Introduction to Phyochorology of Norden

Nordens fyokorologiska grunddrag

by

STEN STURE PATERSON

MEDDELANDEN FRÅN
STATENS SKOGSFORSKNINGSINSTITUT
BAND 50 · NR 5

Corrections to Description of the statistical computations by Olle Persson in Sten Sture Paterson: Introduction to Phyochorology of Norden

Page	
70	Line 12. Replace "have first been fitted graphically" by "have first been adjusted"
71—72	In Tables 8—10. For "ΔF" read "degrees of freedom"
73	Figure 27. Replace "The theoretical regression line" by "The regression line"
	Line 6 from below. Replace "which are often fitted" by "which are often not satisfied"
74	Second column in Table 11. The figure 11 means variable y_1

Meddelanden från Statens skogsforskningsinstitut, Band 50:5.

Preface

The present work is an attempt to determine the timber producing capacity of the site by means of its natural conditions, particularly the features of climate. Investigations of this kind are of special importance for the evaluation of the potential productivity of areas lacking forests or where the forests have a structure rendering a direct determination of the productive capacity impossible. Research in this field may also strengthen our knowledge of the relationships between productive capacity and the natural conditions of the site.

In 1958 the International Union of Forest Research Organizations received a request from FAO to submit a statement concerning the method developed by St. St. Paterson for determining the yield potential of large forest areas. A working party under the chairmanship of Dr. J. Weck, professor of the Bundesforschungsanstalt für Forst- und Holzwirtschaft at Reinbek by Hamburg, was appointed with the object of studying the matter further. It was found most feasible to assign the treatment of various geographical regions to each member of the working party. Thus I received the task of investigating the problem as regards the Scandinavian countries and Finland.

The investigation is based partly on yield data obtained from the sample plots established by the Forest Research Institute of Sweden in virgin stands and partly on yield data benevolently submitted by the forest research organizations in Denmark, Finland and Norway. On behalf of the Forest Research Institute of Sweden I want to express our sincere gratitude for the generous contributions made by our neighbour countries.

The material has been compiled by Dr. St. St. Paterson who was employed by the Institute for the period Nov. 1st 1959—June 30th 1960 and thereafter during shorter periods for complementary work. In the paper now presented he has reported on the investigation and its results.

Stockholm, March, 1961

Charles Carbonnier

LIST OF CONTENTS

Page

DEFINITIONS 6

INTRODUCTION 7
  Regional phyochorology 7
  Phyochorology of the site 8
  Productivity and potential productivity 8

THE PLANT PHYSIOLOGICAL FEATURES OF FOREST PHYOCHOROLOGY 9
  Assimilation, respiration, transpiration 9
  Carbodioxide assimilation 10
  The plant physiological importance of light 10
  The plant physiological importance of temperature 11
  The influence of solar radiation on the radial growth 14
  The influence of the annual temperature range on vigour 15
  The influence of soil temperature on vigour 17
  The length of growing season and its influence on vigour 18
  The importance of water for plant life 21
  The occurrence of dry and arid periods within the area of investigation ... 23
  The ombro-thermal regions of Norden 41
  Hygro-thermal division 41

THE MATERIAL OF INVESTIGATION 43
  Forest data 43
  Yield data of the Swedish localities included in the investigation by Professor Ch. Carbonnier 45
  The meteorological material 47
  Decrease in length of growing season at rising altitude 53

THE RELATIONSHIP BETWEEN CLIMATE AND FOREST YIELD 60
  The plant physiological production balance 60
  Photosynthesis and respiration in plant parts versus stands 61
  The investigation method concerning the relationship 64
  Report on the statistical computations by Mr. Olle Persson, Civ. Eng.... 69
  The results of the statistical computations 75
  Comparison with the potential productivity of other Nordic countries 79

THE RELATIONSHIP BETWEEN SOME EDAPHIC FACTORS AND FOREST YIELD 90
  The electric conductivity of soil 90
  The influence of soil texture on the mean annual increment 92
  The influence of soil depth, depth of the humus cover and horizons 93

THE POTENTIAL PRODUCTIVITY OF NORDEN'S FORESTS 95

SUMMARY 104

SAMMANFATTNING (SUMMARY IN SWEDISH) 107
  List of plates and illustrations 109
  List of tables 109
  Published sources of information and literature used 110

Acknowledgements

Performing this research task, the author has enjoyed the opportunity of discussing arising problems with appropriate experts of the Forest Research Institute of Sweden as well as others. The author wishes to express his sincere gratefulness to the professors Ch. Carbonnier, E. Hagberg and C.-O. Tamm and to Mr. O. Persson, Civ. Eng. for their valuable comments on and critical scrutiny of this work.

Mr. Å. Wiksten, MF. is responsible for the English translation, which was revised by Miss Juliet Blair. Maps and miscellaneous other exhibits have been drawn by Mrs. A. Neuschel. The tedious typing of tables etc. has been carried out by Mrs. J. Koltai and Mrs. M. C. Joseph. To all these persons the author is much indebted.

Stockholm, March, 1961

Sten Sture Paterson

Definitions

Phyochorology,	Gr. phyo—produce and choros—land; science of the ecology and the geographic occurrence pattern of areal production
Phyochor,	land area with equal production potential and bounded by two isophytes
Solar radiation,	the total radiation energy received by the ground surface and comprising both direct and diffuse sunlight
Isophyte,	line connecting places with equal growth potential
Climato-isophyte,	line connecting places with equal plant growth ability resulting from climate expressed by the *CVP* index (St. St. Paterson, 1956, p. 8)
Productivity,	production actually occurring
Potential productivity,	a future, attainable production provided that certain conditions concerning the production factors are met with
Dry period,	(Germ. "Trockenzeit": Sw. "torrtid") that part of the year when the temperature (t) curve in a climate graph is situated above the precipitation (p) curve at the scale ratio $t = 3\ p$
Arid period,	(Germ. "Dürrezeit": Sw. "arid tid") that part of the year when the temperature curve in a climate graph is situated above the precipitation curve at the scale ratio $t = 2\ p$.

Introduction

Regional phyochorology

In 1955 J. Weck published his work "Forstliche Zuwachs und Ertragskunde" where he presented a mathematical expression of the climate in toto which was closely correlated with the average forest yield in Germany. Half a year later the present author submitted his paper "The Forest Area of the World and its Potential Productivity" where it was shown by means of the so called *CVP* index that a similar globally valid aggregate expression of climate was closely correlated with the average forest yield. Although the papers were presented independent of each other, they both combine climate and areal production. The problem thereby assumes a distinct economical touch. The author is stressing this character by presenting a world map with phyochores exemplifying the silvan bio-effect of climate. The average timber production capacity expressed in cu.m. per hectare and annum can then be obtained directly.

The publication of the author's work in 1956 was followed by a discussion in which international experts seemed to agree (J. Weck, 1957, 1958; A. W. Küchler, 1957; J. Pardé, 1958, 1959 a, and 1959 b; F.A.O., 1958, p. 25, f; C. J. Robertson, 1958, and others) that the work provides interesting possibilities for an estimate of the sustained forest yield capacity and for probably valid comparisons (F.A.O. 1958, p. 25) by means of values presented concerning the potential productivity of various regions. Among the critics are particularly those who question the method of omitting entirely the site factors (A. W. Küchler, 1957; E. Rostlund, 1959). The reason for their standpoint seems to be that they make no difference between interregional investigations the mathematical basis of which is the mean value, and a detail investigation founded on individual data.

The interregional investigation attempts to construct a representative picture of the average yield capacity within each region specially separated. Each region is required to concur with a uniform area of production. Uniformity primarily pertains to the climatic conditions where the main body of the forest area is located. The method consequently requires a suitable regional division. The importance of this has been elucidated by the author's compilation of the forest yield values presented for Germany by Weck (1955, p. 124 ff) and their distribution by various areas. The climate factor has not been considered at the delineation of these areas since 20 per cent of the regions would appear directly unsuitable with regard to the *CVP* index. If they are excluded from the material, the relationship between yield and *CVP* is strengthened from $r_{xy} = 0.64$[1] to $r_{xy} = 0.86$ (ST. ST. PATERSON, 1957, p. 382 ff).

Phyochorology of the site

At the detail investigation the yield of the site constitutes the supplementary variable to the climate index applicable to the location. Each individual value used for both variables is absolute and concisely defined. This means that the influence of outside factors will affect the relationship to full extent. Consequently, variations in the edaphic conditions between various sites are expressed directly. Increased dispersion of data supporting the correlation is therefore a natural result. Simultaneously, the possibilities of studying the basic causes of this increase are improved as well as finding a mathematical expression thereof which can be combined with the climate index for the ultimate object of improving the correlation.

Productivity and potential productivity

It is of importance at phyochorological investigations of the kinds mentioned here to define closely the nature of the yield data supporting the compilation. Here it should be distinguished between productivity, which is expressing something actually achieved, and potentiality, which implies something possible in the future, assuming that certain conditions are met with. It should be stressed that the former expression will be the basis of the latter expression since productivity represents production values attained under ideal yield conditions. Local growth potential conditions are thus given regional validity.

The present investigation leads on naturally from the author's work of 1956 with global aspects. The present work concerns the geographically delineated area of Norden[2].

Leaving the large averages, we work instead with the individual data. By means of material now available it will be of special interest to investigate the extent to which the relationship previously found between climate and growth potential will prove valid. Attempts of improving the *CVP* index further will also be made. In a later stage of the investigation it is tried to express the soil factor which is correlated with production in a way corresponding to that of climate.

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[1] According to E. STRIDSBERG (1958, p. 436) the correlation coefficient has erroneously been given the value 0.69 in the work cited.

[2] In this work **Norden** includes Denmark, Finland, Norway, and Sweden. Iceland, also belonging to Norden, is here excluded.

[3] In the following **soil** is used in the sense of loose soil layers; subsoil = uneffected mineral soils; and true soil (or solum) decomposed by influence of atmosphere, plants and animals.

A combination of both variables, climate and soils, will then express the strongest relationship with the growth potential since they constitute the most important factors of production and the remaining contributory factors while chance will have a subordinate rôle.

According to the suggestion of the sponsor, the International Union of Forest Research Organizations permanent committee, on recommendation from FAO, the object of this investigation has been stated as "The study of site indices for determining the potential productivity of forests" (F. FIRAT, letter of March 18th, 1959). The international research party appointed for this purpose has later through its chairman, Dr. J. WECK, formulated its task to "evolve a suitable index for determining the potential productivity of forests" (J. WECK, letter in March, 1959). Thus the main research objects are partly to find a site index and partly to calculate the potential productivity of forest areas on the basis of this site index.

The plant physiological features of forest phyochorology

Assimilation, respiration, transpiration

The production of substance in the forests is governed by the plant physiological processes assimilation, respiration and transpiration (cf. H. POLSTER, 1950). In terrestrial plants a close relationship exists between assimilation and transpiration since the processes occur by means of common canals of gas exchange (stomata), and between assimilation and respiration since the energy required for the metabolism of the assimilation products is produced by respiration (ibid. p. 74. f). At a given temperature assimilation is strongly dependent on light whereas respiration is mainly conditioned by temperature (ibid. p. 44). Transpiration requires supply of water and is also influenced by light according to the relationship with assimilation mentioned above.

For reasons of plant physiology meteorological data primarily concerning light, temperature and water supply are therefore of special interest. This was the standpoint of the author in 1956 (p. 46 and 68). The choice of climate data was then limited by the requirement that they should be available wherever meteorological records have been kept. Thus they were to consist of simple temperature and precipitation data. When the investigation comprises a limited region which is covered with a long established net of meteorological stations, it is reasonable to expect that considerably more detailed data on light, temperature and water supply are available. However, as shown in the following presentation, this is not the case.

Carbodioxide assimilation

According to F. F. BLACKMAN (1905) the carbodioxide assimilation is composed of one photochemical process and a chemical process. Whereas the photo-chemical process is proportional to light intensity but independent of temperature, the chemical process, also called the "the Blackman reaction", is independent of light but increases with rising temperature. Assimilation is an interaction of these two processes (G. HYGEN, 1939).

The plant physiological importance of light

A comparison between the curves representing the photosynthesis and respiration of the plants clearly shows how the carbohydrate balance of the plants is regulated by both these physiological processes. The intensity of the photosynthesis varies with light intensity and species. Among the species it is distinguished between light demanding species and shade tolerant species according to their capacity of maximum photosynthesis under various light conditions.

This makes it necessary to separate species with different light reactions, e.g. Norway spruce and Scots pine, at phyochorological investigations of detail nature, particularly if light is brought into the discussion as a special factor of production. The necessity of considering the influence of light on various species has been stressed e.g. by the LADEFOGED investigations (1956, p. 490) of the water consumption per sq. m. foliar surface of the trees. The water consumption of oak is 2½ times that of beech at approximately 80 per cent daylight and otherwise equal conditions, but equal at low light intensity (10 %).

Light reaching the plants is composed of two kinds, direct and indirect light. Current meteorological observations are made at some Swedish stations only concerning the direct light. This is carried out by means of heliographs of various constructions, which register the duration of full sunlight. Expressions of the total light intensity and variations, however, are not obtained this way. The geographic occurrence and annual variations of the sunlight were treated by H. E. HAMBERG (1909), who developed a method of computing the number of sunlight hours from data on the basis of determinations of cloudiness collected at 3rd class stations. By a method corresponding to that used by Hamberg for a presentation of cloudiness and frequency of sunlight on the Scandinavian peninsula it would be desirable also to elucidate the seasonal and regional variations of the light intensity. A basis for such a presentation is lacking, however, and thus it is practically impossible at present to develop a phyochorological relationship involving the factor of light. As a substitute we must use the general observation based on experience that the intensity of light is to some extent directly proportional to and correlated with temperature. The relationship between light intensity and temperature, however, varies with latitude as well as altitude. This further amplifies the rough approximation inherent in the substitution of a temperature value for the factor of light because of deficient material of observation in conjunction with bio-climatic relationships. The relationship between light intensity and temperature can be rather uniform only within a limited range of latitude with small altitudinal differences.

The plant physiological importance of temperature

Temperature belongs to the most well-known elements of climate. Various types of mean temperature values for Sweden have been presented by H. E. Hamberg (1908, 1914, and 1922) and A. Ångström (1938). The temperature value most suitable for plant physiological circumstances depends on the nature of the subject matter. The complex composition of the plant growth power means different temperature reactions for the various components. This can be studied by means of the utilization of the assimilation products in plants. Thus, the major portion of the assimiliation products are immediately used for growth at high temperature whereas low temperature mainly means a storage of the products (H. Polster, 1950, p. 36). This also becomes obvious at a close study of the duration of e.g. the height and radial growth of the trees and their accumulation of stored nutrients. I. Hustich (1948) showed in his investigations of Scots pine in Finland that the height growth occurs in the late part of May and June in southern Finland and a month later in the northern parts of the country (ibid. p. 67). Radial growth is most vigorous in July (ibid. p. 66), foliage increment in July and in early August. In August the surplus of assimilation products are accumulated as stored nutrients. Other processes of differentiation in the cell division, too, are correspondingly tied to certain seasons. I. Hustich presented the following summary (p. 67): "During the first part of the spring the important *generative processes* occur while May—June is devoted to the cell elongation proper. July—August is the time for the *cell differentiation* and the formation and storage of reserve nourishments."

Earlier L. G. Romell (1925) carried out growth period investigations in Scots pine and Norway spruce. The observations made by S.-O. Andersson (1953), too, concerned the time of termination of the annual diameter growth in the same species. The results of these two investigations agree well with those presented by Hustich for Scots pine. The graphs published by Romell show that the strongest height increment in Scots pine occurs in May-June in southern Sweden and approximately 10 days later in northern Sweden with respect to the initial stage. In Norway spruce the most intensive growth occurs in June and the first half of July in southern Sweden whereas the process is restricted to June in northern Sweden. The radial increment Romell found to be simultaneous with that of height, the former process, however, extending over a slightly longer period and reaching into the month of August. Romell's statement that shoot development and radial increment are initiated and terminated under the influence of entirely different factors (ROMELL, 1925, p. 103) is remarkable in this context.

Diameter increment and its relationship with climate was also investigated by B. EKLUND (1957). He found the annual ring width variations in Norway spruce to be most strongly correlated with the number of days during the time May 16th—July 31st when the maximum temperature is at least + 16° C ($r = 0.72$, ibid. p. 24). Low temperature values for July—August exert influence by reducing the annual ring index in the next growing season (ibid. p. 53).

E. MORK showed in his work (1941) concerning the relationship between temperature and daily variations in the height increment of Norway spruce a remarkably strong correlation ($r = 0.90 \pm 0.006$, E. MORK, 1941, p. 83) between the temperature of the six warmest hours of the day and the height increment percentage (ibid. 1960, p. 235). He also stated good agreement between the curve for soil temperature at 2^{00} P. M. at a depth of 10 cm and that for the height increment percentage (ibid., p. 52).

The various physiological processes affecting or influencing the volume increment of trees apparently represent a complex set of factors greatly varying in heat requirements with time. The volume increment is a suitable aggregate expression of the interaction of these factors. The relationships between the volume increment and the increment of height and diameter, and the temperature value of July treated by I. HUSTICH in 1948 (p. 66), have been used as a basis for the following table. It should be noted that data pertain to Scots pine in northernmost Finland.

Table 1. The correlation between radial growth, growth in length, growth in cu. m. of the pine in Utsjoki-Enare and the mean temperature in Sodankylä

	Growth in length	Radial growth	Cubic growth	July temp.
Growth in length	—	0.09±0.22	0.72±0.11	0.23±0.21
Radial growth	0.09±0.22	—	0.63±0.14	0.86±0.06
Cubic growth	0.72±0.11	0.63±0.14	—	0.61±0.14
July temp.	0.23±0.21	0.86±0.06	0.61±0.14	—

It is rather surprising that the good correlations between volume increment and height increment, and between volume increment and radial increment are no higher. The determination coefficient (r^2) in the two cases is 0.52 and 0.40, respectively, which means that the variance of volume growth is determined by the variance of height and increment to an extent of 50 per cent and 40 per cent, respectively. The fact that no relationship between length increment and radial increment can be reported ($r = 0.09 \pm 0.22$) may be considered a vindication of the ROMELL statement, cited above, that the two increment processes are influenced by entirely different factors. While HUSTICH's measurements of the height growth were made on the shoots of the branches, the terminal leaders were measured by ROMELL (Norway spruce and Scots pine) and MORK (Norway spruce). This difference in measurement technique clearly affects the results. Thus, HUSTICH found no appreciable relationship ($r = 0.23 \pm 0.21$) between height increment and July temperature, whereas MORK (1941, p. 52) was able to present a very strong correlation between increment and the mean temperature of the six warmest daily hours of the entire growing season, as well as that of July. The difference between the temperature values obtained by these two research workers, however, may not play any major rôle in this context. MORK (ibid., p. 73) arrived at the conclusion that the monthly mean temperature of the six warmest hours of the day closely agrees with the monthly mean value of temperature at $2^{\circ\circ}$ P. M. Since the latter value approximately equals the maximum temperature of the day, we can consider the statement of O. LANGLET (1935, p. 396 ff) that monthly mean values of the daily mean temperature and those of extreme temperature values exhibit a nearly complete correlation. It is difficult to evaluate the importance of the difference in geographical location between the Hustich and the Mork areas of observation. A compilation of the observations of Romell, Hustich, and Mork seems to reveal no probable reasons for assuming that the difference in localities of observation should be of importance in this context. If the Hustich observations from a boundary forest region are applicable to a locality with more favourable climate, the conditions found by Hustich and Mork may indicate that the extension of branches and the height increment are influenced by entirely different factors. Thus, the importance of light for the height increment has been indicated by W. TRANQUILLINI (1959, p. 135), who found that increase in the height growth of Pinus cembra at an age of 25 years is a stimulus reaction caused by a reduction of the light supply in the densely and self-shading crown developed at that age.

The previous argumentation shows that an equalization of the responses of various species should be avoided in studies where height, length and volume growth are involved. This also pertains to Scots pine and Norway spruce as shown in the Romell investigation cited and in the analyses made here of the results obtained by Mork and Hustich. Detailed analyses of phyochorological work must consequently be treated separately for each species to produce satisfactory results and the dependence of primarily height and diameter growth on temperature should be closely investigated. According to

HUSTICH's investigations, the volume growth appeared to be most strongly correlated with the height growth (0.72 ± 0.11) and slightly more weakly with the radial growth (0.63 ± 0.14) and the July temperature (0.61 ± 0.14). Simultaneously, the relationship between the height growth and the July temperature was very weak (0.23 ± 0.21) but noticeably strong between the radial growth and July temperature (0.86 ± 0.06). In agreement with the previous discussion, these correlation conditions show that the volume growth produced at a certain site is a function of a radial growth heavily influenced by temperature and a height growth presumably regulated by a climate factor varying with the species. Light is probably this factor for Scots pine and temperature for Norway spruce. E. MORK provided evidences for the dependence of height growth of Norway spruce on temperature by presenting a close relationship between the six warmest hours of the day and the height increment percentage on fresh-moist sites with the correlation coefficient 0.855. The relationship is weaker on dry sites due to insufficient moisture.

The influence of solar radiation on the radial growth

Associated problems were elucidated by TH. WILHELMI (1959) in a work concerning the radial increment and its dependence on the solar radiation (direct + indirect light) and air temperature. The observation that the curves of solar radiation and temperature represented by relative numbers cross each other in the middle of the growing season seems to be most significant. Exhibiting high values during the first half of this time period, the solar radiation decreases rapidly during the latter half whereby its curve is changing position in relation to the temperature curve (Fig. 1). Wilhelmi explained this by the maintenance of temperature at a high level during the latter half of the growing season by wind-born heat supply. This, however, can only be a part explanation. Studying the radiation curve, we find it to climb rapidly in spring and early summer; it declines more rapidly in the middle of the growing season (mid-July) subsequently to descend slowly and nearly congruently with the temperature curve. This course is probably closely associated with the distribution of precipitation during the growing season. At Reinbek spring has deficient precipitation in relation to other seasons. Abundant precipitation is recorded toward the end of June and in July, which means a large increase of cloudiness in relation to that in spring, i.e. a decrease of light in addition to that caused by the passing of summer solstice.

According to the changes of climate, this inversion of the relationship between the relative values for temperature and solar radiation indicated by Wilhelmi may be expected to occur at various occasions, varying strength, or fail to appear altogether. **It must be considered an urgent task for re-**

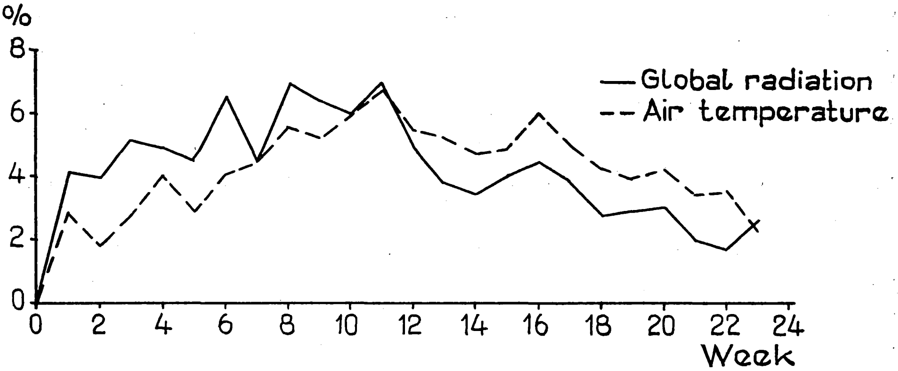

Figure 1. Solar radiation and weekly mean temperature of air in per cent of the total value of the growing season of 1957.

search in this field to enable a delineation of regions with equal temperature—light relationships by intensified collection of material. This would provide an opportunity to explore the potential specific features of the various species in their requirements concerning the factors discussed. It would be possible after such a delineation to incorporate for each species the results obtained into a bioclimatic regional division of the kind tried by the author in 1959 for forest cover types in general. A big step forward would then be taken toward a more definite knowledge of the formation of assimilated products and wood, which are two processes according to WILHELMI (p. 209): "Zwei voneinander zu trennende Prozesse, die miteinander wohl verbunden sind, deren einer aber von Strahlung und Temperatur abzuhängen, deren andere nur temperaturbedingt zu sein scheint."

The influence of the annual temperature range on vigour

Ignoring the annual variations in the bioeffect of climate and their importance for the special plant physiological processes expressed in height (length), diameter and volume increment, accumulation of nutrients etc., it can be concluded on the basis of the present standpoint of research that the temperature of the warmest month during the standard period (T_v) is the best and most easily available expression of the influence of the temperature climate on the forest growth power. The effect of the mean temperature of the warmest month, however, is dependent on the preceding and succeeding development of the vegetation. The temperature amplitude (T_a) here enters the picture as an important factor. It expresses the range between the mean temperature values of the warmest and the coldest months of the year. The daily amplitude will not be used in this context since its influence seems to change from positive to negative. Thus, a small daily amplitude in climate with equal daily temperature and in one case equal length of day and night is expressing an inferior balance of substance production, but a superior balance in the second case with light during the main part of the day. The variability of the magnitude of nightly respiration with the conditions discussed is a reason for this.

According to the definition, the annual amplitude can have a minimum value of zero, i.e. the mean temperature values of the warmest and the coldest months are equal. In this situation T_v is an expression of the most growth promoting temperature climate occurring within the equatorial regions. The ratio $\frac{T_v}{T_a}$ is then infinite. As the T_a-value rises this ratio steadily decreases toward fractions of digits thus indicating the growth potential decreasing influence of the winter cold. If the mean temperature of the coldest month (T_k) had instead been used in this case, the result would have been entirely different. At equal values of T_v and T_k, i.e. equatorial conditions, the ratio equals one. If an example is taken for comparison from a temperature region where $t_v = 16°$ C and $T_k = 1°$ C are commonly associated temperature values, the ratio becomes sixteen times that obtained in the first example. This would mean a temperature climate in the temperate region more suitable for plant growth than in the equatorial regions.

This complex of matters has previously been discussed by the author, who then presented the following view points (ST. ST. PATERSON, 1957, p. 384): "The higher the ratio $\frac{T_v}{T_a}$ the more even and higher is the heat supply during the year. In Germany T_a varies between 16° C and 20° C whereas T_v simultaneously changes but slightly, thus the ratio $\frac{T_v}{T_a}$ may be considered nearly constant. This explains why T_a lacks importance according to Weck. In Sweden, however, T_a fluctuates between the values 17° C and 27° C (in the present material between 16° C and 29° C, author's remark) and is associated with corresponding magnitude of differences between T_v values for the extreme stations (10° C—18° C, author's remark). This will be still more accentuated in Soviet Asia, where T_a varies between 23° C and 65° C and T_v between 4° C and 32° C. It is logical that the temperature ratio must decrease at increasing latitude and deepening continental situation as shown by the examples. We need only consider the heat quantities used in spring for the smelting of snow masses and thawing of frozen soil, i.e. heat otherwise available for plant growth." (cf. also F. LAUSCHER, 1958, p. 102.)

The influence of soil temperature on vigour

Water and precipitation in solid form have great importance for growth power by releasing or binding large amounts of heat. Associated effects influence both air temperature and in a still larger extent soil temperature. The latter temperature has a direct and strong influence on the length growth of plant roots. The comprehensive investigations by K. LADEFOGED (1939) showed that the length growth increases according to a geometrical sequence between 2° C and 14° C, after an arithmetic succession between 14° C and 24° C finally to culminate at 26° C. The maximum mean soil temperature in Sweden at a depth of 20 cm is approximately 16° C, in northernmost Sweden at Kiruna not even 10° C (A. ÅNGSTRÖM, 1946, p. 54). The main part of the country is consequently characterized by low soil temperature values that only exceptionally and for a short time of approximately one month reach the values most inductive to root growth. Root hairs are the tree organs most effectively absorbing water; occasionally mycorrhiza may be more important. Since their development is associated with the root growth, the relationship between the transpiration flow, i.e. the means of nutrient transport and the temperature regulator of the plant, and photosynthesis is clear.

Although sufficient material is lacking for a close investigation of the relationship between soil temperature and $\frac{T_v}{T_a}$, conclusions regarding the existence of such a dependence can be drawn logically. The relationship is strengthened as well as that with the growth potential if a factor describing the slope of the temperature curve at the annual flection between the turning points that define amplitude is added to the previous ratio. The range of the curve located above the temperature limit and expressing the lowest heat supply necessary for the existence of plants is then of particular interest. The factor sought is an expression of the length of the growing season.

The length of the growing season and its influence on vigour

The growing season is a term to be defined flexibly. Definition will change according to the character of investigation and the special view points attached to what shall be considered a plant physiological limit of the beginning and the end of the growing season. From a forestry point of view it may here be preferred to choose the time when the root activity is noticeable, time between bud bursting and leaf fall or between flowering and leaf fall. It is more difficult to establish the growing season according to the time when the basic life processes, photosynthesis, respiration and transpiration occur. Although these processes should logically constitute the safest basis, they cannot be used since they occur also during winter under certain conditions. This has been stated by e.g. L. IWANOFF (1924) in his classical work concerning the winter transpiration and by R. O. FREELAND (1944) in a study of photosynthesis and respiration.

Apparently, the principles for the computation of the growing season vary greatly. Here, only some examples will be mentioned:

E. A. MITSCHERLICH found (1933) that the plants require a mean temperature of minimum + 5° C for their growth during the growing season.

K. RUBNER stated (1934) a close coincidence of the timber line and the 60-day isotherm for 10° C. These values have then been used as base minimum values for the heat requirements of forest trees as well as for the length of the growing season. Exceptions are the alpine areas, where these values are lower due to the increased importance of the solar radiation temperature at rising altitude.

A. ÅNGSTRÖM (1946) considered the time of the year during which the mean daily temperature exceeds + 3° C to constitute the growing season. This temperature value was chosen on account of its close agreement in time with the start of spring farming and the end of autumn farming.

W. LAUER (1952) developed E. DE MARTONNES aridity index of 1926 for areas with arid season (s) to elucidate the moisture conditions of the individual months. The growing season thus comprises an aridity index of 20, the latter value is computed from the function $i = \frac{12\,p}{t + 10}$, where p is the mean monthly precipitation and $t =$ the mean monthly temperature.

Scrutinizing the Rubner values described above, A. AUSTIN MILLER found superior agreement between the timber line and the isoline suggested by A. F. SCHIMPER for the months exceeding + 6° C. This value has subsequently been used for a computation of the minimum requirements of various forest types with respect to the length of the growing season.

F. BAGNOULS and H. GAUSSEN (1953) and successors found the relationship $P \leq 2\,T$ agreeing with the plant ecological conditions to indicate an arid month ($P =$ precipitation, $T =$ temperature, both factors pertaining to monthly mean values). The growing season will then comprise the number of months when $P > 2\,T$.

A large number of additional methods of computing the length of the growing season have been presented. Among the wellknown ones are those developed by C. W. THORNTHWAITE, D. SZYEMLIEWICS, C. H. MERRIAM, L. EMBERGER and A. GIACCOBE. A closer discussion of these methods, however, would be superfluous in this context. Summary descriptions of works in this field are presented by L. EMBERGER (1955) and perhaps most comprehensively by K. KNOCH and A. SCHULZE (1954).

In the *CVP* index suggested for global aspects (1956), the author used two different, mutually supplementary systems for a determination of the length of the growing season. Depending on the minimum factor with respect to vegetation (heat or water), either the temperature limit of + 3° C developed by Ångström and cited above, or the Martonne-Lauer method of compiling the aridity was used. Furthermore, a minimum growing season of two months with a minimum mean temperature of + 10° C according to Rubner was required (cf. ST. ST. PATERSON 1956, pp. 93, 98, 101, 102, 103, 106 a.s.o., foot note 1 and map, Fig. 17, p. 108). The work published by the author also showed " that a growing season of at least three months is necessary to make it possible for forests to exist at the border of the dry desert" (ibid., p. 183).

Reviewing the author's work of 1956, J. Weck wanted to define the growing season according to Rubner + 10° C as follows (J. WECK, 1957, p. 224): "Zur Vegetationszeit zählen die humiden Monate, woweit sie die Mindestdurchschnittstemperature von + 10° C erreichen: die Mindestvegetationszeit für Entwicklung und Dauer natürlicher Wälder beträgt 2 Monate." — According to a definition suggested by J. PARDÉ (1958, p. 201; 1959, p. 50) and based on the conditions prevailing in France the growing season is defined as follows:

"1° en zone non méditerranéenne, de compter comme mois de végétation active ceux pour lesquels la température moyenne mensuelle est d'au moins 7°;

2° en zone méditerranéenne, de porter cette limite inférieure à 10°, en défalquant de plus les mois pour lesquels la pluviosité en mm est inférieure à deux fois la température moyenne mensuelle en degrés centigrades."

Due to the detail character of the present work, the author has aimed at finding the most accurate material possible for further compilation. From this point of view, months are too crude time units for measuring the length of the growing season. A measurement in no. days would be desirable. An extraordinarily good method of computing the no. days is available in the climate graph developed by H. Walter and in summarizing investigations by Bagnouls-Gaussen, Seljaninow and Walter (H. WALTER, 1955). The number of days comprised in the growing season can here be obtained graphically whether thermally or hygrically limited.

The matter of choosing temperature most suitable for the computation of the number of days now remains. Methodically, the choice is determined by the covariable of temperature brought into the picture. A literature review shows that the most commonly used covariable has been based either on various kinds of plant ranges or on different kinds of fenological observations. Both methods have their disadvantages.

Concerning plant ranges there is a great inaccuracy in ascertaining the border lines since one is dependent on the current conditions. The conditions, however, need not represent the virgin state of nature but can be more or less influenced by man and animals. Thus, a relationship between such a boundary and a temperature value is not true but variably depending on chance.

Concerning the externally visible stages in the annual rhythm of vegetation which constitute the phenological observation material, the weaknesses are entirely different. As a variable we select one certain part process of the large complex of plant life. Our observations will pertain to a detail of plant growth of which we are unable to say definitely whether it expresses the most feasible relationship with the growing season. We need an expression of this time which is closely related with some general status of physiology.

In his studies of the relationships between climate and the physiological variability of Scots pine, O. LANGLET (1936) produced results, which are very interesting in this context. Using 39 Scots pine strains for which normal values of dry matter content had been determined, this worker found the best relationship with the number of days with + 6° C and + 8° C when comparing dry matter content and various temperature values. The number of days with higher and lower temperature values displays greater dispersion. According to Langlet, the choice between + 6° C and + 8° C is unimportant but he simultaneously stated that + 6° C better agrees with "the presumptive growing season" of the conifers (O. LANGLET, 1936, p. 340, ff).

Resting on physiological reasoning, this temperature value of Langlet agrees with corresponding, differently calculated temperature values suggested by J. Pardé (+ 7° C) for non- mediterranean regions and by A. F. Schimper (+ 6° C). The author has therefore settled on 7° C as a limiting value for computing the length of the growing season. Moreover, the growing season must comprise at least three months with a mean temperature of + 6° C. It should be noted, however, that this temperature value is calculated on the basis Scots pine material. It must therefore be assumed vaguely that the same physiological temperature reactions occur in Norway spruce and birch, which are also represented in this material.

The determination of the length of the growing season has been carried out by means of the climate diagram designed by H. Walter and discussed above (p. 17). Such a climate diagram has been constructed for each meteorological station presented in Tab. II, a total of 467. For reasons of limited space all of these have not been included here but are found on the sheet "Northwestern Europe" in "Klimadiagramm—Weltatlas" (Climate diagram—World Atlas) under edition by H. WALTER and H. LIETH. One graph only, 141

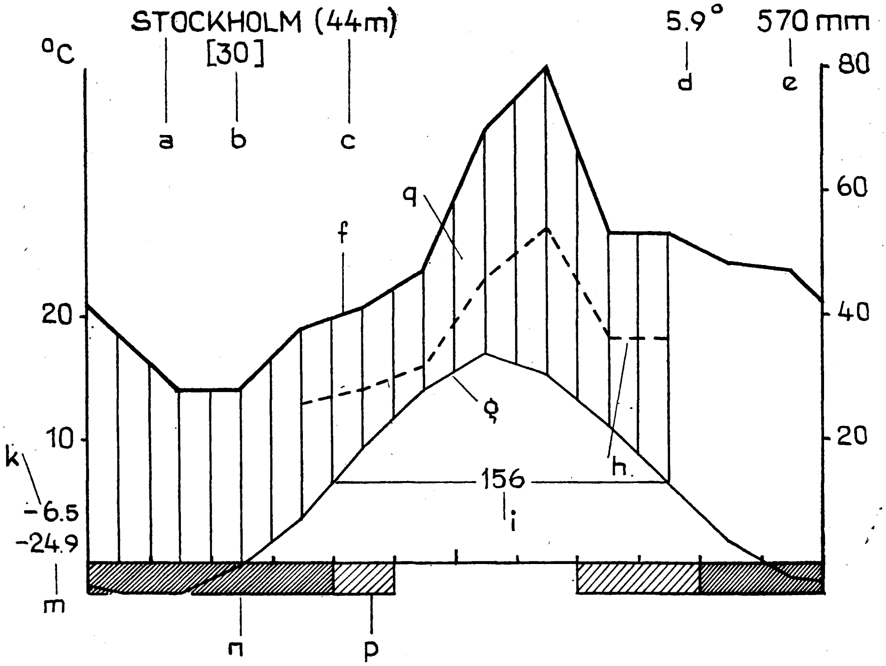

Fig. 2. Climate diagram of Stockholm. Design pattern of a climate diagram. The letters stand for:

a = station
b = no. years of observation
c = altitude
d = mean annual temperature in ° C
e = mean annual total of precipitation mm
f = mean monthly values of precipitation
g = mean monthly values of temperature
h = precipitation curve in the scale of 1: 3 (1° C = 3 mm)
i = growing season (no. days), Figures below as T 25 (10) mark dry and arid period, respectively
k = mean minimum of the coldest month
m = absolute minimum
n = month with a mean minimum temperature below zero centigrades
p = month with absolute minimum below zero centigrades
q = humid period

Stockholm, is shown (Fig. 2) for a description of its contents and the practical procedure used when the length of the growing season has been determined.

The importance of water for plant life

Water is the last of our three factors presented as important for plant life. The importance of transpiration for the production of substance and the relationship between carbodioxide intake and transpiration has already been stressed in the introduction to this chapter against the background of both processes having common gas diffusion canals. Water furthermore constitutes the solvent for soil nutrients; it carries the assimilation products within the plant; it protects the organs of photosynthesis against damaging high temperature caused by heavy solar radiation, by releasing heat at the transpiration process, and it participates directly in the assimilation process since the formation of a carbohydrate molecule requires the presence of two molecules of water (E. C. WASSINK, 1956, p. 295).

The consumption of water is different in various plants and plant cover types. Moreover, one plant individual has the capacity of adapting its water requirements within certain limits, particularly with respect to temporary changes in the relationship between temperature and precipitation. Certainly, a genetical adaptation of the plants to their environment is the background of these circumstances. The natural water balance in vegetation has been subject to special investigations by e.g. K. LADEFOGED (1956), O. STOCKER (1931, 1933, 1935, 1956), M. G. STÅLFELT (1934, 1935, 1956) and H. WALTER (1939). Similar studies carried out by A. PISEK and E. CARTELLIERI (1931, 1932, 1933, 1939, 1941), U. BERGER-LANDEFELT (1935), M. HENRICI (1937 ff) a.o. have had a more regional (Landschaft) ecological character. The figures presented regarding the requirements of the plant cover all lack accuracy with respect to the absolute figures, but as a basis of relative values they provide a good picture of the mutual magnitude (cf. P. FILZER, 1951, p. 82, ff).

The supply of water is better known than the plant consumption of water. The measurements of precipitation carried out at the meteorological stations are our most common source of information in this respect. This information is very important since it describes the hygrometric character of a region and thus also the shaping of plant cover types. Growth potential increases with rising precipitation to a certain upper limit, where additional humidity has an opposite effect. It will then be questioned whether this influence on the growth potential is caused by the total annual precipitation or by certain parts thereof. This point may be elucidated and the following circumstances must be considered in particular: the length of the growing season, the ombrothermal situation and the condition and availability of the soil water reserve for plant growth during the same period of time. The length of the growing season varies for different plants. The possibilities of utilizing the soil water reserve during dry periods by means of the capillary movements are greater for a plant cover with deep root system than for plants with a shallow root system, cf. K. LADEFOGED, 1956. Generally, too, the perennial plants are more dependent on the annual precipitation, which regulates the water table, than are the annuals, which are presumably most dependent on a certain period of precipitation. The level of the water table at various times is decisive in this context. Under ideal conditions this level is always sufficiently high to constitute a reserve of water. Simultaneously good drainage will prevent this soil water from becoming too high and detrimental to the respiration of the roots. The ideal situation, however, is rather uncommon in nature. Variably large fluctuations occur both as an annual rhythm and as temporary disturbances on account of e.g. abnormal rainfall or total deforestation within an area.

