The aim of this literature review was to compare the properties of Finnish spruce sawn goods to those from Central European spruce and fir species. However, it was found that no statistically proper study has been made. Therefore, conclusions are based on the studies which have dealt with the wood material properties. As a rule, materials used in the studies are small and no adequate sampling has been made. Therefore, conclusions can only be preliminary and should be checked by sampling studies made of Finnish and Central European spruce sawn goods.

The main conclusions are based on the fact that spruce grows faster in Central Europe than in Finland. Therefore, the mean growth ring width must be greater. In spruce there is a distinct relationship between the growth ring width and the number of wood properties. Therefore, it is supposed that Finnish spruce wood is heavier and stronger than spruce wood from Central Europe. On the other hand, shrinkage properties can be worse in Finland due to higher density; although the effect of narrow growth rings can diminish the effect of density. The branch size is possibly greater in Central Europe than in Finland, due to better growth. The proportion of dead branches could be higher as well, due to the silvicultural practice to use a narrower spacing than in Finland. However, pruning is only carried out in Central Europe and due to this, knothole material is more common there than in Finland.

The role of various wood defects is possibly greater in Central Europe due to insects and higher animals, especially Red deer which is not found in Finland. Wind and snow breaks can be more common, too. However, all the conclusions based on the differences in growth rate are so vague that nearly nothing can be said of the possible differences in various properties. The measured results concerning density, strength and shrinkage, are not in conflict with the assumptions. However, the reported differences are so small that they are not convincing. Therefore, adequate sampling studies are needed.

In forest ecosystem research, particularly in studies focused to the understory vegetation, light climate below the canopy has to be taken into account in the site characterization. The technique based on hemispherical photographs enables one to characterize the light climate of a site reliably (Hill 1984, Evans & Coombe 1959, Anderson 1964, Pope & Lloyd 1974, etc.). When the number of sites under study is large the method is rather time-consuming since the trees are not evenly distributed and it is therefore necessary to photograph each forest site more than once. In very large inventories such as the National Forest Inventories, only standard parameters of the tree stand can be measured. When these data are to be analyzed, one can either neglect the light climate in site characterization or estimate it roughly by using the available tree stand measurements. In forest vegetation studies, only average estimates of the light climate are necessary, since the interest is in light reaching the community and not the fate of light within the community.

The present study was undertaken with the aim to develop simple empirical regression models for predicting the light climate on the basis of standard tree stand parameters. Regression estimates can be applied to site characterization e.g. in a posteriori analyses of
large vegetation data sets such as those collected during the National Forest Inventories. Although the relationships between the radiation extinction and tree stand structure have earlier been confirmed (e.g. Monsi & Särki 1953, Kellomäki & al. 1980, Ross 1981), this study reports the possibilities and problems involved in approximating light climate when only incomplete data of the stand structure are available.

This study is an independent, methodical part of research project carried out in co-operation with the Finnish Forest Research Institute and financed by the Academy of Finland. The author is grateful to Mr. Teuvo Levala and Mr. Pekka Tamminen for the measurements of the standard tree stand parameters, and to Prof. Eino Mäkkönen for valuable contribution to the study. The author also wishes to thank Prof. Matti Leikola and Prof. Paavo Pelkonen for their comments on the manuscript. Computing work was carried out by the author in the University of Uppsala, Institute of Ecological Botany. The author wishes also to thank the Swedish contributors, Prof. Eddy van der Maarel, Dr. Colin Prentice and Ms. Päivi Hennola.

2. MATERIAL AND METHODS

The study material was collected during the summer 1984. Ordinary field work (see e.g. Kuusipalo 1983) was first performed, and sampling of the plots included into accurate site analysis was done on the basis of these data. The size of the whole data set is 410 forest stands, and among them 40 stands were included into the subsample. Sampling was done in such a way that pine-dominated, spruce-dominated and mixed stands representing different forest site types were incorporated. Sample plots were located in the districts of Mikkeli and Luumäki, southern Finland. Descriptive data of the subsample are presented in Table 1.

