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DETERIORATION OF FOREST GROUND VEGETATION AND DECREASE OF RADIAL GROWTH OF TREES ON CAMPING SITES

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SELOSTE:

LEIRINNÄN VAIKUTUS METSÄN ALUSKASVILLISUUTEEN JA PUIDEN KASVUUN

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The ground cover vegetation and tree growth at several camping sites in southern Finland were investigated. The deterioration of ground vegetation appeared to be unavoidable in these areas, and only a few grass species were tolerant to heavy trampling. Only moderate deterioration was, however, detected when the trampling level was lower than 10 000—15 000 user days. On the other hand, the ground cover was completely destroyed when the trampling level exceeded 100 000 user days. A considerable decrease in radial growth appeared to be associated with destruction of the ground vegetation. The decrease was abrupt and was found to continue throughout the whole period of use. After ten years' use the growth in the trampled areas was 35 % lower than that in untrampled areas. A further decrease in radial growth is expected in the future.

INTRODUCTION

Deterioration of the ground cover is the most frequent result of the recreational utilization of forest areas. Only seldom does its effect remain aesthetical. Under heavy trampling the whole ecological system of a particular forest area is jeopardized and great problems are encounted in restoring trampled areas. The problems are especially important in camping areas and must be taken into account in the management of such areas (cf. MAGILL and NORD 1963, MCCOOL *et al.* 1969, MERRIAM *et al.* 1971).

In boreal forests, the low trampling tolerance of the ground cover is due to the presence of dwarf shrubs, mosses and lichens. These species are dominant in the late successional stage. For example, FRISSEL & DUNCAN (1965), HOLMSTRÖM (1970) and KELLOMÄKI and SAASTAMOINEN (1975) have demonstrated that they have a low tolerance even to occasional trampling. Grasses and herbs are also susceptible to damage caused by heavy trampling but they seem to tolerate moderate levels of trampling. In the long run, however, only a few grass species are capable of tolerating continuous trampling (cf. BATES 1935, LAPAGE 1967). For this reason, specific grass communities are characteristic of camping sites or other sites subjected to trampling.

MAGILL and NORD (1963) have also emphasized the role of ground vegetation in protecting the soil in recreation areas (cf. also LUTZ 1945, MCCOOL *et al.* 1969, MERRIAM *et al.* 1971). For example, LAPAGE (1962) has demonstrated a decrease in the radial growth of conifers as a result of trampled root systems and changes in the soil properties (cf. also GRABLE and SIEMER 1968, SETTERGREN and COLE 1970, BURDEN and RANDERSON 1972). Especially, the decrease in thickness of the humus layer and increase in the basic density of the mineral soil seem to be of importance as regards the growth of trees in recreation areas. Therefore, the management of ground vegetation plays an important role in conserving the quality of the recreation environment.

The aim of the present paper is to investigate the changes in forest ground cover occurring as a result of trampling. In addition, attention is paid to the effect of trampling on the radial growth of trees. Both factors are utilized in assessing the trampling tolerance of a forest ecosystem.

This paper belongs to the series of studies concerning the ecological effects of recreation and tourism on forest ecosystems. The project is being carried out in the Department of Environmental Conservation, University of Helsinki, in cooperation with the Department of Silviculture, University of Helsinki. The study project is funded by the Academy of Finland, National Board for Man and Biosphere (MAB) Project. We acknowledge the financial support.

MATERIAL AND METHODS

The study material includes ten camping sites located in southern Finland, between the 60th and 62nd latitudes, 100–200 m above sea level. The location of the study areas is shown in detail in Fig. 1. The areas were investigated in July through August, 1973.

All the study areas belong to the south boreal vegetation zone, and mainly represent sites of the *Vaccinium* site type, *i.e.* sites of medium fertility. The tree stratum in the areas consists mainly of Scots pine *(Pinus sylvestris* L.) and represented mature stands at the age of 70–120 years. Only the camping areas not exposed to specific silvicultural treatment, e.g. thinning or fertilizing, were included in the material. The soil in the camping areas was mainly characterized by sand and sandy morain. The study areas represent several degrees of trampling and duration of utilization. Further details about the characteristics of the camping areas are given in Table 1.

