, and furthermore, the same swamp types occur throughout the country. Thus it has been possible to create sample plot series which are edaphically rather similar, although obviously not identical.

2. Material

21. Indices describing climatic factors

The indices of climate which have been used are based upon temperature maps and tables for the period 1921—1950 presented by K o l k k i (1959). The significance of the following temperature factors has been studied in the calculations:

— Mean annual temperature. In earlier decades mean annual temperature was commonly used as an indicator of temperature conditions (in Finland, e. g., L u k k a l a 1938).

— Duration of growing season. Here the concept ”duration of growing season” means the number of days with a mean temperature exceeding 5°C. The duration of growing season has also been used as an indicator of temperature conditions, even though the lower limit varies with different authors. (E. g. Mitscherlich 1933 (5°C), Langlet 1936 (6°C), Tamm and Carbonnier 1961 (6°C), Paterson 1936 (7°C).

— Number of days with mean temperature exceeding 10°C.

— Thermal sum, that is the sum of daily mean temperatures during the growing season.

There are numerous other logical alternatives from which to chose. For instance, some of the most important temperature factors in Paterson's (1961) well-known formula concerning growth factors are the sum of the mean temperatures of the warmest month, and the amplitude of the mean temperatures of the coldest and the warmest months. Eklund (1957) has observed that the number of days with a temperature exceeding 16°C gives the best correlation with diameter growth in spruce. Thurmann-Moe (1953) has used mean temperatures from June to September as the independent climatic variable in calculating the correlation.

Additional growth-regulating factors are the amount of radiation during the growing season (e.g. Wilhelmi 1954) and the annual rainfall. Since there is no precise information available regarding the amount and significance of the radiation, and as rainfall in Finnish climate is of less importance than temperature, they have not been included in this study. However, average changes in growth have been calculated in regard to latitude separately for the western and eastern parts of the country.

22. Increment figures

The stand characteristics presented in this work are based upon material from sample plots measured by Heikurainen (1959). Included in the calculations, however, are only such swamp types as occur abundantly all over Finland or at least in most of the country. The former constitute the basic material, which includes sample plots on the following swamp site types: *herb-rich spruce swamps, spruce swamps with shallow peat layer, ordinary spruce swamps, ordinary sedge pine swamps,* and *pine swamps with undershrubs.* Additional material is formed by sample plots representing *herb-rich sedge pine swamps cottongrass pine swamps, oligotrophic pine swamps,* and *spruce pine swamps* (cf. Heikurainen 1964). Elimination has been carried out further on the basis of draining effect, tree species, and silvicultural condition. It has been attempted to eliminate variation due to the effect of draining by including in the material sample plots located only along ditches. Birch-dominated stands have not been included in the investigation, nor have pine-dominated stands in spruce swamps or spruce-dominated stands in pine swamps. Stands which have been classified as underproductive or in need of regeneration have been excluded from the material. Thus, there were left 396 sample plots, which formed the basis of the calculations (see Fig. 1).

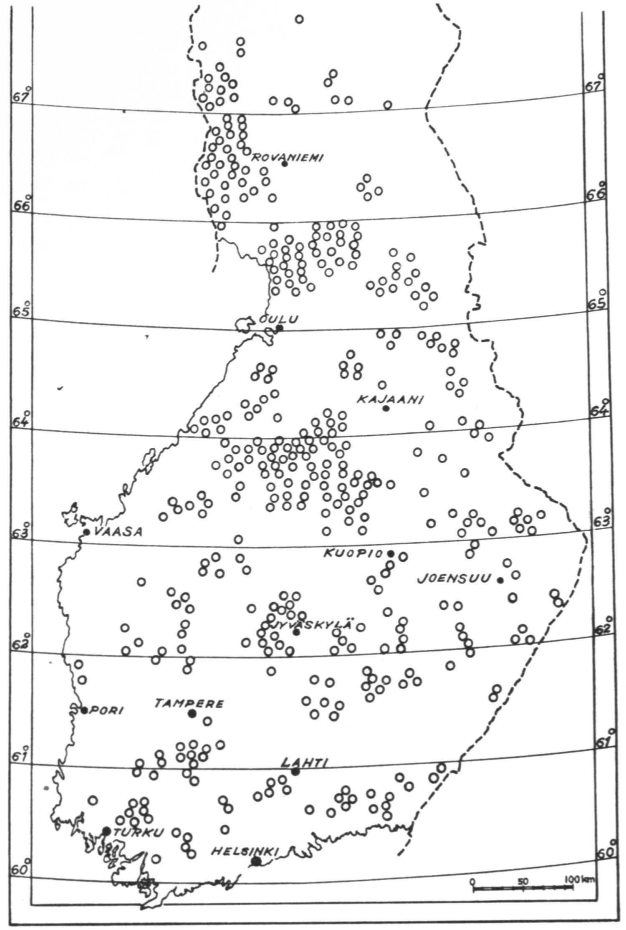

Fig. 1. Dispersion of the sample plots.