In each forest stand, the following standard measurements on tree stand properties were made by a research group of the Finnish Forest Research Institute: total basal area and basal areas of different tree species (relascope method), dominant height of the stand (sample trees), dominant age of the stand (annual rings of sample trees at 1.3 m above soil level), and diameter at 1.3 m. In addition, the author calculated all trees higher than 1 m present on each 16x16 m sample plot to get an accurate estimate for local stand density. More information about the measurement methods are given by Tamminen (1982).

On each sample plot, 9–12 hemispherical photographs were taken from different random points. The measuring system consisted of an Olympus Fish-eye lens, a camera and a 0.3 m tripod. The recommendations by Anderson (1964, 1971) were followed in the different phases of the light measurements to get an accurate percentual canopy coverage value for each forest stand.

The computing work was done with IBM computer using GLM (General Linear Model) and STEPWISE (Stepwise Regression analysis) procedures of the programme package SAS (SAS User’s Guide: Statistics, 1982). In the data analysis, average canopy coverage of the stand was treated as response variable and the tree stand parameters as predictors. As a first step, a preliminary stepwise regression analysis (forward selection, maximum $r^2$ criterion) was performed in order to select the best predictors. After that, the model was elaborated in order to find best possible regression estimate of the canopy coverage (maximum $r^2$ and smallest possible number of predictors). The residuals were examined.

3. RESULTS

As a result of the preliminary stepwise selection, the following variables were incorporated into the model as predictors: total basal area of the stand, basal area of spruce, dominant age of the stand and stand density (stems/plot). No other variables fulfilled the selection criteria. Both raw and arcsine transformed values of the canopy coverage were used as response variables during the stages of model elaboration. Arcus sin-transformation gave slightly better result, as far as the $r^2$ value is concerned. The difference was, however, so small that in the following models raw value is used in order to make the estimation more simple.

The relationship between canopy coverage and total basal area is presented in Figure 1. Explanatory power is about 65 % and the residuals quite large. Since the main tree species, Norway spruce (Picea abies (L.) Karst.) and Scots pine (Pinus sylvestris L.), evidently differ from each other in terms of crown structure and needle biomass, it was concluded that one ought to stress the proportion of spruce in the total basal area. This was done in such a way that the total basal area was weighted by coefficient representing the percentage of spruce. After elaboration by maximizing the explanatory power, weighting coefficient $s$ was derived as follows:
If basal area of spruce equals zero, then $S = 0.5$ (this means that dominance of pine prevails).

If basal area of spruce in the stand is greater than 49%, the total basal area, $S = 1$.

Otherwise, $S = 0.75$.

The model can be presented as follows:

(4) Canopy coverage = $S$. Total basal area.

Since the new relationship appeared to be a curvilinear one, a logarithmic transformation of the predictor variable was done:

(5) Canopy coverage = $\log_{10}(S)$. Total basal area.

The relationship between the response variable and the estimator constructed above is presented in Figure 2. Explanatory power is now about 75% and the range of residuals much less than in the preceding figure. Increment of the model arises from the fact that the shading effect of spruce is stronger than that of pine. Hence simple stressing of the former give reasonable and unsophisticated formula to be used in rough a posteriori estimation of the light climate when only relascope measurements are available in the data set.

The model was elaborated further by incorporating the dominant age of the stand into the model. (Fig. 3) With this model, explanatory power of 80% was achieved.

The highest residuals were encountered with pure pine stands with the total basal area less than 15 m². When the dominant age was replaced by the stand density (Fig. 4), almost equal explanatory power was reached. Now the highest residuals were found with stands characterized by a dense undergrowth associated with a normal stand of dominant trees. It seems likely that both models account for a substantial part of eachother's residual variance. Therefore a model was constructed, in which all predictor variables were included. The result is presented in Figure 5. Explanatory power was almost 85%. This was the very best model involving all of the four variables selected by stepwise procedure. The highest residuals were encountered with stands characterized by a mature but sparse growing stock of pine together with dense undergrowth. Residual plot of the preceding model is presented in Figure 6. Residual pattern seems to indicate some abnormalities that may require corrective attention (see e.g. Anscombe & Tukey 1963). It is possible that canopy coverage values are more likely than underestimated in the middle sequence of the axis but the situation is more balanced near both poles of the axis. On the basis of the presented data, however, further corrections were not possible. Anyway, the model is reasonable and reliable enough to be used for predicting.

