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EFFECT OF TREE SOCIAL STATUS ON BASIC DENSITY OF NORWAY SPRUCE

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Seloste

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The effect of growth rate on wood basic density in even-age spruce plantations was studied on the basis of samples collected from 53 stands; 30 trees were sampled in each stand. The prediction of basic density with the help of growth rate and some other tree characteristics could be improved if the social status of the tree was taken into account. Within a stand, the smaller trees had a lower density, while taller trees had a higher density, than they should have had on the basis of growth rate alone.

1. INTRODUCTION

The basic density of Norway spruce (*Picea abies* (L.) Karst.) has been studied by numerous scientists in the present century and even earlier. The common model postulates that the density in a stem increases from mid-stem towards the top and butt. In the radial direction the density is high near the pith. After a decline it usually increases slowly towards the surface. The variation between stems is explained by the age, since the basic density of the stem increases with age.

Another factor is the growth rate, which has a negative correlation with basic density. Thus the trees grown on fertile sites have a lower density than those from poorer sites. Similarly, planted spruce with good growing vigour have a lower density than trees from dense natural forests. This effect of growth rate typical to spruce, has been demonstrated by numerous Finnish (Wegelius 1941, Sirén 1952, Hakkila 1966, Hakkila and Uusvaara 1968, Saikku 1975, Velling 1976, 1980, Kärkkäinen and Dumell 1983, Kärkkäinen and Hakala 1983) and other Nordic research workers (Wijkander 1897, Kinnman 1923, 1928, G.G. Klem 1934, 1957, Johansson 1939, 1940, Nylinder 1953, Nylinder and Hägglund 1954, Tamminen 1964, G.S. Klem 1965 a, b, 1974, Ericson 1966, Olesen 1973, 1976, 1977, Dalgas 1975, Madsen et al. 1978), among others.

Thus, studies explaining the differences between trees by differences in growth rate are numerous. However, few reports have been published on the role of the competition between trees within a stand and the effect of growth rate between stands. Yet it is important to distinguish the intra-stand and inter-stand variation between trees. It is possible that the effect of growth rate is different within a stand and between stands. There are examples in the literature which show that the relationships can indeed vary.

The purpose of this study was to analyze the effect of tree characteristics on basic density and separate the effect of intra- and inter-stand growth rate variation.

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2. MATERIAL AND METHODS

The planted spruce sample trees were selected to eliminate the effect of intra-stand age variation. Samples gathered originally for other purposes were available from southern Finland. There were 53 plots and 30 trees were measured from each plot. Since some trees were lost during the laboratory work, a total of 1 581 spruce samples were used in the main study. From these trees the basic density at breast height and numerous tree characteristics were determined. Beside these sample trees, 65 trees were cut and sectioned for a regression of stem density on breast height density. Using the derived regression equation, the breast height densities of the 1 581 trees were converted to tree densities.

The age of the trees was 26...88 years, diameter breast height 4...39 cm and height 4...29 m. Otherwise, the sample was as described by Hakkila and Uusvaara (1968), who collected it for other purposes.

The method selected in this study was linear regression analysis. The term "linear" refers to linear with respect to parameters. Of course, numerous transformations of the original variables were used to obtain unbiased estimates of density. As a rule, the original independent variables and their squares were used in stepwise regression analysis. Besides these factors, numerous interaction factors were formulated from previous knowledge. When this was done, the form of the interaction factors was xz (independent variable x multiplied by the independent variable z). This gave a very flexible solution. As an example, if we use the density model

(1) $y = a + b_1d + b_2w$

where y is the basic density, d diameter breast height and w growth rate, the effect of growth rate is constant irrespective of the tree size. If, however, an interaction factor dw is added, we get model (2).

(2) $y = a + b_1d + b_2w + b_3dw$

According to this model, the effect of growth rate can either decrease or increase with the tree size, depending on the sign of the coefficient b_3. Similarly, even secondary interactions (three original variables) can be analyzed, although in practice first-order interactions will be sufficient. Of course, interactions of the squared variables can be computed, too.