The relation between temperature and increment has been clarified mainly on the basis of relative figures for the current annual increment. The transformation of the absolute figures for growth into relative ones was performed principally as follows: (A detailed description of the method has been presented in Heikurainen's previously mentioned work.) Increment figures concerning the sample plots were examined as functions of volume. Growth figures for sample plots situated between the 60° and 62° parallels of latitude were plotted on a coordinate system according to swamp types, after which an appoximating curve indicating the relation between volume and increment was drawn. The obtained curve was regarded as the basic level, receiving the value 100, to which the increment figures of separate sample plots were compared. The basic curves for the relative growth in the additional material had to be drawn from sample plots representing other climate zones, so that they had to be converted to the level indicated by the approximating curve of the basic material. As the majority of the sample plots were concentrated in the part of the increment curves representing smaller stands, inaccuracies of the method probably do not cause any big errors in the relative growth figures.

3. Results

31. Effect of tree species and site quality on the correlation between stand increment and temperature

Differences in growth between spruce and pine as regards temperature were studied on the basis of the relative growth figures and the sum of effective temperature. Used to indicate the temperature in this case were the thermal sums at the meteorological stations closest to the sample plots. Results are shown in Figure 2.

It can be noticed that the calculated regression lines are on the same level, and that they almost coincide. The difference between their slopes is so slight as to have no significance. This means that dependence of increment on temperature is the same for spruce and pine. For this reason these tree species have been treated together in the following discussion.

The importance of site quality in the correlation between stand increment and temperature was studied by means of two examples. Poor sites were represented by

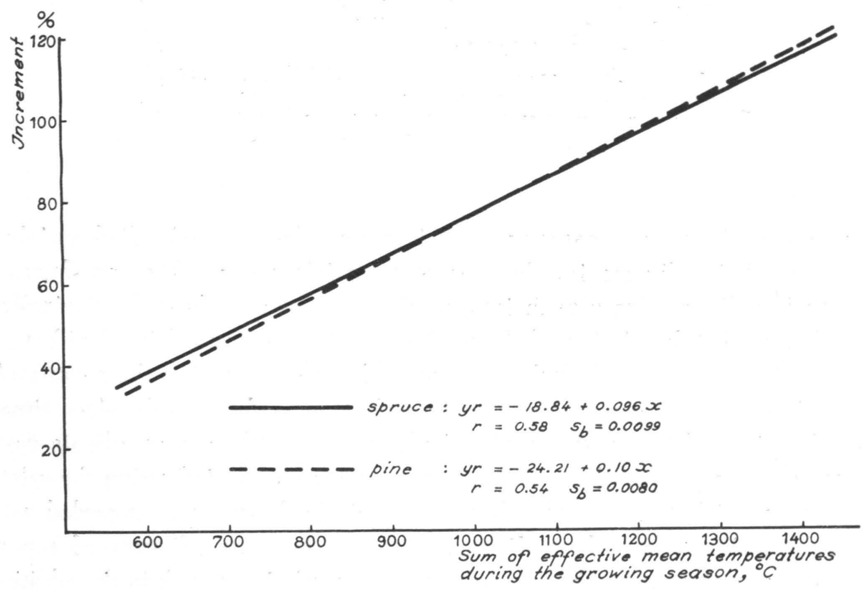

Fig. 2. Dependence of growth on the thermal sum in spruce and pine.

sample plots in *pine swamps with undershrubs* and in *cottongrass pine swamps* (117 in all), and medium sites by sample plots in *ordinary spruce swamps and spruce swamps with shallow peat layer* (113 altogether). The question was approached in two different ways. First, the regression of the relative growth figures of the sample plots in both type groups on the temperature factor (in this case the duration of the

