USE OF CHEMICAL TOTALIZER OF RADIATION IN ENERGY BALANCE MEASUREMENTS

The aim of the investigation was to test, under Finnish conditions, the chemical totalizer of radiation (Frankfurt radiometer) developed by Brechtel (1973), and especially its use in determining evaporation through energy balance calculations. The radiometer is based on the temperature dependence of the inversion rate of a sugar solution. The exponential nature of the relationship, however, limits the usefulness of the method. The basic part of the meter consists of a flat polyethylene container (Fig. 1:5 and Brechtel 1973), which is filled with a sugar solution. The complete measuring units (Fig. 1 and 2) are suspended between two horizontal wires above the measuring point. The inversion rate of the sugar solution is measured as the change in rotation angle using a circle polarimeter.

The experiments consisted of measuring with a Frankfurt radiometer two components of the energy balance, net radiation and sensible heat, above an evaporation pan (Class A Pan) and above various types of plant cover at the University Forest Station (Table 1), and on various peatland sites at Lyly (Table 2) in Central Finland as well as above lysimeters at Otaniemmi in South Finland. For comparison, evaporation from an evaporation pan was measured at the Forest Station and from a shallow peat lysimeter at Lyly. Results are given for those measuring periods only in which the final rotation angle was positive. The parameter for incoming shortwave (global) radiation obtained with the Frankfurt radiometer, i.e. the difference between the rotation angle changes in black and white containers, was compared to global radiation measured by a bellani-type radiometer. The relationship was different for measuring periods of different length (Fig. 3), although daily mean values showed a high uniformity (Fig. 4). Regression is linear up to the amount 20 MJ m⁻² d⁻¹ of global radiation. The difference between results from the polyethylene cup-covered and uncovered containers, which has been used as a parameter for the sensible heat, did not correlate with the mean wind speed (Fig. 5). Furthermore, it became evident that the results obtained using one-faced measuring units and double-faced ones (facing both upward and downward) were not similar (Table 3). In the double-faced units, the 12 mm air layer between the containers does not provide sufficient insulation. The background plates must also be painted white. All the recorded radiation parameters showed highly significant correlation with the pan evaporation values (Table 4). The correlation between the evaporation values calculated from the energy balance equation (latent heat = net radiation - sensible heat) and those measured from the evaporation pan can be seen in Fig. 7. The results also depend on the height at which the measuring units are placed (Fig. 8). The best height was found to be about one metre. The evaporation values obtained from measurements made above the lysimeter were also approximately the same as those obtained by weighing (Fig. 9).

Evaporation from different types of plant cover was compared using several measured parameters (Tables 5–7). Comparison between a tree-covered and an open area remained uncertain because of the different measuring heights (Table 5). The results from the experiment carried out at the University Forest Station show that evaporation was highest from the water surface in an evaporation pan, and in general higher from an 11-year-old Scots pine stand than from a meadow (Table 6). The measurements at Otaniemmi show that evaporation from clay was the lowest and from peat the highest. Evaporation from grass-covered fine sand fell between these two (Table 7). In cases where there were differences in the latent heat of evaporation calculated using the energy balance equation, differences were already to be seen in the parameters for net radiation or outgoing radiation. This is due to the uncertainty in measuring sensible heat by the method in question. It can be concluded from these results that the Frankfurt radiometer is best suited to describing radiation conditions.

INTRODUCTION

Pitkänen (1972) emphasizes the role of user satisfaction in the management of forest areas for recreation. User satisfaction is affected by a large number of different factors, e.g. the environment and the facilities needed in different recreational activities. Special emphasis should be set on developing the recreation area in such a way that user preferences and recreation environment coincide with each other (Kellomäki 1975, Heikinheimo et al. 1977).

A forest area is a changing entirety consisting of stands in different phases of succession. Development of the different stands changes the character of the environment and therefore the optimum conditions for a particular recreational activity can only be maintained for a short time in the absence of active management (cf. Pitkänen 1972). This assumption implies, however, that there really are optimum conditions for different recreational activities and that the recreational activities can be correlated with certain characteristics of the forest environment (cf. Loenen 1975). If this is true, then the relationship between different recreational activities and forest succession can be tentatively presented as in Fig. 1. The effect of the type of recreation in question on a forest environment must also be considered in the management of a recreation area. Above all rubbish accumulation and trampling can rapidly destroy the quality of the environment. Trampling
importance to determine the trampling tolerance of a stand in relation to forest succession (cf. Saastamoinen 1972, Kellomäki and Saastamoinen 1975, Kellomäki 1977). In conclusion, both ecological and behavioral information must be introduced into management processes to provide satisfying recreational experiences (Wagar 1964, Hendee et al. 1968, Kellomäki 1975).

The aim of the present paper is to study the relationship between forest succession and the optimum conditions for selected recreational activities as hypothesized in Fig. 1. In addition, the trampling tolerance of the ground cover has been introduced into the analytical procedure in order to determine the recreational potential of a developing stand.