Both the annual precipitation and the precipitation during the growing season are consequently of importance from a silvan point of view. Considering purely Nordic conditions with current regional changes in the hygrometric climate, we find two different regions. The larger one is characterized by precipitation in sufficient amounts for plant growth during all the months of the year. The smaller region extends along the coast of the Gulf of Bothnia touching the Åland area when passing into the Baltic Sea and continuing southward along the coast all the way to the point of Falsterbo, swinging over on the south side of the isle of Sjaelland and northward along the strait of Stora Bält, further along the east side of Jylland finally to peter out at Læsö. Fig. 18 shows it to be a narrow coast zone in one point only reaching a width sufficient to enclose the isles of Gotland and Öland. From a hygrometric point of view this zone is characterized by such low values of precipitation in relation to temperature during a variable part of the first half of the growing season that drought occurs.

The occurrence of dry and arid periods within the area of investigation

The ombro-thermal curve relationship such as presented in the H. Walter climate diagram has served as an indicator at this regional division. This is primarily based on the observation made by H. GAUSSEN within the mediterranean area that plant growth enters into dormancy because evapo-transpiration exceeds precipitation. This results in drought as soon as the ratio of temperature when doubled exceeds precipitation (cf.Fig.2). Seljaninow has shown for eastern Europe that a change of the ratio to 1: 3 produces the limit between the humid forest region and the dry forest steppe (H. WALTER, 1957, p. 224 f). The scale ratios express two degrees of drought both of which are termed separately in the German language. "Dürrezeit" thus is the extreme drought season, whereas "Trockenzeit" is a moderate drought. An adequate translation of these German terms to Swedish and English is difficult since no corresponding words can be found. The author, however, will here use the word arid in the meaning of "dürr" and dry for "trocken". In the English text "Klimadiagramm — Weltatlas" H. WALTER and H. LIETH use the expression arid in the same sense as that suggested here, but no translation is given for "trocken". Consequently arid is strictly defined on ombro-thermal basis.

According to the previous discussion, we may state that an ombro-thermal climate type corresponding to that of the forest steppe occurs within Norden. The drought season occurs in summer. In the extreme north of the Gulf of Bothnia the drought season occurs in July but is advanced with southerly latitude to comprise the month of June and even parts of May as at Falsterbo and Denmark. Small areas with drought period occur locally in Norway and in one location, Ulstad, even with arid spells. The dry locations in Norway are situated in the innermost parts of the fjords or in deep valley bottoms where high mountains deflect precipitation. The village of Lärdal, at the innermost Sognefjord has a drought period beginning in April and ending no sooner than July, i.e. a total of 108 days. This is the longest drought season recorded in the Nordic countries. It usually amounts to maximum 1½—2 months (yet, Hoburg on the isle of Gotland has 81 days, Ulstad in Norway 87 days and Kysthospitalet in Denmark 97 days). The map on p. 40 shows the number of days included in the drought period at the stations concerned.

The knowledge of the length of the drought period and its geographical location puts the relationship concerning the water management in forests in an informative light. The thermally determined growing season appears to be an insufficient definition of the time factor when included in a mathematical expression of the growth potential. A drought period, which occurs like here during the growing season, means a deficient supply of precipitation in the forest. If this deficit is not compensated, the growth will be reduced, i.e. yield lowered. The only possibility for the trees to cover their demand for water in a situation like this is a supply of either capillary soil water or of a reserve of free soil water. Both these types of water supply can consequently prevent a reduction of the growth potential caused by a drought period. The relationship between the length of the drought period and the amount of capillary water and free soil water will here be decisive. The importance of the capillary soil moisture for plant growth is great, which has been elucidated e.g. by H. HOLSTENER-JØRGENSEN'S investigations (1955, 1956). The discussion between him and C. M. MØLLER (1956), E. OKSBJERG (1956) and M. G. STÅLFELT (1956) further shows a complicated relationship between the capillary water and the free water as influenced e.g. by the vegetative cover, soil texture, humus content and layer density. The argument indicated the necessity of continued research efforts in this field. Special importance is here attached to the amount and duration of the capillary supply of water under the influence of an ombro-thermal drought period. A methodically important contribution to our knowledge of the water consumption of the trees and its dependence on light, air humidity, wind, temperature and soil moisture was furnished by K. Ladefoged (1956). He showed e.g. how a sufficient amount of water for the trees in clayey, sandy and gravelly soils was consumed so rapidly after about three weeks in a drought period that the water intake decreased by 38 per cent on clayey soils and 44 per cent on gravelly and sandy soils for beech, by 67 per cent on gravelly and sandy soils for oak and by 59 per cent on clayey soils for ash (K. LADEFOGED, 1956, p. 499).

As stressed in an other context, special attention must be paid to the seasonal changes in the water table when estimating the forest yield conditions of a site within the region of the drought period. Features such as topography, soil composition, depth of the soils and distance to the bedrock are influential in addition to precipitation.

Improved knowledge of the free soil water conditions therefore requires field investigations within the areas concerned. To elucidate the set of problems generally, it may be mentioned that the precipitation recorded prior to the drought period closely affects the supply of free soil water. Connection with humid areas by a variably developed system of rivers also has an influence.

Considering the conditions in Norden the following observations may be discussed here.

The longest drought periods in Denmark occur on the isle of Bornholm, in northwestern Sjælland, on the isles of Anholt and Læsö. The growing season there varies between 177 and 187 days, one seventh to half of which is drought period (27—97 days). In the extreme case, Kysthospitalet, Fig. 3, with a growing season of 186 days and a drought period of 97 days, this means reduced growth potential conditions from an ombro-thermal point of view from the beginning of the growing season to the month of August. Low values

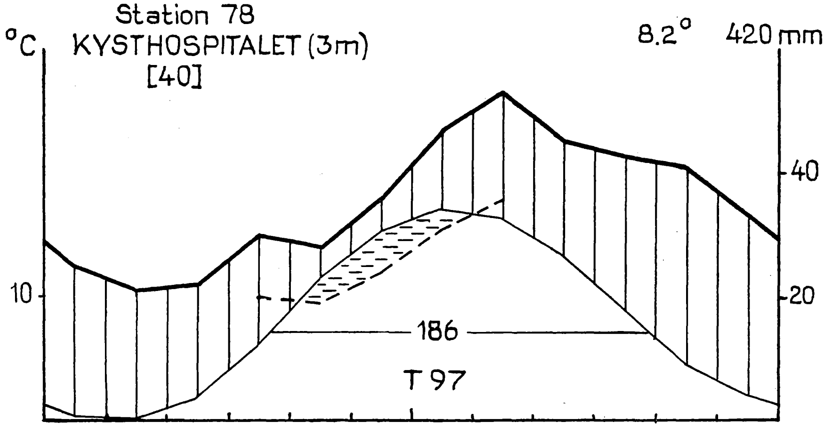

Figure 3. Climate diagram for Kysthospitalet, Denmark.

of precipitation (between 20 and 30 mm) occur earlier in the year and only November and December present slightly higher values, 41 mm and 33 mm, respectively. Moreover, the mean temperature of the coldest month is above 0° C (+ 0.1° C).

No long lasting disturbances thus occur in the natural circulation of water by storage of moisture in the forms of snow or ice (frost). Sudden changes between periods of frost and thaw in winter may possibly cause increased surface runoff. The moderate rise of the water table in the autumn is consequently reverted during February or March to become normal at the beginning of the growing season, which means a low reserve of free soil water. The long drought period (over three months) will therefore exert a strong influence on the forest growth.

Although more moderately expressed, similar conditions are also encountered within other parts of the drought region, which surrounds Jylland almost entirely. Since we deal with mean values comprising 40 years, the delineation cannot be considered accurate but more of a centre line in a fluctuating boundary zone. The whole of Denmark is consequently exposed to the risk of years with variably long drought periods to a considerably greater extent than are regions situated farther away from the drought region.

To elucidate this matter, we will select two stations, one at Askov within the region in Denmark with the highest rainfall, and the other at Hammershus, belonging to the areas most typical for this drought region. We shall study the annual fluctuations of the ombro-thermal conditions for each station by drawing a number of climatograms (cf. H. WALTER, 1955). Thus, we will investigate the extent to which drought periods affect the more humid station and how often they fail to appear where they are expected to occur normally.

The climate diagram for Askov (Fig. 4) gives the picture of an average climate with distinct humid conditions. Although spring has the lowest precipitation, it still has rainfall sufficient to provide a good margin over the limit of drought period. Details behind the 40-year mean values, however, exhibit rather frequent changes in the ombro-thermal conditions. This is shown in Fig. 5 by the climatogram for each of the years 1916—1925 comprising a randomly selected 10-year span during the basic period 1886—1925. Of the ten climatograms only one, that for 1923, shows no drought period. Nearly similar is the year of 1916, which has a drought period for almost a week in September. The remaining eight years all show a drought period as well as an arid spell of variably serious extent. The severest drought occurred in 1921 when it comprised 96 days (63 of which arid) of the 195 days of growing season. The extent to which the soil water and free water may be able to protect tree growth from detrimental effects is a matter intimitely connected with the amount of previous precipitation. Depending on the rate of surface

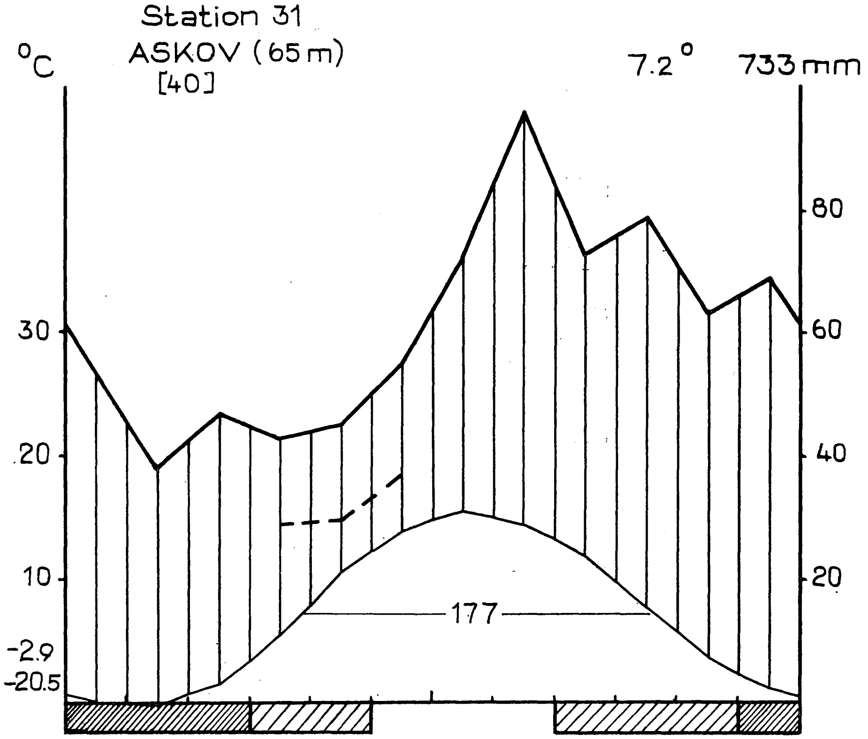

Figure 4. Climate diagram for Askov, Denmark.

runoff and the soil water movements, both autumn and winter rains will here be important and consequently show strong relationships with the growth potential manifested during a drought period. This relationship may then pertain either to one or several months.

Hammershus on the isle of Bornholm is represented by a climate diagram showing a drought of 36 days during the 180 days of growing season (Fig. 6). The drought period mainly occurs in the month of June. During the previous part of the year a very moderate precipitation amounting to about 35 mm a month is recorded. Minimum rainfall occurs in the period August—December. Whether the more abundant water supply of this period is able to replace entirely or partly the moisture deficit of the drought period is a matter not possible to analyze in this context. However, the question whether the drought period occasionally fails to appear during the climatic changes of the year may be elucidated. Moreover, the length of the drought spell during an extremely rain poor period of the year is of interest. The years of 1921 and 1923 will here be considered for comparison. The former year shows for Askov

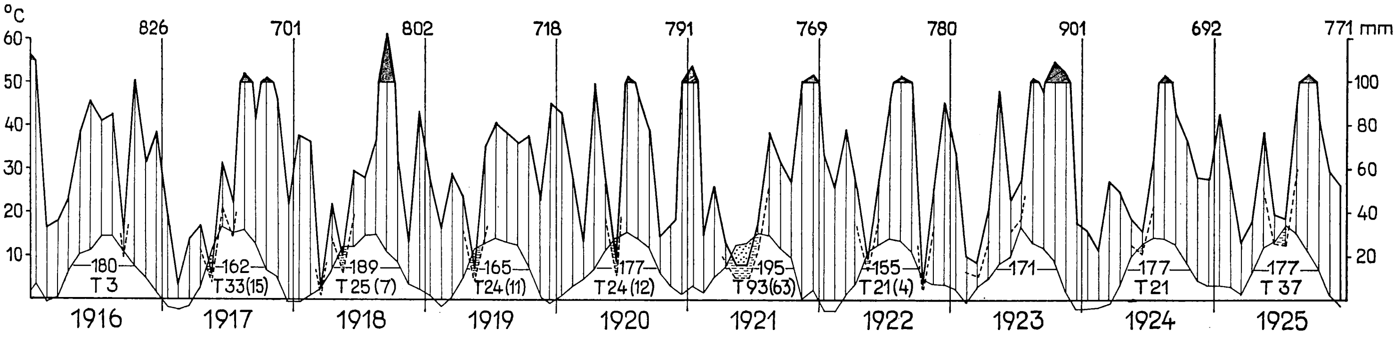

Figure 5. Climatogram for Askov, Denmark, years 1916—1925.

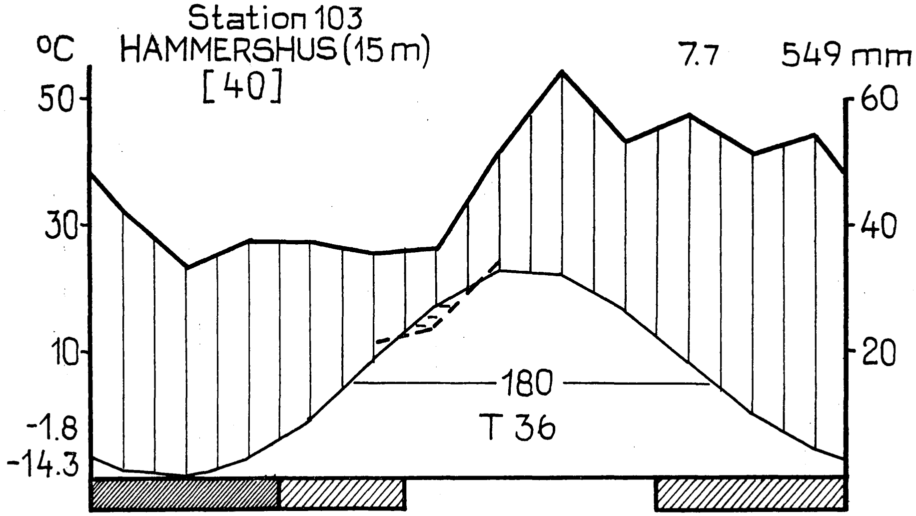

Figure 6. Climate diagram for Hammershus, Denmark.

the longest drought period of the 10-year span whereas the latter year has no such period at all. At Hammershus the year 1921 contained a drought period of 135 days in a growing season of 192 days (cf. climatogram, Fig. 7). We must consequently count on such a long reduction of the growth potential that the minimum limit of tree existence is passed unless the supply of capillary moisture and free soil water is sufficient. This, however, does not seem to have been the case in 1921 since this year was characterized by a very dry beginning where only the month of January displays a normal value of precipitation after the dry autumn of 1920. The growing season 1921 must therefore have been entered with an abnormally low soil moisture and low water table.

Unusually heavy precipitation was recorded at Hammershus, as at Askov, (cf. climatogram, Fig. 5,7) in 1923. Nevertheless, the drought period is still noticeable although postponed to the month of July and comprising 9 days only. Its effect on tree growth may be judged as minor on account of the humidity surplus of the preceding months. During the 53-year observation period 1873—1925 a study of temperature (Climate of Denmark, 1933, p. 115) and precipitation (ibid., p. 192 f) shows that no single year displays an entirely humid growing season.

The ombro-thermal situation in Denmark may be summarized as follows: Parts of the country are located within a dry region with a drought period concentrated about the month of June. Other parts are strongly influenced by their closeness to this dry region as manifested by the frequency of years

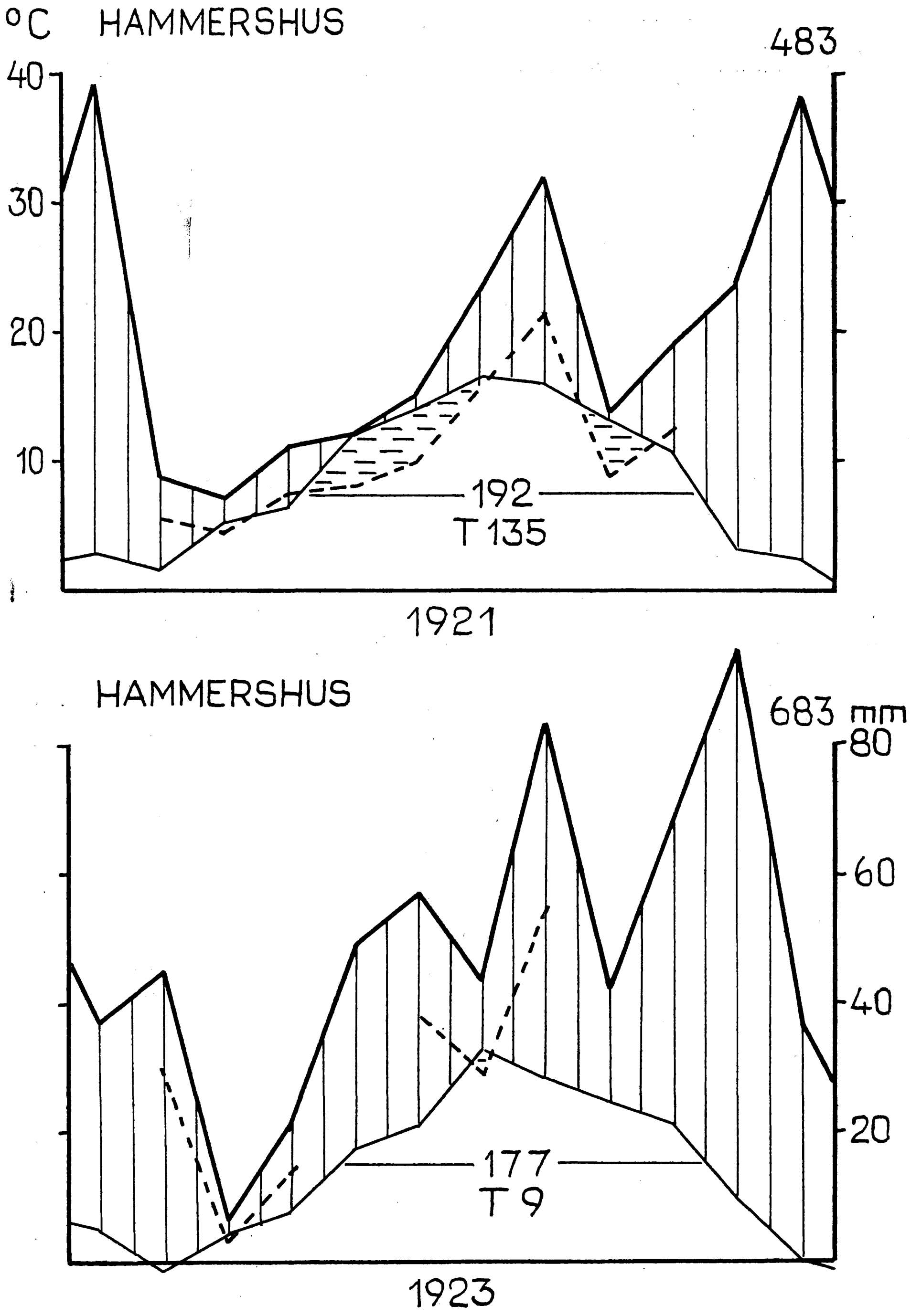

Figure 7. Climatogram for Hammershus, Denmark, years 1921 and 1923.

with drought periods. During the drought spells the growth potential of the trees is dependent on the supply of capillary moisture and free soil water. If this supply of water is deficient, the growth potential is reduced. Precipitation is consequently a periodic minimum factor which means that a certain relation may be expected between the precipitation of one or several months and some indicator of growth potential. This has been shown by E. HOLMSGAARD (1955), who found a certain correlation between the variations of the annual ring width and those of precipitation for the month of June and July. Since the annual ring formation mainly occurs during this period, the result of Holmsgaard seems to be reasonable. It would be interesting in this context to check whether length growth, which mainly occurs in May and June, shows a corresponding correlation with the precipitation of these months.

The longest drought periods in Sweden occur on the isles of Gotland and Öland. They are most extreme at Hoburg on the southern point of Gotland, where they comprise 81 days. This is exactly half of the growing season in the first half of which the drought period occurs. This drought spell may consequently affect particularly the height growth of the trees but also the annual ring development. This situation is typical of the conditions prevailing on the isle of Gotland. The nearby isle of Öland immediately constitutes an improvement in this respect since the drought period here occurs no sooner than three weeks after the beginning of the growing season. Length growth can therefore continue relatively undisturbed. This is the case to a still greater extent within the northern part of the dry region where the drought period usually occurs in the month of July. Potentially, this may affect diameter growth only.

Views discussed above are based on values representing the average conditions of climate. A preliminary evaluation of the variably strong dependence of the growth potential on this medium is possible if the annual changes of the ombro-thermal curves are studied for both the dry and the humid regions. The author has therefore drawn a profile line from the dry region at Kalmar through the humid region over Växjö to Borås. For comparison and for later use in this investigation the locality of Östersund, too, was studied. This place is situated within an area with precipitation maximum in summer (August) — (ST. ST. PATERSON, 1959, p. 117). The frequency of dry periods within the humid region and the occurence of entirely humid growing seasons within the dry region will be discussed as has been done with regard to Denmark.

The climate diagram for Kalmar (Fig. 8) shows a 21-day drought period in the month of July. Since the months of May and June furnish a very slight precipitation surplus, water table and soil moisture may be assumed low already at the beginning of the drought period. Especially on sites with

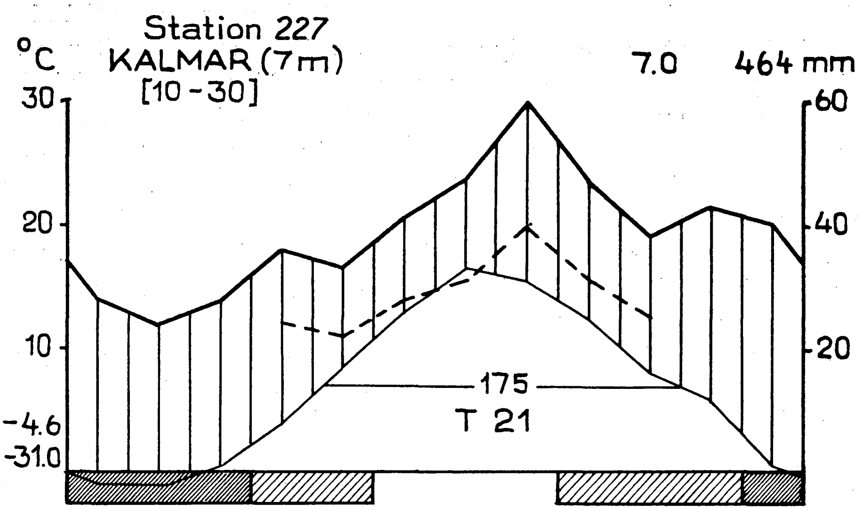

Figure 8. Climate diagram for Kalmar, Sweden.

shallow soil, drought must have a strongly reducing effect on the growth potential and particularly on its diameter growth component. The climatograms of the 10-year period 1916—1925 (Fig. 9) confirm the validity of the average with respect to the individual years as well. No year lacks drought period. The humidity deficit in its ombro-thermal cover is so great that genuinly arid conditions occur in nine out of ten years. The length of the drought periods varies between 39 days (1922) and 156 days (1921). The duration of the arid period fluctuates between 0 (1924) and 117 (1917, 1921). Thus, under extreme conditions only 30 days remain of the growing season when growth can proceed under favourable ombro-thermal conditions. The low annual precipitation and its seasonal distribution strongly confirm the assumption that capillary moisture and free soil water can eliminate only to a minor degree the negative effect of drought on plant growth.

The locality of Växjö, situated in the interior of the country shows a hygrometric status of genuinly humid character (climate diagram Fig. 11). Although the ombro-thermal curves are well separated, their courses infer a certain risk of drought period also in September. The climatograms of this 10-year period show that this is the case (Fig. 10). Drought periods occurred during seven of the years, five of which in the month of May. Four years display arid spells the duration of which extends over maximum 72 days (1921) in a drought period of 105 days. In the same year the growing season comprised 186 days. This extreme year thus shows an ombro-thermal situation when the trees are forced to a 72-day dormancy and a period of 33 days with reduced

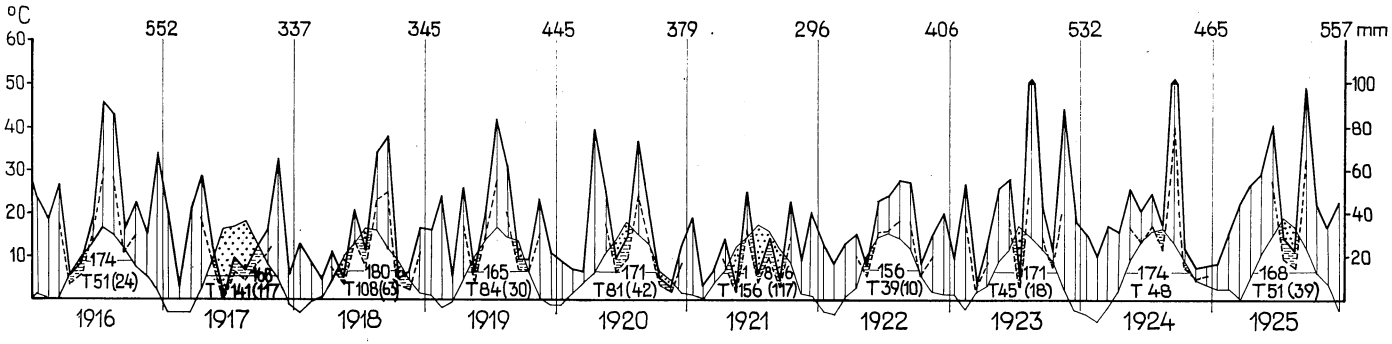

Figure 9. Climatogram for Kalmar, Sweden, years 1916—1925.

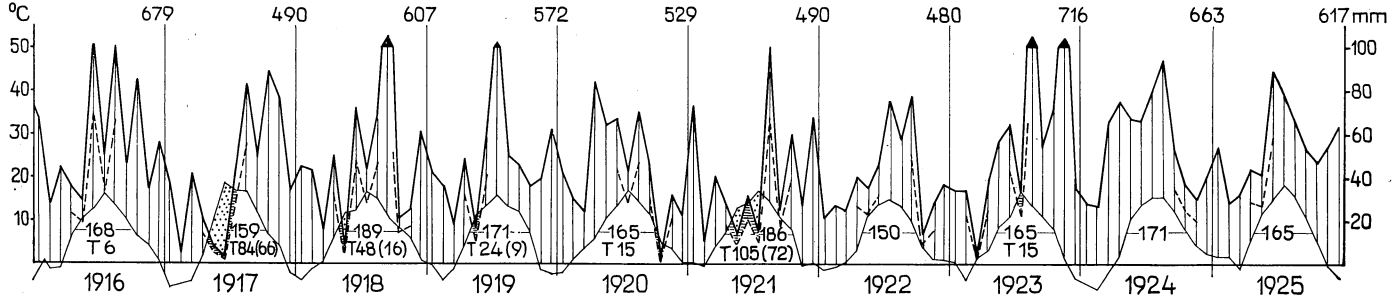

Figure 10. Climatogram for Växjö, Sweden, years 1916—1925.

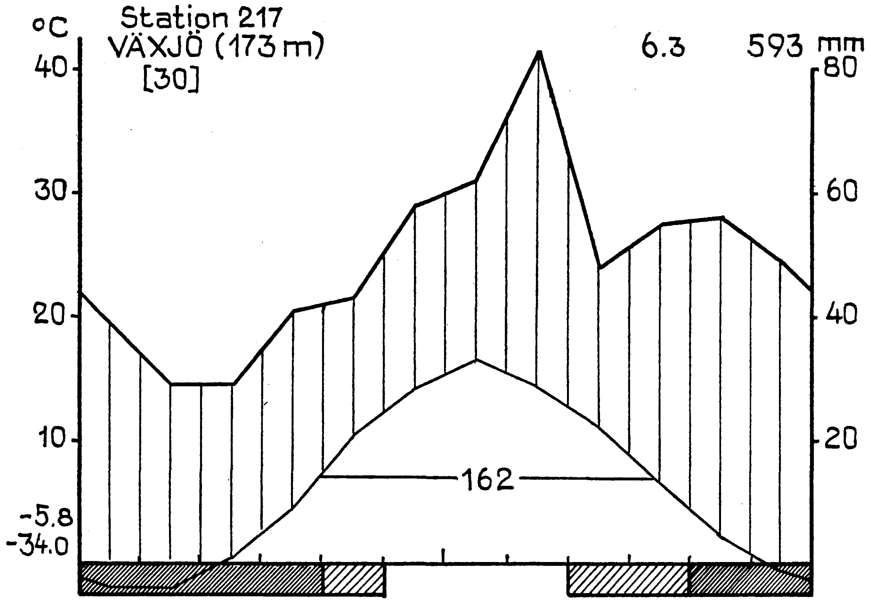

Figure 11. Climate diagram for Växjö, Sweden.

functions—all during the beginning of the growing season. Only 81 days remain with conditions favourable for growth. It is again clear that the soil water will be the saving factor in a disastrous situation such as the one reviewed. The extent to which the soil water is able to fill this function can only be elucidated by a special field investigation. The climate diagram Fig. 11 can now be used only for a statement that winter constitutes a storage of approximately 200 mm precipitation. It is uncertain how large a portion of this amount remains in the form of soil water at the beginning of the drought period.

The city of Borås is located within the high precipitation area in southern Sweden. The climate diagram (Fig. 12) consequently describes highly humid conditions. The indentation of the rainfall curve in May, however, manifests a certain errancy of precipitation during this period, which is also shown by the climatograms, Fig. 13. During the 10-year span chosen, four years have had drought periods three of which had arid elements, frequently in the month of May. The longest drought period comprising 30 days, 17 of which were arid, occurred in 1918. In comparison with Kalmar, Hammershus and Askov the humidity of Borås is a considerable fact. The incidence of drought periods is here more rare and of such a short duration that no risks occur with respect to growth potential reducing effects. The high amounts of precipitation recorded during the other parts of the year will be an insurance.

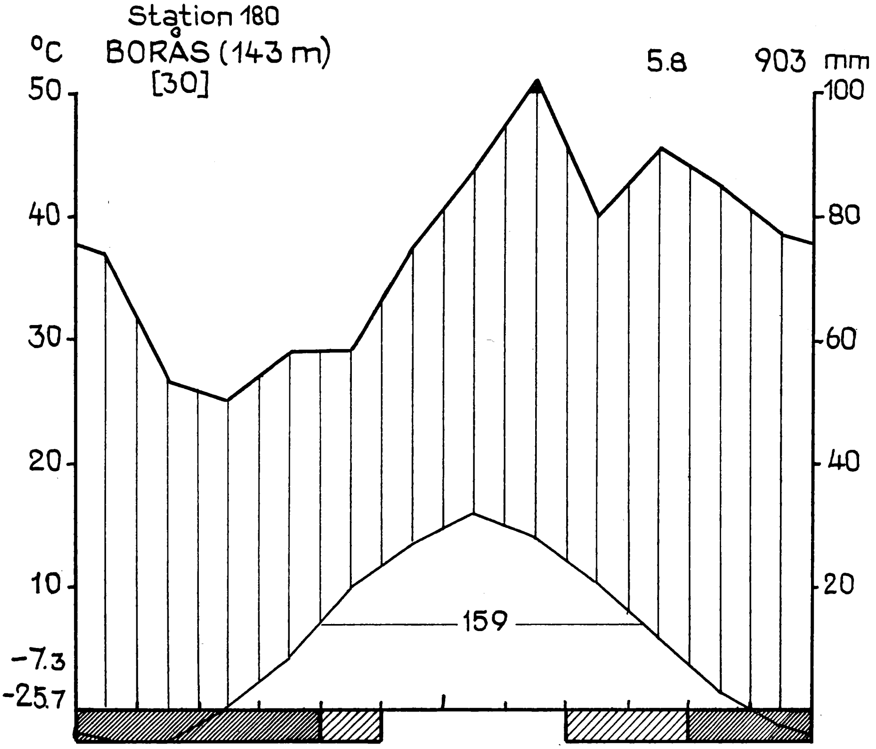

Figure 12. Climate diagram for Borås, Sweden.

The station of Östersund has here been considered for comparison mainly because it has an annual precipitation approximately equalling that of Kalmar, 496 mm as against 464 mm. Simultaneously, it is located within another bioclimatic region according to the author's division of 1959 (p. 117 f).

Precipitation is of a continental type with only one maximum occurring in summer. Previously we have discussed a transition region with two precipitation maxima during the year, one more pronounced in summer and one less pronounced in winter. The climate diagram, Fig. 15, shows that the growing season comprising 120 days is characterized by satisfactorily high humidity. The climatograms, Fig. 14, mainly display the same evidence but they may be read to imply that drought periods have occurred during four of the ten years investigated. The drought periods, however, are consistently weakly developed and they exhibit no arid components during the growing season. The longest drought period occured in 1917, when it comprised 15 days. Yet, any great influence on tree growth could not be observed since soil contained sufficient amounts of water after the thawing of snow and ice accumulated during the five months' long winter.

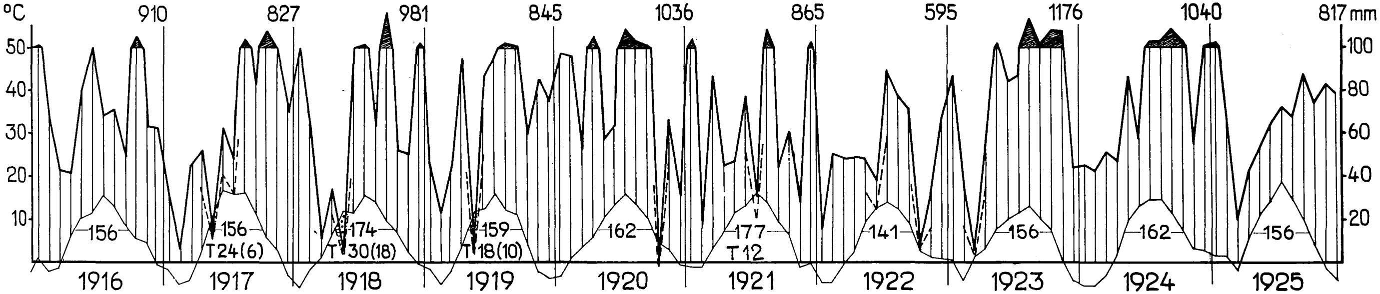

Figure 13. Climatogram for Borås, Sweden, years 1916—1925.

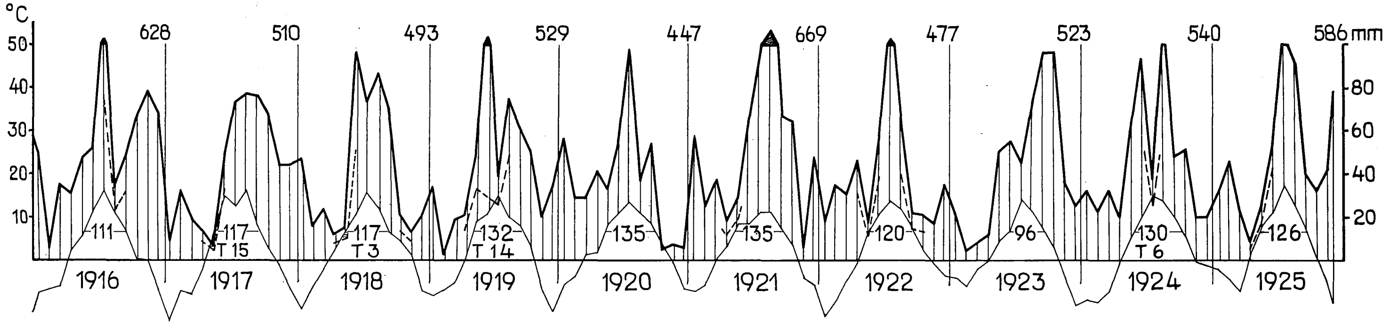

Figure 15. Climatogram for Östersund, Sweden, years 1916—1925.

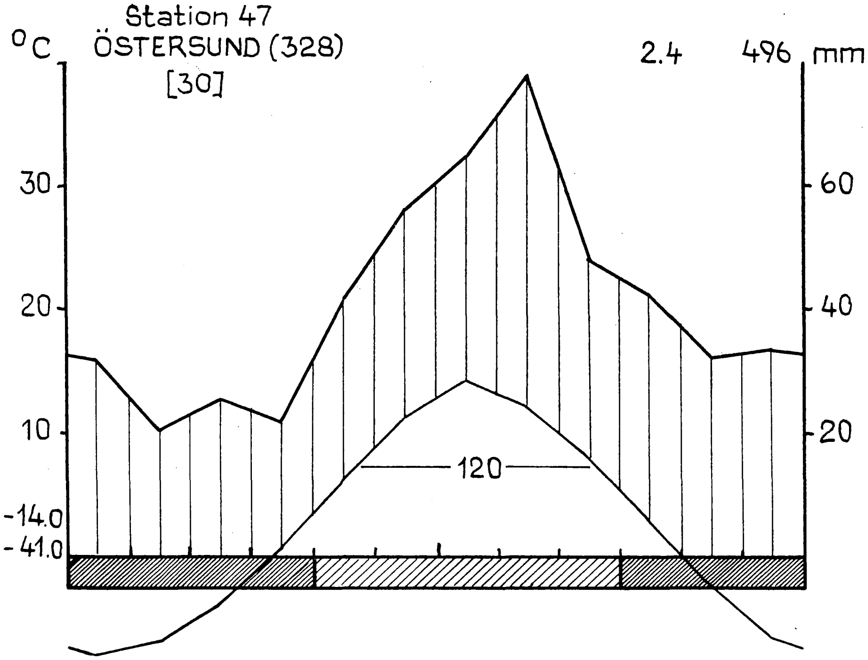

Figure 15. Climate diagram for Östersund, Sweden.

The Östersund area represents an ombro-thermal climate type where water is not a minimum factor from the point of tree growth. Humidity is steadily so high during the growing season that changes in the amount of precipitation cannot be expected to cause corresponding fluctuations in the growth potential or some of its components. This conclusion is also confirmed by the investigations of the relationship between the annual ring variations of spruce within the Östersund latitude and climate carried out by B. Eklund (1957). Contrary to Holmsgaard, Eklund could not find any influence of precipitation on the annual ring variations of Norway spruce which he interpreted as follows: "the humidity available for Norway spruce is sufficient for the assimilation processes during the period when the annual ring formation mainly occurs, even in summers low in precipitation". (B. EKLUND, 1957, p. 35, cf. also ibid., 1954, p. 120 f.). In the latter paper referred to, a similar result was presented for Scots pine.

A scrutiny of the author's climate diagrams published in "Klimadiagramm — Weltatlas" reveals that humid conditions similar to those of Östersund occur in Norden within regions denoted with D_s in the author's bioclimatic division, i.e. a boreal climate with precipitation maximum in summer. These areas comprise the Swedish inland north of the province of Dalecarlien and the whole of Finland with the exception of a wide coast zone along the Gulf of Bothnia and the Gulf of Finland. Some small isolated areas occur outside this large region in southern Norway and Sweden (cf. map Fig. 18). They are all classified in the **perpetually biohumid region** characterized by steadily humid conditions during the growing season.