3. RESULTS

31. Stem population as a whole

Taking the measured 1 581 spruce trees as a random sample of a population, it is interesting to see how accurately the basic density of the stems can be estimated on the basis of tree and site characteristics. However, it should be emphazized that this kind of procedure where 30 trees were sampled from each stand is not a real random sample of the whole stem population.

Using stepwise regression analysis, the following equation was obtained. The statistical limit used for entering and removing variables was $p = 0,05$.

(3) $y = 402,3 + 1,417h - 49,37w - 0,01392d^2 + 7,030w^2 + 0,3855fh$

$R^2 = 37.9$ %, standard error of the estimate = 16,8 kg/m^3

where

y = basic density of the spruce stem, kg/m^3
h = tree height, m
w = average width of the growth rings at breast height, mm
d = diameter breast height, cm
f = fertility of the site (0 = OMT, 1 = MT, see Cajander 1949).

According to the model, increasing growth rate reduces the basic density at a decreasing rate. The tall trees are denser than short trees, but the effect is weaker on fertile sites (OMT) than on sites of medium fertility (MT). Other factors being constant, the diameter breast height also has an effect, although very small.

The greatest variation in basic density was caused by growth rate. In average trees a 1 mm increase in the average ring width decreased the basic density by 20,6 kg/m^3.

32. The effect of competition

Equation (3) gives similar estimates of basic density for two similar trees, even though one is one of the smallest in a stand and the other, one of the largest in another stand. It is interesting to analyze the validity of this prediction. The test can be made by using the variables of Eq. (3) as compulsory independent variables and by testing the significance of other variables which describe the social status of the tree. For this, the status was described by the differences between the plot average and the tree characteristic (difference in diameter breast height, height, etc). A similar method was employed earlier by Kärkkäinen and Uusvaara (1982).

The resulting equation was (4).

(4) $y = 442,4 - 0,8796a + 2,476h - 64,31w - 16,39w_d + 0,004550a^2 - 0,01586d^2 + 7,509w^2 + 0,4128fh + 1,206fh_d$

$R^2 = 41,1$ %, standard error of the estimate = 16,4 kg/m^3

where

a = age of the tree, years
w_d = difference between stand and tree growth rates, mm
h_d = difference between stand and tree heights, m and other variables are as earlier

As can be seen by comparing equations (3) and (4), two variables describing the social status of trees (difference of growth rate between the stand average and a single tree, similar difference of height) were inserted into the model. At the same time, the age factor was entered into the model.

The interpretation of the result is straightforward: the smaller trees of an even-aged stand which have a low growth rate have lower density than could be expected from the low growth rate alone. Similarly, taller trees of the same stand have higher density than could be expected from the good growing rate. If all the other factors are similar, short trees have a higher and tall trees a lower density than could otherwise be expected.

The dependent variable can also be the difference in basic densities between the stand average and a single tree. The variable is negative if the tree has a higher density than the stand average and positive if it is lower. When the corresponding differences in tree characteristics were taken as independent variables, the following equation was obtained.

(5) $Y_d = 0,3301 - 2,153d_d - 0,5197fd_d + dh_d$
$R^2 = 12,9$ %, standard error of the estimate = 15,0 kg/m^3

where

Y_d = difference in basic density of the stand average and a single tree, kg/m^3
d_d = difference in diameter breast height, cm
h_d = difference in height, m
f = fertility (OMT = 0, MT = 1, see Cajander 1949)
d = diameter breast height, cm

This model is easy to interpret: smaller trees (measured by diameter breast height) have a higher basic density than taller trees, especially on sites of medium fertility (MT). However, the estimate is corrected a little by difference in height and site fertility. The effect of tree size is also quite clear. Each cm in diameter means 2,2 kg/m^3 in tree density. The low coefficient of determination shows, however, that the competition between trees is only one factor affecting density.