![Graph showing the relationship between activity levels and forest succession stages](image)

Fig. 1. Hypothesized relationship between selected recreational activities and forest succession according to Heiskanen et al. (1977).

can also be dangerous ecologically, and great problems are encountered in restoring trampled areas. Therefore it is of primary

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**MATERIAL AND METHODS**

Table 1. Overall picture of the interview stands according to Kellomäki (1975).

<table>
<thead>
<tr>
<th>Number and location of stand</th>
<th>Site type</th>
<th>Development class</th>
<th>Predominant tree species</th>
<th>Height m</th>
<th>Stand area m²/ha</th>
<th>Density 0–9</th>
<th>Volume m³/ha</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Central Park</td>
<td>OMT³</td>
<td>1)</td>
<td>må³)</td>
<td>20</td>
<td>6</td>
<td>2</td>
<td>50</td>
<td>Football pitch in sight</td>
</tr>
<tr>
<td>2</td>
<td>MT</td>
<td>4</td>
<td>må</td>
<td>23</td>
<td>18</td>
<td>6–7</td>
<td>180</td>
<td>Ground vegetation deteriorated</td>
</tr>
<tr>
<td>3</td>
<td>VT</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Stand partly on rocky terrain, electricity power line</td>
</tr>
<tr>
<td>4</td>
<td>VT</td>
<td>2–3</td>
<td>må</td>
<td>7</td>
<td>16</td>
<td>9</td>
<td>60</td>
<td>Stand partly on rocky terrain</td>
</tr>
<tr>
<td>5</td>
<td>MT</td>
<td>1</td>
<td>må</td>
<td>2</td>
<td>1–5</td>
<td>8</td>
<td>10</td>
<td>Harvesting residues and aspen saplings</td>
</tr>
<tr>
<td>6 Luukkää</td>
<td>VT</td>
<td>1</td>
<td>må</td>
<td>2</td>
<td>1–5</td>
<td>9</td>
<td>10</td>
<td>View of lake</td>
</tr>
<tr>
<td>7</td>
<td>MT</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>MT</td>
<td>2–3</td>
<td>må</td>
<td>22</td>
<td>24</td>
<td>7</td>
<td>240</td>
<td></td>
</tr>
</tbody>
</table>

¹) Site type
OMT = Oxalis-Myrtilus type
MT = Myrtilus type
VT = Vaccinium type
²) Development class
0 = Clear cut area
1 = Seedling stand
2–3 = Middle aged stand
4 = Mature stand
³) Predominant tree species
må = Scots pine
ku = Norway spruce
ko = Birch

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**RESULTS**

Relationship between recreational activities and stand volume

It is supposed that there is an optimum environment, as regards stand characteristics, for each recreational activity. Let x denote the potential for how well a stand is suited for a particular activity, i.e. suitability, and B a particular stand characteristic, then

\( x = x(B). \)

Different stand characteristics were related to recreational suitability as indicated by the questionnaire. The best results were given by the stand volume. The suitability of the stand for different recreational activities are presented as a function of volume in Figs. 2a–2f. Each point represents the mean of at least 160 replies. Stands with high volume are preferred for nature hobbies, and they received a high amenity value. The recreationists seem also to be accustomed to finding berries in stands of high volume. The suitability for skiing, exercise and orientation is low both in seedling and mature stands. The optimum volume for these activities seems to lie within the range 80–200 m³/ha.

![Graph showing relationship between volume and suitability](image)

Fig. 2. Relationship between stand volume and suitability:
Relationship between recreational activities and stand succession

The volume of a stand is closely correlated with the stand age, and hence Figs. 2a–2f outline roughly the dependence of recreational activities on forest succession. Let \( t \) denote the age of stand, then

\[
(2) \quad B = B(t). \]

The equation (1) can now be written as follows

\[
(3) \quad x = x(B) = x(B(t)). \]

The present material does not represent a complete successional series. Therefore the successional series for repeatedly thinned pine stands of *Picea abies* site type was utilized when the functions presented in Figs 2a–2f were transformed into time dependent functions (cf. Korvisto 1959). The approximations for the dependence of different recreational activities on the age of stand are presented in Figs 3a–3f.

The suitability of a stand for recreation varies in time as hypothesized. In particular, mature stands are preferred among recreationists. Furthermore, the present material also emphasizes the role of young and middle-aged stands in recreation areas. In fact, this kind of stand seems to play a more important role than was hypothesized. It is, however, evident that all recreational activities do not have the same role in determining the value of a forest area for recreation. Unfortunately, the present material is not sufficient for studying the emphasis which should be given to different activities in the management of recreational areas.