The maritime location of Norway and her rough topography cause interference phenomena expressed by extreme variations in the ombro-thermal conditions even between places geographically very close. Wind-exposed places along the southern and western coast thus receive abundant precipitation all the year round, e.g. the city of Bergen (Fig. 16). The climate diagram shows that no month has less than 100 mm precipitation. Nevertheless, the annual changes are so great that drought periods occur during the growing season. In the period 1904—1943 twelve years contain drought spells, six of which in the 10-year span 1931—1941. Some of the drought spells are so extreme that

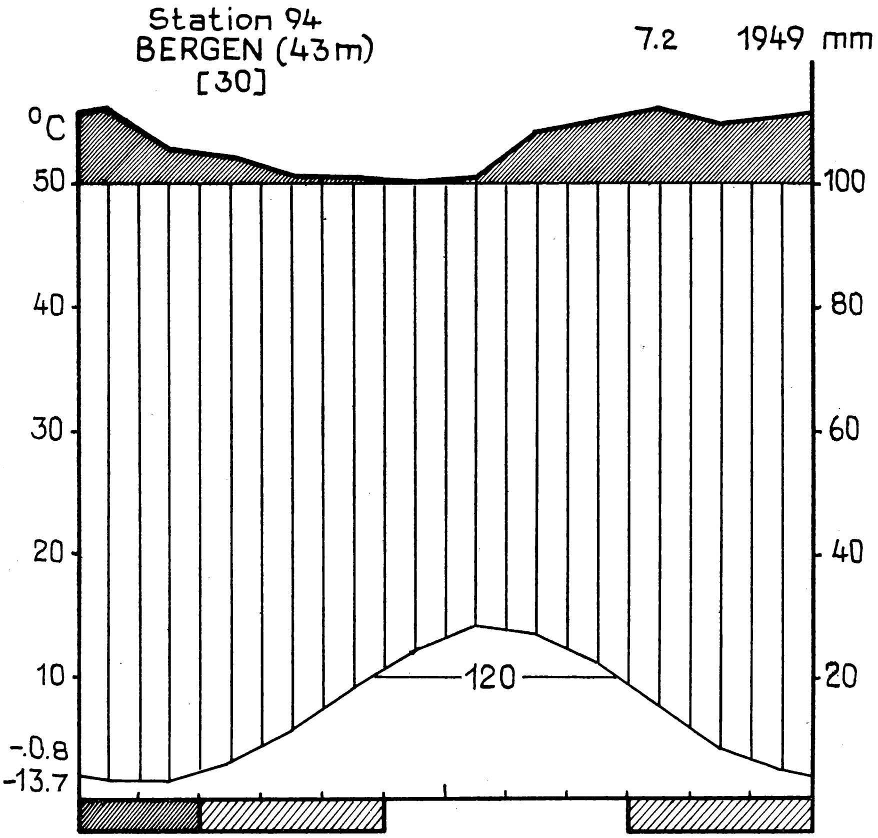

Figure 16. Climate diagram for Bergen, Norway.

arid conditions occur (e.g. April 1918, 5 mm; May 1936, 9 mm; June 1933, 25 mm; July 1910, 24 mm). We may thus state that the southern and western coast of Norway belongs to our intermittent, partially dry region in spite of the high amounts of precipitation.

According to the map, Fig. 18, the perpetually, partially dry region is also found in Norway. However, it does not occur as a continuous area but as small, scattered localities. Generally these places are confined to deep valleys or to the innermost parts of the fjords where rain shadow occurs, in both cases due to deflecting mountaineous areas. An extreme location is represented by the meteorological station at Ulstad, which is outstanding in Norden by having an arid period. Occurring in the months of May and June, the spell comprises the first 36 days of the growing season and is followed by a 33-day drought period (cf. climate diagram, Fig. 17). The part of the growing season with ombro-thermal conditions favourable for tree growth is then only 57 days. The ombro-thermal conditions will here decide whether the existence minimum of forest trees is reached or not. Since the precipitation of autumn, winter and spring is light, the supply of surface water and soil water will be entirely decisive for the creation of a water reserve. Although not covered by meteorological data several places in Norway with locations and ombro-thermal conditions similar to those of Ulstad, must be expected.

As already mentioned, the perpetually biohumid region is also represented in Norway within a limited area in the province of Opland and Buskerud. In our map, Fig. 18, it has been presented as continuous for the sake of simplicity. Actually, it should be divided into small separate areas due to the orographic

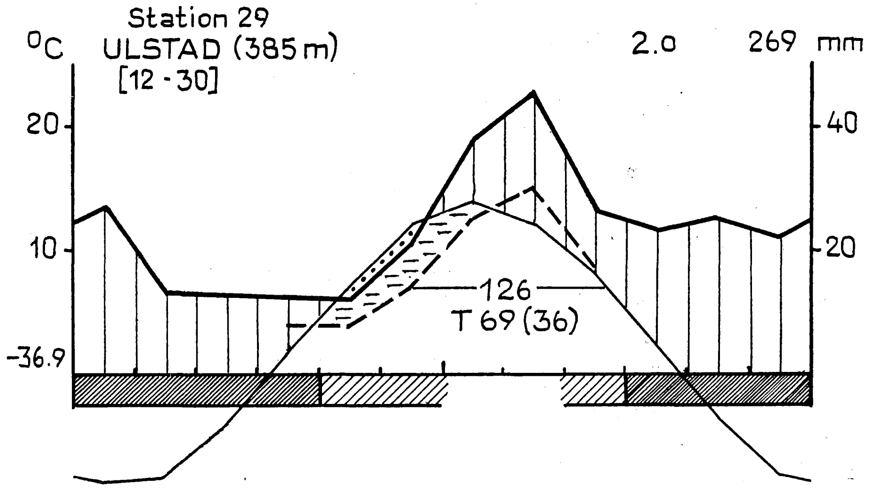

Figure 17. Climate diagram for Ulstad, Norway.

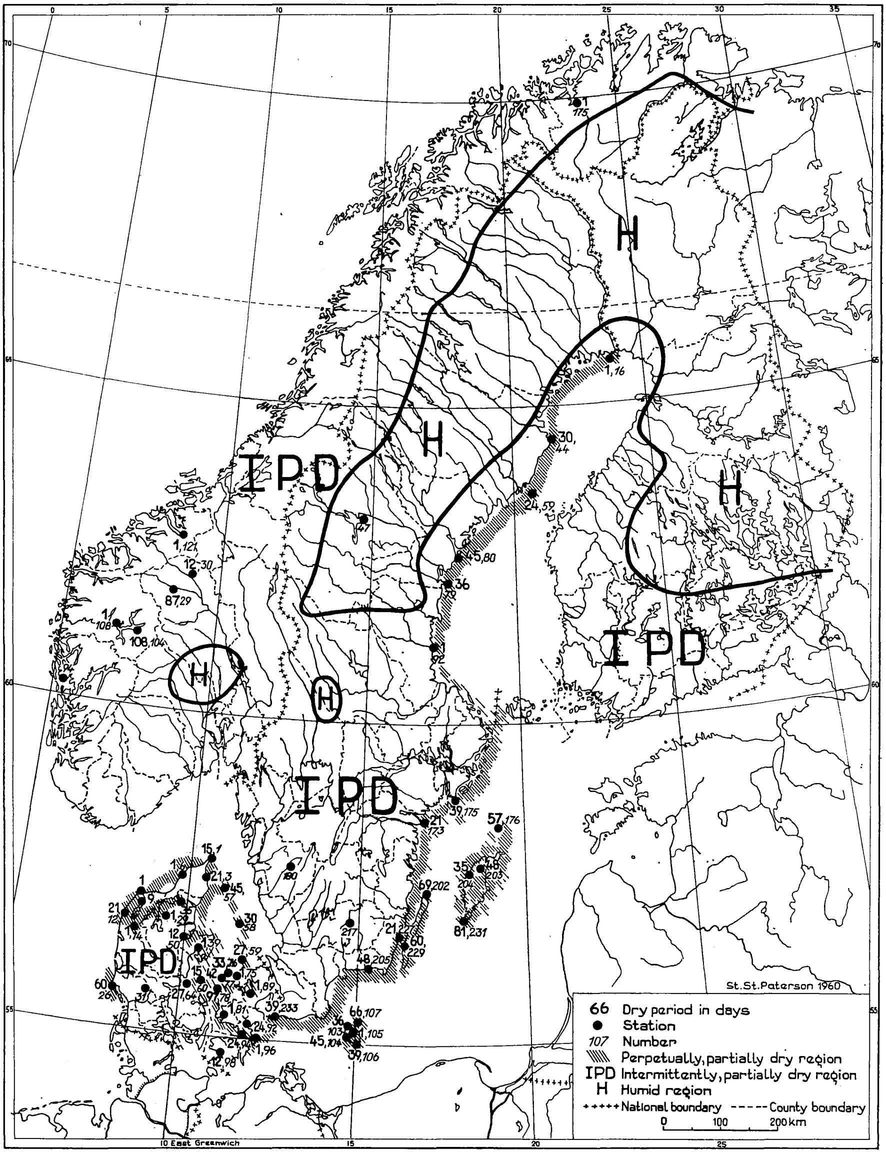

Figure 18. Map of the ombro-hygro-thermal regions of the Nordic countries.

conditions. It is also necessary to count on considerably greater local changes in the ombro-thermal conditions than those occurring within the corresponding region in Sweden.

Regarding ombro-thermal conditions, Finland shows an even transition from a coastal, intermittent, partially dry region to a humid region in the interior and northern parts of the country. The hygrothermal conditions of the latter parts correspond to our definition of the perpetually biohumid region. Places with drought period occur in Finland only in the coast regions, e.g. in the westernmost parts of the Åland archipelago and at Tornio in the northernmost part of the Gulf of Bothnia.

The ombro-thermal regions of Norden.

The investigation of the ombro-thermal conditions in Norden has produced three different regions. This is one region more than those which could initially be separated i.e. the partially dry and the humid regions. The regions are (cf. map, Fig. 18):

The perpetually, partially dry region with annually occurring drought period during the growing season. The drought spells occur during May—August or during parts of this period and may thus affect the genetic cell division, height (length) and diameter growth as well as the storage of nutrients.

The intermittent, partially dry region where years with entirely humid growing season alternate with years with partial drought period. Mostly the drought spell occurs in the latter half of May and in June and its effect on tree vegetation is limited primarily to the height growth assuming that height and diameter growth are independent of each other.

The humid region where drought spells certainly may occur but over such a short period as to preclude any reducing effect on the growth potential of trees. Observing the edaphic factors, we find a water balance previously assumed as characteristic of the perpetually biohumid region.

It is of interest to compare this regional division with that obtained by O. F. S. Tamm in his study of the humidity of climate in Sweden. This research worker separates six regions of humidity: the sub-arid, the light-humid, the normal humid, the strongly humid, the super-humid and the mountaineous regions (O. S. F. TAMM), 1959, p. 30). It is only the sub-arid region that displays an approximate similarity to our perpetually, partially dry region. The lack of similarity otherwise is natural on account of the different principles used for delineation with respect to both method and time (concerning the method used by Tamm, cf. further p. 65). In application the regional division suggested by Tamm, on the basis of his humidity values, gives a description particularly of the runoff conditions, whereas the present author's system is aiming at a definition of the plant physiological effects of precipitation.

Hygro-thermal division

In the discussion of the regional division presented here, the rôle of the capillary moisture and the free water in the soil as drought period compensation is repeatedly questioned. A fairly exhaustive answer requires a surrender of the climatic basis of evaluation used when studying the mutual position of the ombro-thermal curves, and a transition to a corresponding analysis of hygro-thermal curves specially designed for the purpose. The hygro-thermal curves would then represent the composite influence of climate and edaphic conditions on the supply of water.

The difficulty of transfer to the hygro-thermal method is inherent in the lack of data concerning the moisture status of the soil at various occasions and in various situations. Field investigations are needed concerning the annual changes of the water table (the depth of the water table is generally known within Sweden, e.g. by the investigations of O. Arrhenius, which show that the average depth of the water table varies between 120 cm and 200 cm) (O. ARRHENIUS, 1956, p. 6) and, too, the soil moisture at various levels. The latter information would be obtained by measuring the resistance, technical equipment for which is available e.g. "Colman fiber glass resistance units". Current and geographically scattered observations of this kind must be considered compulsory for improved knowledge of the yield conditions of the site, particularly in regions with drought period.

The reason for our discussion of water supply and its relation to the forest yield capacity was to find the most feasible expression of the water factor in our yield index. The following conclusions may be drawn as a result of this discussion.

In phyochorological work of summary nature such as the author's global investigations of 1956 and similar work concerning Sweden in 1958, a satisfactory result is obtained with values for the annual precipitation as partial base data. Reservation must be made for extremely humid stations with a water surplus which cannot be utilized for forest growth but rather counteract it. On the basis of analysis of the scatter diagrams with production and *CVP* as variables, the optimum precipitation in Norden seems to amount to 600 mm.

At phyochorological detail investigations based on the yield conditions of the site, the annual precipitation is an all too vague expression of the hygrical conditions. Continued research in future must here be aimed at procuring values for soil moisture particularly in the root horizon, and the seasonal variations of the water table. Further compilation of the data obtained will produce an expression of the hygro-thermal growing season which is a component more adequate for a yield index than precipitation, particularly for areas with drought period. Due to varying water requirements and ability of adapting within certain limits their growth processes to prevailing water supply, each species must have a defined,

hygro-thermal growing season of its own. Such a specification must be made with consideration of the time during which the trees function with reduced effect due to drought. It must then also be clarified whether this reduced effect is directly proportional to the simultaneously reduced transpiration. M. G. Stålfelt (1944) presented examples of the latter factor, which show that Norway spruce annually transpires 211 mm on a dry site and 378 mm at high water table.

Data on water supply available for this investigation are composed of precipitation values pertaining to daily, monthly and annual averages. Due to the conditions in the Nordic countries, the annual precipitation probably is no better or worse an expression of humidity than precipitation during selected parts of the year. Lacking a hygro-thermal expression, we therefore choose to use the mean annual precipitation for the standard period 1901—1930 as being the most easily available for practical purposes.

Material of Investigation

The basis of our investigation is partly composed of meteorological data and partly of forest yield data. In both cases the values have been computed for other purposes and they are therefore not fit to fill the special requirements of an investigation of this kind. A specification of these requirements at the outset would be impossible, however. Since new avenues are explored part results are obtained, which provide information on the special requirements regarding the basis of investigation.

Forest data

Yield data from 174 sample plots in Sweden are included in the study. Each plot contains an area of approximately 40×40 m. Material of lesser extent has been obtained from Denmark, Finland and Norway.

It should be stressed that the Swedish yield data represent sites, the yield conditions of which are well utilized by fully closed, natural stands. In other places where open stands have been established for various other reasons, the yield capacity of the site is less well utilized. The following compilation is consequently based on values for well utilized sites. Due to the subjective choice of sites, however, the sample plots may not always be representative for average climatic conditions, but better than normal edaphic ones, which may result in too high yield data. This seems to be the fact especially in some parts of North Sweden. Nevertheless, our material offers a good basis for a computation of the potential productivity of the entire country.

Since the Swedish material is largest with respect to comprehensiveness and

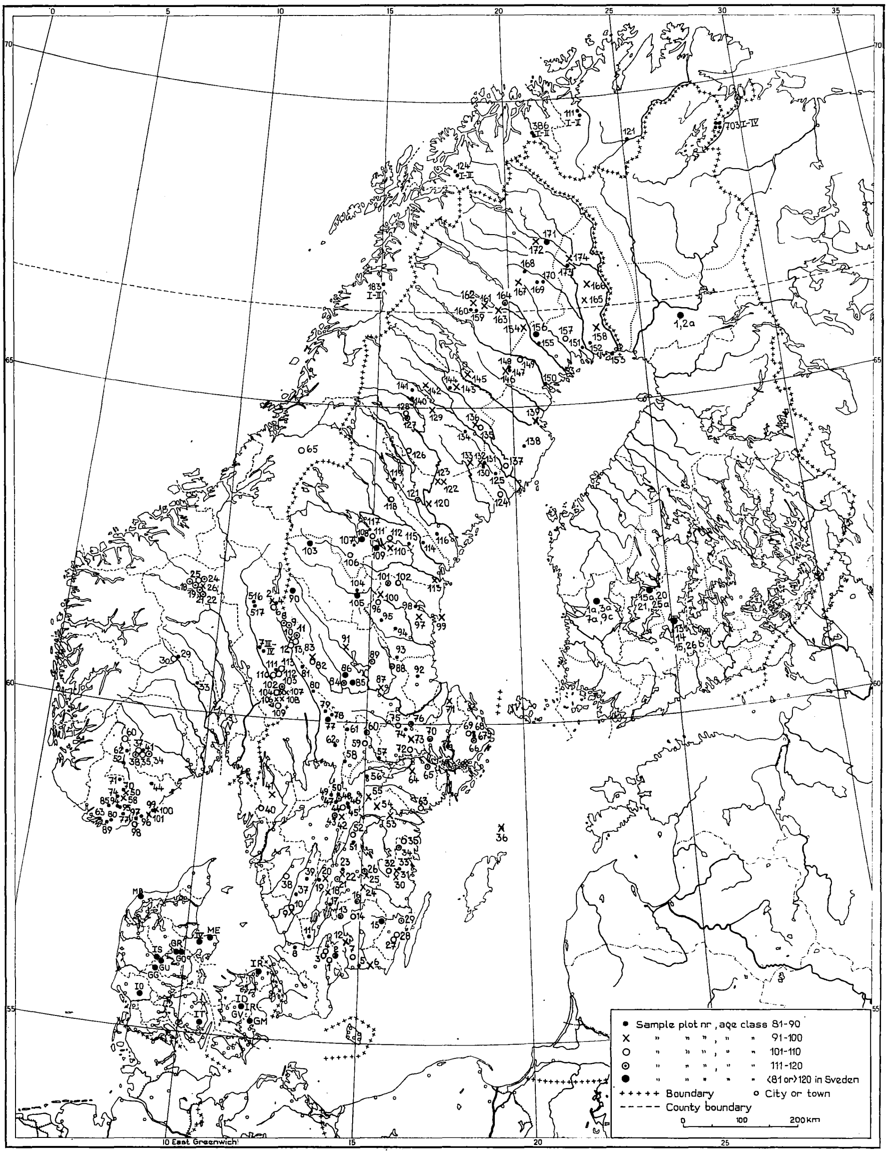

Plate I. The geographical location of the sample plots investigated.

geographical distribution, it has been found suitable to use it exclusively at the further compilation. The sample plot data from our neighbour countries will be used for comparisons at a later stage of the investigation and for a testing of the conclusions drawn from the Swedish data. The comparability of the various groups of material will then be discussed. The description of the Swedish yield data has been prepared by professor Charles Carbonnier. The locations of the sample plots are shown in the map, Plate I.

Yield data of the Swedish localities included in the investigation

By Charles Carbonnier

The yield capacity of the site has been characterized by the mean increment per hectare expressed in cu. m. stem wood over bark and above the stump. The mean increment of a site is inter alia dependent on species, method of stand establishment and management as well as length of rotation period. It has appeared that the highest yield of even-aged, pure stands is recorded after natural thinning or a thinning programme barely preceding the natural mortality. Heavy thinning, however, reduces the total yield (Petterson, 1951 and 1955, Carbonnier, 1954, 1957 and 1959). Mean increment in virgin stands, e.g. stands which have not been thinned or otherwise managed, may consequently be considered a good expression of the yield capacity of a site.

The Forest Research Institute of Sweden has recorded a large number of observations made in sample plots scattered over the entire country. Fully closed, naturally established stands of Scots pine and mixed stands with Scots pine in the ages between 81 and 120 years have been utilized for this investigation. Outside these age limits a small number of plots have also been included to represent climatically extreme localities. The composition of the sample plots as regards species and ages is presented in Tab. I.

Allowance for natural mortality

The plots in virgin stands are of a temporary nature and they have been measured once only. The depletion caused by natural thinning prior to the measurements has consequently not been registered.

An evaluation of the amount of mortality has been based on studies of naturally thinned check plots in permanent thinning experiments. In nothern Sweden, including Norrland and the province of Kopparberg, 28 naturally thinned experimental plots in Scots pine stands and mixed stands with Scots pine have been utilized. In these plots the natural mortality has been recorded in conjunction with the revisions which are carried out with an interval of approximately 5 years. The total yield expressed in per cent of remaining green timber has been dotted over age in a graph at each revision. Although dispersion was considerable, a graphical fitting was attempted for each site class.

The following series of relative numbers (Tab. 2) were obtained:

Table 2. Total yield in relation to the volume of green timber at various stand ages

Scots pine site index h_{100} m	Total yield in relation to remaining green timber at age				
	80	90	100	110	120
16	1.05	1.09	1.13	1.18	1.22
18	1.11	1.16	1.20	1.26	1.30
20	1.17	1.22	1.28	1.34	1.39
22	1.23	1.29	1.35	1.41	1.48

Site class expression h_{100} indicates the height of the largest tree at an age of 100 years.

Due to deficient material within the age interval of interest, no corresponding relative numbers could be deducted for site indices above $h_{100} = 22$ and for South Sweden. The numbers presented above have therefore been used as an allowance basis for the entire country, whereby plots with a site index higher than $h_{100} = 22$ are adjusted according to the series for $h_{100} = 22$.

The comparability of the yield data

Since the investigation is based on data from virgin, naturally established stands, it is reasonable to state that the influence of various methods of establishment and various treatments on yield is eliminated.

It would have been desirable to limit the investigation to pure stands of Scots pine or Norway spruce. This, however, was not possible on account of the composition of the material available and the rather limited interval of age considered to be covered by the investigation. The data reported are therefore representing both pure Scots pine stands and mixed stands with Scots pine, where Norway spruce and, although in minor proportions, broad-leaved species also occur.

The method of investigation is i.a. based on the fact that variations in the mean increment are minor within a rather wide age interval around the culmination point of the mean increment. Within narrow age groups near the culmination point it is therefore reasonable to compare directly the mean increment values observed and to ascribe the increment variations to the site quality variations, if the stands are otherwise comparable.

At the statistical computations the material has been grouped in the following age classes: 81—90 years, 91—100 years, 101—110 years, and 111—120 years.

The meteorological data

According to results obtained in the preceding chapter, the following meteorological data are of current interest:

T_v = mean temperature of the warmest month

T_a = amplitude between the mean temperature values of the warmest and the coldest months

N = the annual precipitation

G = length of growing season in no. days per year when the mean temperature amounts to or exceeds +7° C. Moreover, at least three months should display a mean temperature of +6° C or more.

E = ratio for solar radiation according to the author's computations of 1956, p. 36 f.

On the basis of the data presented above, the computation of the *CVP* index previously designed by the author is carried out by means of the formula:

$$CVP = \frac{T_v \times N \times G \times E}{T_a \times 360 \times 100}$$

The sole difference here from the formula introduced previously is the expression of the length of the growing season in days instead of months. The reason is that improved accuracy may logically be assumed. Furthermore, the previously used letter P (precipitation) has been replaced by N (German: Niederschlag, Sw. nederbörd) to avoid confusion with the P[4] used in *CVP*.

The meteorological material is gathered from stations for which values concerning mean monthly temperature and mean monthly precipitation are available in meteorological tables. The number of stations with complete data of this kind amounts to 107 in Denmark, 31 in Finland, 190 in Norway and 139 in Sweden (cf. map, Plate II). In Finland and northern Sweden the number of meteorological stations is very low, which means large areas without observations.

Some condensation of the net of stations has been obtained in Sweden by a utilization of the denser net of precipitation stations. Temperature values have been calculated for 98 stations of this kind by means of a table for normal monthly values of air temperature at sea level and various altitudes. (A. ÅNGSTRÖM, 1938) and after adjustments for altitude and potential temperature anomalies. The course of procedure is further described in conjunction with the determination of the sample plot climate values. Distinction between climate stations with complete data of observation and stations with partly computed values has been made in the map by different symbols, Plate II. *CVP* has been

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[4] This latter change has been made after that Professor H. Walter, Stuttgard-Hohenheim has drawn attention to this possibilitity of confusion.

calculated for all the climate stations when sufficient as a basis for the construction of climate isophytes. Table II presents all the climate stations with their *CVP* indices and data necessary for its computation.

A *CVP* index was to be computed for each sample plot. Climate data needed for a computation of the *CVP* indices of the sample plots have only exceptionally been obtained directly from existing meteorological tables since the locations of the sample plots and those of the meteorological stations seldom coincide (cf. the maps, Plate I p. 44 and Plate II p. 49).

The climate data for the sample plots have been computed according to the following method. For each sample plot two of the nearest climate stations are selected so that the line connecting the places is passing through or very close to the sample plot. The location of the sample plot on the line and the values observed at the climate stations are used for a computation of the temperature and precipitation values for the sample plot by interpolation. A generalized statement is also involved since it is assumed that the change of the climate factors between the known station values follows a linear scale, although this is generally not the case. Any great error, however, cannot occur with this method since the differences between the known station values are of moderate magnitude only, for temperature tenths of one centigrade, for precipitation some ten mm. Differences in altitude between the meteorological stations and the sample plot have been compensated for by an adjustment of temperature on the basis of correction factors designed by Wild 1881 (cf. A. ÅNGSTRÖM, 1938, p. 24). The adjustment occasionally concerns both the temperature of the warmest month and the temperature of the coldest month.

Values used here for the vertical temperature gradient were computed by Wild on the basis of Russian data. Since it may be questioned whether they are applicable also to conditions prevailing in Scandinavia, some investigations have been carried out. These investigations were initiated by O. V. JOHANSSON in his treatise "Die Temperaturänderungen mit der Höhe an der Erdoberfläche in der Skandinavien" where the material was divided into three groups:

A. Well ventilated stations, relatively small height differences
B. Well ventilated stations, height differences 600 m or more
C. Valley stations, relatively small height differences (temperature inversion in winter).

The investigation by Johansson, which is interesting not least from a methodical point of view, was repeated by I. BRUUN in 1957 on the basis of more recent and complete meteorological data. The material was divided into the same groups. A partial control of the Wild gradients was also carried out by S. RUDBERG, 1957. The material was collected from stations located north of 60th latitude (N) but excluding lighthouse stations (cf. Ångström, 1938,

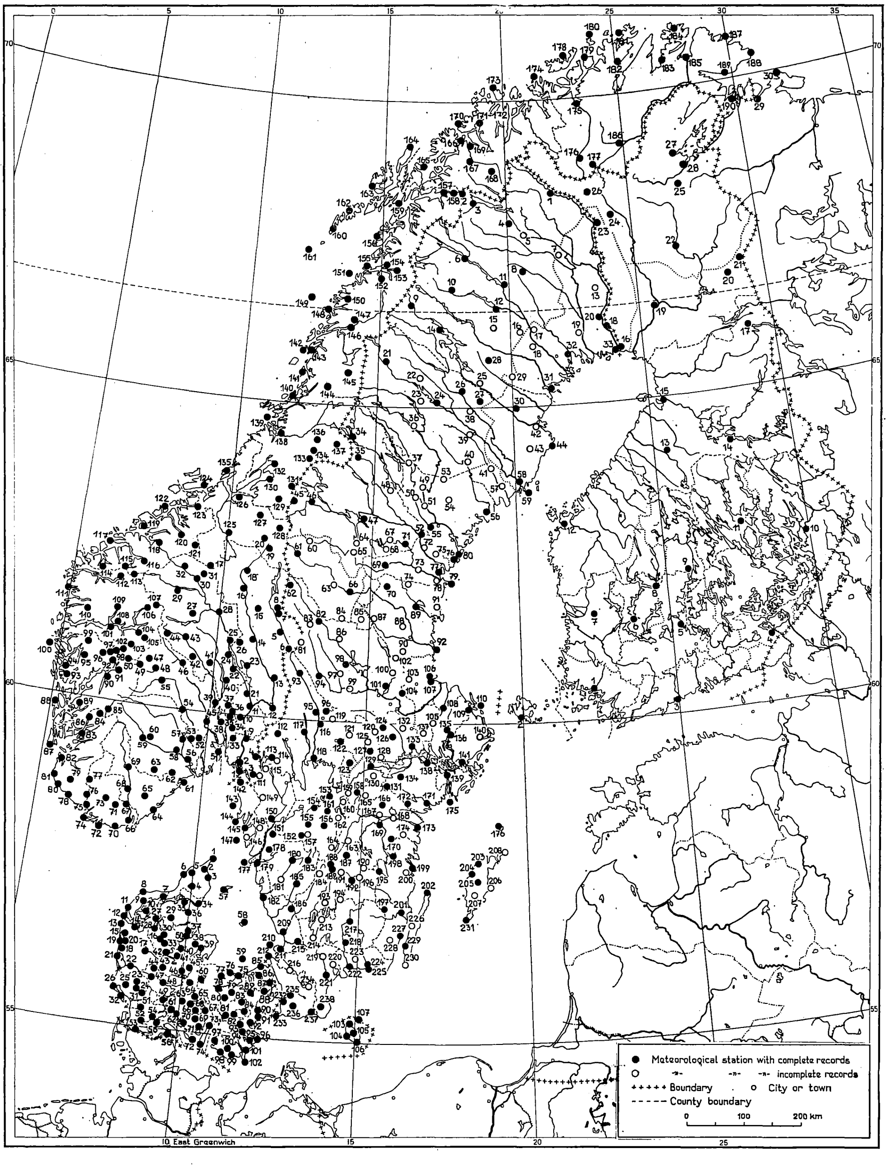

Plate II. The geographical location of the climate stations.

tab. I) and it was restricted to the months of April—September. The values presented by Wild (A. Ångström, 1938, p. 9) are compared in the following table with the values obtained by Bruun (1957, p. 45) and Rudberg (1957, p. 41).

Table 3. Temperature decrease by altitude according to Wild, Bruun and Rudberg

	J	F	M	A	M	J	J	A	S	O	N	D	Year °C 100 m
Wild	0.36	0.43	0.48	0.56	0.58	0.61	0.59	0.60	0.53	0.46	0.20	0.25	0.47
Bruun A	0.42	0.52	0.69	0.82	0.82	0.82	0.69	0.75	0.73	0.76	0.60	0.52	0.70
B	0.36	0.38	0.48	0.61	0.70	0.71	0.69	0.63	0.61	0.55	0.47	0.37	0.55
A & B	0.38	0.42	0.54	0.68	0.74	0.74	0.69	0.67	0.64	0.62	0.51	0.42	0.60
Rudberg				0.37	0.41	0.53	0.61	0.57	0.52				

The comparison shows partly coinciding values for the Wild and Bruun mean values for the groups A and B. This is particularly the case when one decimal is used, which is applied in this investigation for altitude adjustments. The differences are great between the Rudberg values and the others for the spring months, April and May but very close to the Wild values for the months June—September. Considering the properties of the material, the Bruun A-group seems to be comparable with the Rudberg data, but here the groups display quite a large discrepancy.

Our compilation shows that the temperature adjustment for altitude can be carried out on the basis of the Wild values since no essential deviations are obtained at the computation of the *CVP* index. Both the Bruun and the Rudberg investigations show that a grouping of the Nordic data according to the principles used by O. V. Johansson is necessary for a computation of more accurate correlation factors. In the present case, however, the requirements of accuracy are such that a compilation of this kind is superfluous.

The procedure of computation when determining the temperature data of a sample plot or a precipitation station is shown in the following example.

Interpolated mean temperature values for the coldest (T_k) and the warmest (T_v) months are to be computed for the precipitation station 16 Puottaure. The station map, Plate II, shows that several possibilities occur when choosing adjacent stations with complete climate data. The stations 14 Vuonatjviken and 20 Övertorneå are located almost on a line with Puottaure in east—west direction. The meteorological tables (A. Ångström, 1938, p. 18 f) show directly the mean temperature of these stations adjusted to sea level (*mk*). An adjustment must be made for the difference in latitude (φ) between the stations as well as for the altitude (h) of the precipitation station. Both the latter adjustments are carried out by means of existing standard tables (cf. Ångström, 1938, p. 24, tables 10 and 11). Our computations have been summarized in the following table.

The final values thus obtained for the stations 14 and 20 are the temperature values applicable to 16 Puottaure. Exactly equal values should have been obtained for corresponding temperature data but differences have occurred.

Station No.	14		20	
	Tk	*Tv*	*Tk*	*Tv*
mk	—11.40	14.51	—11.37	16.06
φ........	0.10	0.02	0.15	0.03
h........	— 1.13	—1.86	— 1.13	—1.86
	—12.43	12.67	—12.35	14.23

The T_k values diverge with only 0.08° C which is a very slight discrepancy, particularly since the temperature values included in the *CVP* index are used only with one decimal. The agreement is less good between the T_v values, the difference amounting to 1.56° C. The cause of this discrepancy is to be found in factors other than geographical latitude and altitude. These factors are joined in the term anomaly. The Ångström anomaly map for the month of July (A. ÅNGSTRÖM, 1938, plate IV) shows that our station line is passing from an area in west with negative anomaly (— 1.5° C) to the boundary areas adjacent to Finland in the east with a positive anomaly (+ 0.06° C). The sum of the values presented represents the difference of the temperature values of the stations. We now adjust the T_v-values previously computed and obtain.

12.67° + 1.5° = 14.17° and 14.23° — 0.06° = 14.17°, respectively. Thus complete agreement is obtained.

Assuming that the change of anomaly occurs linearly, we can now compute the temperature anomaly for the month of July at Puottaure. This place is located at a point dividing the line from Vuonatjviken to Övertorneå in the ratio 25: 31. The difference in anomaly between the stations 14 and 20 is divided accordingly i.e. the temperature anomaly of Vuonatjviken (origin) — 1.5° C should be raised with + 0.69° C to give the anomaly for Puottaure, i.e. — 0.81° C. The actual July temperature thus is 14.17° C — 0.81° C = 13.36° C. The same value is obtained if the computations are based on the Övertorneå station.

The same procedure is used when the T_k-value is adjusted for the anomaly.

The value of T_k now calculated is subject to a certain criticism. The Ångström map of anomalies (ibid., plate I) shows that our station line is crossing over an area with negative anomaly exceeding those reported for the stations used (cf. Fig. 19). This means that the change of anomaly is non-linear, which contradicts the assumption needed for our computations. We must therefore try to find two other climate stations with a more suitable direction of the connecting line. This seems to be the case of the stations 12 Jokkmokk and 32 Högsön (cf. Fig. 19). They provide the following values:

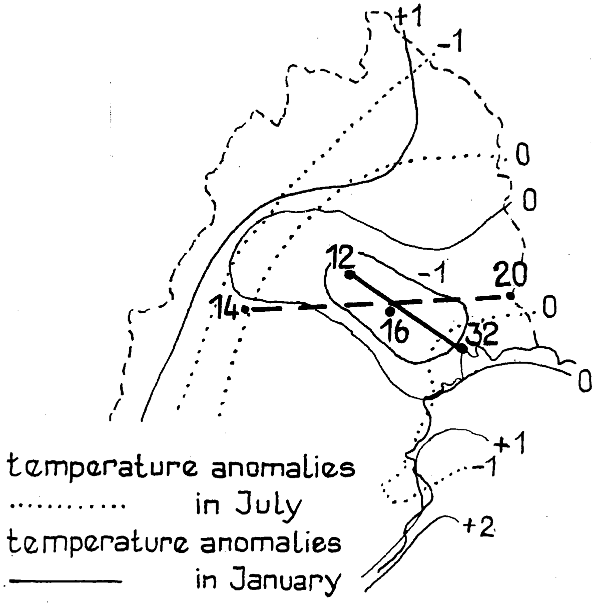

Figure 19. The location of the station lines in relation to anomalies.

Station No.	12		32	
	Tk	*Tv*	*Tk*	*Tv*
mk ……	—13.01	16.22	—11.36	15.88
φ……..	0.30	0.07	—0.50	—0.10
h……..	—1.13	—1.86	—1.13	—1.86
Anomaly.	2.21	—0.32	1.06	0.12
	—11.63[5]	14.11[5]	—11.93[5]	14.04[5]

Corresponding temperature values are used for a computation of the mean value to which the temperature anomaly of the month calculated according to the method previously discussed, is added. We then obtain the following temperature values for Puottaure:

	Tk	*Tv*
Anomaly…	—11.78 — 1.83	14.07 0.17
	—13.61	14.24

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[5] The difference from the other station is caused by the anomaly admitting a computation of mean temperature with an accuracy of about ± 0.2° C (A. Ångström, 1938, p. 69).

The values for T_v and T_k now obtained must be considered to reflect the influence of temperature anomaly better than the temperature values derived in the first attempt.

The method developed above for the computation of temperature has consistently been used in the following for the procurement of data needed for precipitation stations and for sample plots. Data thus obtained are reported in a special foot note in table II.

The influence of topography, exposure, altitude and gradient on the amount of precipitation is known as to its general features. The magnitude of this influence is determined for certain small localities of investigation. The results show that precipitation and light conditions vary widely within small areas (P. E. VÉZINA, 1960, p. 133). It is consequently impossible to generalize with the observations available and to arrive at correction factors applicable within other areas. We must therefore ignore the local variations of precipitation. The entailing disadvantages are not so serious in Denmark and in south and middle Sweden since the net of precipitation stations is relatively dense. In northern Sweden and in large areas of Norway and Finland where the stations are sparse and located mainly in valleys, however, the disadvantages are great. This means that observations are largely deficient in the highland areas which are important for forestry. It must here be pointed out that considerable differences may occur particularly between the precipitation climate of valleys and that of the highland, a difference the magnitude of which we have no means of evaluating.

The method used when the length of the growing season is computed has been described previously. Exceptions, however, have been made for practical reasons for climate stations and sample plots with interpolated temperature values. In these cases a determination of the length of the growing season would involve a computation of at least four temperature values, two for spring and two for autumn according to the procedure now described. This would be a very tedious work without a result corresponding in accuracy to the efforts since the errancy of the local climate remains. Thus the considerably simplified procedure with interpolation between the growing season of the known stations was applied to obtain the growing season of the locality concerned. Here, too, it is assumed that the change in the length of growing season between the climate stations is linear. Moreover, the interpolation must be preceded by an adjustment for altitude, which is influential in this context.

Decrease in length of growing season at rising altitude

Investigating the relationships between the length of the growing season and latitude as well as altitude, O. LANGLET (1936, p. 344 f) found that the growing season decreases by approximately 5 days per 100 m increase in altitude. The computations are based on the assumption of a linear regression, and local conditions of climate were not considered, nor regional differences in air humidity, carbodioxide content of air, cloudiness and air pollution. The existence of such differences has been proved by e.g. Czech investigations (cf. M. NOSEK, 1958, p. 482). The weaknesses are discussed by Langlet who furthermore stressed that the method provides no expression of either change in height at various altitudes or a varying influence of northward transfer at various altitudes. It would be of interest to study the results of an arrangement and compilation of the Langlet material by altitude. The most important matter in this context is the influence of height changes at various altitudes and it will therefore be studied closer.

The reduction of the length of the growing season at rising altitude should be studied under conditions where altitude alone is the variable and factors such as continentality, maritimity, latitude, mass elevation and other influencing factors mentioned in this context are constant. This is most feasibly arranged in small areas with great altitudinal differences, where meteorological stations are established at nearly vertical distances from each other. Conditions of this kind are found in Norway.

Initially we shall select three comparably well situated station Oslo I, Oslo (Blindern) and Tryvasshögda. The distance between these stations is less than 10 km, which means that the meteorological differences between the stations are mainly to be considered caused by differences in altitude. The station Oslo I is located in the park of the observatory at an altitude of 22 m, whereas the Oslo—Blindern altitude is 94 m. The latter station is considered by I. BRUUN, state meteorologist, (1957, p. 23) to be representative of the temperature conditions prevailing in the interior Oslo fjord at this altitude. The distance between these two places of observation is slightly more than three kilometers in north—south direction. Within this distance the growing season decreases from 162 days to 153 days, which means a reduction of one day per 8 m rise. The distance between Oslo-Blindern and Tryvasshöjda is approximately 7 km and the altitudinal difference is 418 m. Here the reduction of the length of the growing season amounts to 24 days, i.e. a reduction of one day per 17 m increase in altitude. Tryvasshögda is considered (ibid. p. 28) to provide representative temperature values for the area of Nordmarka at this level. Due to the topographic conditions great local variations may occur concerning the sub-zero temperature values. Their influence on the computation of the length of the growing season, however, must be considered minor only.

The station Holmenseter is located between Oslo-Blindern and Tryvasshögda. Altitude is here 294 m and the growing season thus decreases at a rate of one day per 15 m rise, but at a rate of one day per 20 m rise from Holmenseter to Tryvasshögda.

Observations concerning the relationship between the length of the growing season in the Oslo area and altitude are now supplemented with the stations listed in Table 4.

Tab. 4. Decrease in the length of growing season at increasing altitude for various stations

Stations of comparison	Altitude	Difference in altitude	Growing season	Difference	m/day
	meter		days		
Kongsberg II-Knutshytta.	155—717	562	143—114	29	19
Hamar-Vang på Hedmark.	139—219	80	141—138	3	27
Flisa-Åsnes..............	183—234	51	137—133	4	13
Dovre-Dombås...........	570—643	73	105—102	3	24
Engerdal I och II.......	538—479	59	100—108	8	7
Dalen i Telemark I och II.	102— 77	25	151—147	4	—6
Mandal I och II.........	6—138	132	173—168	5	26
Ullensvang I och II	55— 30	25	165—168	3	8
Bergen I och II.........	20— 43	23	174—171	3	8
Bergen II-Rundemannen..	43—560	517	171—108	63	8
Bergen I-Rundemannen ..	20—560	540	174—108	66	8
Molde I och II..........	18— 50	32	154—150	4	8
Bodö III och IV........	33— 10	23	122—119	3	8
Tromsö I och II	45—102	57	98— 91	7	8

Some of the stations listed in Table 4 are less representative from a meteorological point of view.