Table 2. Correlations between the variables.

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<tr>
<th>Table 2. Käytännössä olevien liitosten korrelaatio.</th>
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<tr>
<td>1. Canopy coverage</td>
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<td>2. Total basal area</td>
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<td>3. Basal area of pine</td>
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<td>4. Basal area of spruce</td>
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<td>5. Dominant age</td>
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<td>6. Stem diameter plot</td>
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Figure 1. Regression between the canopy coverage (SHR) and total basal area (TOT). Legend: $A =$ observed value $P =$ predicted value. Note: 26 observations hidden.


Correlation matrix of the variables involved is presented in Table 2. Since there exist rather strong mutual correlations among the predictor variables, the model cannot be interpreted as a causal one (cf. Kuusipalo 1984). However, because the main emphasis is on predicting the light regime rather than explaining it, mutual correlations are acceptable (cf. e.g. Leskinen 1977).
Figure 2. Regression between the canopy coverage and estimate ESTIM = log10 (S-TOT). For further explanation, see the text.

Legend: A = observed value. P = predicted value.

Note: 18 observations hidden.

Ennustettu arvo = ESTIM = log10 (S-TOT) vähennettynä questionnaire. Tarkempi selitys tekstissä.

Huomautus: 18 pistettynyt havainto. 

Figure 3. Regression between the canopy coverage and estimate ESTAG = 0.35 + 0.38·ESTIM - 0.001·AGE (dominant age). For further explanation, see the text.

Legend: A = observed value. P = predicted value.

Note: 9 observations hidden.

Ennustettu arvo = ESTAG = 0.35 + 0.38·ESTIM - 0.001·AGE (pumon ikä) vähennettynä questionnaire. Tarkempi selitys tekstissä.

Huomautus: 9 pistettynyt havainto.
Figure 4: Regression between the canopy coverage (e) and estimate ET = 0.17 + 0.36 ESTIM + 0.07 log (DEN). Drawn regression. DEN = density. 

Legend: A = observed value, P = predicted value. 
Note: 10 observations excluded. 

Figure 5: Regression between the canopy coverage (e) and estimate ET = 0.30 + 0.44 ESTIM + 0.03. AEE + 0.06 log (DEN). 

Legend: A = observed value, P = predicted value. 
Note: 6 observations excluded. 

Figure 6: Regression between the canopy coverage (e) and estimate ET = 0.33 + 2.46 ESTIM + 0.001. AEE + 0.06 log (DEN). 

Legend: A = observed value, P = predicted value. 
Note: 7 observations excluded.
4. DISCUSSION

As emphasized above, causal conclusions ought not to be drawn from predictive regression models. However, referring to previous studies concerning the radiation extinction within forest stands, some indirect interpretations can be made. The extinction of light in the canopy system is determined by the vertical distribution and optical properties of the foliage (e.g. Monsi & Saeki 1953, Kellomäki & Öker-Blom 1981). Light conditions below the canopy of pine and spruce forests depend upon the needle biomass and its distribution in the tree crown (cf. Kellomäki & al. 1980). Needle biomass of an individual tree is related to the size of the tree. No close association between stand height and canopy coverage was found in the present study (cf. Kellomäki & al. 1980). On the other hand, canopy coverage was very strongly associated with the total basal area. As far as an entire forest stand is concerned, the total needle biomass in also dependent on the stand density. Basal area measured by the relascope method is a composite parameter which takes into account both the sizes of individual trees and the stand density. Few tall trees give the same basal area than a dense stand of smaller trees. Therefore, it is reasonable also to include the actual stand density (stems/unit area) into the model together with the total basal area, although they partly measure the same property of the stand.

Optical properties of the foliage depend upon the tree crown, which differs markedly from a tree species to another (see e.g. Horn 1971). Optical properties of needles (colour, size, pattern) are also important. In the present study, a simple empirical correction coefficient was derived to standardize these between-species differences. The presented formula (Fig. 2) implies an assumption that the shading effect of a more or less pure pine stand is only half of that of a more or less pure spruce stand, if basal area is normalized.