Relationship between recreational potential and forest succession

The recreational potential of a stand includes its suitability for different recreational activities and its trampling tolerance as argued earlier. The contribution of such suitability to the recreational potential is called the preference component of recreational potential and the contribution of trampling tolerance the ecological component, respectively. The recreational potential \( \text{rp} \) of a stand can be presented as a function of the preference component \( (p) \) and the ecological component \( (e) \) as follows

\[
(4) \quad \text{rp} = \text{rp} (p, e). \]

The preference components are assumed to be consist of orthogonalized subcomponents which are additive. If the subcomponents are determined by the suitability of a stand for different recreational activities \( (x) \), the preference components can be presented as follows

\[
(5) \quad \text{rp} = b_1 x_1 + \ldots + b_n x_n, \]

where \( b_1, \ldots, b_n \) are coefficients for the suitability of a stand for different recreational activities. In the present study the coefficients presented by Lovén (1973) have been utilized in determining the values of the preference component for different phases of a forest succession. The results are presented in Fig. 4.

The ecological component of recreational potential was determined in two phases. In the first step the proportion of herbs, grasses, dwarf shrubs, mosses and lichens in the ground cover was estimated for each phase of succession from the material of Kaukeri et al. (1978). In the second step, each group was given a coefficient describing its relative trampling tolerance as determined by Kellomäki and Saastamoinen (1975). The ecological component \( (e) \) can be presented as a function of species groups as follows

\[
(6) \quad e = k_{c_1} x_1 + \ldots + k_{c_n} x_n, \]

where \( c_1, \ldots, c_n \) are coverages for each species group and \( k_1, \ldots, k_n \) coefficients for trampling tolerance. The ecological com-

Fig. 3. Relationship between stand age and a: skiing, b: exercise, c: orientation, d: nature hobbies, e: berry picking, f: amenity values.

Fig. 4. Relationship between stand age and preference component of recreational potential.

Fig. 5. Relationship between stand age and ecological component of recreational potential.

Fig. 6. Relationship between stand age and recreational potential of a stand.
The recreational potential has its highest values in relatively young stands. The introduction of trampling tolerance to the analytical procedure emphasizes the role of young and middle-aged stands in recreation areas. On the other hand, additional emphasis on young and middle-age stands is also given by the suitability for recreation motivated by a desire to keep fit. The effect of these activities on the preference seems to characterize totally the dependence of recreational potential on forest succession.

The concept of recreation potential approaches the concept of carrying capacity. Thus, the ranking of stands can be carried out using both behavioral and ecological information. The results emphasize the high capacity of young and middle-aged stands as a result of their high trampling tolerance. On the other hand, the present consideration is partly based on management practices which are timed at timber production. Thus, proper management might increase the trampling tolerance of mature stands and hence their value in recreation activities. This may also be true as regards user preference for stands of all age classes.

The present results also emphasize the importance of variation in tree species composition and age classes in a recreation area, as demonstrated earlier by Haakenstad (1972), Pitkanen (1972), Lovén (1973), Mikola (1975) and Kellomäki (1975). As opposed to earlier results the present paper sets, however, considerable emphasis on the role of young and middle-aged stands. Especially, the differences between recreation activities in relation to forest succession have proved to be of considerable magnitude. Therefore each age class seems to have some sort of recreational value. This fact ought to be taken into account in the management of recreation areas.

The present results deal only with pine stands of the Myrillus site type. The stand successions has been assumed to coincide with the series presented by Korvisto (1959). Therefore the application of the results is valid only within these limits. In principle, the present approach can, however, be generalized to cover other tree species and sites. Production of such a material should facilitate a more comprehensive evaluation of the allocation of forest resources to different purposes. This kind of material is also needed in developing management practices for multiple use forestry.

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SELOSTE:
METSIKÖN ULKOILUPOTENTIAALI

Työssä on teoreettisiin ja empirisiin näkökohtia perustuvat pohdittua kehitysvaiheessa olevien metsiköiden soveltuvuutta ulkoiluun. Tarkastelussa on otettu huomioon sekä metsikön tarjoamat mahdollisuudet eri ulkoilutoiminnolle että pintakasvillisuuksen kulutuskestävyyys. Tulokset korostavat kehitysastevalikoimaltaan monipuolisten metsälalueiden arvoa ulkoilussa.


KULOJEN ESINTYMINEN ULVINSALON LUONNONPUISTOSSA

ANTTI HAAPANEN ja PERTTI SIITONEN

SUMMARY:
FOREST FIRES IN ULVINSALO STRICT NATURE RESERVE

Saaperaut toimitukselel 1978-06-15


Keskimääräisesti paloalaisi arvioidaan metsäkuvoitten kohtaan eriliksi kahdeksan 24 ha. Luonnonpuiston metsät ovat kehittymässä puhtaaksi kuiskoiloksi. Mänyn muoret ikäänokat puuttuvat lähes täysin.

1. JOHDANTO


Viime vuosina kukoologistaan on kiinni-
tettä eri puoliin maailmaa ja myös pohjois-
sella havumetsäyöhykkeellä runsaasti huo-