An increase of 27 m in altitude is required at Hamar-Vang in the Hedmark area to reduce the growing season by one day. This is nearly twice the value (15 m) recorded in the Oslo area at the level of 100—200 m. The station description in "Lufttemperaturen i Norge" states that the lake of Mjösa has a distinctly smoothing effect on the temperature conditions of the surrounding lowland. This explains with great probability the essentially slower decrease of growing season with increasing altitude stated for Hamar-Vang.

At Engerdal I and II an increase of altitude by 7 m reduces the growing season by one day. This is considerably less than the expected difference in altitude for one day's increase or decrease of the growing season and seems to indicate locally pronounced climate conditions. Circumstances associated with the natural situation also indicate this to be the case. Engerdal I is located approximately 70 m above the valley bottom on a steep slope with ENE exposure. Engerdal II is located on the opposite side of the valley with WSW exposure. These locations cause the stations to provide data indicating a temperature climate deviating from the normal. Engerdal I displays lower temperature values than normal for this location on account of an abnormally oblique insolation angle whereas entirely different conditions occur at Engerdal II due to straight angle insolation. Here (Engerdal II) temperature is higher than normal with a positive anomaly particularly distinct in spring and autumn.

The valley in Telemark I and II constitutes an example of temperature inversion which develops under certain conditions. Here it is caused by the deep valley and associated special air movements. In winter the prevailing winds follow the valley downward. A certain foehn-effect arises through this simultaneously as a stagnation of the airmass with accompanying radiation cooling is prevented (I. BRUUN, 1957, p. 9). In summer, air in this valley becomes locally heated, which creates a circulation characterized by warm rising air which is replaced by colder air entering along the valley bottom. This explains why a more favourable year-round temperature climate occurs at a higher altitude than at the bottom.

Mandål I and II show a slowly decreasing growing season at increasing altitude, a 26 m rise gives a reduction of one day as against 8 m per day in the Oslo area. Bruun (1957, 9.20) stated that Mandal II is located 2.5 km north of the community of Mandal with the station Mandal I. The temperature data from Mandal II are considered representative for a large inland area, not so, however, for Mandal and the area south, east and west of this community. The latter area is affected by frosty mist from Mandals-elva (river) in winter and by coast fog in summer.

Bergen I and II and Rundèmannen show equal change of altitude for one day reduction of the growing season, viz. 8 m, a value corresponding to about 11 m in the Oslo area. The value indicates faster changes in temperature climate than normal i.e. we pass from one local climate to another. This is also confirmed by meteorological authorities, who stress that Bergen II is representative only of the immediate surroundings of the harbour in calm winter weather (I. BRUUN, 1957, p. 7). Comparison may here be made with the observations of W. A. Fairbairn in Scotland. He found that the growing season is decreasing by one day for each 8 m increase in altitude within the zone below 500 m. For the zone 500—750 m he obtained 19 m per day reduction, but he considered the latter values less accurate (W. A. FAIRBAIRN, 1955, p. 16). The resemblance to the Bergen conditions is striking.

No climatic discrepancies of this kind occur between the stations of comparison listed in table 4. The values presented for the reduction of growing season at increasing altitude can therefore be considered representative.

A compilation of the values for the remaining 14 representative stations results in the following table summary concerning the reduction of the growing season at increasing altitude within various zones (Table 5).

Table 5 shows that the reduction of the growing season at increasing altitudes

Table 5. Reduction in no. days of the growing season at increasing altitude within various zones

Zone	Increase in altitude per one day reduction of the growing season, m
0—100	8
100—300	15
300—500	20
500—600	24

is not linear but faster at low levels than at high levels. It may be of interest in this context to consider the statement made by I. Bruun in his discussion of the vertical temperature gradient for each month of the year and for four groups of stations selected according to altitude and ventilation conditions. Bruun found that temperature does not decrease linearly with increasing altitude. The gradient of well ventilated stations with relatively small differences is greater than that of stations with similar aeration but with altitudinal differences of 600 m or more.

Data concerning altitude and the length of the growing season of all the stations discussed are compiled in Fig. 20. In spite of its limitation, the material shows an obvious tendency to stronger curvature toward a longer growing season in the altitude zone below 100 m than in the higher zones. The four northernmost stations at Bodö and Tromsö differ clearly from the other material. This and the conditions described by Fairbairn in Scotland, however, may be naturally explained by the fact that the decrease in temperature and length of the growing season at increasing altitude is assumed to be unequal within various latitudes. It would be desirable to add an expression of the frost frequency and its physiological importance for the length of the growing season. W. TRANQUILLINI (1959, 116 pp.) showed for instance that the influence of night frost on photosynthesis in Pinus cembra is less in spring than in autumn. We also know the frost hardiness to be variable within a species. Improved knowledge in this field requires measurements of photosynthesis, and the site climate and values thus obtained should be tested in a yield index.

Since the material of O. LANGLET, in spite of its extent, is influenced by a number of not-zeroed factors and, furthermore, since it is treated according to the unconfirmed assumption of a linear temperature decrease with altitude, only a general picture of the main course of this decrease is obtained. Considering the observations made by Bruun and mentioned above and the author's observations made in this investigation, the latter observations seem

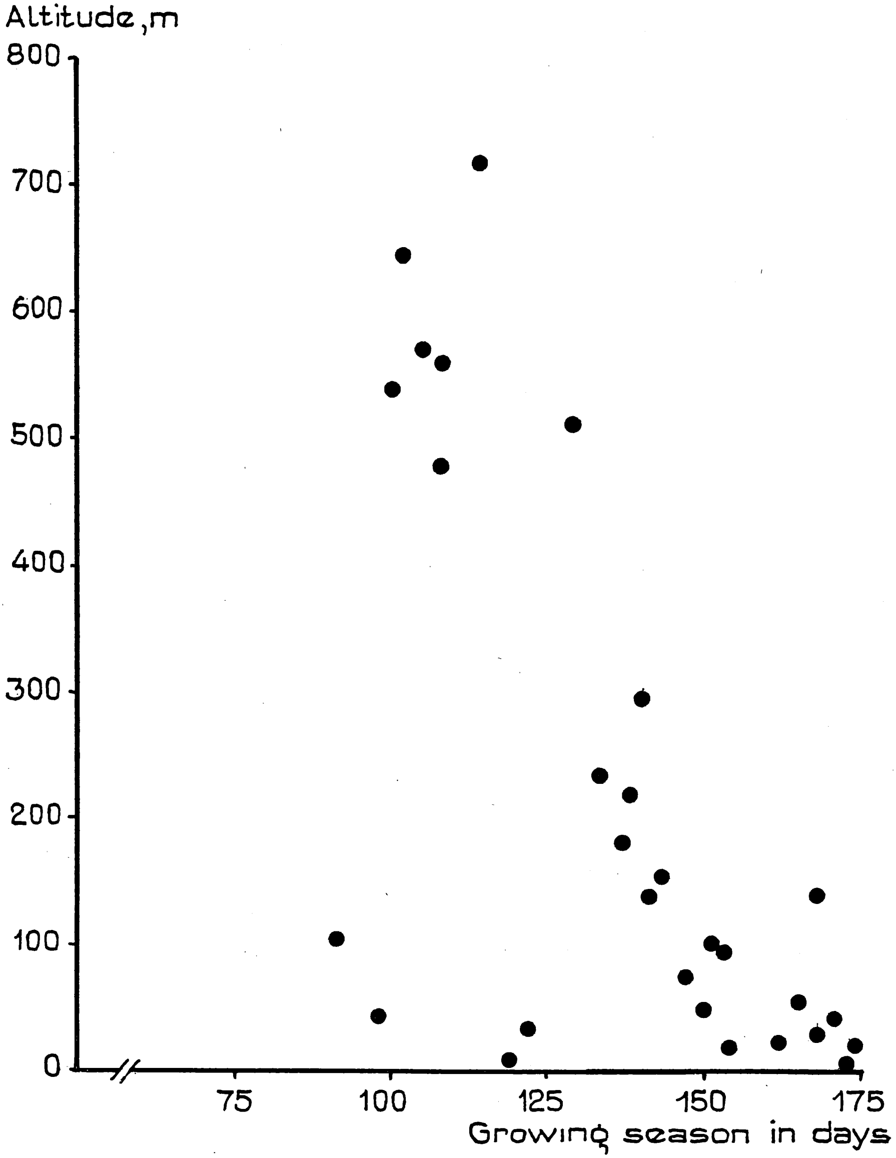

Figure 20. Scatter graph showing the reduction of the growing season at increasing altitudes.

to be most feasible in this context from a theoretical point of view. Practically, the use of one method or the other has no appreciable effect on the *CVP* index.

Observations made concerning the reduction of the growing season at increasing altitudes will be used for a computation of the growing season of climate stations and sample plots which entirely or partly lack meteorological data. Procedure used is according to that described above. Two complete climate stations are selected on each side of the sample plot (or corresponding) and with its connecting line passing through the plot. The growing season of each station is recalculated to the level of the plot according to the proportion of the location of the sample plot on the line connecting the stations. The equal values adjusted in this way constitute the growing season of the sample plot.

The individual sample plots obtain the values presented in Tab. III after necessary adjustments have been made.

The influence of deficiencies remaining in the material in spite of the adjustments made will vary depending on the further treatment. Errors are expressed normally when each climate element is treated separately. When the climate elements are combined, however, the individual errors will enforce or counteract each other. An example will here be presented to show how the errors enforce each other when several climate elements interact.

If a precipitation station situated within a locally and distinctly continental climate area is computed with respect to temperature values it means that values obtained for the mean temperature of the warmest and the coldest months are too low and too high, respectively. These errors are added to each other when the temperature amplitude is computed. A determination of the growing season in no. days on the basis of temperature is also affected by errors in the temperature data. It can generally be stated that the growing season computed will be too short under locally maritime conditions since adjustments for the latter occurrences have not been possible to introduce. Certainly, it would be desirable to eliminate the errors involved. More definite knowledge of the local climate conditions, however, is required and this is possible by means of a meteorological observation station located on the sample plot.

The relationship between climate and forest yield

Data compiled in Table III enable a statistical treatment aimed at an establishment of the relationship between climate and yield. As previously stressed the matematical analysis will comprise only the Swedish data on account of their comprehensiveness. Certain general problem complex associated with the concept of production will be discussed before entering into an explanation of the work procedure.

The plant physiological production balance.

Considering the work methods of the author, J. WECK (1957, p. 124) found that "Zur Gewinnung einer Kennziffer für forstliches Produktionspotential genügt es nicht den Vorgang der Assimilation zu bewerten". The same author returned to this way of reasoning in a later work (1959, p. 12).

WECK supported his statement by means of results from investigations of the production balance of forest stands carried out by P. Boysen-Jensen (1952), C. M. Møller (1945, 1954), D. Müller (1954), J. Nielsen (1954), B. Huber (1955), H. Polster and S. Fuchs (1956). WECK obtained data on the distribution of the real production on roots, branches, foliage, respiration and stem for a beech stand on site quality II from Møller, Müller and Nielsen. Special emphasis is thereby given to the remarkable fact that only a third of the real assimilation (gross production) is deposited as utilizable wood.

Using the distribution percentage according to Møller, Müller and Nielsen, WECK is exploratorily computing values for the real production within various climate regions (ibid., 1957, p. 225). He then arrived at the statement that respiration is essentially higher in the tropics than in Denmark, but its relative amount in per cent of the real production is not necessarily different. A yield table developed for Pinus merkusii, site class II, by J. H. A. Ferguson (1954) provides an original information for the compilation of the real production of a tropical area (Sumatra). Assuming a certain magnitude of the entire respiration and the ratio between day and night respiration varying with growing season, WECK obtained directly or interpolated yield figures which multiplied by the real production provided a value for the empirically established utilizable portion of assimilation.

The review above is a very concentrated presentation of Weck's attempts to improve the relationship between the *CVP*-index and the forest yield potential. The views presented should be considered for dual reasons; partly they tie in with the geographic variation in this context and partly they emphasize the very essential matter of the distribution of the real production by various assimilation products and respiration. It is of importance here to consider the changes in the rate of photosynthesis which are caused for instance by varying geographic latitude and difference in the length of the growing season as well as the intensity of respiration varying at different conditions.

The ratio between the total yield of photosynthesis and respiration (H. POLSTER: "Ökonomische Atmung", 1951, p. 54) is of decisive importance for the magnitude of the apparent assimilation, i.e. the amount of carbohydrates made available for the development of various plant parts.

Photosynthesis and respiration in plant parts versus stands

The process of photosynthesis as well as that of respiration under various conditions with respect to supply of light, heat, moisture and carbodioxide have been explored by the work of several workers e.g. Boysen-Jensen, Burns, Henrici, Heinicke, Holdheide, Huber, Kozlowski, Lundegårdh, Pisek, Polster, Stocker, Stålfelt, Tranquillini, and Zeller. Inspite of the intensive development within this field there are certain gaps in our knowledge which occur as great deficiencies in phyochorological investigations. This is particularly the case of the relationship between the process of photosynthesis in individual plant parts and that of entire tree stands. Investigations carried out by HEINICKE and HOFFMAN and by HEINICKE and CHILDERS seem to indicate that the processes in this respect need not necessarily be similar. Whereas the former research workers found that individual leaves from the apple reached maximum photosynthesis at a light intensity corresponding to a third to a fourth of full sun light, the latter workers stated that the entire apple tree achieved the highest photosynthetic effect only at noon in clear days. A. PISEK and W. TRANQUILLINI (1954) found that the light requirements in dense stands of a species are considerably greater than those of solitary branches from the same tree. The American as well as the Austrian research workers thus confirm the statements made by Boysen-Jensen long ago.

Concerning respiration, too, we know its magnitude under certain conditions (cf. POLSTER, 1951). However, the same deficiency occurs here as in the case of photosynthesis. Observations made pertain to short time periods, parts of the plants investigated or tender plants and the investigations have usually been made under the periods of the growing season which are most favourable for photosynthesis from a climatic point of view (ibid.). The values obtained are therefore representative only to the limited extent determined by the primary data used. The greatest caution must be exercised when attempts are made to compute values of photosynthesis and respiration for entire forest stands from data obtained from branches or solitary seedlings. Too little is yet known of the simultaneous, physiological processes in a branch, a seedling, a tree and an entire stand. The investigations carried out by Heinicke-Hoffman-Childers and Pisek-Tranquillini and mentioned above seem to indicate that the results will be different. Difficulties to find data valid for entire stands from present detail information are further enhanced in view of knowledge provided by micro-climatology concerning the vertical temperature layering in stands. This layering means that the tree crowns are vertically distributed by various temperature zones. Light conditions, too, are different within various parts of the canopy. The interacting influences of the various conditions are not yet sufficiently known to allow the computation of a dependable mean value of the total photosynthesis and respiration of a stand at a given time, and still less with respect to the entire growing season. If feasible equipment is available, analyses of gaseous processes under macro-conditions seem to be avenues that would lead toward a solution.

Previous investigations concerning photosynthesis and respiration comprise only a minor portion of the growing season, i.e. they are made in the course of two-three months and not continuously but in periods of one to several days. A computation of values for the total photosynthesis and respiration from these time-limited data, which furthermore are affected by the methodical deficiencies discussed above, can produce but rough approximations.

Although stating that data now available on photosynthesis and respiration in forest stands per hectare and annum still lack a degree of accuracy sufficient for detailed phyochorological research, we must stress the value of results obtained particularly by comparative investigations of photosynthesis and respiration which have enabled a grouping of our most common species according to their capacity of photosynthesis and economy of respiration. Differences between the species expressed in grams per green-weight, in sq. cm. foliage surface, or for entire stands, are obvious. In conjunction with these comparisons it should be remarked that stand data provide proper relations if the various species display the same yield physiology pattern for the individual tree as well as the stand. The relative values of the annual yield

Table 6. Relative values of the apparent photosynthesis expressed in kg C/ha/annum for various species in Germany

Species	Relative values
Pseudotsuga Douglasii	100
Fagus silvatica	73
Picea excelsa	60
Larix europea	58
Betula verrucosa	48
Quercus robur	34
Pinus silvestris	25

of some common species is elucidated by the following table which is computed from values presented by H. Polster (1951, p. 80) for the assimilation surplus (the apparent photosynthesis) calculated in kg carbon per hectare and annum. The apparatent photosynthesis is obtained by subtracting respiration from the real photosynthesis. The species with the highest surplus has been given the value 100 and other species proportional values (Table 6).

A somewhat changed order is obtained if corresponding relative values are instead computed on the basis of "Derbholzzuwachs" expressed in kg C/ha/annum (ibid., p. 81) for various species in Tab. 7.

Table 7. Relative values of "Derbholzzuwachs" (expressed in kg C/ha/annum for various species in Germany)

Species	Relative values
Pseudotsuga Douglasii...	100
Picea excelsa...........	59
Fagus silvatica.........	53
Larix europea..........	44
Pinus silvestris.........	41
Quercus robur..........	40
Betula verrucosa........	33

In spite of the changed order the tables show clearly the great mutual differences between the species with respect to yield. The relative values in other climate areas, as well as the mutual order of species typical of other climate types, are still beyond our knowledge.

Computing his reduction values, Weck thus used data on the yield balance of beech and assumed values of photosynthesis and respiration within various climate areas. Against the background of this presentation Weck's procedure seems to produce values of a low degree of dependability. However, the method developed by Weck is of great theoretical interest and it will also be practically valuable as soon as the basis of yield physiological data necessary is developed.

At present phyochorological research must be based on yield data in forestry expressed in cu. m. wood or tons of dry matter. Within uniform climate areas we may expect consistent relationships between photosynthesis, respiration and an "economic" yield measured in cu.m. (tons) of wood. Detailed phyochorological investigations may give information whether the relationships are different for other climate areas. However, it is important to collect the yield data from local strains.

The investigation method concerning the relationship

The investigation of the relationship between yield potential and climate has proceeded as follows: a number of scatter graphs were drawn to obtain an exploratory information concerning the relationship; the most suitable graphs were then considered for a regression analysis and determination of the correlation strength.

Experiment 1. Initially a scatter graph was established for each age class on the basis of the author's original equation (1956) for the computation of the *CVP* index where the growing season is expressed in months. All the distribution pictures here show a clear relationship between the variables. No parameters were computed for a determination of this relationship but the pictures obtained were used for a visual comparison with the corresponding presentation in the following experiment.

Experiment 2. It would be desirable from a practical point of view to express already in the formula for *CVP* the prevailing conditions associated with the computation of the length of the growing season and the minimum requirements of its length. In other words it should be clear from the equation that the growing season is determined by the no. days with a temperature of + 7° C or more and that it furthermore must have a minimum duration of 90 days. As stated previously, it may be assumed for logical reasons that a definition in terms of days must give a more accurate value than an expression in months. An equation established on this basis will have the following appearance:

$$CVP = \frac{T_v \times N \times (G - 90) \times E}{(T_a + 7) \times 270 \times 100}.$$

For values of $G < 90$ this expression of *CVP* becomes negative, which means that the climate conditions are unsuitable for tree growth. According to the previous discussion $G = 90$ would indicate conditions occurring at the tree limit. The advantage of increasing T_a by 7 shows particularly for equatorial areas, where the difference between T_v and T_a is slight. Considerably lower index values are obtained. The dispersion graphs show, however, that a somewhat weakened relationship is obtained for Sweden in comparison with that in experiment 1, particularly within the range of low *CVP*-values. This procedure of computation was therefore considered less suitable.

Experiment 3. The next step in the investigation was to study the relationship when *CVP* was determined according to the formula

$$CVP = \frac{T_v \times N \times G \times E}{T_a \times 360 \times 100}$$

The dispersion graphs established on the basis of this formula for various age classes show a picture very similar to that obtained in experiment 1. Further testing by means of statistical computation for the establishment of potential differences was therefore not considered necessary. The latter expression presented here, however, appears most suitable on account of the more distinct definition of composite factors.

Experiment 4. The author stated in his work of 1956 (p. 73) that precipitation particularly within the A- and C-climate regions according to the Köppen scheme exert too great an influence on the *CVP*-index in relation to its effect on the growth potential. The growth appears to show a purely negative response to superhumid amounts of precipitation. It will be shown in the following presentation that the same effect can occur in Norden as well. In this context the annual precipitation consequently gives an unrealistic expression of the growth promoting influence of the water. To correspond to the growth power, the annual precipitation must be reduced by a value representing the surplus water and its negative effects in the form of nutrient leaching etc. However, great difficulties are involved in the establishment of such a reduction factor since it is also dependent on variable factors such as e.g. temperature and site conditions.

O. F. S. TAMM treated in a work (1959) the climatic humidity of Sweden. Humidity (H) was defined as the difference between the annual precipitation and the mean value of the evapo-transpiration. To compute the latter factor Tamm succeeded in establishing a functional relationship with the mean annual temperature. Thus it is possible to establish the evapo-transpiration for each individual point with known temperature value. It would be desirable in this investigation to test an expression of transpiration only in our relationship. The plant physiologically active part of the moisture available would then be represented. Since no such value has been established, it would be interesting to use the Tamm value for evapo-transpiration (E) as a substitute. However, since this value is a function of temperature, we then introduce a new temperature factor and no improvement of the relationship can be expected. Although the humidity values express a humidity where the influence of temperature has been eliminated to the greatest extent possible, they are less useful in this context since they lack the plant physiological influence desired. A weakened relationship was obtained when E and H were tested.

The equation used in experiment 3 appears to be the most suitable one for a computation of the *CVP*-value corresponding to the yield. The relationship obtained in this way is given an exploratory presentation in the dispersion graphs, Fig. 21—24, one for each age class.

A comparison between the graphs seems to reveal that the function lines have a slightly different position as expressed by the inclination in relation

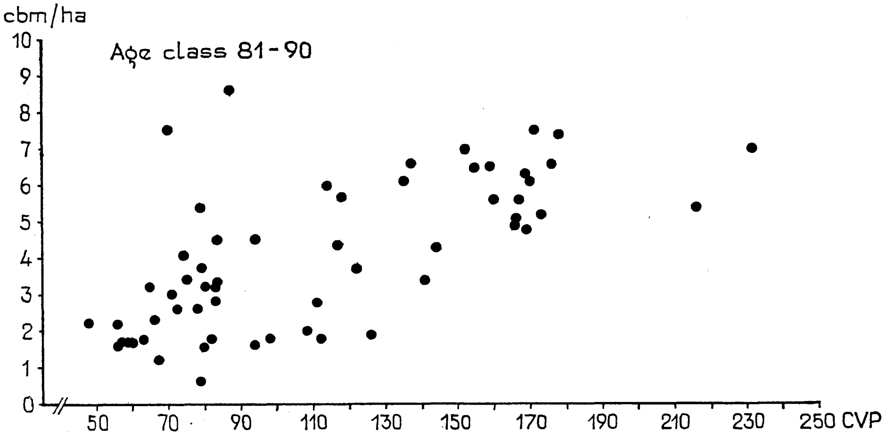

Figure 21. Scatter graph showing the relationship between *CVP* and yield, age class 81—90 years.

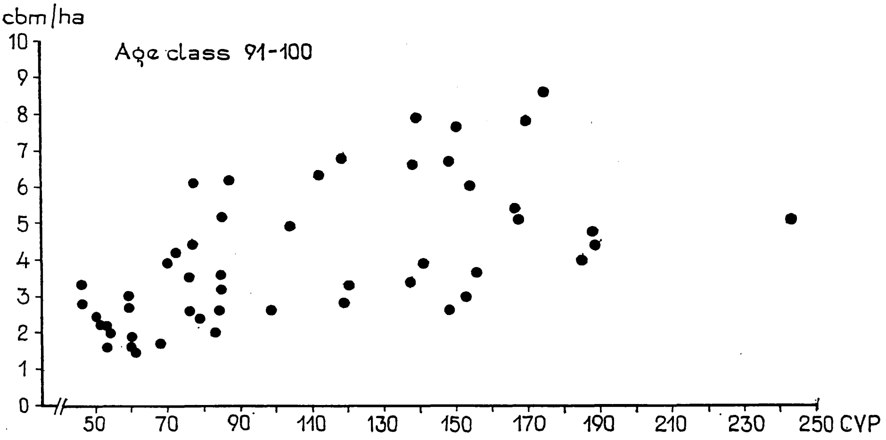

Figure 22. Scatter graph showing the relationship between *CVP* and yield, age class 91—100 years.

to the *X*-axis. To ascertain the actual status exactly, the regression function was calculated for each age and for the total material. The functions are presented in Fig. 25, which reveals certain differences. The curve of the age group 91—100 years is most level whereas those of the groups 81—90 years and 111—120 years are steeper and nearly parallel to each other. The maximum difference at *CVP*-value 200, a point determined by sufficient statistical data, does not fully reach a value of one cu.m per hectare. Discrepancies between the age classes may partly be interpreted as expressions of the fact that the

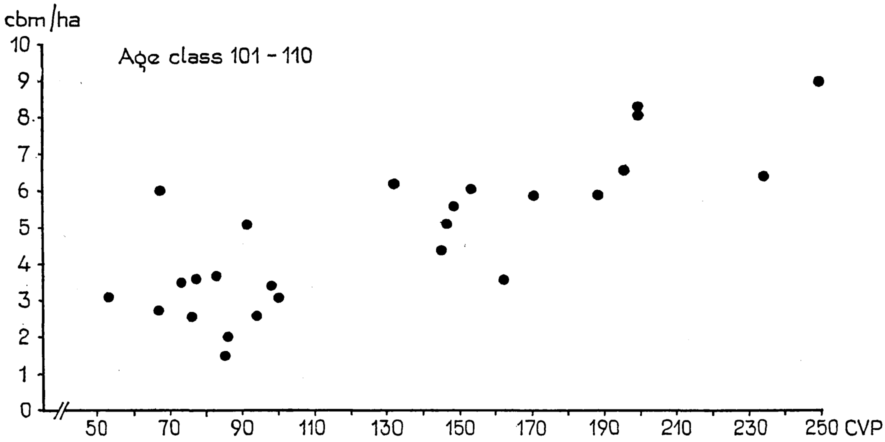

Figure 23. Scatter graph showing the relationship between *CVP* and yield, age class 101—110 years.

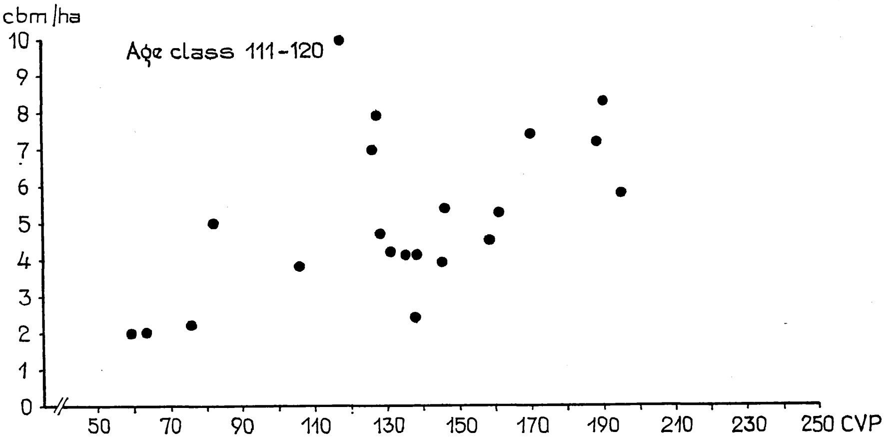

Figure 24. Scatter graph showing the relationship between *CVP* and yield, age class 111—120 years.

mean increment of the stand culminates at various age in different climate types.

The differences between age classes, however, may also be caused by irregularities in the material of the various age groups. Primarily, the non-climatic yield factors i.e. the edaphic factors, may then be considered. Differences between the age groups may thus be caused by dissimilar distribution of sample plots by soil types, sites of different hydrological properties and sites with different nutritional status etc. To procure

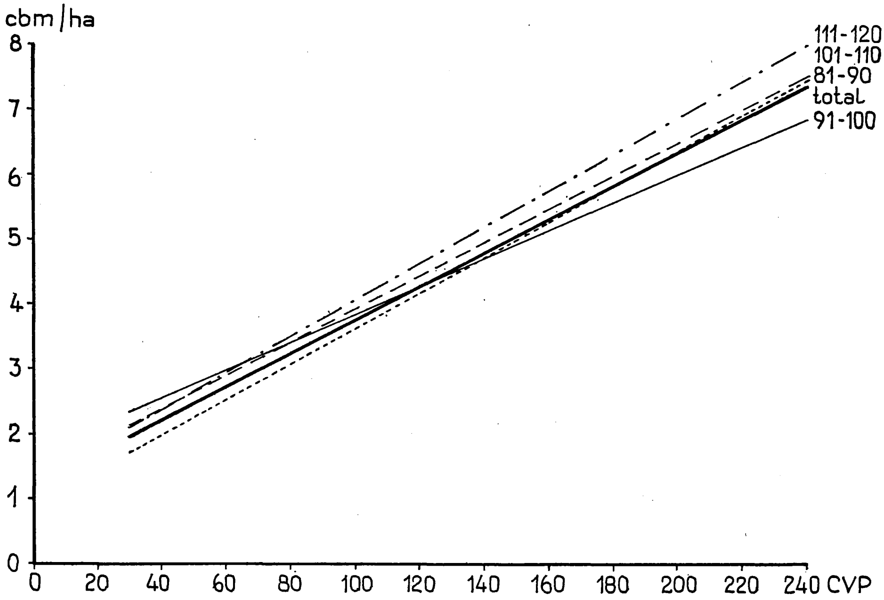

Figure 25. Regression functions for each age class and for the total material.

a survey of our data in these respects, we have investigated their distribution by forest types according to a preliminary physiognomic division carried out by the Forest Research Institute of Sweden on the basis of the scheme classification designed by C. Malmström. This will give an expression of i.a. variations in the hydrological conditions of our plots since the forest types show a clear relationship with the water supply of the sites (C. Malmström, 1949, p. 100, f.; ibid., 1949, p. 233). The relative distribution of the sample plots by forest types within each age class is shown in the graph, Fig. 26. Displaying great variations between the groups, however, the graphs do not show the geographical distribution of the forest types. If all the plots with Geranium type in an age class are found within the range of low *CVP*-values in our function, this distribution must reduce the slope of the corresponding regression line. This may possibly explain why the age group 91—100 years displays a deviating position in relation to other age groups. However, further elucidation of this matter requires a more detailed investigation not possible in this context.

After the comparative studies of the dispersion graphs had been concluded to find the best expression suitable for a computation of *CVP*, a complete statistical treatment of the data could be undertaken. The intention was to clarify by regression analysis the importance of each of the factors included in the *CVP*-index for the relationship between the yield and climate. The

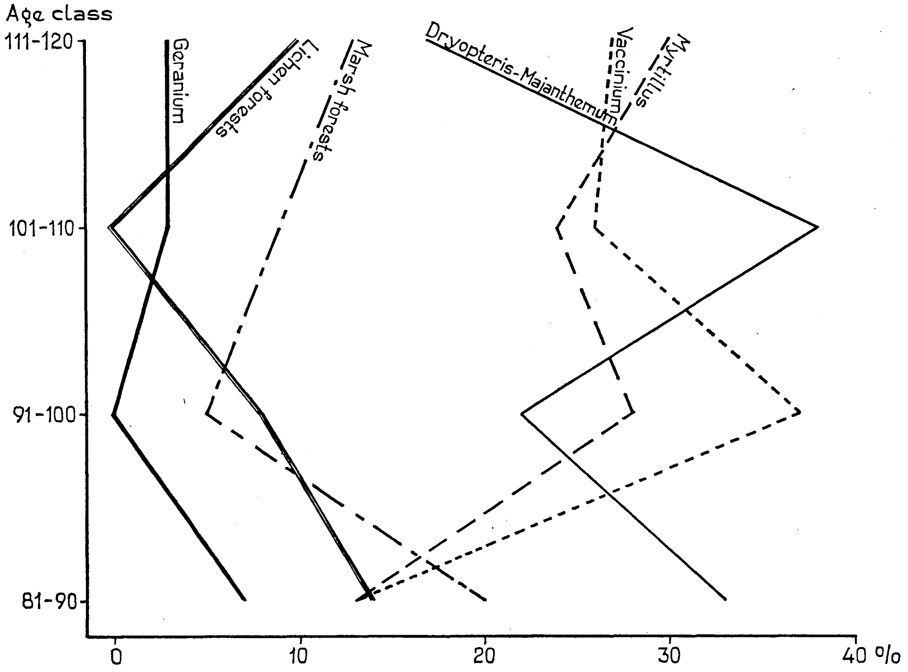

Figure 26. Frequency of the sample plots by forest types in each age class, per cent.

establishment of a correlation matrix would then in addition to the relationship enable a study of the mutual relationships between the composite factors. The statistical computations necessary were carried out under the guidance of Mr. O. Persson, Civ. Eng. at the Forest Research Institute of Sweden, who has also written the following report concerning this work. The meaning of the term *S*, which is an expression of the electric conductivity of the soil, is discussed in a following chapter. The term *E* has not been included in the computation since it was clear from the very beginning that its importance for an improved fit is slight within the relatively limited area covered by this investigation.

Description of the statistical computations

By Olle Persson, Civ. Eng.

Notation:

Yield potential in m³sk per hectare and annum, allowance made for mortality.. y_1

Yield potential in m³sk per hectare and annum, allowance not made for mortality.. y_2

Mean temperature of the warmest month, °C	T_v
Temperature range (difference between the mean temperature values of the warmest and the coldest months)	T_a
Precipitation (mean annual value in mm)	N
Length of growing season in days	G
Electric conductivity of the site	S
Paterson's index $\frac{T_v \cdot N \cdot G \cdot E}{T_a \cdot 360 \cdot 100}$:	CVP

(E = insolation according to pages 47 and 69).

Observations are made concerning y_1, y_2, T_v, T_a, N, G, S and CVP for a total of 174 plots.

Computations.

Both series of y_1 and y_2 have first been fitted graphically by means of a number of regression functions the most important of which are reported in the following presentation (Tables 8—9). Quadratic terms of N and S and $\frac{T_v}{T_a} \cdot G$ have also been tested in the investigation but they have not improved the fit. Fit is approximately equal in both series, and this is shown by the dispersion of the function in per cent of that of the total mean value decreasing similarly.The absolute dispersion, however, is greater for the y_1-series than that for the y_2-series. Only the y_1-series was therefore investigated in some supplementary analyses. This was also carried out for the four age classes 81—90 years, 91—100 years, 101—110 years, and 111—120 years, which are represented by 60, 49, 31, and 22 plots, respectively (Table 10). Within these groups some functions which had produced significant indications at the first tests, were investigated. The regression analysis has been supplemented with a computation of both the total and the partial correlation coefficients up to third order. The correlation coefficients could be derived from the regression coefficients and their standard errors by simple computations. The analysis has been carried out for the total material by means of a standard programme for regression analysis with the electronic computing machine, Facit EDB; the subgroups have been calculated by means of manual computations.

In the following presentation not only the functions but also the standard errors of the coefficients and the standard deviations of the y_1- and y_2-values of the functions are reported. Dispersion may be considered a measurement of the variations of observational errors and the influences of various unknown factors that may affect the yield. Moreover, dispersion values are presented in per cent of the dispersion of the total mean values of the y_1- and the y_2-series. The functions obtained within the groups for the relationship between y_1

Table 8. Regression functions, yield potential adjusted for natural thinning (volume of mortality).

Function No.	1	2	3	4	5
Constant term	—9.00 ±1.95	7.06 ±2.42	7.32 ±2.96	5.57 ±3.24	4.70 ±3.24
Coefficient of T_v	0.870 ±0.128	0.300 ±0.124	0.297 ±0.127	0.101 ±0.196	0.0974 ±0.194
T_a		—0.338 ±0.0380	—0.342 ±0.0477	—0.254 ±0.0822	—0.228 ±0.0824
N			—0.000194 ±0.00127	—0.000516 ±0.00129	—0.0000769 ±0.00130
G				0.0223 ±0.0170	0.0191 ±0.0169
S					0.520 ±0.254
CVP					
Sum of squares of the function	510.37	349.13	349.08	345.58	337.18
ΔF	172	171	170	169	168
Dispersion of the function	1.72	1.43	1.43	1.43	1.42
Dispersion of the function in per cent of the gross mean value	89.1	73.9	74.1	74.0	73.3

Function No.	6	7	8	9	10	11
Constant term	2.49 ±0.299	1.18 ±0.303	12.6 ±0.734	0.341 ±0.727	—3.79 ±0.706	0.778 ±0.319
Coefficient of T_v						
T_a			—0.385 ±0.0330			
N				0.00671 ±0.00125		
G					0.0600 ±0.00525	
S	1.70 ±0.270					0.816 ±0.248
CVP		0.0257 ±0.00241				0.0223 ±0.00257
Sum of squares of the function	525.80	388.71	361.02	553.82	367.50	365.53
ΔF	172	172	172	172	172	171
Dispersion of the function	1.75	1.50	1.45	1.79	1.46	1.46
Dispersion of the function in per cent of the gross mean value	90.5	77.7	74.9	92.8	75.6	75.6

Table 9. Regression functions, yield potential not adjusted for natural thinning (volume of mortality).

Function No.	1	2	3	4	5	6	7
Constant term	— 5.54 ± 1.42	5.93 ± 1.78	5.62 ± 2.17	4.65 ± 2.38	4.05 ± 2.38	2.12 ± 0.215	1.17 ± 0.219
Coefficient of T_v	0.582 ± 0.0933	0.175 ± 0.0911	0.179 ± 0.0927	0.0704 ± 0.144	0.0677 ± 0.142		
T_a		— 0.241 ± 0.0278	— 0.236 ± 0.0349	— 0.187 ± 0.0603	— 0.169 ± 0.0606		
N			0.000235 ± 0.000933	0.0000562 ± 0.000950	0.000361 ± 0.000957		
G				0.0124 ± 0.0125	0.0102 ± 0.0124		
S					0.361 ± 0.187	1.17 ± 0.195	
CVP							0.0181 ± 0.00174
Sum of squares of the function	269.69	187.39	187.32	186.24	182.18	273.84	203.20
ΔF	172	171	170	169	168	172	172
Dispersion of the function	1,25	1,05	1,05	1,05	1,04	1,26	1,09
Dispersion of the function in per cent of the gross mean value	90.6	75.7	75.9	75.9	75.3	91.3	78.6

Table 10. Regression functions of the age classes 81—90 years, 91—100 years, 101—110 years and 111—120 years; yield potential adjusted for natural thinning.

Age class	81—90 years	91—100 years	101—110 years	111—120 years
Constant term	0.906 ± 4.836	1.692 ± 4.834	1.343 ± 0.616	1.262 ± 1.240
Coefficient of CVP	0.0272 ± 0.00422	0.0214 ± 0.00445	0.0254 ± 0.00467	0.0280 ± 0.00939
Sum of squares of the function	133.89	103.73	51.04	54.01
ΔF	58	47	29	20
Dispersion of the function	1.52	1.49	1.33	1.64
Dispersion of the function in per cent of the gross mean value	77.0	82.8	71.6	85.3

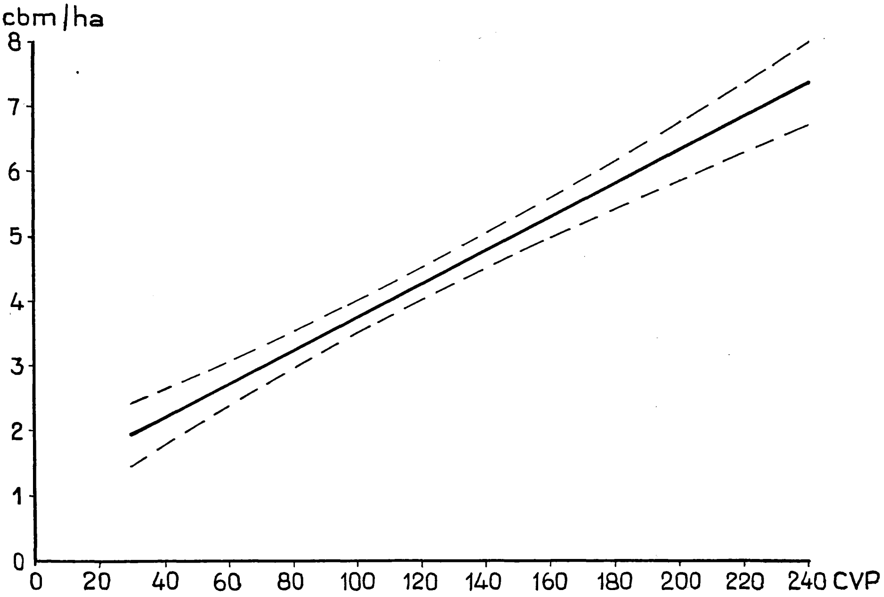

Figure 27. The theoretical regression line of the total material and the 95 per cent confidence belt.

and *CVP* are drawn in Fig. 25, which also shows this relationship for the total material. In Fig. 27 there is also a 95 per cent confidence belt for the theoretical regression line of the total material. No testing of the hypothesis that the groups can be totalled has been carried out since the total material contains some additional observations which have been too few to be totalled into independent groups. An ocular evaluation of the figure, however, does not seem to disprove the hypothesis. The correlation coefficients are finally reported in a matrix for the total material (Table 11), where most of the factors have been compiled, and in four smaller matrices (Tables 12—15) for the groups with but a few factors.