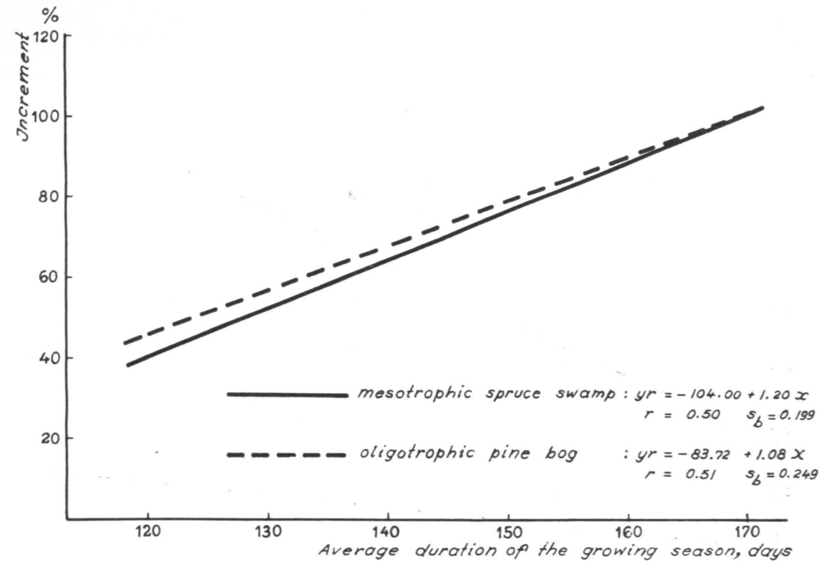

Fig. 3. Dependence of relative growth on duration of the growing season on sites differing in regard to fertility.

growing season) was calculated (Fig. 3). Hereby it could be observed that the differences between the slopes of the regression lines remain within the limits suggested by their standard error; that is, there is no significant difference between the directions of the regression lines. Also, a multiple regression analysis with the original absolute figures in both swamp type groups was performed in which stand volume and temperature factor were arguments, and the annual current growth the dependent variable (Fig. 4) The following formulae are results of the calculations:

pine swamps: $y = -2.43 + 0.04705x - 0.000124x^2 + 0.01804z$ and
spruce swamps: $y = -16.64 + 0.1688x - 0.000647x^2 + 0.0882z$

in which y = current annual growth, x = volume, m^3/ha, and z = duration of the growing season in days.

According to the calculations the effect of the temperature factor on the absolute increment is nearly five times as great on the better sites as on the control sites.

As there is obviously also some relationship between the volume and temperature factors, the pure effect of the temperature factor cannot be isolated in calculations of this kind. Because of this it has not been considered fitting to make any estimate concerning the confidence limits for the coefficient z. It should only be observed that the partial correlation coefficient in the pine swamps was 0.23 and in the spruce swamps 0.32. Figure 4 reveals the correlation between volume increment and duration of growing season in cases when the stand volume equals the mean volume of sample stands in both groups of site types.

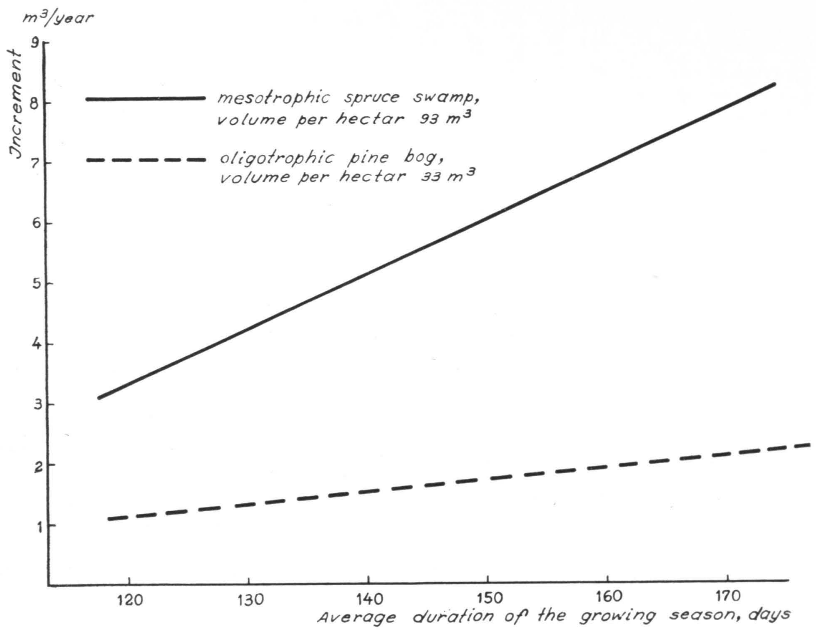

Fig. 4. Dependence of volume increment on duration of the growing season on sites differing in regard to fertility.