Intermediate cases were settled simply by giving the coefficient a value just between those of pure stands. It should be noted, that most of the forest stands in Finland are nearly monocultures, i.e. characterized by a clear predominance of either spruce or pine. Although the presented coefficient serves well in cutting down the residuals (Figures 1 and 2), it is not based on any theoretical implications concerning the differences between tree species. Further studies on canopy structures of spruce and pine are inevitable to confirm the above generalizations and the presented formula.

Obviously, as can also be seen in the correlation matrix, spruce stands are generally denser than pine stands. This explains the unexpected negative correlation between total basal area and dominant age of the stand (see also Kuusipalo 1983). Correlations between basal areas of different tree species and stand age imply that mature pine stands were older than mature spruce stands (cutting interval of pine stand is longer). Hence high dominant age of the stand also indicates pinedominance and, accordingly, lower basal area. Clear negative association between dominant age and canopy coverage may be partly connected to the tree species composition, but also to the fact that dense and young stands are more shady than old, thinned stands. The mechanism governing the changes in canopy closure during the forest growth and stages of management is, however, complicated and no information about it can be derived from the presented data. Therefore, the presented results between dominant age and canopy coverage can be generalized only with reservations.

The aim of the present study was to produce predictive models for indirect extrapolation of light conditions in different kinds of forest stands. A basic assumption involved in this study is that light climate can reliably be measured on the basis of hemispheric photographs (see e.g. Anderson 1964, Horn 1971, Pope & Lloyd 1974). Accepting this, the models seem to serve quite well as practical tools of site characterization, when only standard measurements of the tree stand characteristics are available. However, as stressed in the examination of residuals, dense undergrowth associated with a sparse stand of dominant trees may seriously distort the estimation results. As far as site characterization is concerned, one must keep in mind that...
canopy structure governs not only the illumination level below the canopy but also ecological factors such as microclimate and soil properties. Particularly in comparisons between pine- and spruce-dominated sites, these should be taken into account.

REFERENCES


Total of 14 references.

SELOSTE

PUUSTON STANDARDIITTUNNUSTEN KÄYTÖSTÄ METSIKön VALAISTUSOLJOJEN ESTIMointiin


Kussakin koetelukisikä (40) latviuseppävyvyn laskettelut esimerkiksi sat. kuten kasvattamispäätelikäävillä otettuja ojia tai ojien kantaan lisättyä. Latviuseppävyvyn käytötäni riippuvaan muiden puistonstandardtunusten selittävänä muodostettaessa regressionmallin voimakkuus estimointiin. Puiston pohjakartta-aika yksin selittää 63 % latviuseppävyvyn vaihtelusta. Kun regressionmallin liitetään ku veneen osoittaa kuvaavia korrelaatioja, selitysaikos on 75 %:n. Ruskolukko ja valtapuiston ikä nostavat selitysaikaa 85 %:n ja molemmat erikseen 80 %:n.

1. INTRODUCTION

There are a lot of investigations on the influence of low-frequency vibration on heart rate (HR) and pulmonary ventilation (Bogert, 1967, Coermann, 1965, Dieckmann, 1957, 1958, Hasan, 1970, Sjöfält and Suggs, 1973). There seem to be no investigations on the influence of free vibrations on heart rate variability (HRV). In most terrain machines vibrations occur as a rule together with the other stress factors, i.e. mental load. Sjöfält and Suggs (1973) have studied the influence of vibration together with tracking on heart rate (HR), and on some other factors but not on HRV or respiration rate (RR). They did not study the influence of vibration singly compared with this kind of combined strain. But because the HR was slightly higher during the last 50 seconds of the tracking task than during the first 50 seconds, they concluded that this might be caused by the tracking or by the prolonged vibration exposure. Because HRV, RR and HR are interesting variables in intra-individual comparative studies on the mental strain of the driver, it is useful to know the influence of vibration and the combined effect of vibration, motor action and mental load on these factors.

The purpose of this study was to determine the influence of whole-body vibration of fairly low intensity and the combined influence of the mental load typical for the machine driver and vibration on HRV, RR and HR. The influence of the physical work needed for moving the control devices alone and combined with the mental load and vibration was also studied. Horizontal and rotational vibration is the most harmful vibration in terrain machines.