Nor have the hypotheses of the correlation coefficients been tested. Finally, it must be stressed that significance criteria used at regression analysis are based on certain assumptions which are often fitted in series of observations of the kind presented here. These assumptions also underlie the estimates reported for the standard errors and the correlation coefficients. One must therefore often make the reservation in a context of this kind that a significance may be more formal than real. In spite of this reservation the analysis still has its value when compared with other results obtained on a logical basis.

Table 11. Partial and total correlation coefficients for the total material.

		.2	.3	.4	.6	.8	.10	.23	.24	.26	.28	.210	.34	.36	.38	.310	.46	.48	.410	.68	.610	.810
T_v	11 2	—	0.18	0.42	—0.08	0.36	0.12	—	—	—	—	—	0.18	0.05	0.16	0.14	—0.07	0.34	—0.12	—0.08	—0.05	—0.09
T_a	11 3	—0.56	—	—0.59	—0.24	—0.58	—0.30	—	—0.48	—0.23	—0.50	—.030	—	—	—	—	—0.24	—0.50	—0.20	—0.22	—0.21	—0.25
N	11 4	0.33	—0.04	—	0.04	0.35	—0.31	—0.01	—	0.01	0.32	—0.31	—	—0.04	—0.01	—0.22	—	—	—	0.07	—0.17	—0.25
G	11 6	0.53	0.20	0.62	—	0.57	0.26	0.10	0.44	—	0.48	0.24	0.20	—	0.18	0.15	—	0.48	0.03	—	—	0.21
S	11 8	0.33	0.19	0.41	0.18	—	0.24	0.16	0.31	0.18	—	0.23	0.18	0.16	—	0.19	0.19	—	0.16	—	0.19	—
CVP	11 10	0.50	0.13	0.60	0.12	0.55	—	0.07	0.49	0.10	0.45	—	0.25	0.03	0.13	—	0.20	0.51	—	0.13	—	—

		.234	.236	.238	.231	.246	.248	.2410	.268	.2610	.2810	.346	.348	.3410	.368	.3610	.3810	.468	.4610	.4810	.6810	Total corr.
T_v	11 2	—	—	—	—	—	—	—	—	—	—	0.04	0.16	—0.03	0.04	0.05	0.12	—0.06	—0.12	—0.10	—0.05	0.46
T_a	11 3	—	—	—	—	—0.23	—0.42	—0.16	—0.21	—0.21	—0.26	—	—	—	—	—	—	—0.21	—0.20	—0.18	—0.19	—0.66
N	11 4	—	—0.03	0.01	—0.16	—	—	—	0.04	—0.20	—0.25	—	—	—	—0.02	—0.15	—0.18	—	—	—	—0.14	0.38
G	11 6	0.10	—	0.09	0.07	—	0.38	0.05	—	—	0.20	—	0.18	—0.02	—	—	0.12	—	—	0.03	—	0.66
S	11 8	0.16	0.16	—	0.17	0.19	—	0.15	—	0.19	—	0.16	—	0.14	—	0.16	—	—	0.16	—	—	0.43
CVP	11 10	0.18	0.03	0.08	—	0.23	0.42	—	0.12	—	—	0.15	0.22	—	0.04	—	—	0.18	—	—	—	0.63

Table 12. Correlation matrix for age class 81—90 years.

		Total	.2	.3	.10	.23	.210	.310
T_v	11 2	0.39	—	0.23	0.12	—	—	0.22
T_a	11 3	—0.72	—0.68	—	—0.41	—	—0.45	—
CVP	11 10	0.65	0.57	0.04	—	—0.05	—	—

Table 13. Correlation matrix for age class 91—100 years.

	Total	.2	.3	.10	.23	.210	.310
11 2	0.46	—	0.16	0.12	—	—	0.12
11 3	—0.57	—0.41	—	—0.14	—	—0.14	—
11 10	0.57	0.41	0.17	—	0.12	—	—

Table 14. Correlation matrix for age class 101—110 years.

	Total	.2	.3	.10	.23	.210	.310
11 2	0.31	—	—0.27	—0.27	—	—	—0.36
11 3	—0.72	—0.71	—	—0.30	—	—0.38	—
11 10	0.71	0.70	0.26	—	0.36	—	—

Table 15. Correlation matrix for age class 111—120 years.

	Total	.2	.3	.10	.23	.210	.310
11 2	0.62	—	0.49	0.46	—	—	0.50
11 3	—0.61	—0.48	—	—0.30	—	—0.36	—
11 10	0.55	0.35	0.08	—	—0.10	—	—

The results of the statistical computations

The computations carried out by O. Persson show that the temperature amplitude has the strongest influence on the yield of the climate factors considered. A similar feature, although appreciably weaker, is characteristic of T_v and N, to the same extent of T_a and the growing season G. On account of the interdependence between terms, their influence on the yield is best described only by T_v and T_a according to function No. 2.

$$(2)\quad y = 7.06+0.300\,T_v - 0.338\,T_a$$

Function No. 2 is valid within the limits of the geographical space where the sampling is made with its mutual relationships between the components of climate. This relationship is not constant and thus not generally valid for all climate areas. It must instead be conceived of as varying to the same extent as one or other of the climate elements diminishes toward the limit where it acquires the nature of a minimum factor. According to general experience, temperature is the climate element most decisive for growth in Sweden. The functional relationship in equation 2 must therefore be considered entirely logical. Yet, it is covering only 26 per cent of the variations in the material whereas the remaining 74 per cent refer to not observed factors and measurement errors. It is interesting against the background of views expressed to study the degree of fit when *CVP* is used as variable. We then obtain function No. 7.

$$(7)\ y = 1.18 + 0.0257\ CVP$$

The parameters of the dispersion of this function show slightly inferior values in comparison with corresponding values for function 2. From a statistical point of view, however, function 2 appears as the better one of all those established here on the basis of climate data. It has previously been shown (St. St. Paterson, 1956) how the *CVP*-index covers the mutually varying relationships of the composite factors to give them comparable expression. The best example is provided by the conditions prevailing at the boundaries of dry deserts and cold deserts. Although these areas are conditioned by entirely different minimum factors, precipitation and temperature, respectively, the *CVP*-index presents the same value for both boundaries. In spite of the changed mutual order of the magnitude of the influence of these climate elements on the growth power, they give the same result if entered in the equation for *CVP*.

With the exception of certain strongly humid areas in relation to their surroundings, the discussion above pertains to interregional comparisons based on mean values for yield and on the data of a generalized macro-climate. In the present investigation, where absolute yield values have been used, it has appeared necessary to produce data for the local climate of each site. As shown in a previous chapter these are essential requirements not least with respect to water supply. The division of the Nordic countries into three ombro-hygro-thermal regions shows that the water supply and annual precipitation of individual localities do not run parallel to each other. Nor do they constitute synonymous expressions of the bio-effect since they instead exhibit great variations in this respect. To achieve a better fit, it is necessary to find a suitable expression of the hygrometric conditions of the sites during the growing season and then to replace the annual precipitation with this value in our function.

Table 10 contains the regression functions in the four most important age classes for yield with respect to the *CVP*-index. The best relationship occurs within the group 101—110 years, which appears to have both the lowest dispersion parameters and the highest correlation coefficient, $r = 0.71$. Its function is:

$$y = 1.343 + 0.0254\,CVP$$

This function shows by means of a determination coefficient (r^2) of 0.50 that the factors included cover 50 per cent of the variation of the yield values. The reason for the superior fit in this age group cannot be interpreted as a special age dependence but may be considered dependent on the reduced influence of not included factors on account of the selection.

The relationship of the individual climate elements with the growth potential has been analysed for the total material in Table 11.

The total correlation coefficient of T_v, $r = 0.46$, represents a weak relationship. The partial correlation coefficients inform that T_v is strongly correlated with both T_a and G.

$$r_{11\ 2.3} = 0.18 \qquad r_{11\ 2.6} = -0.08 \text{ and } \qquad r_{11\ 2.3.6.} = 0.05$$

The temperature range and the growth potential are obviously correlated, the correlation coefficient being $r_{11\ 3} = 0.66$. It is interesting to find that this correlation is considerably less influenced by T_v, $r_{11\ 3.2} = -0.56$, than the latter factor is correspondingly influenced by T_a according to the previous paragraph. Considerable influence is exerted by G on T_a since the correlation coefficient decreases to $r_{11\ 3.6} = -0.24$, if G is kept constant. Accessory correlation coefficients of the second and third order cannot impair the latter correlation to any appreciable extent.

Of all climate factors considered, precipitation has the weakest influence on the variation of yield, $r_{11\ 4} = 0.38$. The correlation coefficients of higher order show that precipitation is a variable depending on temperature range and growing season to a considerably larger extent than the latter factors are depending on precipitation.

The growing season shows a clear relationship with the growth potential, $r_{11\ 6} = 0.66$. This relationship is strongly influenced by T_a, $r_{11\ 6.3} = 0.20$ and weakly by T_v, $r_{11\ 6.2} = 0.53$. Precipitation has no pronounced influence.

Observations now made concerning the correlation conditions are supported by the partial coefficients for yield and CVP-index as variables, shown on the last line in the matrix (Table 11).

The partial and total correlation coefficients presented in Table 11 are based on correlation conditions valid for the site. If corresponding correlation coefficients are available and valid for average yield conditions within approximately the same area, i.e. that of Sweden, a comparison between the coefficients of the two groups would provide valuable information particularly concerning the general influence of the edaphic factors. Correlation coeffients of the kind desired, except for the growing season, have been computed by the author with the benevolent assistance of Mr. U. Zachrisson, Ph. Lic. of the statistical institution at the University of Gothenburg (St. St. Paterson, manuscript p. 20). The material comprises a total of 41 yield data, 27 of which orginate from Sweden, 1 from Norway and Denmark, respectively, 3 from U.S.A. 1 from each of Canada, Cameroun, Nigeria and Java, and 5 from Germany. On account of the dominance of the Swedish material and the closely similar Norwegian, Danish, German and Canadian data, the statistical comparability with the present site material should be satisfactory, although not complete. The two groups of material have been compiled in the following table, Table 16.

Table 16. Partial and total correlation coefficients for the relationships between some climate elements and the yield of the site (L) and that of the average (M)

	.2		.3		.4		.23		.24		.34		Tot. Korr.	
	L	*M*	*L*	*M*	*L*	*M*	*L*	*M*	*L*	*M*	*L*	*M*	*L*	*M*
	Correlation coefficient = 0,													
11 2	—	—	18	80	42	66	—	—	—	—	18	80	46	66
11 3	— 56	— 92	—	—	— 59	— 86	—	—	— 48	— 92	—	—	— 66	— 88
11 4	33	36	— 04	02	—	—	— 01	03	—	—	—	—	38	36

The total correlation coefficients indicate a considerably stronger relationship within the *M* groups for the two temperature variables, whereas precipitation has an almost equally weak influence on the variation of yield within both the groups. This feature of precipitation is further evidenced by the partial correlation coefficients. One of the correlation coefficients, $r_{11\ 4.3} = -0.04$ and 0.02 respectively, indicates that precipitation is so strongly related to the temperature range that the importance of the former factor for the correlation is already expressed by T_a. This observation, however, is not to be generalized but is valid only for conditions within the limits of the material. This condition is valid for all the comparisons made in this context. The total correlation coefficients for 11.2 and 11.3 are both lower in the *L*-group than those in the *M*-group. The influence of unconsidered factors has thus been greater within the former group. The partial correlation coefficients indicate this increased influence to affect the T_a-factor to the greatest degree. This influence primarily pertains to the edaphic conditions. Observations now made consequently indicate that the two expressions of temperature describe the general yield conditions better than the conditions prevailing on the local site. Improved fit should be achieved by means of direct data on the site climate.

The partial and the total correlation coefficients presented in the tables 12—15 give a picture of the correlations studied which is more similar to the total material. Here, too, the strong influence of the factor T_a is clearly manifested within each age group.

The weakness in our data on yield caused by the stand composition factor (Z) has repeatedly been mentioned in the preceding discussion. This influence will be elucidated as a completion of our statistical analysis. On the basis of the values presented in Table I for the stand composition, the portion of Scots pine is computed and entered as a new variable after which we obtain the regression functions presented in Table 17.

The regression functions show that the stand composition has an obvious influence on the mean increment. The lowest parameter values for dispersion found in this study are recorded in function 17. This is the case also with the functions 18 and 19 in comparison with corresponding functions where *CVP*-index is included and obtained previously (Table 8). Function 17, however, cannot be used since three fourths of its values are not significant.

Comparison with the potential productivity of other Nordic countries

The applicability of the regression functions now obtained may be tested by a comparison with yield data for localities in Denmark, Finland and Norway. The comparison, however, cannot be expected to provide complete agreement because of deviating features in the material which will be elucidated in the following presentation. Since no data concerning the electric conductivity of the sites are available from the other Nordic countries, no equations containing this term have been applicable. The best regression function then appeared to be function No. 16 (Table 17).

$$y = 6.80 - 0.019\ T_v - 0.177\ T_a - 0.0013\ N + 0.0295\ G - 0.0217\ Z$$

However, as shown by the table, several of the values included in this function are not significant. For this reason and to avoid the time-consuming data processing involved in the solving of the next best function No. 14 for each sample plot and the subsequent comparison of the value obtained with that recorded, the author has found it most suitable to use the function No. 18 in which the *CVP*-index is included. The slightly greater dispersion of this latter function is not so great that the comparison is appreciably impaired. Since it is impossible to express an opinion of the probability of one function or the other and since they are not directly comparable, it is not possible on statistical basis to say which is the most suitable one to use. The choice must rest on logical arguments.

Function No 18: $y = 3.47 + 0.0204\ CVP - 0.0222\ Z$

Omitting Z, we have previously (Table 8, p. 71) obtained function No. 7

Table 17. Regression functions showing the influence of stand composition on the yield potential. Allowance made for mortality (natural thinning).

Function No.	12	13	14	15	16	17	18	19
Constant term	+7.210 ± 0.407	—3.066 ± 1.973	+7.9156 ± 2.3156	+9.0427 ± 2.8380	+6.8026 ± 3.0745	+5.9669 ± 3.0727	+3.4658 ± 0.5866	+3.0272 ± 0.5850
Coeff. of T_v		+0.6399 ± 0.1206	+0.2573 ± 0.1187	+0.2424 ± 0.1209	—0.0187 ± 0.1868	—0.0211 ± 0.1851		
T_a			—0.277 ± 0.0387	—0.2950 ± 0.0466	—0.1769 ± 0.0796	—0.1529 ± 0.0797		
N				—0.0008 ± 0.0012	—0.0013 ± 0.0012	—0.0009 ± 0.0012		
G					+0.0295 ± 0.0162	+0.0264 ± 0.0161		
S						+0.4929 ± 0.2403		+0.7830 ± 0.2352
CVP							+0.0204 ± 0.0026	+0.0172 ± 0.0027
Z	— 0.040 ± 0.005	—0.0326 ± 0.0050	—0.020 ± 0.0047	—0.0208 ± 0.0048	—0.0217 ± 0.0047	—0.0215 ± 0.0047	—0.0222 ± 0.0050	—0.0217 ± 0.0048
Sum of squares of the function	476.43	408.69	314.49	313.32	307.30	299.76	348.15	326.74
Degrees of freedom	172	171	170	169	168	167	171	170
Dispersion of the function	1.66	1.55	1.36	1.36	1.35	1.34	1.43	1.39
Dispersion of the function in relation to that of the total mean value, per cent	86.1	80.0	70.3	70.4	69.9	69.3	73.8	71.7

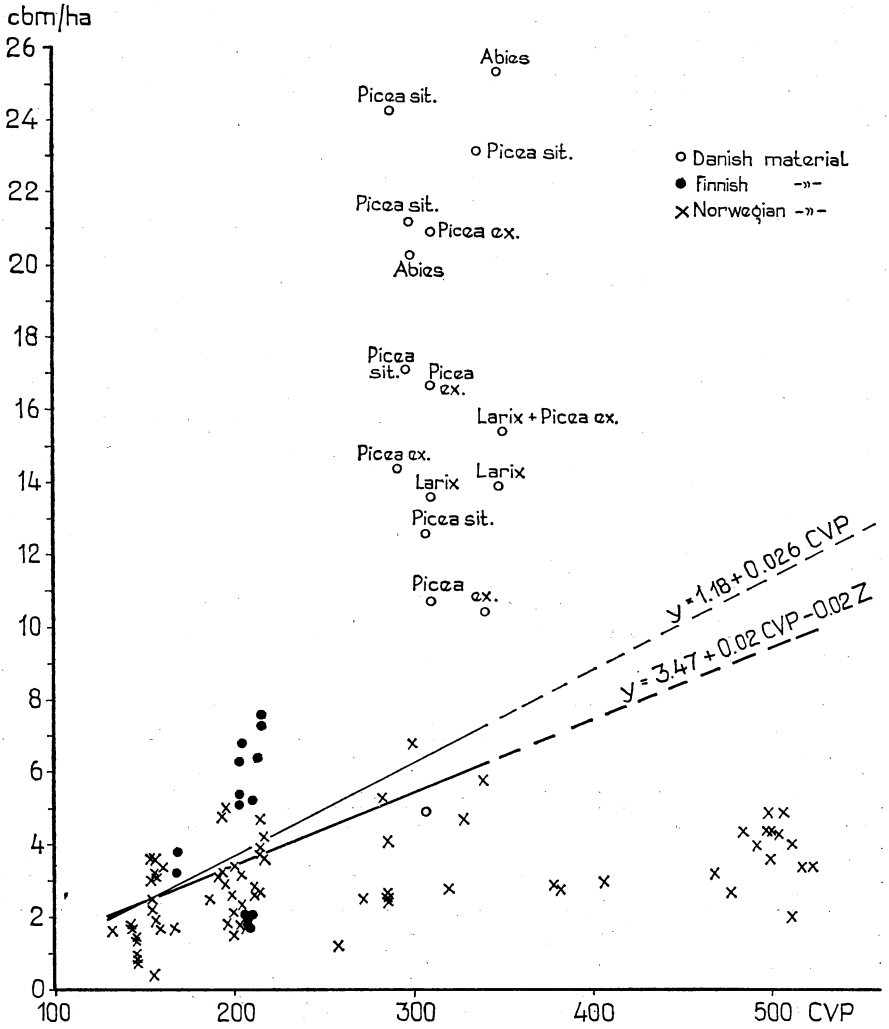

Figure 28. Relationship between the yield and climate of the site in the Nordic countries. Comparisons between scatter graphs and regression functions.

for the total Swedish material, $y = 1.18 + 0.026$ *CVP*. Its relationship to function No. 18 is of interest to study in this context.

The functions Nos. 7 and 18 as well as the material representing the countries of comparison are expressed in Fig. 28 by means of a scatter graph for yield with respect to *CVP*.

The material representing Denmark comprises 15 sample plots with 16 increment values. With one exception the latter values are found in Fig. 28

to be decidedly higher than the other material of comparison. Moreover, the Danish yield values are scattered in the graph without obvious relationship to *CVP*. Dispersion is considerable. The reasons for this are to be found primarily in two circumstances; species and rich soil. The sample plots represent four species, all of which are exotics. Since the stands are also established by planting, they are alien to this investigation.

Data on the mean increment from 14 sample plots in virgin stands have been made available from Finland. The values deviate slightly from the Swedish ones by being based on volume above the ground whereas the Swedish values are computed for the volume above the stump. The Finnish values are therefore estimated to exceed the Swedish values by 1—2 per cent. Allowance has been made for mortality. The stand composition is more heterogeneous than that in the Swedish material. Thus, six of the plots are representing pure Scots pine stands, two plots contain more than 50 per cent Scots pine whereas the other plots contain spruce or birch as predominant species (cf. notes to Table III). The plots have the variable soil texture composition typical of the moraine with the exception of four plots where sand is predominant. (Y. VUOKILA, acc. to letter). The statistically limited material thus displays great differences. Nevertheless, it shows a certain agreement with the Swedish regression functions according to Fig. 28. The best agreement is obtained for the pure Scots pine stands on moraine soils. The lowermost points are referring to the Scots pine plots on sand. The influence of the edaphic factors on dispersion is obvious. Due to the small extent of the material it is unknown whether it represents average or extreme yield conditions. A comparison between Finnish and primarily Swedish mean yield seems to indicate that extreme elements may be involved in the Finnish data, cf. author's scatter graph of 1956 (ST. ST. PATERSON, 1956, p. 79). This comparison shows that the Finnish mean yield of various forest districts is lower than the material of comparison in most cases.

The Norwegian data originate from 73 sample plots in virgin stands. The stands are pure Scots pine with the exception of eight plots with inmixture of spruce or broad-leaved species not exceeding four per cent. This maximum inmixture pertains to one plot only whereas the other plots display an admixture of only some promille. The volume computation has been carried out according to certain standards at the Forest Research Institute of Sweden. The material has benevolently been made available by the Norwegian Forest Research Institute under the supervision of A. BRANTSEG. As shown in the map, Plate I, the sample plots are not evenly distributed over the country but more in groups. To obtain a more even geographical distribution, some attempts were made to include some plots in virgin spruce stands. This appeared impossible, however, since the spruce stands were too young. Concerning the northernmost plots in the upper part of the Pasvik river, it should be noticed that the culmination age is approximately 200 years. In the case of western Norway no suitable material is available.

The dispersion of the Norwegian material in our graph, Fig. 28, shows certain essential, specific features. We generally find for Scots pine a closer agreement with the adjusted function than with the unadjusted one. More especially it appears that the point scatter at *CVP*-values up to about 130 is rather evenly distributed on both sides of the function and with moderate dispersion. At still higher *CVP*-values, however, the points are increasingly situated below the function and its continuation which is statistically unsupported and in the figure is dashed. We here have an obvious proof of the influence of precipitation. In the *CVP*-range 130—260 are plots, all of which are located in the interior of South Norway, *i.e.* largely the province of Telemarken, where precipitation ranges between 800 and 1,000 mm. *CVP*-values above 260 obtain their high value on account of abundant precipitation exceeding 1,000 mm a year. The high values of precipitation mean that the real forest yield will be 25 per cent below the level indicated by *CVP* as a climatic potential. This great difference is caused by the dual effect of precipitation. Partly it affects *CVP* to a far greater extent than that corresponding to its growth power promoting effect and partly it impairs the site conditions particularly by a leaching of easily soluble nutrients. The latter effect of high amounts of precipitation has been elucidated by O. Arrhenius in an investigation of the chemical denudation in the mountaineous regions (O. ARRHENIUS, 1957). In spite of favourable, mineralogically rich rock, the sites are here the poorest sites in Scandinavia and the nutrient concentration display a clear decrease at increasing amounts of precipitation. Similar conditions are most likely prevailing within the parts of Norway now discussed. Another reason contributing to the gap between yield and *CVP* may be the incompatibility of the species to the site. Our discussion is based on yield data of Scots pine which prefers light and not too moist sites. It is therefore reasonable to suggest that sample plots represented in the graph by *CVP* values higher than 160 would be higher yielding with other species, assuming they are suitable from an edaphic point of view as well.

The excessively strong influence of high precipitation values on the *CVP* index stated above, shows that precipitation should be introduced as a variable in the expression of index at a reduced value. During attempts to find a suitable form of reduction, $\sqrt{N}$ instead of N was introduced in the expression of *CVP*. Simultaneously, the yield values were cleaned from data pertaining to sample plots situated on sedimentary soils. The no. sample plots useful for this investigation was thereby reduced from 174 to 149. The ulterior motive of this measure was an attempt to produce a more uniform material from an edaphic point of view. As a result dispersion of CVP decreased more (6 per cent) than that of the individual climate elements (4 per cent).

In the following regression analysis some signs of radicals other than $\sqrt{N}$ were also tested (Table 18). The analysis shows that only $\sqrt{N}$ affects the relationship and then by improvement. The subsequent equation is thus obtained for the material treated.

$$CVP_1 = \frac{T_v \cdot \sqrt{N} \cdot G \cdot E}{T_a \cdot 360 \cdot 100}$$

The effect of substituting N for $\sqrt[3]{N}$ on the relationship has not been tested. An improvement does not appear probable if Fig. 29 and Fig. 30 are compared. A division of the material into two groups representing southern and northern Sweden is made in the graphs simultaneously with a report of the entire material. Northern Sweden here comprises Norrland and the province of Kopparberg, southern Sweden the rest of the country. It appears that the curves representing the functions with CVP_1 are very closely located whereas those with CVP obviously part, particularly with respect to South Sweden in relation to the other curves. The graphs also show that the functional relationship for northern Sweden is climbing faster than that for southern Sweden, which implies a curvilinear relationship. The curvature, however, is largely

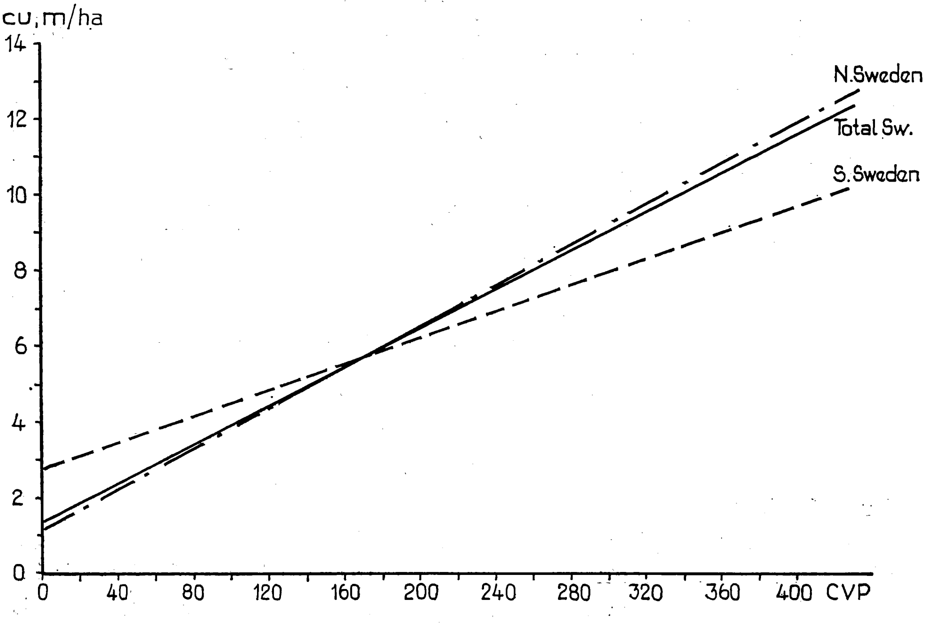

Figure 29. Relationships between yield and CVP for southern and northern Sweden, respectively, and for the whole of the country.

straightened by the introduction of $\sqrt{N}$ in the graphic presentation shown in Fig. 30. The regression line for the whole of Sweden entered in Fig. 30 provides a better and more realistic picture of the relationship than function No. 7 (Table 9) previously obtained. Our new function No. 6 (Table 18) is written as follows:

$$y = 0.443 + 0.814\ CVP_1$$

Being most suited methodically, this function will be applied in the computation of the potential yield in a subsequent chapter.

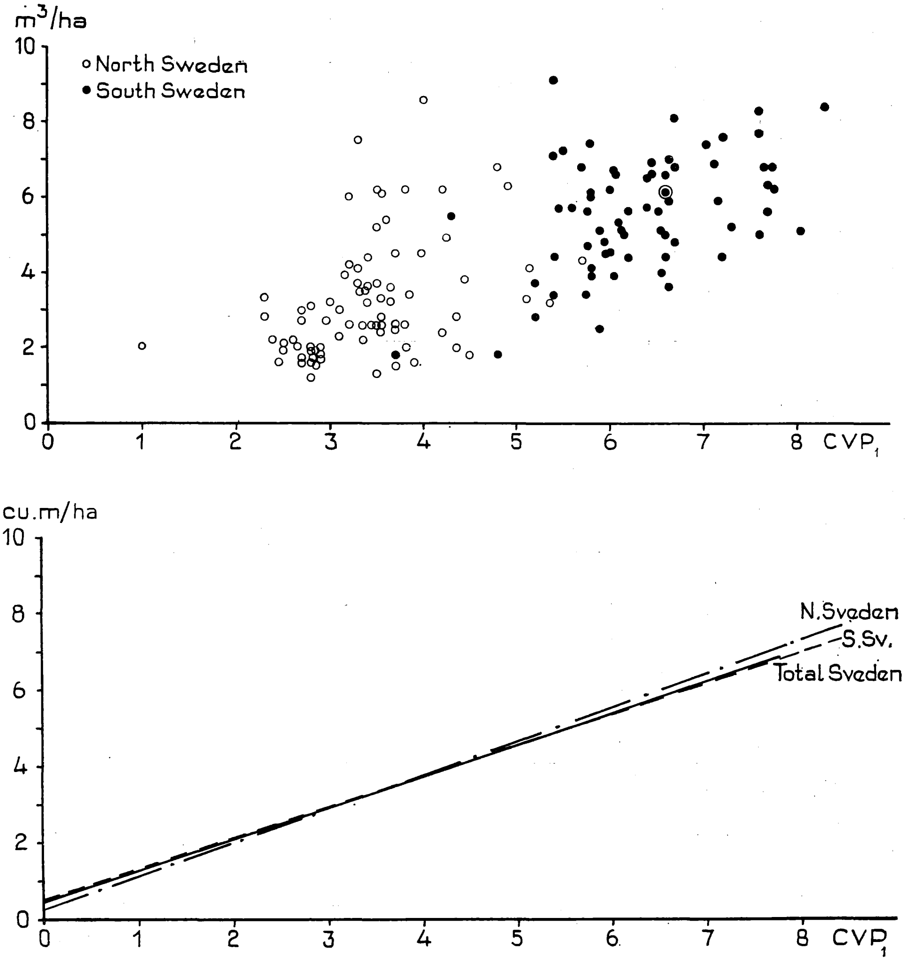

Figure 30. Relationships between yield and CVP_1 for southern and northern Sweden, respectively, and for the whole of the country.

Table 18. Regression functions for the testing of possibilities for an improved relationship by entering radicals of certain terms used in the *CVP* expression as well as for the testing of the relationship between production and altitude (*H*), latitude (*B*), and precipitation less the evapo-transpiration according to O. F. S. Tamm (*N-E*).

Function No.	1	2	3	4	5	6	7
Constant term	— 11.0 ±2.00	13.3 ±0.746	0.590 ±0.769	— 26.1 ±3.98	22.3 ±1.48	0.443 ±0.344	— 1.57 ±0.562
Coeff. of T_v	1.01 ±0.132						
T_a		— 0.408 ±0.0334					
N			0.0065 ±0.00131				
$\sqrt{T_v}$				7.83 ±1.02			
CVP_1*						0.814 ±0.0685	
$\sqrt{T_a}$					— 3.84 ±0.315		
H							
$\sqrt{CVP}$							0.559 ±0.0522
B							
N-E							
Sum of squares of the function	399.29	277.71	479.64	400.11	277.24	284.85	313.79
Degrees of freedom	147	147	147	147	147	147	147
Dispersion of the function	1.65	1.37	1.81	1.65	1.37	1.39	1.46
Dispersion of the function in relation to that of the total mean value, per cent	85.0	70.9	93.1	85.1	70.8	71.8	75.3
Correlation coeff., total and partial (p)	0.53	— 0.71	0.38	0.53	— 0.71	0.70	0.66

$$* \; CVP_1 = \frac{T_v \cdot \sqrt{N} \cdot G \cdot E}{T_a \cdot 360 \cdot 100}$$

Function No.	8	9	10	11	12	13	14
Constant term	6.07 ± 0.273	27.9 ± 2.10	4.84 ± 0.487	-4.13 ± 4.01	18.2 ± 4.22	-11.9 ± 2.24	12.7 ± 0.733
Coeff. of T_v				0.615 ± 0.242	0.371 ± 0.141	1.05 ± 0.138	
T_a							-0.342 ± 0.0364
N							
$\sqrt{T_v}$							
CVP_1*							
$\sqrt{T_a}$							
H	-0.00776 ± 0.00104			-0.00371 ± 0.00189			-0.00356 ± 0.000940
$\sqrt{CVP}$							
B		-0.384 ± 0.0342			-0.317 ± 0.0420		
N-E			-0.00205 ± 0.00176			0.00142 ± 0.00157	
Sum of squares of the function	406.31	300.71	553.76	389.01	287.08	397.04	252.88
Degrees of freedom	147	147	147	146	146	146	146
Dispersion of the function	1.66	1.43	1.94	1.63	1.40	1.65	1.32
Dispersion of the function in relation to that of the total mean value, per cent	85.7	73.7	100.1	84.2	72.3	85.0	67.9
Correlation coeff., total and partial (p)	-0.52	-0.68	-0.095	-0.16 (p)	-0.53 (p)	0.08 (p)	-0.30 (p)

$$* \ CVP_1 = \frac{T_v \cdot \sqrt{N} \cdot G \cdot E}{T_a \cdot 360 \cdot 100}$$

Function No.	15	16	17	18	19	20	21
Constant term	14.7 ± 4.29	14.2 ± 0.819	2.89 ± 0.738	33.0 ± 3.42	— 1.42 ± 0.606	10.9 ± 3.66	0.981 ± 5.83
Coeff. of T_v						0.100 ± 0.204	0.454 ± 0.136
T_a	— 0.374 ± 0.107	— 0.412 ± 0.0329				— 0.337 ± 0.0380	— 0.427 ± 0.105
N			0.00526 ± 0.00115	— 0.00262 ± 0.00140	0.0195 ± 0.00156		
$\sqrt{T_v}$							
CVP_1*							
$\sqrt{T_a}$							
H			— 0.00709 ± 0.000991			— 0.00296 ± 0.00153	
$\sqrt{CVP}$							
B	— 0.0344 ± 0.105			— 0.442 ± 0.0460			0.0959 ± 0.109
N-E		— 0.00294 ± 0.00123			— 0.0210 ± 0.00195		
Sum of squares of the function	277.51	267.28	355.17	293.67	267.76	252.46	257.62
Degrees of freedom	146	146	146	146	146	145	145
Dispersion of the function	1.38	1.35	1.60	1.42	1.35	1.32	1.33
Dispersion of the function in relation to that of the total mean value, per cent	71.1	69.8	80.4	73.1	69.8	68.0	68.7
Correlation coeff., total and partial (p)	— 0.03 (p)	— 0.19 (p)	— 0.51 (p)	— 0.62 (p)	— 0.67 (p)	— 0.16 (p)	0.07 (p)

$$* \; CVP_1 = \frac{T_v \cdot \sqrt{N} \cdot G \cdot E}{T_a \cdot 360 \cdot 100}$$

Function No.	22	23	24	25	26	27
Constant term	7.37 ± 2.82	9.22 ± 7.49	11.6 ± 3.75	4.23 ± 6.57	11.4 ± 7.90	5.63 ± 2.47
Coeff. of T_v	0.344 ± 0.137	0.128 ± 0.231	0.0821 ± 0.205	0.379 ± 0.152	0.0862 ± 0.236	0.411 ± 0.127
T_a	— 0.354 ± 0.0397	— 0.363 ± 0.110	— 0.347 ± 0.0396	— 0.407 ± 0.106	— 0.351 ± 0.111	— 0.341 ± 0.0383
N						
$\sqrt{T_v}$						
CVP_1*						
$\sqrt{T_a}$						
H		— 0.00282 ± 0.00163	— 0.00267 ± 0.00156		— 0.00266 ± 0.00164	
$\sqrt{CVP}$						
B		0.0294 ± 0.115		0.0604 ± 0.114	0.00415 ± 0.119	
N-E	0.00168 ± 0.00131		— 0.00122 ± 0.00133	— 0.00146 ± 0.00137	— 0.00120 ± 0.00137	
Sum of squares of the function	256.09	252.35	251.00	255.60	251.00	258.99
Degrees of freedom	145	144	144	144	143	146
Dispersion of the function	1.33	1.32	1.32	1.33	1.32	1.33
Dispersion of the function in relation to that of the total mean value, per cent	68.5	68.3	68.1	68.7	68.3	68.7
Correlation coeff., total and partial (p)	— 0.11 (p)	0.02 (p)	— 0.08 (p)	— 0.09 (p)	— 0.07 (p)	— 0.59 (p)

$$* \; CVP_1 = \frac{T_v \cdot \sqrt{N} \cdot G \cdot E}{T_a \cdot 360 \cdot 100}$$

The relationship between some edaphic factors and forest yield

In the preceding chapter it has been shown how the *CVP*-index and the individual composite climate factors excluding precipitation display impaired relationships with the growth potential when the variable changes from an expression of average yield within a certain area to an expression of the yield of a particular site. The reason is primarily to be found in the increased influence of edaphic factors.

To arrive at a practically useful index for the yield capacity of an individual site, it is therefore necessary to combine an expression of the one or the most important edaphic factors with an expression of climate. Some attempts to that affect will be made in the following presentation.

The dependence of plant growth on the moisture conditions of a site during various periods of the growing season has been discussed in a previous chapter. The need for continued and expanded research in this field thereby appeared very great. Knowing of the hygrometric conditions of the site, we may add that it will then be possible to cover part of the influence of topography by means of the influence of the site gradient on the movements of the soil water. Since the moisture retaining capacity of the site is related to the soil texture, the importance of the latter feature in this context would be considered in this way.

Attempts made in this investigation to find an expression of the site factor feasible to incorporate with our climate function have been tied to material already available and collected in conjunction with the lay-out of the experimental plots. Moreover, we have soil samples from the *C*-horizon, descriptions of the soil structure and notes describing whether the *B*-horizon rests directly on the bedrock.

The electric conductivity of soil

One method has been tested in particular to find a mathematical expression of the site factor. The method is based on the procedure used by D. R. HOAGLAND and J. S. BURD for the measurement of the electric conductivity of the site. Thus, an expression of the concentration of soluble nutrients available in the soil is obtained. The method has recently been used in Sweden by O. Arrhenius, who found a strong relationship between the conductivity and the forest yield as well as the crop of winter wheat (O. ARRHENIUS, 1957, p. 322, f). These relationships have been stated on the basis of mean values from a very comprehensive material after the omission of all places with soil depth less than one meter ("either to the bedrock or to constant water surface have been omitted", ibid., p. 321). Arrhenius further found that the top soil (corresponding to the $A + B$-horizons) has a conductivity considerably higher than that of the subsoil (approximately the C-horizon) — (ibid., 1956, p. 10). The latter observation is of particular interest in this context since we have samples from the C-horizon only.

Conductivity has been determined in the soil laboratory of the Forest Research Institute. The values obtained are reported in column S, Table III, and expressed in the form of conductivity values defined by $10^4 \times$ the specific conductivity (Kungl. Lantbruksstyrelsen, 1950).

The introduction of conductivity (S) as a special term in our regression functions (Tables 8 and 9) effects a slightly improved fit. In association with function No. 4 the dispersion of the function is reduced by 0.7 per cent. This function, however, does not show any statistical improvement of significance in relation to function No. 2.

CVP_1 has not been tested in this context since it was developed in the final stage of this work. The statistical processing presented here was then completed. Since the relative importance of the conductive capacity for the relationship cannot be expected to display any great variation in combination with CVP_1, an investigation of this factor was not expected to produce a result justifying associated costs. Neither has an investigation of the influence of the stand composition on the relationship with CVP_1 for the same reason been found necessary.

Combined with the CVP-index, too, S reduced the dispersion parameter by 2.1 per cent to 75.6 per cent. The regression function is presented by function No. 11.

$$y = 0.778 + 0.816\ S + 0.0223\ CVP$$

The total correlation coefficient of S is 0.43 (Table 11) corresponding to a determination coefficient of 0.18. The partial correlation coefficients seem to indicate certain relationships between S and T_a, G and CVP. It is remarkable that precipitation has no influence on S.