On the basis of calculations with both relative and absolute growth figures it seems obvious that the decrease in growth with falling temperature is of the same magnitude in different sites when calculated in percentages; or inversely: the difference in yield capacity between good and poor sites, expressed in absolute measures, is clearly smaller in unfavourable climatic conditions than in favourable (cf. Tamm and Carbonnier 1961).

32. Dependence of stand increment on some temperature factors

In the preceding section temperature indices obtained directly from the meteorological stations were used. However, there are too few stations of this kind in our country, and their location very often is not decided on the basis of the mean

altitude of the district but according to population centers, which generally have taken shape along water courses in regions at lower altitudes than the surrounding country side. Therefore, the temperature indices from individual stations may give more or less faulty information about weather conditions in the vicinity (cf. Paterson 1961, p. 53 and 58). In the following the correlation between relative growth figures and the thermal sum, and the standard error of the estimate (dispersion about the regression line) will be presented first for cases when the temperature factor has been obtained from the meteorological stations directly and then for those obtained from Kolkki's (1959) temperature map.

	r	se
Meteorological station	0.55	23.61
Adjusted value	0.68	15.48

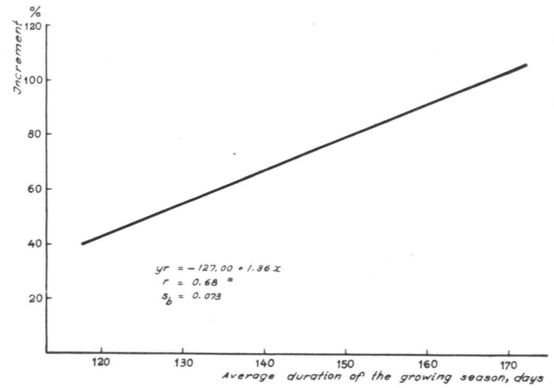

Fig. 5. Dependence of growth on duration of the growing season.

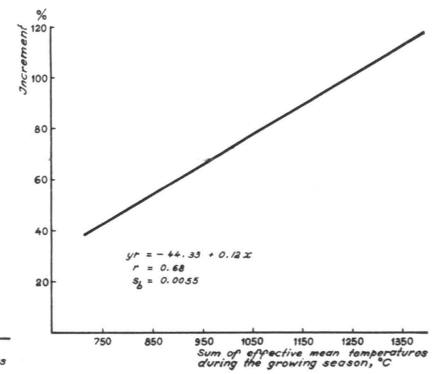

Fig. 6 Dependence of growth on the thermal sum.

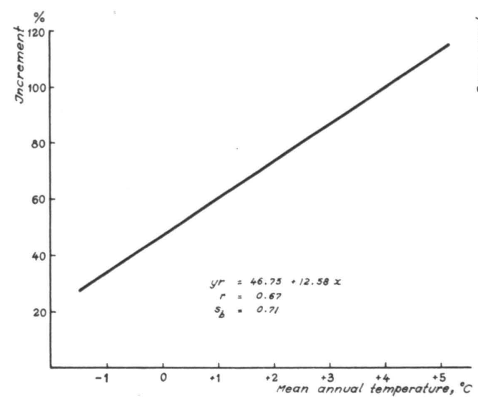

Fig. 7. Dependence of growth on mean annual temperature.

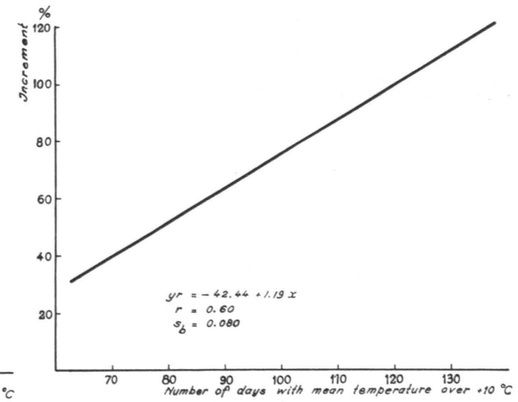

Fig. 8. Dependence of growth on the number of days with mean temperature exceeding 10°C.

Thus, using the adjusted figures of the temperature maps it was possible to obtain a clearly smaller dispersion. In the following calculations only these figures have been used.