4. DISCUSSION

The results of this paper demonstrate that the effect of growth rate on basic density is complicated. The prediction based on growth rate and some other tree characteristics can be improved if the social status of the tree in the stand is taken into account. The status can be operationalized, for example, by the difference in diameter breast height between the stand average and the tree. According to the results, the small trees of a stand have a lower and taller trees a higher density than they should have on the basis of growth rate alone. This effect of social status is relative of course; in absolute terms the taller spruce trees have a lower density than the smaller ones.

There are no comparable investigations published so far. However, Nylinder (1953) and Hildebrandt (1954) have noticed that in an even-aged spruce stand the wood of tallest trees is lightest and that of medium-sized heaviest. The wood of the smallest trees is lighter than that of medium-sized. This result supports the conclusion that the growth rate alone cannot determine the basic density, but there is also a competition factor besides this. Of course, another fact is that the regression of basic density on growth rate depends on age. This has been noticed in numerous studies (e.g. Olesen 1977, Madsen et al. 1978, Nepveu and Birot 1979, Lewark 1979).

The estimation accuracy in the samples of this study was improved only a little, however. Without status variables the standard error of the estimate was 16,8 kg/m^3 and with them 16,4 kg/m^3. This decrease is of little importance only in practical wood density predictions.

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Total of 34 references

SELOSTE

KUUSEN ASEMAN VAIKUTUS PUUAINEEN TIHEYTEEN

Yleisesti on tiedossa, että kuusella puuaineen tiheys alenee vuosiluston paksuuden kasvaessa. Sitä vastoin on lähes tutkimatta, millainen on kasvunopeuden vaikutus erotettaessa toisistaan metsikön sisäinen ja metsiköiden välinen vaihtelu.

Tutkimuksen aineistona käytettiin Hakkilan ja Uusvaaran (1968) keräämää istutuskuusikkomateriaalia, johon kuului 53 koealaa, kultakin 30 puuta, joista oli mitattu kuiva-tuoretiheys rinnantasalta. Erillisen kaatokoepuuaineiston avulla rinnankorkeustiheydet oli muunnettu koskemaan koko runkoa.

Käsillä olevassa työssä käytettiin regressioanalyysiä tasaikäisen metsikön puiden tiheysvaihtelun selittämiseen. Osoittautui, että käsiteltäessä koko puujoukkoa yhtenä ryhmänä tiheys aleni puiden kasvunopeuden parantuessa. Pituuden lisääntyessä tiheys hiukan kohosi. Pituuden vaikutus oli mustikkatyypin kasvupaikalla suurempi kuin käenkaali-mustikkatyypin kasvupaikalla. Li-

säksi merkitystä oli hiukan myös rinnankorkeusläpimitalla: sen suuretessa tiheys aleni muiden tekijöiden pysyessä vakioina.

Työn toisessa vaiheessa lisättiin em. regressiomalliin puun asemaa metsikössä kuvaavia muuttujia. Näitä olivat puun läpimitan, pituuden ym. tekijöiden erot kunkin metsikön keskiarvoon. Näin menetellen saatiin otetuksi huomioon, että määräkokoinen puu saattoi olla nuoren metsikön suurimpia puita tai vanhan metsikön pienimpiä puita.

Osoittautui, että puun asemalla oli vaikutusta puuaineen tiheyteen. Tasaikäisen metsikön pienillä puilla oli alhaisempi tiheys kuin pelkästä kasvunopeudesta voitiin päätellä, ja vastaavasti suurilla puilla oli korkeampi tiheys kuin kasvunopeus antoi edellyttää. Puun aseman vaikutus ei ollut suuri, mutta kuitenkin selvästi osoitti, että kasvunopeus vaikuttaa monimutkaisella tavalla tiheyteen, jossa puun asemalla muihin verrattuna on merkitystä.