By means of two kinds of scatter graphs, one type with the CVP-index alone as an independent variable, the second type with $CVP \times S$ as an independent variable—the mean annual increment is the dependent variable in both cases—it has been possible to investigate the change of position of the individual points from one graph to the other. **It appears that conductivity values below 0.5 effect an improved fit, conductivity values of 0.8 and above give an impaired fit, whereas intermediate values have no distinct influence. The observations may be interpreted to mean that a nutrient**

concentration for conductivity values below 0.5 is too low for the trees to exploit the climatic bioeffect of its site. Equilibrium between the latter property and the supply of nutrients occurs at conductivity values between 0.5 and 0.8 whereas the bioclimatic effect is insufficient for the forest to utilize the good nutrient status of the sites at still higher conductivity values. A final establishment of the correctness of these conclusions requires strengthened research efforts in this field. The importance will be of great practical value since the results will indicate avenues to follow toward an improvement of the yield conditions of the site in artificially established stands.

Investigations of the conductivity of the site provide some, though minute, explanations of the yield variations. However, it must be stressed that we have used values for the nutrient status obtained from the *C*-horizon, which is not entirely representative for the supply of nutrients in the root zone. Continued work along this line should primarily concentrate on investigations of the conductivity of the *B*-horizon, possibly also of the effect of the arithmetic mean value of *A*-, *B*-, and *C*-horizons on the relationships with the mean increment. The results obtained here as well as those originating from the investigations carried out by O. Arrhenius provide strong indications that a further developed method can make conductivity a feasible and easily reproducible expression of the site factor; which may promise to give a satisfactory description of the productivity of the site in combination with the *CVP*-index.

The influence of soil texture on the mean annual increment

The influence of soil texture on the mean increment has been studied in a summary way by means of dispersion graphs with the *CVP*-index and the mean increment as variables. The soil texture has been classified for each sample plot according to the grain of the main fraction. When soil texture is noted for each point in the dispersion graphs, a certain tendency appears in the position of the various soils. The coarse-grained, relatively sorted soils, *e.g.* gravel and sand, are generally associated with low yield values. Loam with light inmixture of sand is mostly coupled with high yield values. Other soils in various mixtures are combined with yield of an average magnitude. Continued investigations should be aimed at finding an expression of the mean grain size per volume unit of soil within the *B*-horizon. The relationship between this expression and the hygrometric properties of the soil should be examined simultaneously by the application of formulas for the relationship between the soil texture and the water retaining capacity of the soil. It is probable that the expression of texture can be defined adequately by the hygrometric properties of the soil (cf. Holstener-Jørgensen, 1958).

The influence of soil depth, depth of the humus cover and horizons

Among the sample plots originally selected were some plots which subsequently were omitted since they differed markedly from the others. Since the environment of their sites displayed great differences only with respect to the depth of the soil, the latter factor must be considered as causing the deviations. It is a known fact that shallow soil generally means that the site is easily subject to drought as well as inferior yield conditions in general. An expressive proof is provided by J. Låg in his investigations of the relationship between soil depth and site quality. The relationships obtained are presented in the following tables (J. Låg, 1958, p. 71, f).

Table 19. Relationships between soil depth and site quality in the forests of Telemark

Total soil depth	Frequency of plots by site classes, per cent					Total no. plots
	1[1]	2	3	4	5	
0—20 cm . . .	—	0.4	17.5	47.1	34.5	1,986
20—70 cm . . .	0.8	6.1	40.1	38.6	14.4	4,699
> 70 cm . . .	6.4	21.0	48.8	19.6	4.7	5,589

Table 20. Relationship between soil type and site quality in the forests of Agder

Soil type	Frequency of sample plots by site classes, per cent					Total no. plots
	1	2	3	4	5	
Podzol.	0.7	6.7	41.0	33.1	18.5	6,814
Brown soil. . .	12.7	36.7	41.9	8.1	0.6	738

Table 21. Relationship between humus layer and site class in the forests of Sør-Trøndelag

Total soil depth	Humus cover cm	Frequency of sample plots by site classes per cent					Total no. plots
		1	2	3	4	5	
0—20 cm	0— 3	1.0	10.2	39.8	26.5	22.5	98
	3—10	—	2.1	20.8	43.8	33.3	384
	>10	—	0.7	13.4	40.8	45.1	142
20—70 cm	0— 3	4.0	24.2	49.9	17.3	4.6	711
	3—10	0.1	5.1	44.1	36.3	14.4	1 519
	>10	0.1	1.2	25.3	47.1	26.3	724
exceeding 70 cm . .	0— 3	7.5	24.9	37.1	17.6	12.9	1 185
	3—10	1.0	9.4	48.9	26.6	14.1	849
	>10	0.2	3.4	36.1	39.5	20.8	499

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[1] Site class 1 indicates a mean annual increment exceeding 6.8 cu. m per hectare whereas site class 5 corresponds to a mean annual increment of 1.2—1.9 cu. m per hectare.

The tables show clearly a concentration of plots with low site classes to the shallow soils (Table 19) and to sites with heavy humus cover (Table 21). The high productivity of the brown soils in relation to that of the podzols is also clear (Table 20). It must be stressed, however, that differences are not exclusively caused by soil depth, humus cover and soil type but also by other factors such as climate, altitude, slope etc. In spite of the latter factors, soil depth has a great influence on yield and it should therefore be determined for depths less than one meter at each site examination. In this respect, too, it should be investigated in the future whether soil depth is reflected by the hygrometric properties of the soil.

The potential productivity of Norden's forests

The relationships previously shown to exist between climate and to some extent the edaphic conditions on one side and the forest yield on the other have been possible to express in two different forms or functions. One function presents yield directly in figures on the basis of the individual contribution of the participating terms. With the knowledge of the magnitude of the participating terms of a site, it is thus possible to compute the potential yield. The second procedure involves relating yield to a complex climate factor, the CVP and CVP_1 index, respectively. Among the functions established and tested, three functions emerge as being superior. In function No. 14, Table 17, where the electric conductivity of the soil and the species mixture have been considered, a minimum standard deviation of the function amounting to 70,3 per cent of that of the total mean value has been obtained. If the species mixture and the electric conductivity are disconsidered, corresponding parameter amounts to 74.0 per cent in function No. 4, Table 8 and for CVP 77.7 per cent (function No. 7, Table 8) and for CVP_1 71.8 per cent (function No. 6 Table 18). It should be stressed, however, that the value of CVP_1 is not fully comparable with the two others since it is based on a different selection from the material.

The multiple regression functions each give a yield value, the CVP and CVP_1 index, respectively, which reflects the climatic conditions and associated changes. Presenting a value of the climatic bioeffect expressed in figures, our index therefore provides great advantages methodically. The regional occurence of the climatic bioeffect may be studied by means of climato-isophytes entered on a map according to a method developed previously by the author (St. St. Paterson, 1956, p. 121). Since the climatic bioeffect must be considered to vary with species from a hypothetical point of view, the index enables a simplified study of such variations as well as a presentation of a regional productivity relief map valid for each species (ibid., 1959, p. 160). A simplified map of this kind without intensity shading of the various phyochores is presented in the map enclosed, Fig. 31, which shows two different systems of climato-isophytes. One of the systems pertains to CVP and a choice of iso-lines based on function No. 18, where the admixture of Scots pine is considered. The second system refers to CVP_1 and its function No. 6, Table 18, in which the influence of species mixture is disconsidered. Comparative numbers of both the systems are shown in Table 22.

After application of the author's method of 1956 (ibid., 1956, p. 123 f.), half the interval between the index values above is added to or subtracted

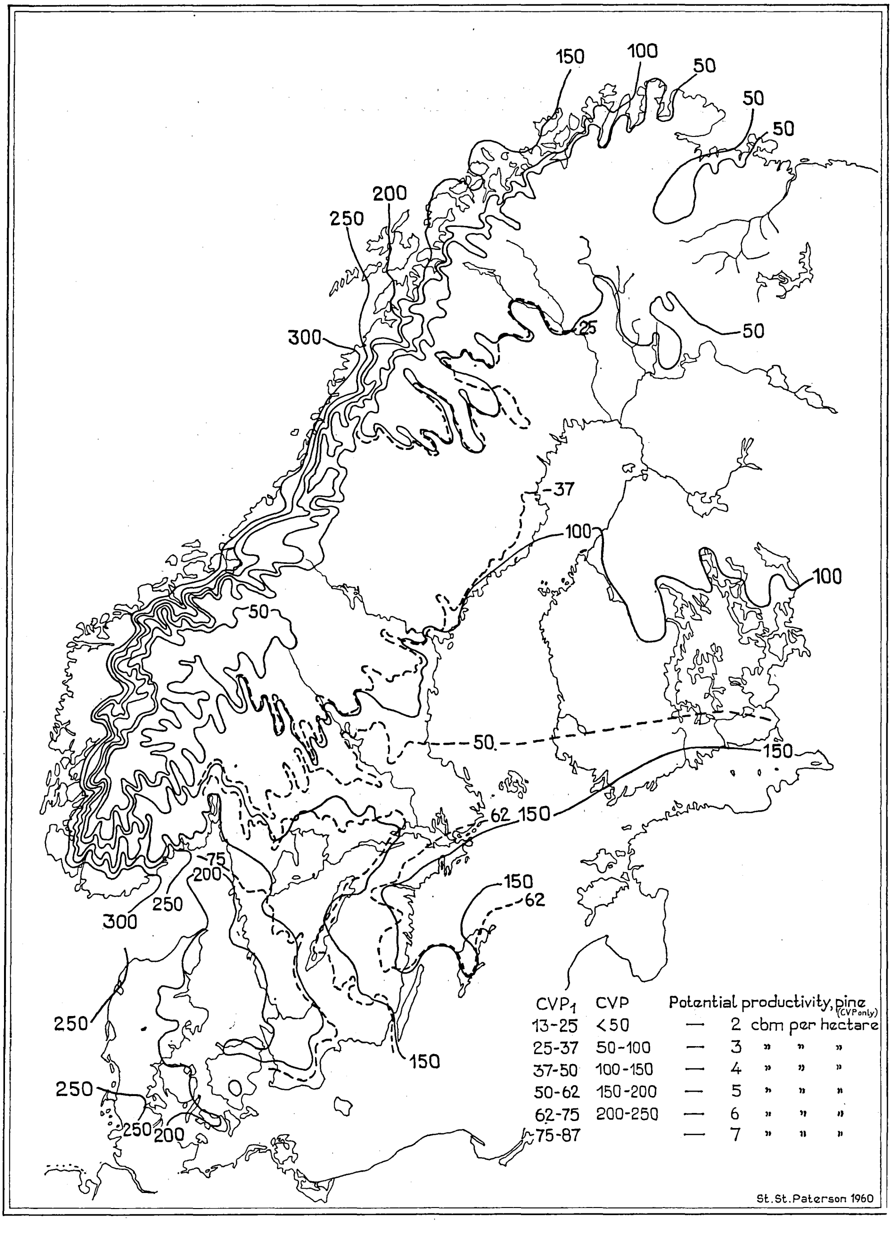

Figure 31. Regional relief map of productivity.

Table 22. The potential yield of pure Scots pine stands and Scots pine stands with light admixture of Norway spruce and deciduous species, and the *CVP* and CVP_1 values corresponding to these yield values

Potential yield cu.m/ha	Scots pine stands *CVP*	Stands with admixture of Scots pine, CVP_1
1	—	0.68
2	27	1.91
3	77	3.14
4	127	4.37
5	177	5.60
6	227	6.83
7	277	8.06
8	327	9.29

from each index value. Values so derived represent the limit values of a productivity, the mean value of which corresponds to the figures presented in the table above. The limit values correspond to the climato-isophytes sought, which, entered on the map, will delineate a number of phyochores. The method now requires a determination of the forest land area situated within each phyochor. The total potential yield is easily obtained if this area is multiplied by the mean yield of the phyochor concerned.

Being the function most suitable for this purpose, function No. 6, Table 18, was finally chosen as a basis for the computation of the potential productivity of the Nordic countries conducted here. The following table has been established.

Table 23. Relationship between potential productivity and median CVP_1 index value

Range	CVP_1 index × 10 centre	Potential productivity cu. m/ha
0—13	6.8	1
13—25	19.1	2
25—37	31.4	3
37—50	43.7	4
50—62	56.0	5
62—75	68.3	6
75—87	80.6	7

Particular difficulties affect the determination of the forest land area within the individual phyochores which do not generally follow statistically reported divisions. For the purpose of statistics concerning area, access is required to accurate, detailed information regarding the distribution of forest land on each side of a bordering climato-isophyte. In the present case the forest land area within our phyochores could be ascertained by means of material available in the department of forest survey at the Forest Research Institute of Sweden. This material has been compiled as a basis for "Atlas of Sweden" and its presentation of forest land according to the method of absolute squares. Statistically reported areas entirely located within a phyochor could be directly determined with respect to area on the basis of this material. The areas situated on each side of the border line were computed by counting corresponding squares in the "Atlas of Sweden". This work was carried out by Mr. O. KRONESTEDT, forest technician, benevolently supervised by Mr. V. ARMAN, M.F. The area distribution obtained is reported in Table 24.

Table 24. Area of productive forest land and mountainous conifer forests in sq. km distributed by phyochores within regions

Region	—25		25—37		37—50	50—62	62—75	75+	Total	
	Forest land	Mountainous conifer forest	Forest land	Mountainous conifer forest	Forest land				Forest land	Mountainous conifer forest
I..........	13,175	4,075	52,466	488	2,850	—	—	—	68,491	4,563
II + III...	—	—	48,521	3,080	22,700	8,450	—	—	79,671	3,080
IV + V....	—	—	—	—	4,942	30,410	29,853	10,090	75,295	—
I—V	13,175	4,075	100987	3,568	30,492	38,860	29,853	10,090	223457	7,643

The corresponding area distribution by phyochores in Denmark, Finland and Norway has been compiled by considerably simplified methods, which entailed larger generalization. As a basis the author has utilized his map of the forest area of the world (1956), which was compiled according to the method of absolute squares by entering the climato-isophytes of current interest. This method may be considered to provide satisfactory estimates for Denmark and Finland where the climato-isophytes are located far apart. The distribution of the Norwegian forest land area, however, is less accurately determined. The heavily cut-up topography of this country effects rapid, vertical changes of the phyochores which will thus be very narrow. A determination of the distribution of the forest land area with greater accuracy on the basis of these narrow phyochores would require maps with a large scale providing an abundance of details corresponding to that of the topographic map. This tedious procedure is considered beyond the object of this chapter which is to give a broad presentation.

The lack of meteorological stations and the generalization enforced by the map scale (Fig. 31) will mean that mountainuos conifer forests are also found within the phyochores 25—37 in Table 24. It is known, however, that their geographic location is associated with the occurrence of mountainous areas. Placing the montainous, coniferous forests within the phyocohores 0—13 and on the basis of this experience, we obtain the following picture (Table 25) of the potential yield conditions within the main forest regions of Sweden (cf. map, Fig. 32).

Table 25. The potential productivity of the Swedish forest land area distributed by regions and phyochores

Region	Phyochor						
	0—13	13—25	25—37	37—50	50—62	62—75	75+
	cu. m per hectare						
	1	2	3	4	5	6	7
I mill. ha	0.46	1.32	5.25	0.29	—	—	—
» cu. m	0.46	2.64	15.75	1.16	—	—	—
II/III mill. ha	0.31	—	4.85	2.27	0.85	—	—
» cu. m	0.31	—	14.55	9.08	4.25	—	—
IV/V mill. ha	—	—	—	0.49	3.04	2.99	1.01
» cu. m	—	—	—	1.96	15.20	17.94	7.07
Total, mill. ha	0.77	1.32	10.10	3.05	3.89	2.99	1.01
» cu. m	0.77	2.64	30.30	12.20	19.45	17.94	7.07

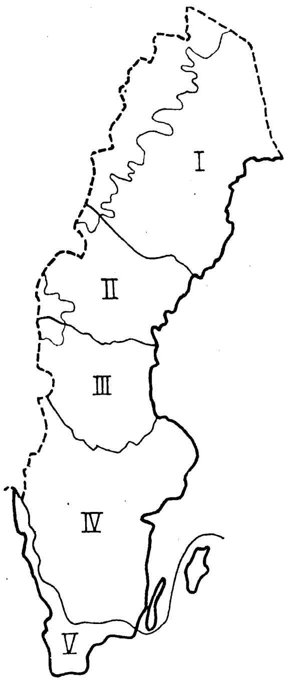

Figure 32. Regional division used by The National Forest Survey in Sweden.

If the country is divided into a northern and a southern part and including as usual the regions IV and V in the latter part, area and potential yield are distributed as follows.

	Area, mill. ha	Potential yield, mill. cu. m.
Northern Sweden	15.60	48.20
Southern »	7.53	42.17
The whole of Sweden	23.13	90.37

It appears from the summary above that slightly less than a third of the national forest area is located in the southern part of Sweden. This minor part simultaneously represents 47 per cent of the total potential productivity. A division of the country into two equal halves would mean that the southern part would contain about two thirds of the total potential yield.

It may be interesting to compare the values for potential yield now presented with the mean annual increment at normal age class distribution according to the national forest survey.

According to Table 26 the mean annual increment at normal age class distribution in the Swedish forests would amount to 65.28 mill. cu.m. Of these 32.57 mill. cu.m. would be found in the northern part and 32.71 mill. cu.m. in the southern part, i.e. 50 per cent in each.

The annual increment has been computed with a high degree of accuracy on the basis of systematic sampling. It represents the increment at the current status of forest resources.

The potential productivity has been obtained on the basis of yield recorded in sample plots in fully stocked, virgin stands. Particularly on the high grounds of northern Sweden, these stands must be considered as examples of yield attainable under not too unfavourable conditions. Experience has shown that calamities of various kinds, e.g. attacks of fungi and insects and seedling mortality directly associated with the severe climate often cause open stands in practice. These circumstances mean that many yield values obtained from sample plots in northern Sweden are probably higher than can normally be expected in this geographic region.

According to the national forest survey, increment is equally distributed by northern and southern Sweden. Provided this distribution is accepted, the calculated potential yield of Sweden would be reduced from 48.20 mill. cu.m. to 42.17 mill. cu.m., or by 12.5 per cent and thus the total national potential yield would be established at 84 mill. cu.m. Corresponding adjustment should also be made with respect to Norway and Finland.

Table 26. Mean annual increment. All species. Forest-land and range land*.

Region		Age class									% per cent	Mean increment per hectare	Area sq. km.	Total yield capacity 1,000 cu. m.
		0	I	II	III	IV	V	VI	VII—VIII	IX				
I	Increment, cu. m./ha..	0.230	0.355	1.517	1.906	2.190	2.301	1.848	1.261	0.901				
	Area distribution, current, per cent ...	9	4	9	8	13	17	13	14	13	100	1.533	68,700	10,530
	normal, per cent .... (rotation period 135+5 years)	4	14	14	14	14	14	14	12	—	100	1.577		10,830
II+III	Increment, cu. m./ha..	0.403	0.874	2.700	3.455	3.843	3.617	2.992	2.304	1.467				
	Area distribution, current, per cent ...	6	4	10	13	20	18	14	11	4	100	2.929	77,400	22,670
	normal per cent .... (rotation period 115+5 years)	4	17	17	17	17	17	11	—	—	100	2.809		21,740
IV+V	Increment, cu. m./ha ..	0.593	1.873	5.173	5.547	5.257	4.527	3.893	3.297	2.361				
	Area distribution, current, per cent ...	5	9	20	25	22	11	5	2	1	100	4.544	76,500	34,760
	normal per cent .... (rotation period 90+5 years)	5	21	21	21	21	11	—	—	—	100	4.276		32,710
	Acc. to current age distribution											3.053	**	67,960
	Total I—V..................												222,600	
	Acc. normal age distribution...											2.934		65,280

* The table has been compiled by Mr. V. ARMAN.
** Mountainous forests not included.

As a result of the preceding discussion, the regression lines previously presented will be situated too high in the graph within the range below approximately 125 *CVP* and 4.4 CVP_1, respectively.

Summarized, the comparison made shows that the mean annual increment at normal age class distribution according to the material of the national forest survey amounts to 65 mill. cu.m., whereas the sample plots in virgin, fully stocked stands present a value of 84 mill. cu.m. for the climatically conditioned potential yield.

Based on CVP_1 a summary of the potential productivity of the Nordic forests is compiled in table 27.

Table 27. The potential productivity of Norden

Phyochor $CVP_1 \times 10$	Area mill. ha	Potential productivity, cu. m/ha	Total potential productivity, mill. cu. m.	
Denmark				
62—75	0.125	6	0.75	
75—87	0.25	7	1.75	2.5
Finland				
0—13	2	1	2	(approx. 50 mill.
13—25	2	2	4	cu. m. should be re-
25—37	12	3	36	duced by 12.5 per
37—50	3	4	12	cent, i.e. 6.3 mill.
50—62	2	5		cu. m cf. p. 100)
62—75	0.7	6	10	
			4	68 (—6.3)
Norway				
0—13	2	1	2	(approx. 11 mill.
13—25	1.5	2	3	cu. m. should be re-
25—37	1	3	3	duced by 12.5 per
37—50	1	4	4	cent, i.e. 1.4 mill.
50—62	0.5	5	2.5	cu. m cf. p. 100)
62—75	0.5	6	3	
75—87	0.5	7	3.5	21 (— 1.4)
Sweden				
0—13	0.8	1	0.8	(should be reduced
13—25	1.3	2	2.6	by 6.03 mill. cu. m.
25—37	10.1	3	30.3	cf. p. 100)
37—50	3.0	4	12.0	
50—62	3.9	5	19.5	
62—75	3.0	6	18.0	
75—87	1.0	7	7.0	90.2 (— 6.03)

It may be of interest to compare the values obtained for the total potential productivity with the previous determination made by the author and with the official estimates of the mean annual increment and the annual depletion by felling operations. Excluding Denmark, the latter estimate is too low since timber removed for private consumption is not included.

Table 28. Comparison between estimated values of the potential productivity, mean annual increment and annual depletion

Country	Potential productivity acc. St. St. Paterson		Increment	Depletion 1957—58
	1956	1961		
	mill. cu. m			
Denmark	(1.8)	(2.5)	2	2
Finland	67.5	62	55	36[1]
Norway	27.5	20	16	9
Sweden	84.8	84	68	44[2]

In the case of Denmark the figures concerning the potential productivity have been placed in brackets since they do not represent a forest natural to Denmark.

The relationship between increment and depletion, respectively, and the potential productivity according to CVP_1 provides an idea of the current degree of utilization of the climatically conditioned growth potential of the present forests. The highest degree of utilization is found in the case of Finland, where both increment and the potential productivity exceed depletion by 53 per cent and 72 per cent, respectively. Then follows Sweden where increment exceeds depletion by approximately 55 per cent while the potential productivity exceeds the latter by 90 per cent. Increment and the potential productivity in Norway exceed depletion by 78 per cent and 122 per cent respectively. In the latter country, however, reservations must be made due to the importance of the negative influence of precipitation.

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[1] mean value of the 1954 and 1957 estimates.

[2] » » of the 1954, 1957, and 1958 estimates.

Sources: F A O. Yearbook of Forest Products Statistics 1955 and 1959.
HAGBERG, E. 1959. Status of the Swedish Forests.
PATERSON, ST. ST., 1956.

Summary

Due to deficient material of observation the great importance of light as plant physiological factor cannot be considered at investigations of the relationships between climate and yield. The climate of light of the site, particularly at the upper part of the plant cover facing the atmosphere should be investigated by measurements of the solar radiation. A feasible instrument for this purpose is for example the Robitzsch automatic recording radiation meter (cf. TH. WILHELMI 1959, p. 205).

The volume increment produced at a certain site is a function of a strongly temperature dependent radial growth and a length and height growth probably governed by a climate factor varying for different species.

The relationship between light and heat must be studied by measurements on the site which may be expected to provide more accurate knowledge of the formation of assimilation products (radiation dependent) and the formation of wood (temperature dependent).

The length increment of tree roots is dependent on the soil temperature. Associated with the length growth of roots is the formation of root hairs, which are the most effective water absorbing organs of the trees. Strong relationships can therefore be assumed between the soil temperature and photosynthesis as well as transpiration. The soil temperature of the site should therefore be subject to continuous observations.

The author elucidates the unfeasibility of determining the length of the growing season by means of conditions prevailing at plant range boundaries or during some special vegetative development stage in the annual rhythm An expression describing some general, physiological condition is a better basis. The author finds that dry matter content and the relationship stated by O. LANGLET between the normal value of dry matter content and the no. days with a temperature exceeding + 6° C or + 8° C are expressions of this kind. Accordingly, and considering the views expressed by J. PARDÉ and A. F. SCHIMPER, the author has chosen a temperature of + 7° C as the most suitable limit for a computation of the length of the growing season in forestry. The determination of this season is made by means of climate diagrams compiled by H. WALTER.

Discussing the water as plant physiological factor, the author elucidates the great importance of an annual drought period. Such a period occurring, the thermally determined growing season is not a proper definition of the time factor. The ombro-thermal situation must also be considered as well as the

hygro-thermal status. The water table and especially the capillary soil water have great importance for the growth potential by constituting a reserve during drought periods. Values particularly for the soil moisture of the root zone, the free water and their seasonal variations must be established by field observations. This provides a possibility of expressing the hygro-thermal growing season, which will be a more adapted component in a yield index for the site than the annual precipitation. Each species should be given a defined, hygro-thermal growing season of its own.

Since precipitation displays great local variations, the precipitation climate of the site should be determined by direct measurements. Adjustment for altitude must be made when interpolated temperature values are to be calculated for a sample plot or a precipitation station. Scrutinizing various correction factors, the author states some difference between the values computed by I. BRUUN for Norway and those presented by WILD for Russia. The difference, however, is not of a magnitude justifying a denouncing of Wild's values for use in Sweden.

Studying the conditions of adjacent climate stations in Norway, the author has found that the reduction of the growing season at increasing altitude is presumably not linear but faster at a low level than the decline occurring at a high altitude zone (Table 5).

On the basis of J. WECK's discussion of the need for a judgement of the forest yield potential by means of the magnitude of the real assimilation, the author presents a summary of our present knowledge of the rates of assimilation, respiration and transpiration. The author finds that our knowledge of these important processes is still based on approximate values affected by methodical deficiencies. Data on photosynthesis and respiration now available therefore lack accuracy sufficient for their use in detailed phyochorological investigations. However, differences between various species can be established by comparative investigations of photosynthesis and respiration. Here, too, examples showing the necessity of treating each species separately are found. The transpiration, respiration and photosynthesis of the stand should be subject to strengthened research efforts.

With reservations made on account of the limited material, the statistical computations have shown that:

> The *CVP*-value of the site is equally utilized in all the age classes invetigated here.
>
> The volume increment of the trees increases with rising age in the age classes investigated.

The temperature amplitude is the climate factor covering most of the variation of the relationship between climate and yield in Sweden. Although showing nearly equal effect, the length of the growing season is strongly correlated with the temperature amplitude and more strongly than vice versa according to the partial correlation coefficients (Table 11). Precipitation has a hardly noticeable influence. When other climate conditions are kept constant an increase in precipitation beyond a certain point effects reduced yield. A value of 600 mm seems to be the turning point.

The climate of the site must be subject to direct observations to provide accurate analyses of the yield factors by means of phyochorology.

The stand composition has an apparent influence on the magnitude of the mean increment.

Comparisons between the Swedish and the Norwegian material show the latter data to display a considerably lower yield potential, particularly at high index values. This may be explained by the reduction of yield caused by the leaching of soil nutrients on account of large amounts of precipitation and by the fact that Scots pine is a species less suited to sites of this type.

The electric conductivity of the soil in the *C*-horizon shows a weak influence on yield. An improved relationship may be obtained, however, if conductivity is measured in the *B*-horizon or if a mean value representing the *A*-, *B*- and *C*-horizons is used. Certain observations made in this investigation may be interpreted to mean that nutrient concentrations indicated by conductivity values below 0.5 are too low for the forest to utilize the climatic bioeffect of the site while complete utilization occurs at conductivity values between 0.5 and 0.8; at still higher conductivity values the forest is unable to utilize the favourable nutrient status of the soil. Continued research in this field is required to reach a final conclusion.

The influence of soil texture on the mean increment seems to have the following general tendencies: coarse, relatively sorted soils are associated with low yield values whereas loam with light inmixture of sand is coupled with high yield.

Investigations made in Norway show a clear correlation between i.a. soil depth and site quality to the effect that shallow sites show low quality. The soil depth should therefore be determined at site examinations at least for soil depths of less than one meter.

After a choice of suitable climato-isophytes, the CVP-, resp. CVP_1-index enables the establishment of regional relief maps showing productivity for each species. Such a map is presented in this report for Scots pine. The potential forest yield (potential productivity) is finally computed for the Nordic countries (Table 27) and compared with the annual values of increment and timber removed in felling observations (Table 28).

Sammanfattning

Nordens fyokorologiska grunddrag

Fyokorologi är läran om den areella produktionens ekologi och geografiska spridningsbild. I denna undersökning är närmast sambandet mellan klimat och skoglig produktion föremål för bearbetning.

Förf. ger först en kort översikt över den skogliga fyokorologiens växtfysiologiska grunder. Här påtalas att ljusets betydelse ej kan beaktas vid en sambandsundersökning av ifrågavarande slag på grund av bristande observationsmaterial. Ståndortens ljus- och temperaturklimat måste bli föremål för närmare undersökningar, om säkrare kännedom skall vinnas rörande assimilatbildning (strålningsbunden) och träbildning (temperaturbetingad).

Ett starkt samband synes föreligga mellan marktemperaturen, som reglerar trädrötternas längdtillväxt, och fotosyntesen ävensom transpirationen. Ståndortens marktemperatur bör därför bli föremål för fortlöpande observation.

Olika tillvägagångssätt diskuteras rörande bestämning av vegetationsperiodens längd. På grundval av arbeten gjorda av O. Langlet, J. Pardé och A. F. Schimper finner förf. + 7° C vara den lämpligaste temperaturgränsen för beräkning av den skogliga vegetationsperiodens längd. Metodiskt utföres beräkningen med hjälp av H. Walters klimatdiagram.

Vid behandlingen av vattnet som växtfysiologisk faktor understryker förf. den stora betydelsen av förekomsten av en årlig torrtid. Uppträder en sådan blir den termiskt bestämda vegetationsperioden ej riktig ur växtfysiologisk synvinkel. Hänsyn bör tagas till såväl den ombrotermiska situationen som till den hygrotermiska. Grundvattnet och det kapillära markvattnet förs här in i bilden såsom varande av stor betydelse för växtkraften genom att tjänstgöra som reserv under torrtider. Värden på främst rotskiktets markfuktighet ävensom på grundvattennivån samt på dessa bådas säsongvariationer måste fastställas genom framtida fältundersökningar. Först härefter ges möjlighet till att finna ett uttryck för den *hygro-termiska vegetationsperioden,* vilken blir en mera rättvisande komponent i ett produktionsindex för ståndorten än vad årsnederbörden är. Varje trädslag bör givas sin egen definierade hygro-termiska vegetationsperiod.

Genom att studera förhållandena vid varann närbelägna klimatstationer i Norge finner förf. stöd för att vegetationsperiodens avtagande med stigande höjd ej sker lineärt utan med större hastighet på lägre nivå än på högre (tabell 5).

Vi sakna ännu tillräckliga data rörande fotosyntes och respiration för att dessa skall vara direkt användbara vid detaljerade fyokorologiska undersökningar.

Med reservation för materialets begränsning framgår ur den statistiska bearbetningen att:

Ståndortens *CVP* utnyttjas lika i alla här berörda åldrar;

Volymökningen hos träden stiger med tilltagande ålder inom här berörda åldrar;

Temperaturamplituden är den klimatfaktor, som i Sverige fångar upp mest av spridningen inom sambandet mellan klimat och produktion. Nära nog samma effekt visar vegetationsperiodens längd. Denna är emellertid starkt korrelerad med temperaturamplituden och starkare än motsatsen enligt vad som kan utläsas ur de partiella korrelationskoefficienterna (tab. 11).

Nederbörden har ett föga märkbart inflytande. En ökning av nederbörden vid i övrigt konstanta klimatförhållanden innebär sjunkande produktion. Vändpunkten härför synes ligga vid ca 600 mm:s årsnederbörd.

Ståndortsklimatet måste bli föremål för direkta observationer för att man skall kunna nå fram till säkra analyser av produktionsfaktorerna genom fyokorologisk metod.

Beståndsblandningen har en tydlig inverkan på medeltillväxtens storlek.

Jämförelse mellan det svenska och norska materialet visar, att det senare vid framför allt högre indexvärden har en betydligt lägre produktionspotential. Förklaringen kan tänkas ligga i en genom höga nederbördsmängder orsakad urlakning av markens närsalter med åtföljande produktionsnedsättning, samt i att tallen är ett för dessa ståndorter mindre lämpligt trädslag.

Markens elektriska ledningsförmåga inom *C*-skiktet visar ett svagt samband med produktionen. Ett förbättrat samband kan dock förväntas uppkomma, om ledningsförmågan inom *B*-skiktet, eventuellt dess medelvärde för *A*-, *B*- och *C*-skikten lägges till grund istället. Vissa nu gjorda iakttagelser kunna tolkas så, att en närsaltskoncentration på upp till ledningstalet 0,5 är för lågt för att skogen skall kunna utnyttja sin ståndorts klimatiska bioeffekt, ett fullt utnyttjande av den senare föreligger vid ledningstal mellan 0,5 och 0,8, medan vid ännu högre ledningstal klimatets bioeffekt framstår som otillräcklig för att skogen skall kunna utnyttja markens goda näringstillstånd. Ett slutgiltigt bekräftande av dessa antaganden kräver fortsatta forskningar på området.

Jordartssammansättningens inflytande på medeltillväxten synes ha följande allmänna tendens: grovkorniga, relativt oblandade jordarter följas av låga produktionsvärden; som motsats härtill står mjäla med svag inblandning av sand med åtföljande höga produktionssiffror.

I Norge gjorda undersökningar visa en tydlig samvariation mellan bl. a. markdjup och bonitet på så sätt, att grund mark ger låga boniteter. Vid varje ståndortsundersökning bör därför markdjupet bestämmas på ned till minst en meters djup.

CVP_1-indexet — skiljer sig från *CVP*-indexet genom att nederbörden ingår med sitt rotvärde — möjliggör, efter lämpligt val av klimatoisofyter, upprättande av en för ett givet trädslag anpassad produktivitetsrelieflandskapskarta. Som avslutning beräknas den skogliga potentiella produktiviteten i de nordiska länderna (tab. 27) och jämföres med den årliga tillväxten och avverkningen (tab. 28).

Plates and figures

Figure 1. Solar radiation and weekly mean temperature of air in per cent of the total value of the growing season in 1957 15
Figure 2. Design pattern of a climate diagram 21
Figure 3. Climate diagram for Kystehospitalet, Denmark 25
Figure 4. Climate diagram for Askov, Denmark 27
Figure 5. Climatogram for Askov, Denmark, years 1916—1925 28
Figure 6. Climate diagram for Hammershus, Denmark 29
Figure 7. Climatogram for Hammershus, Denmark, years 1921 and 1923 30
Figure 8. Climate diagram for Kalmar, Sweden 32
Figure 9. Climatogram for Kalmar, Sweden, years 1916—1925 33
Figure 10. Climatogram for Växjö, Sweden, years 1916—1925 33
Figure 11. Climate diagram for Växjö, Sweden 34
Figure 12. Climate diagram for Borås, Sweden 35
Figure 13. Climatogram for Borås, Sweden, years 1916—1925 36
Figure 14. Climatogram for Östersund, Sweden, years 1916—1925 36
Figure 15. Climate diagram for Östersund, Sweden 37
Figure 16. Climate diagram for Bergen, Norway 38
Figure 17. Climate diagram for Ulstad, Norway 39
Figure 18. Map of the ombro-hygro-thermal regions of the Nordic countries 40
Figure 19. The location of the station lines in relation to anomalies 52
Figure 20. Scatter graph showing the reduction of the growing season at increasing altitude 58
Figure 21. Scatter graph showing the relationship between *CVP* and yield, age class 81—90 years 66
Figure 22. Scatter graph showing the relationship between *CVP* and yield, age class 91—100 years 66
Figure 23. Scatter graph showing the relationship between *CVP* and yield, age class 101—110 years 67
Figure 24. Scatter graph showing the relationship between *CVP* and yield, age class 111—120 years 67
Figure 25. Regression functions for each age class and for the total material 68
Figure 26. Frequency of the sample plots by forest types in each age class, per cent 69
Figure 27. The theoretical regression line of the total material and the 95 per cent confidence belt 73
Figure 28. Relationship between the yield and climate of the site in the Nordic countries. Comparisons between scatter graphs and regression functions. 81
Figure 29. Relationships between yield and *CVP* for southern and northern Sweden, respectively and for the whole of the country 84
Figure 30. Relationships between yield and CVP_1 for southern and northern Sweden, respectively, and for the whole of the country 85
Figure 31. Regional relief map of productivity 96
Figure 32. Regional division used by The National Forest Survey in Sweden 99
Plate I. The geographical location of the sample plots investigated 44
Plate II. The geographical location of the climate stations 49

Tables

Table 1. The correlation between radial growth, length growth and growth in cu. m of the pine in Utsjoki-Enare and the mean temperature at Sodankylä (Finland) 12
Table 2. Total yield in relation to the volume of green timber at various stand ages 46
Table 3. Decline of temperature at increasing altitude according to various authors 50
Table 4. Reduction of the growing season at increasing altitude for various stations 55
Table 5. Decrease in length of growing season at increasing altitude for various altitudinal zones, no. days 57

Table 6. Relative values of the apparent photosynthesis expressed in kg C per hectare and annum for some species occurring in Germany 62
Table 7. Relative values of "Derbholzzuwachs" expressed in kg C per hectare and annum for some species occurring in Germany 63
Table 8. Regression functions, yield potential adjusted for natural thinning (volume of mortality) 71
Table 9. Regression functions, yield potential not adjusted for natural thinning (volume of mortality) 72
Table 10. Regression functions of the four age classes 72
Table 11. Correlation matrix for the total material 74
Table 12. » » » age class 81—90 years 75
Table 13. » » » » » 91—100 » 75
Table 14. » » » » » 101—110 » 75
Table 15. » » » » » 111—120 » 75
Table 16. Partial and total correlation coefficients of the relationships between certain climate elements and the yield values of the individual sites and the total material 78
Table 17. Regression functions showing the influence of stand composition 80
Table 18. Regression functions for the testing of possibilities for an improved relationship by entering radicals of certain terms used in the *CVP* expression 86
Table 19. Relationship between soil depth and site quality 93
Table 20. » » soil type and » » 93
Table 21. » » humus depth and site quality 93
Table 22. The potential yield of pure Scots pine and Scots pine with admixture, and the *CVP* and CVP_1 values corresponding to these yield values 97
Table 23. Relationship between the potential productivity and the median CVP_1-index value 97
Table 24. Area of productive forest land and conifer forests in sq. km distributed by phyochores within regions 98
Table 25. The potential productivity of the Swedish forest land area distributed by regions and phyochores 99
Table 26. Mean annual increment. All species, forest land and range land 101
Table 27. The climatically conditioned potential productivity in Norden 102
Table 28. Comparisons between estimated values of the potential productivity and annual values of increment and timber volume removed in felling operations 103
Table I. Yield data of the Swedish sample plots 115
Table II. Climatological data of the meteorological stations in the Nordic countries:
Denmark 119
Finland 122
Norway 123
Sweden 128
Table III. Yield, climate data and *CVP*-index of forest sample plots in the Nordic countries:
Denmark 135
Finland 136
Norway 137
Sweden 139

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Table I. Yield data of the sample plots.