All temperature factors which have been used are dependent on each other, for which reason each one was dealt with separately. The regression of relative growth on temperature indices seems to be represented best, at least according to these data, by a linear model.

Changes in the relative growth figures were studied as a function of the following temperature factors: duration of the growing season (Fig. 5), thermal sum (Fig. 6), mean annual temperature (Fig. 7), and number of days with mean temperature exceeding 10°C (Fig. 8). In addition, regression equations for the decrease in growth in a latitudinal direction going from south to north were calculated separately for the eastern and western parts of the country (Fig. 9).

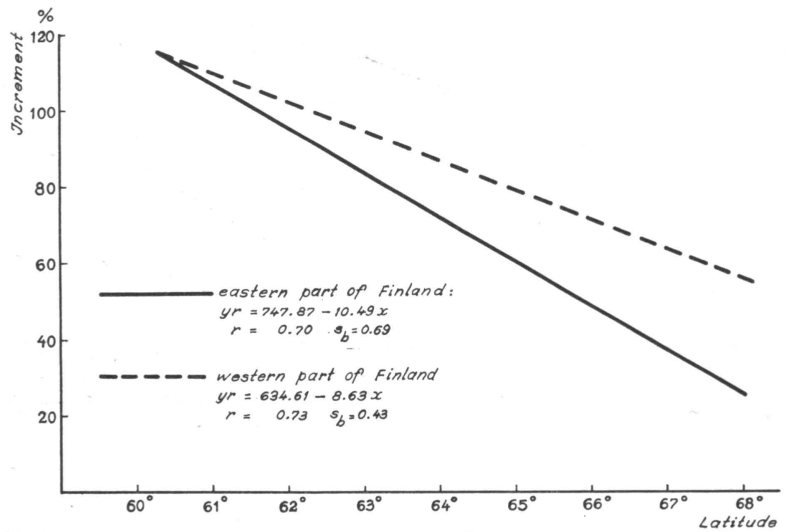

Fig. 9. Correlation between growth and parallels of latitude in East- and West-Finland.

The correlation coefficients and the slopes of the regression lines in the figures reveal that all tested indices are equally good in explaining the decrease in growth. The correlation coefficients varied from 0.73 to 0.60, and the analyses of variance performed showed that the dependence of growth on these factors was highly significant in all cases. On the other hand, the steeper decrease or growth from south to north in the eastern parts of Finland did not show any statistical significance, although the direction of the difference seems reasonable because of the more continental climate and the altitude of the eastern part of the country.

4. Interpretation of results

There were many sources of error in the material, each of which respectively reduces the accuracy of the results and makes a more detailed and delicate handling of the material unjustified. A source of error in regard to climate factors was the sparsity of the network of meteorological stations in North- and East-Finland, leading to an undue influence of casual factors upon the readings of the observation stations as well as on the adjusted figures. Neglected meteorological factors, such as annual rainfall, radiation during the growing season, etc., have their own importance in analyses of the rate of growth.

The growth figures have, furthermore, been obtained from material which was originally gathered for other purposes. Thus, influence of the stage of development and structural variation in the stands, variation according to silvicultural condition, etc., is difficult to eliminate completely from the growth figures. Nor can the differences in drainage effect be removed, although variation in this respect has been reduced by including in the material only sample plots located along ditches. Small-scale topography, altitude, etc., of the sample plots have also been neglected in the examination, although they, no doubt, have their given importance in the formation of the local microclimate.

The effect of the mentioned factors appears in the calculations as random dispersion. The fact that there is so little difference in the slopes of the regression lines as there is justifies the assumption that the factors left beyond the examination are of minor importance in the formation of growth as compared with temperature factors. No one of the tested temperature indices proved to be clearly better than the others. The results, for their part, help to clear up the diversity of conceptions encountered in literature concerning the matter. Under Finnish conditions it seems obvious that latitude is able to describe equally well the possibilities for stand increment.

It is interesting to observe that there seem to be no differences due to tree species or site quality in the relative amounts growth under different climatic conditions. Thus, the differences in the absolute growth between poor and fertile sites are noticeably smaller in North-Finland than in the southern parts of the country. In the authors' opinion this implies that the lasting maximal increase of growth which can be produced, for instance, by using soil-improving agents must be less in unfavourable temperature conditions than in favourable. This view is supported also by Tamm and Carbonnier (1961).

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