Current No.	Sample plot No.	Province	Site index of Pine h_{100}[1] meter	Age	Volume of green timber				Annual mean increment	
					Pine	Spruce	Broad-leaved species	Total	Green timber	Green timber + estimated mortality
					m³ per hectare over bark					
1	725	Kristianstad	24.2	104	387.2	93.7	0.0	480.9	4.6	6.3
2	98	»	24.7	112	219.5	224.9	0.0	444.4	4.0	5.6
3	300	»	29.6	104	234.2	345.5	4.2	583.9	5.6	7.7
4	301	»	28.7	106	172.3	450.4	11.0	633.7	6.0	8.3
5	506	Blekinge	23.0	85	272.9	74.4	1.8	349.1	4.1	5.2
6	508	»	27.4	100	257.9	293.7	0.0	551.6	5.5	7.4
7	502	»	24.9	106	147.9	183.7	105.9	437.5	4.1	5.7
8	708	Halland	29	72	416.2	0.0	0.3	416.5	5.8	6.8
9	714	»	25.1	91	82.8	302.4	—	385.2	4.2	5.1
10	710	»	23.5	105	316.2	114.8	47.5	478.5	4.6	6.2
11	740	Kronoberg	25.4	84	335.4	2.2	0.1	337.7	4.0	5.0
12	169	»	24.4	97	360.3	0.2	6.7	367.2	3.8	5.0
13	549	»	24.9	116	344.4	205.5	—	549.9	4.7	6.9
14	541	»	20.4	105	126.9	142.5	23.0	292.4	2.8	3.6
15	746	»	25.9	80	217.3	93.0	0.1	310.4	3.9	4.8
16	804	Jönköping	18.8	117	153.5	177.9	7.8	339.2	2.9	3.9
17	116	»	25.5	81	183.2	212.6	7.7	403.5	5.0	6.1
18	111	»	24.6	93	52.5	339.1	—	391.6	4.2	5.1
19	822	»	25.3	89	179.7	171.6	1.8	353.1	4.0	5.1
20	823	»	22.2	98	162.1	188.8	13.3	364.2	3.7	4.8
21	109	»	21.5	113	153.6	212.0	5.7	371.3	3.3	4.5
22	108	»	23.0	96	99.8	365.6	—	465.4	4.8	6.0
23	100	»	25.7	82	192.5	223.0	0.1	415.6	5.1	6.2
24	801	»	25.8	93	356.0	154.7	17.0	527.7	5.7	7.4
25	104	»	21.0	96	77.4	174.2	—	251.6	2.6	3.4
26	103	»	21.4	115	280.3	53.0	—	333.3	2.9	4.1
27	173	Kalmar	20.8	103	273.7	1.7	0.0	275.4	2.7	3.5
28	174	»	25.0	110	339.6	112.8	0.0	452.4	4.1	5.8
29	519	»	24.6	116	359.6	44.4	0.1	404.1	3.5	5.0
30	50	»	17.5	100	252.2	1.5	—	253.7	2.5	3.0
31	49	»	20.7	94	259.5	0.0	6.0	265.5	2.8	3.6
32	51	»	23.3	107	312.5	112.1	—	424.6	4.0	5.6
33	53	»	28.3	85	48.4	342.2	53.4	444.0	5.2	6.5
34	60	»	25.5	120	309.8	155.2	0.0	465.0	3.9	5.7
35	61	»	22.9	104	371.1	0.4	5.1	376.6	3.6	5.1
36	397	Gotland	17.1	99	220.1	—	—	220.1	2.2	2.6
37	306	Älvsborg	27.0	82	112.3	320.6	21.6	454.5	5.5	6.8
38	312	»	27.7	107	309.5	312.0	30.7	652.2	6.1	8.4
39	303	»	29.9	82	221.0	237.8	—	458.8	5.6	6.9
40	750	»	20.8	101	272.6	181.8	0.2	454.6	4.5	5.9
41	764	»	20.2	95	110.8	191.7	4.4	306.9	3.2	4.0
42	141	Skaraborg	22.2	98	283.0	36.2	—	319.2	3.3	4.4
43	645	»	26.3	114	455.3	148.8	—	604.1	5.3	7.6
44	644	»	23.7	108	306.8	145.6	—	452.4	4.2	5.9
45	385	»	25.4	82	90.6	212.6	134.5	437.7	5.3	6.6

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[1] Height of the largest tree at 100 years.

Current No.	Sample plot No.	Province	Site index of Pine h_{100}[1] meter	Age	Volume of green timber				Annual mean increment	
					Pine	Spruce	Broad-leaved species	Total	Green timber	Green timber + estimated mortality
					m³ per hectare over bark					
46	749	Skaraborg	26.1	86	241.5	3.8	54.9	300.2	3.5	4.4
47	126	»	29.3	83	293.5	160.9	—	454.4	5.5	6.8
48	125	»	25.5	112	393.8	156.2	—	550.0	4.9	7.0
49	124	»	26.7	81	86.3	341.9	4.3	432.5	5.3	6.6
50	319	»	22.4	86	139.8	237.5	1.1	378.4	4.4	5.6
51	66	Östergötl.	21.4	88	242.6	2.5	18.4	263.5	3.0	3.7
52	71	»	25.9	107	402.5	34.6	0.1	437.2	4.1	5.7
53	78	»	26.8	98	448.9	56.0	0.1	505.0	5.2	6.9
54	76	»	26.2	92	353.4	81.8	—	435.2	4.7	6.1
55	658	Örebro	26.0	97	476.3	110.6	—	586.9	6.1	8.1
56	653	»	25.5	85	309.3	135.2	—	444.5	5.2	6.6
57	732	»	25.3	84	71.1	278.8	65.4	415.3	4.9	6.1
58	261	»	24.7	85	118.6	260.8	3.1	382.5	4.5	5.6
59	281	»	23.0	114	282.6	147.8	—	430.4	3.8	5.3
60	284	»	16.6	117	225.5	1.6	—	227.1	1.9	2.4
61	276	»	17.7	84	91.6	136.9	8.0	236.5	2.8	3.2
62	259	»	26.5	85	215.7	35.5	51.3	302.5	3.6	4.5
63	208	Södermanl.	23.0	103	268.8	123.2	0.0	392.0	3.8	4.7
64	200	»	24.3	96	174.1	285.0	26.6	485.7	5.1	6.7
65	223	»	24.0	115	345.4	197.7	0.0	543.1	4.7	6.8
66	241	Stockholm	27.7	116	558.5	169.4	0.4	728.3	6.3	9.1
67	245	»	22.6	87	180.4	102.9	24.9	308.2	3.5	4.4
68	242	»	23.6	89	64.1	339.7	3.7	407.5	4.6	5.7
69	240	»	26.2	110	503.5	46.2	6.4	556.1	5.1	7.1
70	327	Uppsala	22.0	118	335.7	45.9	—	381.6	3.2	4.7
71	324	»	19.5	93	107.6	106.5	—	214.1	2.3	2.8
72	3	Västmanl.	22.0	109	231.9	109.1	—	341.0	3.1	4.4
73	1	»	21.2	96	126.5	160.7	—	287.2	3.0	3.9
74	13	»	23.6	81	255.2	138.9	—	394.1	4.9	6.1
75	39	»	14.4	110	141.0	1.0	4.2	146.2	1.3	1.5
76	32	»	27.4	113	392.2	182.2	—	574.4	5.1	7.9
77	493	Värmland	20.0	72	156.4	0.0	1.9	158.3	2.2	2.5
78	492	»	16.5	84	142.1	—	0.5	142.6	1.7	1.8
79	489	»	21.4	82	219.4	6.7	—	226.1	2.8	3.4
80	452	»	27.4	85	243.1	89.5	41.2	373.8	4.4	5.5
81	299	»	14.8	85	109.0	32.1	5.3	146.4	1.7	1.8
82	418	Kopparberg	17.1	102	221.5	0.4	1.5	223.4	2.2	2.6
83	419	»	18.0	100	206.4	0.0	5.6	212.0	2.1	2.6
84	421	»	21.0	115	302.7	0.1	8.1	310.9	2.7	3.8
85	1294	»	22.7	72	165.8	127.8	80.2	373.8	5.2	6.2
86	1297	»	14.0	80	190.9	1.8	2.7	195.4	2.4	2.4
87	199	»	17.2	95	272.6	1.0	—	273.6	2.9	3.3
88	693	»	20.6	113	279.0	47.7	15.7	342.4	3.0	4.2
89	408	»	21.3	116	328.5	2.4	—	330.9	2.9	4.1
90	1328	»	18.0	124	164.0	12.0	6.3	182.3	1.5	1.9
91	405	»	22.9	96	339.6	5.9	0.2	345.7	3.6	4.9

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[1] Height of the largest tree at 100 years.

Current No.	Sample plot No.	Province	Site index of Pine h_{100}[1] meter	Age	Volume of green timber				Annual mean increment	
					Pine	Spruce	Broadleaved species	Total	Green timber	Green timber + estimated mortality
					m³ per hectare over bark					
92	189	Gävleborg	22.1	87	213.4	52.4	25.5	291.3	3.3	4.3
93	335	»	15.4	84	139.8	0.2	0.0	140.0	1.7	1.8
94	638	»	18.1	89	150.6	2.9	1.9	155.4	1.7	2.0
95	687	»	19.7	87	180.4	0.1	17.2	197.7	2.3	2.8
96	338	»	19.2	103	200.9	63.3	10.4	274.6	2.7	3.4
97	677	»	21.9	98	274.1	173.6	0.0	447.7	4.6	6.1
98	675	»	27.9	83	507.7	67.9	1.6	577.2	7.0	8.6
99	662	»	24.3	98	157.4	130.6	170.7	458.7	4.7	6.3
100	685	»	18.1	100	269.1	15.4	3.3	287.8	2.9	3.5
101	680	»	15.9	114	193.2	0.0	1.1	194.3	1.7	2.0
102	681	»	18.6	107	287.1	28.6	0.5	316.2	3.0	3.7
103	1022	Jämtland	12.0	122	122.3	1.8	2.6	126.7	1.0	1.1
104	623	»	10.9	81	51.7	0.0	0.1	51.8	0.6	0.6
105	624	»	14.1	72	91.0	—	—	91.0	1.3	1.3
106	339	»	17.7	101	255.8	0.3	4.3	260.4	2.6	3.1
107	1016	»	28.7	90	212.4	305.4	2.0	519.8	5.8	7.5
108	1025	»	25.6	79	339.9	56.8	0.8	397.5	5.0	6.2
109	847	»	16.4	71	159.1	3.4	1.6	164.1	2.3	2.5
110	841	»	23.3	94	260.8	114.0	0.8	375.6	4.0	5.2
111	849	»	20.3	101	359.1	70.8	42.8	472.7	4.7	6.0
112	851	»	19.4	102	407.4	0.5	3.6	411.5	4.0	5.1
113	880	Västernorrl.	25.3	97	249.5	245.4	—	494.9	5.1	6.8
114	613	»	22.6	83	153.2	207.3	—	360.5	4.3	5.4
115	858	Jämtland	19.1	81	175.9	0.0	—	175.9	2.2	2.6
116	896	Västernorrl.	20.6	89	242.1	6.7	0.4	249.2	2.8	3.4
117	1030	Jämtland	23.2	88	306.3	7.9	—	314.2	3.6	4.5
118	1044	»	18.7	107	200.9	95.1	12.6	308.6	2.9	3.6
119	1036	»	20.9	90	254.3	8.7	0.4	263.4	2.9	3.7
120	1113	Västernorrl.	23.0	97	347.5	95.3	11.1	453.9	4.7	6.2
121	1104	»	19.9	114	416.2	3.4	1.7	421.3	3.7	5.0
122	1117	»	22.0	93	226.5	0.1	1.5	228.1	2.5	3.2
123	1116	»	23.3	95	248.6	0.1	1.7	250.4	2.6	3.6
124	1284	Västerbot.	19.6	109	136.7	128.7	—	265.4	2.4	3.1
125	555	»	20.4	85	173.9	15.4	35.7	225.0	2.6	3.2
126	1148	»	15.0	109	113.3	26.3	12.6	152.2	1.4	1.5
127	771	»	16.9	112	196.0	6.8	—	202.8	1.8	2.2
128	772	»	17.6	107	209.6	14.6	5.4	229.6	2.1	2.6
129	773	»	21.3	91	311.6	0.7	4.1	316.4	3.5	4.4
130	560	»	22.2	85	227.7	20.5	26.3	274.5	3.2	4.1
131	564	»	19.8	90	127.2	—	—	127.2	1.4	1.7
132	565	»	17.0	95	186.1	11.1	—	197.2	2.1	2.4
133	571	»	21.2	100	257.0	65.3	—	322.3	3.2	4.2
134	579	»	16.6	90	129.1	1.2	—	130.3	1.4	1.6
135	1258	»	19.6	101	140.5	48.5	88.0	277.0	2.7	3.5
136	1257	»	21.6	95	155.1	5.9	31.8	192.8	2.0	2.6
137	1280	»	16.5	108	184.2	—	—	184.2	1.7	2.0

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[1] Height of the largest tree at 100 years.

Current No.	Sample plot No.	Province	Site index of Pine h_{100}[1] meter	Age	Volume of green timber				Annual mean increment	
					Pine	Spruce	Broadleaved species	Total	Green timber	Green timber + estimated mortality
					m³ per hectare over bark					
138	1290	Västerbot.	23.3	83	279.0	22.7	2.5	304.2	3.7	4.5
139	1204	»	15.2	93	163.3	8.3	—	171.6	1.8	2.0
140	1453	»	18.4	81	170.0	8.7	20.5	199.2	2.5	2.8
141	1434	»	18.3	89	239.8	2.3	5.8	247.9	2.8	3.3
142	1441	»	22.6	91	265.8	1.5	9.1	276.4	3.0	3.9
143	776	»	16.8	92	213.7	—	—	213.7	2.3	2.6
144	775	»	19.1	82	191.7	10.5	27.7	229.9	2.8	3.2
145	967	Norrbotten	15.6	92	111.3	18.5	—	129.8	1.4	1.5
146	973A	»	16.7	96	144.6	0.4	1.1	146.1	1.5	1.7
147	973	»	16.1	90	100.6	1.2	0.4	102.2	1.1	1.2
148	970	»	20.0	83	90.0	92.3	27.8	210.1	2.5	3.0
149	905	»	18.7	107	201.1	4.4	17.0	222.5	2.1	2.6
150	913	»	14.7	88	136.8	—	—	136.8	1.6	1.6
151	933	»	17.8	83	54.7	29.2	39.9	123.8	1.5	1.7
152	930	»	19.0	86	175.9	—	15.9	191.8	2.2	2.6
153	935	»	14.2	84	113.7	14.4	—	128.1	1.5	1.6
154	1087	»	23.8	93	151.7	5.9	80.5	238.1	2.6	3.3
155	1078	»	17.4	85	116.6	0.1	4.4	121.1	1.4	1.6
156	1082	»	17.6	79	139.9	—	9.0	148.9	1.9	2.1
157	958	»	19.9	110	198.9	4.6	17.5	221.0	2.0	2.7
158	947	»	17.0	96	69.5	23.9	59.8	153.2	1.6	1.9
159	987	»	15.7	88	103.3	21.1	14.3	138.7	1.6	1.7
160	994	»	17.1	89	172.9	—	—	172.9	1.9	2.2
161	991	»	15.1	97	122.8	7.8	14.5	145.1	1.5	1.6
162	992	»	16.0	91	167.7	1.1	16.2	185.0	2.0	2.2
163	995	»	15.4	94	136.7	—	—	136.7	1.5	1.6
164	989	»	16.6	113	124.4	34.9	30.6	189.9	1.7	2.0
165	1422	»	22.0	96	192.0	3.1	23.9	219.0	2.3	3.0
166	1430	»	16.4	99	220.6	0.4	11.5	232.5	2.3	2.7
167	1404	»	16.1	93	169.5	2.9	12.3	184.7	2.0	2.2
168	997	»	15.4	89	144.3	0.8	4.1	149.2	1.7	1.8
169	1062	»	21.7	90	201.5	4.7	16.5	222.7	2.5	3.2
170	1063	»	18.9	90	92.4	1.1	75.8	169.3	1.9	2.3
171	1069	»	17.0	72	129.2	—	—	129.2	1.8	1.9
172	1405	»	16.7	95	153.4	—	13.2	166.6	1.8	2.0
173	1416	»	17.4	84	164.5	—	—	164.5	2.0	2.2
174	1414	»	19.8	92	205.1	1.7	1.7	208.5	2.3	2.8

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[1] Height of the largest tree at 100 years.

Table II. Climatological data of the meteorological stations in the Nordic countries

Denmark

Nr	Station	Alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP
1	Skagen Fyr	3	16,0	15,7	573	183	70	208
2	Gaardbogaard	8	15,7	16,5	625	168	70	194
3	Fredrikshavn	5	16,0	16,0	579	177	69	196
4	Raunstrup	15	16,2	16,8	615	171	69	194
5	Hjørring	24	15,3	15,9	646	171	69	204
6	Rubjerg Knude Fyr	67	15,3	15,6	587	174	69	192
7	Aagaard	12	15,6	15,8	671	174	69	221
8	Hanstholm Fyr	46	14,9	14,9	628	174	69	209
9	Thisted	12	15,5	15,5	716	178	69	244
10	Tødsø	34	15,3	15,3	695	177	69	236
11	Vestervig	19	15,2	14,8	701	183	69	253
12	Thyborøn	3	15,4	14,8	632	186	68	231
13	Bovbjerg Fyr	41	15,3	15,2	709	183	68	247
14	Humlum	25	15,3	15,3	652	177	68	218
15	Bækmarksbro	8	15,4	15,4	710	175	67	231
16	Bodholt	90	15,6	16,4	681	164	67	198
17	Herning	54	15,6	15,9	730	174	67	232
18	Birkebæk Dal	39	15,4	16,0	762	176	68	244
19	Husby	8	15,3	15,0	719	180	68	249
20	Staby	14	15,1	14,9	760	177	67	254
21	Lyngvig Fyr	18	15,5	15,0	687	188	67	248
22	Tarm	7	15,5	15,4	713	178	67	238
23	Grindsted	41	15,8	16,3	700	175	67	221
24	Høllund-Søgaard	77	15,4	15,9	758	174	67	238
25	Varde	12	15,3	15,1	755	180	67	256
26	Blaavandshuk Fyr	15	15,3	14,7	504	183	67	179
27	Astrup	22	15,7	15,7	654	177	68	219
28	Søvang	3	15,0	15,4	641	171	68	202
29	Aalestrup	23	15,4	16,0	595	171	68	185
30	Viborg	24	15,8	15,9	632	178	68	211
31	Askov	65	15,6	15,7	733	177	67	240
32	Fanø	5	15,7	15,2	687	186	67	246
33	Palstrup	53	15,4	15,6	639	174	68	207
34	Hals	3	16,1	16,4	556	177	69	185
35	Aalborg I	3	16,4	16,3	611	180	69	212
36	Terndrup	22	15,6	16,3	653	171	69	205
37	Gjerlev	34	15,7	16,0	596	174	68	192
38	Mørke	42	15,7	16,0	583	174	68	188

Denmark (cont.)

Nr	Station	Alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP
39	Kolindsund	3	16,2	16,5	593	174	68	191
40	Norringure	71	15,2	15,7	650	171	68	203
41	Kalbygaard	91	15,5	16,3	670	171	68	206
42	Silkeborg	30	16,1	16,3	672	177	68	222
43	Bryrup	60	15,1	15,9	695	169	67	208
44	Fruergaard	79	15,1	15,8	696	168	67	208
45	Malling	50	15,6	15,7	573	177	67	188
46	Tvingstrup	66	15,6	16,0	621	174	67	196
47	Givskud	85	15,3	16,0	680	168	67	203
48	Vejle	3	16,8	16,4	714	186	67	253
49	Stenderup	3	15,8	15,5	681	183	67	236
50	Randers	5	16,0	16,3	583	174	68	188
51	Gram	20	15,5	15,3	740	180	66	247
52	Løgumkloster	14	15,4	15,1	736	180	66	248
53	Tönder	4	15,8	15,4	750	182	66	257
54	Rugbjerg	64	15,5	15,5	747	177	66	242
55	Aabenraa	5	16,1	15,7	762	183	66	262
56	Sønderborg	15	16,0	15,6	665	186	66	233
57	Læsö	4	16,7	17,1	576	180	69	194
58	Anholt	5	16,8	17,0	555	185	68	192
59	Hesselø	16	16,3	16,4	474	183	68	163
60	Samsø	15	16,1	15,6	537	186	67	192
61	Baagø	3	16,0	15,6	572	183	67	200
62	Assens	6	16,3	16,0	645	186	66	224
63	Etterup	70	15,7	15,9	637	177	67	207
64	Æbelø Fyr	6	16,1	15,9	521	186	67	183
65	Hofmansgave	4	16,0	15,6	576	183	67	201
66	Odense	15	16,4	16,3	621	186	67	216
67	Knudshoved	3	16,2	15,9	500	183	66	171
68	Aarslev	48	15,8	16,0	636	177	66	204
69	Egeskov	60	15,8	16,0	666	174	66	210
70	Hvedholm	32	16,4	16,2	631	183	66	214
71	Svendborg	9	16,4	16,2	627	182	66	212
72	Marstal	8	16,4	15,8	591	189	66	213
73	Stensgaard Möllegaard	22	16,5	16,4	563	184	66	191
74	Søndenbro	7	16,8	16,2	551	189	66	198
75	Nykøbing	9	16,8	16,7	626	184	67	216
76	Odden	2	16,5	16,4	509	186	67	177

Denmark (cont.)

Nr	Station	Alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP
77	Sejrø Fyr	4	16,3	16,1	428	186	67	150
78	Kysthospitalet	3	17,2	17,1	420	186	67	146
79	Søndersted	33	16,0	16,5	570	174	67	179
80	Frihedslund	28	16,6	17,1	575	181	67	188
81	Tystofte	13	16,7	16,8	522	183	66	174
82	Hindholm	27	16,2	16,7	584	178	66	185
83	Ringsted	55	16,5	17,2	622	175	67	194
84	Haslev	50	16,6	16,7	640	177	66	206
85	Søborg Sø	3	16,5	17,0	585	177	67	187
86	Lille Dyrehavegaard	40	16,6	17,3	659	179	67	211
87	Rungsted	6	16,6	16,7	601	182	67	202
88	Landbohøjskolen	13	17,0	17,3	579	183	67	194
89	Boserup Sanatorium	13	16,2	16,6	539	177	67	173
90	Gjorslev	20	16,6	16,8	555	192	66	193
91	Fakse	50	16,3	17,1	598	177	66	185
92	Faksinge Sanatorium	17	16,9	16,9	578	183	66	194
93	Sallerup	3	16,4	16,6	532	183	66	176
94	Vordingborg	9	17,1	17,1	536	187	66	184
95	Bogø	27	16,4	16,4	573	183	66	192
96	Stege	3	16,9	16,6	548	186	66	190
97	Mariebjerg	9	16,4	16,0	591	186	66	207
98	Lidsø	1	16,7	16,7	567	183	66	190
99	Egholm	3	16,4	16,6	551	183	66	183
100	Maribo	16	16,8	16,7	653	186	66	224
101	Sønder Alslev	16	16,5	16,4	566	183	66	191
102	Gedser Fyr	6	16,5	16,4	532	185	65	179
103	Hammershus	15	16,3	16,1	549	180	66	183
104	Rønne	10	16,5	16,5	539	180	66	178
105	Udenfor Almindingen	116	15,8	17,1	651	171	66	189
106	Dueodde Fyr	5	16,6	16,8	516	177	66	165
107	Christiansø	6	16,3	16,0	419	179	66	140

Finland

Nr	Station	Alt.	T_v	T_a	N	G	E	CVP
		m.	°C	°C	mm	days	%	
1	Åbo (Turku)	14	17,0	22,7	612	149	74	140
2	Mariehamn(Maarianhamina)	1	15,6	19,0	558	143	73	133
3	Helsinki (Helsingfors)	9	17,0	20,0	699	151	73	182
4	Lappeenranta(Villmanstrand)	108	17,4	25,9	653	141	75	129
5	Padasjoki	110	17,0	25,0	541	136	75	104
6	Tampere(Tammerfors)	84	16,8	23,8	628	141	75	130
7	Lavia	40	16,6	24,6	567	134	76	108
8	Vilppula	100	16,8	25,2	596	139	76	117
9	Jyväskylä	109	16,2	24,7	638	134	77	120
10	Joensuu	81	16,6	26,1	605	129	77	106
11	Kuopio	110	16,4	25,9	618	132	78	112
12	Vasa (Vaasa)	4	13,5	20,1	585	129	78	110
13	Haapavesi	100	15,0	25,8	512	114	79	74
14	Kajaani	140	15,0	25,6	627	118	80	96
15	Uleåborg (Oulu)	2	15,7	25,7	545	120	81	90
16	Torneå (Tornio)	10	15,2	27,0	495	108	82	69
17	Kuusamo	266	13,6	26,3	606	102	82	73
18	Ylitornio	3	15,7	28,0	549	117	83	83
19	Rovaniemi	80	15,7	27,3	454	117	83	70
20	Salla (Aaliuki)	-	15,5	27,7	450	111	84	65
21	Salla (Kuolajärvi)	-	14,6	28,8	409	102	84	49
22	Sodankylä	179	13,8	27,7	520	98	84	59
23	Muonio	300	13,3	28,0	365	98	85	40
24	Pallasjärvi	-	13,3	26,2	467	95	85	53
25	Laanila	-	12,2	26,5	471	88	86	46
26	Enontäkiö	440	13,3	28,2	405	90	86	47
27	Inari	153	13,1	27,3	477	90	87	50
28	Ivalo	134	12,8	26,0	467	89	86	49
29	Petsamo	13	13,1	25,1	423	99	87	53
30	Vaitolahti	4	11,1	17,5	450	89	88	62
31	Nuorgam(Neuvola)	20	10,9	23,1	417	81	88	39

Norway

Nr	Station	Alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP
1	Halden	1	17,1	19,2	690	160	72	197
2	Brekke Sluse	114	16,1	19,5	806	148	72	197
3	Krappeto	105	15,7	19,2	757	150	72	186
4	Öymark	126	15,7	19,8	741	147	72	173
5	Trysil	362	13,9	23,4	705	117	75	102
6	Plassen	340	14,2	24,5	707	120	75	102
7	Engerdal I	538	12,3	21,9	508	100	76	60
8	Engerdal II	479	13,2	22,1	579	108	76	79
9	Eidsberg	140	16,0	19,8	720	129	72	150
10	Kjeller	109	16,2	22,3	770	145	73	164
11	Hvam	162	15,3	21,4	599	143	71	121
12	Åbogen	145	15,4	22,2	568	138	73	110
13	Flisa	183	15,5	23,5	624	137	74	116
14	Rena	225	15,4	25,5	730	129	75	118
15	Ytre Rendal II	253	14,3	22,5	466	123	76	77
16	Alvdal	485	13,2	23,6	473	110	76	61
17	Hjerkinn	953	10,6	18,1	222	83	76	23
18	Tynset I	490	12,9	24,6	340	111	77	42
19	Röros	628	11,4	21,9	449	87	77	44
20	Kongens Grube	856	10,0	18,8	497	64 1)	77	-
21	Eidsvall	190	15,2	20,8	599	138	74	124
22	Ö. Toten	270	15,2	22,1	573	138	74	112
23	Hamar	139	16,1	23,1	532	141	74	107
24	Biri	128	16,1	24,5	732	141	75	141
25	Lillehammer I	190	15,7	23,3	610	141	75	121
26	Mesnali	571	13,5	21,0	756	111	75	112
27	Sikkilsdal	1015	10,8	19,9	694	87	75	68
28	Listad	290	15,1	24,0	405	132	76	71
29	Ulstad (Lom)	385	14,0	22,6	274	123	76	44
30	Dombås	643	12,5	20,6	371	102	76	48
31	Fokstua	952	10,3	19,8	387	72	76	31
32	Lesjaverk	630	12,7	21,3	385	105	76	51
33	Ås	95	16,4	20,4	793	150	73	194
34	Sörmarka	157	15,9	20,2	706	147	73	166
35	Oslo I	22	17,5	21,0	685	162	73	188
36	Oslo (Blindern)	94	16,9	21,0	768	153	73	192
37	Tryvasshögda	512	14,2	19,5	992	129	73	189
38	Asker	154	16,4	20,9	899	152	73	217
39	Hönefoss	90	17,2	22,4	620	156	73	151

1) only 2 months with +7°C

Norway (cont.)

Nr	Station	Alt. m..	T_v °C	T_a °C	N mm	G days	E %	CVP
40	Kutjern	493	13,7	21,5	757	127	74	126
41	Tonsåsen	631	12,5	21,2	802	115	74	112
42	Åbjörsbråten	635	12,9	21,2	554	112	73	77
43	Vollen i Slidre	403	14,1	23,7	574	123	75	88
44	Vang i Valdres	471	13,4	20,2	501	123	75	85
45	Modum I	135	16,0	21,8	718	141	73	151
46	Nesbyen I	164	15,4	25,4	453	135	74	76
47	Sveingården	810	12,0	19,4	606	108	74	83
48	Geilo	794	11,7	18,7	683	93	74	82
49	Hangastöl II	995	10,2	18,6	747	81 2)	74	-
50	Slirå	1300	6,7	15,7	1095	0 3)	74	-
51	Horten	15	16,7	19,1	855	157	72	235
52	Kongsberg II	155	15,6	21,5	801	143	73	169
53	Knutehytta	717	13,0	18,3	964	114	73	158
54	Veggli	226	14,3	21,5	833	129	73	145
55	Dagali	887	11,0	18,4	522	87	74	56
56	Skien	28	16,3	20,9	787	156	72	192
57	Notodden	22	16,9	22,0	759	153	72	178
58	Gnarv	26	16,3	21,1	749	149	72	172
59	Dalen i Telemark I	102	16,2	19,8	876	150	72	215
60	Dalen i Telemark II	77	15,9	19,7	831	147	72	197
61	Jomfruland	15	16,8	17,8	860	164	73	270
62	Vefall i Drangedal	68	16,1	20,0	1011	156	72	254
63	Tveitsund	252	15,3	18,4	976	129	72	209
64	Grimstad II	7	16,8	16,8	1184	178	71	416
65	Mykland	265	15,7	18,3	1184	150	71	301
66	Kristiansand S	22	16,2	16,6	1297	168	70	413
67	Hægeland	174	15,0	18,0	1546	164	71	417
68	Byglandsfjord	207	15,0	17,6	1269	147	71	314
69	Austad	240	15,1	18,3	916	144	72	218
70	Mandal I	6	15,8	15,6	1331	173	70	453
71	Bjelland	110	14,2	17,9	1386	138	71	299
72	Lindesnes II	10	14,4	13,5	843	174	70	304
73	Gardöl	200	14,7	16,9	1417	149	71	362
74	Lista	13	14,2	13,4	1050	171	70	370
75	Flekkefjord	4	16,6	15,9	1768	173	70	562

2) only 2 months with +7°C   3) no month with +7°C

Norway (cont.)

Nr	Station	Alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP
76	Bakke	53	15,2	15,6	1800	161	71	557
77	Tonstad	57	15,0	16,1	1697	159	71	496
78	Vibberodden	17	14,6	13,3	995	159	71	342
79	Eikeland	250	14,4	14,6	2163	162	71	682
80	Kvassheim	7	13,7	12,5	1093	170	71	402
81	Obrestad	24	13,5	12,3	1018	169	71	372
82	Stavanger	67	14,1	12,5	1078	174	72	423
83	Sand i Ryfylke	2	14,4	14,0	2010	165	72	682
84	Röldal	430	13,5	17,6	1438	124	73	277
85	Svandalsflona	1048	9,1	15,3	1175	- 4)	73	-
86	Sauda	5	14,4	16,1	2033	186	73	686
87	Skudenes I	2	14,0	11,9	1221	180	73	524
88	Slåtterög	15	13,5	11,4	1314	174	73	549
89	Indre Matre	24	13,9	12,7	2854	171	73	1083
90	Ullensvang I	55	15,3	15,2	1634	159	74	538
91	Eidfjord	5	15,4	15,4	915	165	74	310
92	Granvin	345	13,8	16,9	1738	134	74	391
93	Syfteland	55	13,9	14,2	2159	155	73	664
94	Bergen II	43	14,2	12,6	1944	174	74	784
95	Bergsdal	540	11,6	16,8	2201	108	74	337
96	Voss I	56	15,1	18,5	1376	153	74	353
97	Raundal	700	13,2	17,8	1454	120	74	266
98	Upsete	851	10,7	16,0	1557	84	74	180
99	Eksingedal II	300	13,9	15,5	2328	136	74	584
100	Hellisög Fyr	20	13,2	11,0	1237	169	74	516
101	Vangsnes	53	15,3	14,7	920	158	75	315
102	Myrdal	870	10,1	15,5	1266	77	74	131
103	Stondal	657	11,6	16,3	743	99	74	108
104	Lærdal	3	16,1	17,2	444	162	75	140
105	Ljösne	107	16,5	17,9	375	165	75	119
106	Fortun	27	14,5	18,9	739	141	75	167
107	Fanaråken	2062	2,5	14,2	1261	- 5)	75	-
108	Leikanger	22	15,7	15,6	937	165	75	324
109	Fjærland	5	14,7	17,7	1670	141	75	407
110	Förde i Sunnfjord	3	14,7	16,4	2171	155	75	628
111	Florö	2	13,6	11,4	2161	168	75	902

4) only 2 months with +7°C

5) no month with +7°C

Norway (cont.)

Nr	Station	Alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP
112	Stryn	6	15,6	16,3	1110	156	76	350
113	Opstryn	205	14,5	15,2	991	150	76	299
114	Nordfjordeid	71	14,4	14,7	1852	147	76	563
115	Hellesylt	11	14,9	14,8	1624	153	76	528
116	Tafjord	27	14,8	13,6	837	169	77	329
117	Ålesund	6	13,2	10,7	1239	165	77	539
118	Åndalsnes	20	14,0	14,1	1269	152	77	410
119	Molde II	50	14,2	14,1	1380	147	77	437
120	Sunndalsöra	4	13,5	13,7	902	150	77	285
121	Sunndal	195	13,8	17,3	700	136	77	162
122	Kristiansund I	23	13,2	11,2	1271	162	78	526
123	Vinjeöra	15	13,8	15,7	1350	137	78	352
124	Sandstad	22	13,3	12,6	1187	147	79	404
125	Berkåk	424	12,4	18,3	647	103	78	98
126	Trondheim I	58	14,2	16,2	764	141	79	207
127	Selbu	197	13,9	17,5	795	132	78	181
128	Stugudal	615	11,4	18,4	652	96	78	84
129	Meråker	218	13,6	17,9	849	123	79	174
130	Stöp	40	14,6	17,9	681	138	79	168
131	Sulstua	251	13,1	19,0	939	114	79	162
132	Steinkjer	5	15,0	18,6	732	141	79	183
133	Kjevli	195	13,6	19,2	876	103	80	142
134	Snåsa	141	14,4	18,7	874	110	80	165
135	Vallersund	4	13,3	13,0	912	147	79	301
136	Grong	72	14,0	18,4	1344	123	80	280
137	Nordli I	401	12,2	20,8	790	97	80	100
138	Namsos	20	14,1	16,2	1178	168	80	383
139	Sörgjæslingan	6	12,9	12,2	879	144	81	301
140	Rossvikvågen	13	13,0	13,1	1153	138	81	355
141	Brinnöysund I	4	13,0	13,2	1086	138	82	336
142	Skålvær	4	12,6	12,4	880	131	82	267
143	Alstahaug	8	13,7	14,6	1333	138	82	393
144	Majavatu	352	12,5	18,8	881	99	81	130
145	Hattfjelldal	208	13,3	22,0	874	105	82	126
146	Rana	13	13,4	16,4	1320	120	83	298
147	Mo i Rana I	8	13,8	19,6	1346	117	83	256
148	Tonnes i Helgeland	15	13,4	13,5	1030	135	83	318
149	Myken	19	12,2	11,5	857	126	84	267

Norway (cont.)

Nr	Station	Alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP
150	Glomfjord	39	12,8	13,7	1937	123	84	519
151	Fleinvær	4	12,1	11,8	945	126	84	285
152	Rognan	28	12,7	18,7	714	111	84	126
153	Sulitjelma	151	13,8	19,2	1040	114	84	199
154	Fauske	15	13,2	16,1	987	117	84	221
155	Bodö I	17	12,8	14,6	852	125	84	218
156	Grötöy	5	13,0	13,5	868	117	85	231
157	Narvik	32	13,5	16,9	645	114	86	140
158	Björnfjell	512	11,0	21,5	749	69[6]	86	-
159	Offersöy	16	13,3	15,3	935	93	86	181
160	Sörvågen	20	12,4	12,5	1493	117	85	409
161	Röst	8	11,2	10,5	712	114	85	204
162	Eggum	4	11,3	12,2	1143	112	86	283
163	Bö i Vesterålen	7	12,0	13,6	993	114	86	239
164	Andenes	5	10,7	12,5	808	99	87	165
165	Sandsöy i Senja	17	11,9	13,9	688	106	87	151
166	Gibostad	6	12,1	16,0	748	100	87	137
167	Fagerlidal	72	13,7	21,4	656	105	87	107
168	Dividalen	226	13,5	22,5	296	99	87	42
169	Navaren	5	12,5	18,7	903	101	87	147
170	Sommaröy i Senja	2	11,1	13,2	651	102	88	136
171	Tromsö I	45	11,6	15,4	1013	97	88	181
172	Tromsö II	102	11,4	15,3	940	91	88	156
173	Torsvåg	22	10,6	12,2	603	96	88	123
174	Loppa	10	11,4	13,8	865	99	88	173
175	Alta	14	12,8	20,7	298	102	88	46
176	Kautokeino	306	13,0	27,5	310	87	87	31
177	Siččajavre	382	12,5	27,4	322	81	86	28
178	Galten	4	11,2	14,2	855	90	89	150
179	Hammerfest	23	11,7	15,3	722	95	89	130
180	Ingöy	4	9,4	12,0	641	75[6]	89	-
181	Gjesvær	5	10,6	14,5	763	90	89	124
182	Kistrand	12	11,2	17,5	400	88	88	55
183	Lebesby	10	11,6	18,2	506	84	89	67
184	Mehamn	4	10,2	15,3	935	81[6]	89	-
185	Tana II	5	12,0	21,8	423	91	88	52
186	Karasjok	129	13,2	27,9	316	93	87	34
187	Makkaur Fyr	11	9,9	14,9	555	78[6]	89	-
188	Vardö	13	8,9	14,3	573	74[6]	88	-
189	Ekkeröy	7	10,2	16,8	361	81[6]	88	-
190	Kirkenes	5	12,1	22,1	402	90	88	48

6) only 2 months with +7°C

Sweden

Nr	Station	T_v °C	T_a °C	N mm	G days	E %	CVP
1	Karesuando	13,0	27,2	326	87	85	32
2	Riksgränsen	10,6	21,1	844	69 1)	84	-
3	Abisko	11,1	21,9	267	81	84	26
4	Kiruna	12,0	23,9	453	81	84	43
5	Svappavara	13,5 2)	25,2 2)	418	102 2)	84	53
6	Suorva	11,8	22,6	404	90	84	44
7	Junosuando	14,2 2)	27,6 2)	405	95 2)	84	46
8	Gällivare	14,5	26,7	462	102	84	60
9	Merkenäs	11,5	22,8	573	84	84	57
10	Kvikkjokk	13,6	26,5	510	96	84	59
11	Porjus	14,5	27,6	453	99	84	55
12	Jokkmokk	14,7	27,5	469	105	83	61
13	Apua	14,7 2)	28,4 2)	471	100 2)	84	57
14	Vuonatjviken	11,5	24,7	506	84	83	46
15	Nausta	13,5 2)	28,0 2)	451	93 2)	83	47
16	Puottaure	14,2 2)	27,8 2)	551	102 2)	83	66
17	Näsberg	14,2 2)	27,6 2)	404	105 2)	83	50
18	Åminne 3)	15,5	29,9	444	120	82	63
19	Morjärv	15,7 2)	27,9 2)	512	114 2)	82	75
20	Övertorneå	15,7	28,0	440	114	83	65
21	Tärnaby	12,2	22,8	604	120	82	88
22	Abborberg	12,2 2)	25,3 2)	498	121	81	65
23	Långvattnet	13,6 2)	25,4 2)	544	127	81	83
24	Stensele	14,1	26,0	504	132	81	81
25	Hedberg	13,9 2)	24,3 2)	458	103 2)	81	61
26	Johannisberg	14,3	24,9	557	108	81	78
27	Malå	14,6	27,4	448	108	81	58
28	Stormyrheden	13,7	24,1	537	96	82	67
29	Haraliden	13,1 2)	23,5 2)	555	94 2)	81	65
30	Dalliden	14,9	24,4	561	111	81	86

1) Only 2 months with +7°C 2) Interpolated value

3) Temperature values according to Hamberg (1908, p.24) pertain to the period 1859-1900. Precipitation values according to Wallén (1951) for the present weather station Övre Svartlå.

Sweden (cont.)

Nr	Station	T_v °C	T_a °C	N mm	G days	E %	CVP
31	Piteå	15,9	25,1	465	122	81	81
32	Högsön	15,9	28,0	404	117	82	61
33	Haparanda	15,6	26,9	533	114	82	80
34	Gäddede	12,6	21,2	610	105	80	85
35	Munsvattnet	13,0	21,8	563	102	80	76
36	Storholmen	14,2[4]	25,6[4]	519	123[4]	80	79
37	Hoting	15,2[4]	25,9[4]	521	129[4]	80	88
38	Bjurfors	13,6[4]	25,0[4]	474	120[4]	81	70
39	Svanmyren	13,6[4]	24,0[4]	571	120[4]	80	86
40	Viska[5]	13,7	25,2	500	111	80	67
41	Örträsk	14,6[4]	23,8[4]	496	120[4]	80	81
42	Sunnanå	15,0[4]	22,3[4]	470	129[4]	81	92
43	Bygdsiljum	14,0[4]	21,8[4]	563	115[4]	80	92
44	Bjuröklubb	14,8	22,0	425	120	80	76
45	Storlien	11,2	18,2	915	67	78	82
46	Duved	13,2	22,1	630	111	78	90
47	Östersund	14,3	22,2	497	120	78	83
48	Gisselås	14,8[4]	24,0[4]	506	114[4]	79	78
49	Östra Junsele	15,5	25,7	550[4]	123	79	90
50	Ramsele	15,3[4]	25,3[4]	512	123[4]	79	84
51	Ådalsliden	15,8[4]	25,5[4]	522	127[4]	79	90
52	Bispgården	15,3	24,8	482	126	78	81
53	Tjälsbyn	14,2[4]	24,0[4]	544	120[4]	79	85
54	Skalmsjö	14,8[4]	23,3[4]	568	123[4]	79	97
55	Forse	16,1	25,9	507	119	78	81
56	Kasa	14,7	21,1	558	123	78	104
57	Nyåker	15,7[4]	23,9[4]	560	120[4]	79	96
58	Umeå	15,6	23,0	564	123	79	103
59	Holmö Gadd	14,6	19,4	419	120	79	83
60	Ljungdalen	12,4[4]	22,6[4]	559	101[4]	78	67
61	Ljusnedal	12,9	23,9	470	102	77	55
62	Storsätern	12,1	22,5	568	93	76	60
63	Linsäll	14,3[4]	24,4[4]	532	117[4]	76	77
64	Norrböle	14,1[4]	22,8[4]	445	118[4]	78	70

4) Interpolated value

5) Temperature values according to Hamberg (1908, p.24) pertain to the period 1859-1900.

Sweden (cont.)

Nr	Station	T_v °C	T_a °C	N mm	G days	E %	CVP
65	Tossåsen	14,5[6]	23,5[6]	350	119[6]	78	56
66	Sveg	14,7	24,6	512	121	76	78
67	Boggsjö	13,9[6]	23,9[6]	552	114[6]	78	79
68	Sösjö	13,5[6]	23,5[6]	592	110[6]	78	81
69	Ånge	15,6	25,5	451	129	77	76
70	Ramsjö	14,7	25,0	469	120	76	70
71	Ljungå	14,8	24,6	507	120	77	78
72	Oxsjö	14,5[6]	22,2[6]	476	118[6]	78	79
73	Stöde	15,5[6]	24,5[6]	602	130[6]	77	106
74	Gäddtjärnsåsen	13,4[6]	23,6[6]	635	107[6]	77	83
75	Lagfors	15,0	22,8	590	123	77	102
76	Härnösand	15,4	21,0	632	132	77	131
77	Sidsjö	15,6	22,6	574	132	77	112
78	Häljum	15,3[6]	21,0[6]	599	131[6]	77	122
79	Brämö	14,6	20,1	446	132	77	91
80	Lungö	15,3	19,9	371	130	78	80
81	Storhögen	12,7[6]	23,1[6]	676	110[6]	75	85
82	Särna	14,3	25,6	562	117	76	78
83	Nornäs	13,9[6]	24,7[6]	594	116[6]	75	81
84	Ulvsjö	13,3[6]	23,1[6]	728	111[6]	75	97
85	Lillhamra	14,4[6]	23,6[6]	702	120[6]	75	107
86	Älvdalen	15,5[6]	23,5[6]	600	130[6]	75	107
87	Los	14,2[6]	22,9[6]	646	119[6]	75	99
88	Svedåsen	14,1[6]	22,2[6]	614	116[6]	75	94
89	Bjuråker	16,0	22,8	471	135	76	94
90	Katrineberg	15,0[6]	21,4[6]	623	130[6]	75	118
91	Strömsbruk	15,5[6]	20,0[6]	517	138[6]	76	117
92	Storjungfrun	15,3	18,6	449	138	75	106
93	Likenäs	15,0	23,1	710	132	74	125
94	Malung	15,3	23,1	600	129	74	105
95	Ekshärad	15,5	22,6	619	138	73	119
96	Knon	16,1	22,7	680	144	73	141
97	Johannisholm	15,5[6]	22,8[6]	582	131	74	107
98	Siljansfors	15,5	22,8	687	132	74	127
99	Nås	16,0[6]	22,8[6]	566	137[6]	74	112
100	Rönndalen	16,0[6]	21,5[6]	516	138[6]	74	109
101	Falun	16,8	22,6	548	146	74	122

6) Interpolated value

Sweden (cont.)

Nr	Station	T_v °C	T_a °C	N mm	G days	E %	CVP
102	V. Svartnäs	14,7[7]	20,7[7]	602	135[7]	75	120
103	Botjärn	15,4[7]	20,2[7]	634	137[7]	75	138
104	Stjärnsund	16,1	21,7	580	141	74	125
105	Runhällen	16,3[7]	20,8[7]	534	147[7]	73	125
106	Hälsan	16,3	20,7	532	144	74	124
107	Gävle	16,1	20,2	533	144	74	126
108	Väsby	15,9	20,9	527	141	74	116
109	Harg	16,6	22,2	518	150	73	118
110	Understen	15,2	16,8	411	141	73	106
111	Kölfors	14,6[7]	19,3[7]	750	150[7]	72	170
112	Adolfsfors	16,2	22,1	645	144	73	138
113	Kyrkerud	15,8	20,3	714	145	72	161
114	Noretjärn	16,3[7]	21,1[7]	607	141[7]	72	132
115	Kölen	14,8[7]	19,5[7]	700	148[7]	72	157
116	Forshult	15,9	21,9	706	141	73	147
117	Rottneros	16,7	21,1	577	153	73	142
118	Karlstad	17,3	20,5	631	159	72	169
119	Malmbacka	14,4[7]	21,1[7]	771	136[7]	73	145
120	Ställdalen	16,0[7]	21,2[7]	642	140[7]	73	138
121	Gåsbernhyttan	15,5[7]	21,3[7]	755	138[7]	73	154
122	Filipstad	16,3	21,3	812	150	73	189
123	Kedjeåsen	15,5	20,7	774	138	72	160
124	Kloten	15,4	20,8	725	138	73	150
125	Nyberget	15,7[7]	20,3[7]	703	144[7]	73	159
126	Färna	16,4	20,7	559	150	73	135
127	Nora	16,7	20,6	673	150	72	164
128	Björklund	16,7[7]	20,0[7]	658	155[7]	72	170
129	Örebro	17,1	19,7	610	160	72	169
130	Kävesta	17,0[7]	19,7[7]	555	159[7]	72	152
131	Högsjö	16,7	19,6	552	159	72	150
132	Sätra brunn	16,7[7]	21,0[7]	552	150[7]	73	134
133	Västerås	17,3	20,7	545	157	73	145
134	Bie	17,0	21,0	599	153	72	148
135	Uppsala	16,9	20,7	545	153	73	138
136	Ultuna	16,5	20,4	516	150	73	127
137	Hyvlinge	16,8[7]	20,6[7]	498	154[7]	73	127
138	Ulvhäll	17,2[7]	20,3[7]	493	157[7]	72	131

7) Interpolated value

Sweden (cont.)

Nr	Station	T_v °C	T_a °C	N mm	G days	E %	CVP
139	Södertälje	17,0	20,0	558	156	72	148
140	Norr-Järsö	15,8[8]	18,9[8]	468	150[8]	73	119
141	Stockholm	16,8	19,3	570	156	72	155
142	Strömstad	17,1	18,9	667	168	72	203
143	Väderöbod	16,5	16,5	615	177	71	215
144	Hållö	16,6	17,0	583	177	71	199
145	Kristineberg	16,8	17,6	817	174	70	264
146	Bråttkärr	16,7[8]	17,5[8]	700	165[8]	70	214
147	Måseskär	16,5	16,8	521	174	70	173
148	Simmersröd	17,1[8]	18,2[8]	758	174[8]	70	241
149	Bäckefors	15,7[8]	19,2[8]	798	158[8]	71	203
150	Vänersborg	16,8	18,8	693	165	71	202
151	Koberg	16,3	18,3	641	162	70	180
152	Vedum	15,7	17,8	603	162	70	168
153	Sjötorp	16,5	19,0	515	159	71	140
154	Hönsäter	16,5	18,8	596	162	71	167
155	Skara	15,7	18,5	582	153	71	149
156	Skövde	16,2	18,6	661	159	71	181
157	Edsvära	15,6[8]	17,9[8]	523	159[8]	70	141
158	Askersund	16,6	19,6	642	156	71	167
159	Sörbytorp	16,1[8]	19,7[8]	714	153[8]	71	176
160	Lindhult	16,0[8]	19,0[8]	655	152[8]	71	165
161	Götlunda	16,2	18,8	554	159	71	150
162	Spethult	16,4[8]	18,9[8]	689	161[8]	71	190
163	Drottningtorp	14,8[8]	18,5[8]	556	142[8]	70	123
164	Strömbäck	15,5[8]	17,7[8]	566	156[8]	70	150
165	Mariedam	16,4[8]	19,4[8]	676	154[8]	71	174
166	Finspång	16,2	19,5	566	151	71	140
167	Grönkulla	16,6[8]	19,2[8]	550	160[8]	71	150
168	Halleby	16,8[8]	19,1[8]	540	163[8]	71	153
169	Linköping	17,0	19,1	511	163	71	146
170	Adelsnäs	16,1	19,3	530	153	70	132
171	Nyköping	16,7	18,9	559	159	71	155
172	Ålberga	16,8	19,9	553	156	71	144
173	Övre Gränsö	17,2	19,3	582	162	71	166
174	Holmbo	17,1[8]	19,1[8]	567	160[8]	70	158
175	Landsort	16,0	17,5	430	153	71	119
176	Gotska Sandön	16,3	17,2	498	159	71	148
177	Vinga	16,7	16,9	654	183	70	230

8) Interpolated value

Sweden (cont.)

Nr	Station	T_v °C	T_a °C	N mm	G days	E %	CVP
178	Kilanda	15,7	17,4	796	165	70	230
179	Göteborg	17,2	17,5	738	195	70	275
180	Borås	15,9	18,3	903	159	70	243
181	Rydal	16,3[9]	18,1[9]	898	168[9]	69	260
182	Varberg	16,7	17,4	571	180	69	189
183	Ulricehamn	14,9	18,0	799	147	70	189
184	Tranhult	14,0[9]	17,3[9]	794	139[9]	69	171
185	Åstafors	15,1	17,9	833	153	69	206
186	Kinnared	15,6	17,9	911	159	69	242
187	Lommaryd	14,8	18,3	537	144	70	122
188	Jönköping	16,2	17,9	535	162	70	153
189	Flahult	14,8	18,2	673	145	70	154
190	Prästkulla	14,9[9]	18,5[9]	567	146[9]	70	130
191	Gödeberg	14,3[9]	17,8[9]	703	139[9]	70	153
192	Lannaskede	15,8	18,9	643	153	69	158
193	Värnamo	16,0[9]	18,2[9]	652	157[9]	69	172
194	Toraliden	15,2[9]	18,0[9]	625	149[9]	69	151
195	Hässleby	16,1	19,0	574	153	69	143
196	Nyabyberg	15,7[9]	18,7[9]	573	153[9]	69	141
197	Kimramåla	15,8	18,1	517	156	69	135
198	Ogestad	13,2	16,0	562	153	70	138
199	Västervik	16,9	18,3	548	164	69	159
200	Falsterbo bruk	16,7[9]	18,2[9]	583	162[9]	69	166
201	Sandbäckshult	15,9	18,1	566	153	69	146
202	Ölands norra udde	16,7	17,2	415	168	69	130
203	Tingstäde	16,6	18,2	495	162	69	140
204	Visby	16,1	16,8	513	166	69	156
205	Buttle	16,3	18,1	591	159	69	162
206	Östergarn	16,4[9]	17,6[9]	413	161[9]	69	119
207	Hemse	16,2[9]	17,5[9]	535	160[9]	69	152
208	Fårö	16,9[9]	17,9[9]	446	159[9]	70	130
209	Halmstad	17,2	17,6	747	180	68	248
210	Hallands Väderö	16,6	16,8	591	183	68	202
211	Båstad	16,8	17,5	764	177	68	245
212	Kullen	16,2	16,5	590	177	68	194
213	Lagan	15,9[9]	17,9[9]	696	162[9]	69	192
214	Strömsnäs	14,8[9]	16,4[9]	812	161[9]	68	223

9) Interpolated value

Sweden (cont.)

Nr	Station	T_v °C	T_a °C	N mm	G days	E %	CVP
215	Knäred	15,6	17,3	791	162	68	218
216	Kolleberga	16,1[10]	17,2[10]	749	169[10]	67	221
217	Växjö	16,6	18,6	593	162	69	164
218	Ekefors	15,7	18,1	639	159	68	166
219	Osby	16,0[10]	17,2[10]	690	168[10]	68	204
220	Mjönäs	16,2[10]	17,4[10]	646	173[10]	68	197
221	Kristianstad	16,9	17,2	551	177	67	178
222	Karlshamn	16,8	17,4	562	174	68	178
223	Hoby	16,3[10]	17,6[10]	552	168[10]	68	162
224	Ronneby	16,3	17,4	575	171	68	174
225	Kungsholmen	16,8	17,3	511	171	68	160
226	Borgholm	16,4[10]	17,4[10]	466	173[10]	69	146
227	Kalmar	16,6	17,1	465	175	68	149
228	Ölvingstorp	16,4[10]	17,7[10]	517	174[10]	68	157
229	Mörbylånga	16,7	18,5	441	162	68	122
230	Ölands södra udde	17,2[10]	18,4[10]	414	165[10]	68	121
231	Hoburg	15,9	16,6	423	162	69	126
232	Malmö	16,6	16,8	526	180	67	174
233	Falsterbo	16,6	16,4	443	183	67	153
234	Älmhult	15,7[10]	16,9[10]	792	167[10]	67	229
235	Lund	16,5	17,1	616	177	67	196
236	Svedala	16,3	17,1	558	177	67	175
237	Ystad	16,1	16,1	564	180	67	189
238	Bollerup	16,8	17,6	581	174	67	180

10) Interpolated value

Table III. Yield, climate data and *CVP*-index of forest sample plots in the Nordic countries

Denmark

Tree species	Sample plot			Annual mean increment	Station		Corrected climatic values of the sample plot					CVP	CVP_1
	letter	age	alt. m.	m^3/ hectare	nr	alt. m.	T_v °C	T_a °C	N mm	G days	E %		
Picea excelsa	IQ	46	30	16,7	86	40	16,5	17,2	659	178	67	209	8,14
	IO	48	60	10,4	31	65	15,6	15,7	733	176	67	239	8,83
	IT	50	60	20,9	69	60	15,8	16,0	666	174	66	210	8,14
	GG	52	65	10,7	43	60	15,1	15,9	695	170	67	209	7,93
	IV	52	25	14,4	38	42	15,8	16,0	583	176	68	191	7,91
	IS	65	70	4,9	43	60	15,0	15,8	695	168	67	206	7,81
Picea sitchensis	GM	35	110	17,1	84	50	16,2	16,5	640	169	66	195	7,71
	MB	47	45	23,2	9	12	15,3	15,4	716	174	69	237	8,86
	ID	51	40	21,2	83	55	16,6	17,2	622	177	67	198	7,94
	ME	62	5	24,3	50	5	16,0	16,3	583	174	68	188	7,79
	GU	69	90	12,6	43	60	15,0	15,8	695	168	67	206	7,81
Abies grandis	GR	44	85	20,2	40	71	15,1	15,7	650	169	68	200	7,84
	IR	44	45	25,3	51	40	15,5	15,3	740	179	66	246	9,04
Larix leptolepis	GO	45	50	13,6	40	71	15,3	15,7	650	174	68	208	8,16
	GV	52	40	13,9	51	40	15,5	15,3	740	180	66	247	9,08

Temperature observed during 40 years, 1886-1925.
Termometer position 1,3-2,0 m above the ground; times of observation:
8 A.M., 2 P.M. and 21 P.M.
Before publication the simple arithmetic means obtained from these observations have been corrected to "true means" by considering the minimum night temperature. (Climate of Denmark, 1933, p.226) The rain gauge placed approx. 1,5 m above the ground, no snow (or rain) screen (ibid., p. 228).

Finland

Sample plot			Annual mean increment	Station		Corrected climatic values of the sample plot						
nr	age	alt. m.	m³/ hectare	nr	alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP	CVP_1
13[1]	70	120	6,3	5	110	16,9	24,9	541	135	75	103	4,43
15[2]	70	120	5,4	5	110	16,9	24,9	541	135	75	103	4,43
266[3]	76	110	6,8	5	110	17,0	25,0	541	136	75	104	4,47
14[4]	90	120	5,1	5	110	16,9	24,9	541	135	75	103	4,43
3a[5]	84	50	1,7	7	40	15,9	23,3	567	132	76	108	4,54
1a[5]	95	50	1,9	7	40	15,9	23,3	567	132	76	108	4,54
9c[5]	105	50	1,9	7	40	15,9	23,3	567	132	76	108	4,54
7a[5]	119	50	2,0	7	40	15,9	23,3	567	132	76	108	4,54
25a[6]	61	110	7,6	8	100	16,7	25,2	596	138	76	115	4,71
15a[7]	86	110	7,3	8	100	16,7	25,2	596	138	76	115	4,71
20[8]	102	180	5,2	8	100	16,3	25,0	596	134	76	110	4,51
21[9]	111	140	6,4	8	100	16,6	25,1	596	136	76	113	4,63
1[5]	100	120	3,8	19	80	15,5	27,1	454	113	83	68	3,19
2a[5]	100	120	3,2	19	80	15,5	27,1	454	113	83	68	3,19

1)birch only

2)birch - 76 %
spruce & pine - 24 %

3)spruce - 54 %
birch - 46 %

4)pine - 13 %
spruce - 87 %

5)pine only

6)birch - 50 %
pine - 47 %
spruce - 3 %

7)pine - 94 %
birch - 6 %

8)spruce - 76 %
birch - 24 %

9)pine - 92 %
spruce - 8 %

The data of the notes concerning the composition of the stand refer to the numerical distribution and not to the share of each tree species of the total annual mean increment what is the case with the Swedish material.

Norway

Sample plot			Annual mean increment m^3/ hectare	Station		Corrected climatic values of the sample plot					CVP	CVP_1
nr	age	alt. m.		nr	alt. m.	T_v °C	T_a °C	N mm	G days	E %		
89	81	130	4,3	70	6	15,0	15,3	1331	159	70	403	11,05
80	85	90	3,4	70	6	15,3	15,4	1331	162	70	417	11,43
63	81	200	5,8	72	10	13,5	14,5	843	156	70	238	8,20
97	86	120	2,7	66	22	15,6	16,4	1297	157	70	377	10,47
98	108	80	4,0	66	22	15,8	16,4	1297	161	70	391	10,86
96	80	90	4,4	66	22	15,8	16,5	1297	159	70	384	10,66
101	93	30	4,9	64	7	16,7	16,8	1184	175	71	406	11,80
99	87	50	3,6	64	7	16,6	16,8	1184	173	71	399	11,60
100	96	50	4,4	64	7	16,6	16,8	1184	173	71	399	11,60
77	80	110	3,2	66	22	16,8	18,1	1297	157	70	368	10,33
95	80	240	4,4	67	174	14,6	17,9	1546	160	71	398	10,12
94	81	230	4,9	67	174	14,7	18,0	1546	160	71	398	10,12
85	82	90	3,0	71	110	14,3	17,9	1386	140	71	306	8,22
74	86	200	2,9	71	110	13,7	17,8	1386	132	71	278	7,47
58	99	190	4,0	67	174	14,9	18,0	1546	163	71	411	10,45
50	94	190	2,0	67	174	14,9	18,0	1546	163	71	411	10,45
70	90	200	3,4	67	174	14,8	17,7	1546	162	71	413	10,50
71	80	360	2,8	68	207	14,0	17,2	1269	138	71	281	7,89
44	84	150	4,7	63	252	15,9	18,6	976	136	72	227	7,27
52	88	230	2,8	69	240	15,2	18,4	916	145	72	219	7,24
62	85	365	6,8	69	240	14,3	18,0	916	137	72	199	6,58
60	104	700	1,2	69	240	12,3	17,4	916	122	72	158	5,22
38	114	300	2,6	59	102	15,0	19,5	876	137	72	185	6,25
35	110	300	4,1	59	102	15,0	19,5	876	137	72	185	6,25
37	108	300	2,6	59	102	15,0	19,5	876	137	72	185	6,25
41	84	300	2,5	59	102	15,0	19,5	876	137	72	185	6,25
34	111	325	5,3	59	102	14,8	19,4	876	136	72	182	6,15
29	83	600	3,6	46	164	12,8	24,5	453	112	74	54	2,54
30	101	350	1,7	46	164	14,3	25,0	453	123	74	66	3,10
33	86	405	5,0	46	164	13,5	22,5	630	124	73	95	3,78
109	110	280	3,4	12	145	14,6	21,9	568	129	74	100	4,20
106	93	370	4,8	12	145	14,0	21,8	568	124	74	93	3,90
108	93	400	3,1	12	145	13,8	21,7	568	123	74	91	3,82
104	110	230	3,2	12	145	14,9	22,0	568	132	74	104	4,36
102	93	280	1,5	12	145	14,6	21,9	568	129	74	100	4,20
107	95	370	3,2	12	145	14,0	21,8	568	124	74	93	3,90
103	112	240	2,3	12	145	14,8	21,9	568	132	74	104	4,36

Norway (cont.)

Sample plot			Annual mean	Station		Corrected climatic values of the sample plot						
nr	age	alt. m.	increment m^3/ hectare	nr	alt. m.	T_v °C	T_a °C	N mm	G days	E %	CVP	CVP_1
110	108	200	3,9	13	183	15,4	23,5	624	136	74	114	4,56
111	86	200	3,8	13	183	15,4	23,5	624	136	74	114	4,56
112	104	200	4,7	13	183	15,4	23,5	624	136	74	114	4,56
113	104	200	2,7	13	183	15,4	23,5	624	136	74	114	4,56
7^{III}	101	250	3,6	14	225	15,2	25,4	730	127	75	116	4,29
7^{IV}	101	250	4,2	14	225	15,2	25,4	730	127	75	116	4,29
10	93	440	1,8	81Sv	600	13,7	23,5	676	117	75	96	3,69
11	120	460	2,9	81Sv	600	13,5	23,3	676	116	75	95	3,65
12	103	360	1,8	81Sv	600	14,1	23,4	676	121	75	103	3,96
13	105	400	2,1	81Sv	600	13,9	23,4	676	119	75	100	3,85
8	117	410	2,6	5	362	13,6	23,3	705	115	75	99	3,73
9	118	570	2,5	5	362	12,6	23,0	705	107	75	86	3,24
2	95	560	1,7	7	538	12,2	21,9	508	99	75	58	2,57
4	81	530	3,4	7	538	12,4	22,0	508	100	75	60	2,66
6	107	630	0,4	7	538	11,8	21,8	508	96	75	55	2,44
18	119	570	3,0	30	643	13,0	21,9	382	110	76	53	2,71
19	118	500	1,9	30	643	13,4	22,0	382	113	76	56	2,87
21	118	500	3,2	30	643	13,4	22,0	382	113	76	56	2,87
22	120	500	3,1	30	643	13,4	22,0	382	113	76	56	2,87
24	120	550	2,2	30	643	13,1	21,9	382	111	76	54	2,76
25	107	550	2,5	30	643	13,1	21,9	382	111	76	54	2,76
26	98	520	3,6	30	643	13,3	22,0	382	112	76	55	2,81
65	130	100	2,5	134	141	14,6	18,7	874	113	80	171	5,78
124^{I}	109	70	1,8	167	72	13,7	21,4	656	105	87	107	4,18
124^{II}	109	70	1,8	167	72	13,7	21,4	656	105	87	107	4,18
386^{I}	121	90	1,7	176	306	13,7	25,6	305	106	87	42	2,40
386^{II}	121	90	1,7	176	306	13,7	25,6	305	106	87	42	2,40
111^{I}	158	25	1,4	175	14	12,7	20,6	298	101	88	45	2,61
111^{II}	158	25	1,4	175	14	12,7	20,6	298	101	88	45	2,61
121	102	150	1,6	186	129	13,1	27,9	316	90	87	32	1,80
703^{I}	160	100	0,8	190	5	12,4	24,5	440	86	87	46	2,19
703^{II}	160	100	0,8	190	5	12,4	24,5	440	86	87	46	2,19
703^{III}	160	100	0,9	190	5	12,4	24,5	440	86	87	46	2,19
703^{IV}	160	100	0,9	190	5	12,4	24,5	440	86	87	46	2,19
183^{I}	88	110	2,6	152	28	12,2	18,5	714	101	84	111	4,15
183^{II}	88	110	2,8	152	28	12,2	18,5	714	101	84	111	4,15

Sweden

Age class 71-80

Sample plot		Annual mean increment	Station		T_v	T_a	N	G	E	S	CVP	CVPxS
nr	alt. m.	m^3/ hectare	nr	alt. m.	°C	°C	mm	days	%	10^{-2} ohm cm		
156	180	2,1	17	185	14,4	27,6	404	105	83	0,42	51	21
109	350	2,5	68	450	14,1	23,7	592	116	78	1,02	89	91
108	335	6,2	64	380	14,4	22,9	445	120	78	1,18	73	86
15	144	4,8	197	146	15,8	18,1	517	156	69	0,90	135	122
8	70	6,8	215	70	15,6	17,3	791	162	68	1,15	218	
105	350	1,3	66	363	14,8	24,6	512	122	76	0,33	79	
85	378	6,2	99	230	15,1	22,4	566	128	74	0,86	100	
86	352	2,4	97	280	15,1	22,7	582	127	74	0,58	101	
77	215	2,5	119	385	15,4	21,5	771	146	73	0,81	163	
171	260	1,9	5	335	14,0	25,4	418	107	84	0,40	58	

Sweden

Age class 81-90

Sample plot		Annual mean increment	Station		T_v	T_a	N	G	E	S	CVP	CVPxS
nr	alt. m.	m^3/ hectare	nr	alt. m.	°C	°C	mm	days	%	10^{-2} ohm cm		
150	25	1,6	31	9	15,9	25,1	465	120	81	0,41	80	33
152	70	2,6	19	40	15,5	27,8	512	110	82	0,55	72	40
151	55	1,7	32	8	15,6	27,9	404	111	82	0,58	57	33
153	10	1,6	33	9	15,6	26,9	533	114	82	0,48	80	38
148	375	3,0	28	445	14,1	24,2	537	100	82	0,77	71	55
147	405	1,2	29	450	13,4	23,8	555	96	81	0,49	67	33
159	285	1,7	12	255	14,5	27,4	469	103	83	0,89	59	53
160	335	2,2	12	255	14,2	27,3	469	100	83	0,50	56	28
168	300	1,8	8	365	14,9	26,8	462	105	84	1,03	63	65
169	260	3,2	8	365	15,1	26,9	462	108	84	0,72	65	47
170	250	2,3	8	365	15,2	27,0	462	109	84	0,62	66	41
155	120	1,6	18	30	15,0	29,7	444	110	82	0,59	56	33
173	185	2,2	7	220	14,4	27,5	405	97	84	1,19	48	57
125	175	3,2	41	205	14,8	23,9	496	122	80	0,46	83	38
130	310	4,1	41	205	14,0	23,6	496	113	80	0,65	74	48
131	220	1,7	41	205	14,5	23,8	496	119	80	0,31	80	25
134	300	1,6	39	410	14,3	24,3	571	126	80	0,28	94	26
138	205	4,5	43	130	13,5	21,6	563	120	80	2,29	94	215
144	360	3,2	26	400	14,5	24,9	557	110	81	0,61	80	49
141	424	3,3	23	420	13,6	25,4	544	127	81	0,96	83	80
140	423	2,8	23	420	13,6	25,4	544	127	81	0,74	83	61
104	345	0,6	66	363	14,8	24,6	512	122	76	0,27	79	21
115	220	2,6	71	220	14,8	24,6	507	120	77	0,76	78	59
107	378	7,5	64	380	14,1	22,8	445	118	78	1,84	70	129
117	325	4,5	47	328	14,3	22,2	497	120	78	0,65	83	54
119	293	3,7	48	320	15,0	24,1	506	115	79	0,62	79	49
114	215	5,4	72	215	14,5	22,2	476	118	78	0,60	79	47
116	254	3,4	52	165	14,8	24,6	482	120	78	0,47	75	35
93	316	1,8	90	250	14,6	21,3	623	126	75	0,73	112	82
92	110	4,3	103	165	15,7	20,3	634	141	75	1,69	144	243
94	240	2,0	88	400	15,1	22,4	614	125	75	0,96	108	104
98	179	8,6	89	73	15,4	22,6	471	128	76	0,79	87	69
95	265	2,8	87	405	15,0	23,2	646	127	75	0,73	111	81
81	473	1,8	93	160	13,1	22,3	710	114	74	0,39	98	38
80	280	5,5	93	160	14,3	22,7	710	124	74	0,62	114	71
79	200	3,4	96	193	16,1	22,7	680	144	73	1,11	141	157

Sweden

Age class 81-90 (cont.)

Sample plot nr	Sample plot alt. m.	Annual mean increment m^3/ hectare	Station nr	Station alt. m.	T_v °C	T_a °C	N mm	G days	E %	S 10^{-2} ohm cm	CVP	CVPxS
78	350	1,8	96	193	15,1	22,3	680	135	73	0,64	126	81
62	116	4,5	123	165	15,8	20,8	774	141	72	1,07	166	178
58	172	5,6	123	165	15,5	20,7	774	138	72	0,85	160	136
61	203	3,2	121	225	15,6	21,3	755	139	73	1,06	156	165
56	51	6,6	130	45	17,0	19,7	555	159	72	1,47	152	223
57	46	6,1	128	50	16,7	20,0	658	155	72	1,27	170	216
74	65	6,1	132	75	16,8	21,1	552	151	73	0,92	135	124
68	25	5,7	140	15	15,7	18,8	468	149	73	1,85	118	218
67	30	4,4	140	15	15,7	18,9	468	148	73	1,10	117	129
51	201	3,7	163	250	15,1	18,6	556	139	70	1,34	122	163
49	75	6,6	153	50	16,3	18,9	515	156	71	1,62	137	223
47	131	6,8	160	180	16,3	19,1	655	155	71	0,87	171	149
50	165	5,6	160	180	16,1	19,0	655	153	71	0,90	167	150
45	185	6,6	159	185	16,1	19,7	714	153	71	1,12	176	197
46	156	4,4	160	180	16,2	19,1	655	154	71	0,88	169	149
39	200	6,9	185	37	14,1	17,5	833	138	69	0,69	178	123
37	155	6,8	124	100	15,3	17,9	911	155	69	0,63	231	146
23	290	6,2	191	350	14,7	17,9	703	142	70	1,02	159	164
17	166	6,1	193	140	15,8	18,1	652	155	69	1,09	169	184
19	389	5,1	184	340	13,7	17,2	794	137	69	1,52	166	252
11	150	5,0	214	110	14,6	16,4	812	158	68	1,04	216	227
33	117	6,5	200	45	16,3	18,1	583	154	69	1,43	155	222
5	40	5,2	222	7	16,6	17,3	562	170	68	2,48	173	429

Sweden

Age class 91-100

Sample plot		Annual mean increment	Station		T_v	T_a	N	G	E	S 10^{-2}	CVP	CVPxS
nr	alt. m.	m^3/ hectare	nr	alt. m.	°C	°C	mm	days	%	ohm cm		
158	115	1,9	20	58	15,3	27,8	440	108	83	0,59	60	35
145	530	1,5	25	440	14,4	24,0	458	99	81	0,47	61	30
146	400	1,7	29	450	13,4	23,8	555	97	81	0,48	68	33
161	410	1,6	12	255	13,8	27,2	469	96	83	1,10	53	27
162	400	2,2	12	255	13,8	27,1	469	97	83	0,67	53	27
163	275	1,6	12	255	14,6	27,5	469	104	83	1,09	60	30
154	275	3,3	17	185	13,7	27,4	404	99	83	0,76	46	23
167	450	2,2	11	375	14,0	27,4	453	95	84	1,79	51	26
172	320	2,0	5	335	13,6	25,2	418	103	84	0,59	54	27
174	230	2,8	7	220	14,1	27,5	405	94	84	1,42	46	23
165	170	3,0	13	210	14,9	28,4	471	103	84	0,72	59	30
166	170	2,7	13	210	14,9	28,4	471	103	84	0,94	59	30
132	230	2,4	41	205	14,4	23,7	496	118	80	0,60	79	25
133	340	4,2	41	205	13,8	23,6	496	112	80	0,60	72	36
129	400	4,4	24	328	13,7	25,9	504	128	81	0,42	77	32
143	300	2,6	26	400	14,9	25,1	557	113	81	0,54	84	42
139	85	2,0	42	15	14,6	22,2	470	120	81	2,10	83	42
136	290	2,6	38	400	14,3	25,3	474	126	81	0,44	76	33
142	458	3,9	22	550	12,7	25,4	498	125	81	0,83	70	35
110	389	5,2	68	450	13,9	23,6	592	113	78	0,66	85	43
113	71	6,8	78	40	15,1	20,9	599	127	77	0,44	118	52
120	176	6,2	51	130	15,5	25,4	522	124	79	0,91	87	44
123	350	3,6	53	355	14,2	24,0	544	120	79	0,54	85	42
122	350	3,2	53	355	14,2	24,0	544	120	79	0,36	85	31
99	43	6,3	91	10	15,3	19,9	517	134	76	1,57	112	56
97	304	6,1	89	73	14,6	22,2	471	118	76	0,72	77	39
100	397	3,5	66	363	14,5	24,5	512	119	76	1,29	76	38
87	156	3,3	101	122	16,6	22,5	548	144	74	1,76	120	60
91	295	4,9	86	255	15,3	23,4	600	127	75	0,66	104	52
83	445	2,6	81	600	13,6	22,8	676	118	75	0,62	99	50
55	129	8,1	165	130	16,4	19,4	676	154	71	1,42	174	87
73	40	3,9	133	18	17,2	20,7	545	154	73	0,98	141	71
71	17	2,8	108	35	16,0	20,9	527	143	74	1,16	119	60
64	62	6,7	134	60	17,0	21,0	599	153	72	1,02	148	74
54	56	6,1	166	45	16,1	19,5	566	150	71	1,64	138	69
53	82	6,9	168	70	16,7	19,1	540	161	71	1,36	150	75

Sweden

Age class 91-100 (cont.)

Sample plot nr	Sample plot alt. m.	Annual mean increment m^3/ hectare	Station nr	Station alt. m.	T_v °C	T_a °C	N mm	G days	E %	S 10^{-2} ohm cm	CVP	CVPxS
42	124	4,4	162	115	16,3	18,9	689	160	71	0,88	188	94
41	200	4,0	159	80	15,0	19,0	798	149	71	1,39	185	93
25	221	3,4	190	300	15,4	18,7	567	151	70	0,93	137	69
22	340	6,0	191	350	14,4	17,9	703	140	70	0,74	154	77
18	180	5,1	193	140	15,8	18,2	652	154	69	0,77	167	84
24	229	7,4	196	220	15,6	18,7	573	152	69	1,53	139	70
20	216	4,8	184	340	14,7	17,5	794	147	69	0,96	188	94
12	145	5,0	218	145	15,7	18,1	639	159	68	1,52	166	83
31	108	3,6	200	45	16,3	18,0	583	154	69	0,78	156	78
30	133	3,0	200	45	16,2	18,1	583	153	69	1,32	153	77
36	12	2,6	176	12	16,3	17,2	498	159	71	0,48	148	74
9	147	5,1	186	100	15,3	17,8	911	162	69	1,14	243	122
6	34	7,4	224	6	16,1	17,3	575	167	68	1,36	169	85

Sweden

Age class 101-110

Sample plot nr	Sample plot alt. m.	Annual mean increment m^3/ hectare	Station nr	Station alt. m.	T_v °C	T_a °C	N mm	G days	E %	S 10^{-2} ohm cm	CVP	CVPxS
149	65	2,6	28	445	16,0	25,1	537	121	82	0,50	94	47
157	130	2,7	19	40	15,2	27,7	512	104	82	0,58	67	34
128	370	2,6	36	345	14,0	25,8	519	122	80	0,50	76	38
126	275	1,5	37	240	15,0	25,8	521	127	80	1,40	85	
135	340	3,5	38	400	14,0	25,1	474	123	81	0,57	73	37
137	137	2,0	41	205	15,0	23,9	496	125	80	0,83	86	43
124	45	3,1	57	70	15,8	24,0	560	123	79	0,47	100	47
106	410	3,1	65	350	14,1	23,4	350	116	78	0,57	53	27
111	445	6,0	64	380	13,7	22,7	445	115	78	0,99	67	34
112	215	5,1	67	375	14,9	24,3	552	124	78	0,71	91	46
118	332	3,6	48	320	14,7	23,9	506	113	79	0,63	77	39
96	385	3,4	87	405	14,2	23,3	646	120	75	1,32	98	49
102	422	3,7	74	415	13,4	23,6	635	107	77	1,34	83	42
82	435	2,6	81	600	13,7	23,5	676	117	75	0,67	96	48
72	15	4,4	133	18	17,3	20,7	545	157	73	1,88	145	73
75	135	1,5	132	75	16,3	20,9	552	145	73	1,78	127	64
69	30	7,1	140	15	15,7	18,9	468	148	73	1,11	117	59
63	25	4,7	171	18	16,7	18,9	559	158	71	0,76	154	77
52	153	5,7	163	250	15,4	18,7	556	148	70	1,80	132	66
44	140	5,9	160	180	16,2	19,1	655	155	71	1,53	170	85
40	133	5,9	150	54	16,3	18,6	693	157	71	1,50	188	94
38	125	8,4	181	75	16,0	18,0	898	163	69	1,31	249	125
14	186	3,6	217	173	16,5	18,6	593	161	69	0,81	162	81
32	117	5,6	195	172	16,4	19,1	574	157	69	0,78	148	74
35	138	5,1	174	45	16,6	18,9	567	151	70	1,56	146	73
27	40	3,5	228	15	16,2	17,6	517	171	68	1,07	154	77
28	45	5,8	228	15	16,2	17,6	517	170	68	1,15	153	77
10	150	6,2	186	100	15,3	17,8	911	156	69	1,03	234	117
7	115	5,7	223	30	15,8	17,4	552	158	68	1,28	150	75
3	96	7,7	219	75	15,9	17,2	690	165	68	1,76	199	100
4	97	8,3	219	75	15,8	17,1	690	165	68	1,97	199	100
1	95	6,3	220	90	16,2	17,4	646	172	68	3,66	195	98

Sweden

Age class 111-120

Sample plot nr	Sample plot alt. m.	Annual mean increment m^3/ hectare	Station nr	Station alt. m.	T_v °C	T_a °C	N mm	G days	E %	S 10^{-2} ohm cm	CVP	CVPxS
164	305	2,0	11	375	15,0	27,6	453	103	84	0,43	59	25
127	370	2,2	36	345	14,0	25,8	519	122	80	0,80	76	38
121	215	5,0	50	205	15,2	25,3	512	122	79	0,50	82	41
101	328	2,0	70	215	14,0	24,8	469	113	76	1,33	63	32
89	185	4,1	98	260	16,0	23,0	687	137	74	0,95	135	68
84	295	3,8	99	230	15,6	22,7	566	133	74	0,85	106	53
88	235	4,2	102	350	15,4	21,0	602	142	75	1,19	131	66
59	176	5,3	125	185	15,8	20,3	703	145	73	1,34	161	81
60	160	2,4	120	165	16,0	21,2	642	140	73	0,79	138	69
70	27	4,7	137	35	16,8	20,6	498	155	73	1,06	128	64
76	65	7,9	105	80	16,4	20,8	534	149	73	1,64	127	64
66	30	9,1	140	15	15,7	18,9	468	148	73	1,63	117	59
65	46	6,8	138	5	17,0	20,2	493	152	72	1,08	126	63
48	140	7,0	160	180	16,2	19,1	655	155	71	1,14	170	85
43	110	7,6	162	115	16,4	18,9	689	161	71	1,14	190	95
26	211	4,1	190	300	15,4	18,7	567	152	70	0,72	138	69
21	294	4,5	191	350	14,6	17,9	703	142	70	0,77	158	79
16	350	3,9	194	290	14,8	17,9	625	146	69	2,37	145	73
13	168	6,9	213	140	15,7	17,8	696	160	69	1,01	188	94
34	152	5,7	170	97	15,8	19,2	530	149	70	1,23	126	63
29	35	5,0	201	37	15,9	18,1	566	153	69	1,55	146	73
2	95	5,6	220	90	16,2	17,4	646	172	68	0,90	195	98

Age class 121-130

90	700	1,9	62	680	12,0	22,5	568	92	76	0,62	59	
103	570	1,1	60	615	12,7	22,7	559	103	78	0,54	70	