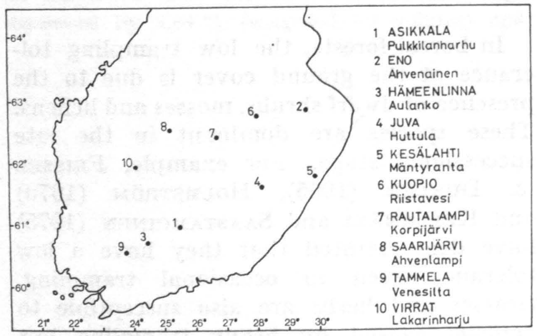

Fig. 1. Location of the study areas.
Kuva 1. Tutkimusalueiden sijanti.

Sampling of the ground vegetation took place after the growth of the main ground cover species, *i.e.* dwarf shrubs and other vascular plants had ceased. For the sampling, each study area was stratified into three sections: severly deteriorated, only partially deteriorated and undeteriorated. In the severely deteriorated section only occasional patches of the original vegetation still remained. In this section the root systems of the trees had also become exposed to the effects of weather as a result of heavy trampling. In the partially deteriorated section there were only occasional patches of deteriorated vegetation, and the root systems of the trees were protected by the ground cover and a layer of humus. In the undeteriorated section no traces of

Table 1. Characteristics of studied camping areas.
Taulukko 1. Tutkittujen leirintäalueiden piirteitä.

Camping area *Leirintäalue*	Site type *Metsätyyppi*	Year opened *Perustamisvuosi*	Use, 1 000 userdays *Käyttö, 1 000 vrk*	Area, ha *Pinta-ala, ha*	Section a) *Osa-alue*	Volume, m³/ha *Kuutiomäärä m³/ha* Pine *Mänty*	Spruce *Kuusi*	Decidious trees *Lehtipuut*	Mean age, yr *Keski-ikä, v*	Mean diameter, cm *Keskiläpimitta, cm*	Mean height, m *Keskipituus, m*
Asikkala	VT	1960	92	11	1	165	—	2	96	27.9	18.4
					2	145	—	8	85	29.0	25.8
Eno	MT	1967	17	2	1	219	—	—	102	26.0	19.7
					2	58	13	12	33	18.5	13.5
Hämeenlinna	lehto	1962	227	4	—	—	—	—	—	—	—
Juva	MT	1963	35	2	—	—	—	—	—	—	—
Kesälahti	VT	1966	7	4	1	165	—	—	67	21.3	16.0
					2	166	—	—	75	26.2	21.9
Kuopio	CT	1970	12	5	—	—	—	—	—	—	—
Rautalampi	VT	1966	6	3	1	149	—	—	116	26.2	20.4
					2	157	—	—	100	27.6	22.8
Saarijärvi	VT	1959	212	26	1	155	—	—	76	24.1	19.0
					2	154	—	—	80	26.0	19.4
Tammela	OMT	1964	77	1	1	261	9	78	91	38.7	22.0
					2	—	—	—	—	—	—
Virrat	VT	1968	39	10	—	—	—	—	—	—	—

a) 1: Severely deteriorated
Voimakkaasti kulunut
2: Undeteriorated
Kulumaton

trampling were detectable either in the ground cover or in the tree stratum.

The method used in sampling the ground cover is presented in Fig. 2. The same schema also shows the details of the tree stratum sampling. Ground cover sampling was carried out in the same sample areas selected for the tree stratum measurements. There were from one to six such areas in each section depending on its size (cf. ILVESSALO 1965). A circle 300 m² in size was used as the sampling area.

In the ground cover sampling, four subsamples were selected systematically from each sample area as presented in Fig. 2. The size of each subsample was 1 m². The coverage of each species was determined separately both in the field and bottom layers. The measurements were concentrated on four systematically located measuring points 400 cm² in size (cf. Fig. 2). In data processing the measurements were pooled and the species specific mean values represented the whole subsample.

The tree stratum measurements were carried out in the severely deteriorated and undeteriorated sections of the camping areas only. The sample trees were allocated according to the frequency distribution of tree diameter at breast height, *i.e.* 1.3 m above the soil level. (cf. ILVESSALO 1965). Thus, four to eleven sample trees were selected using a relascope from each sample area. The following characteristics were

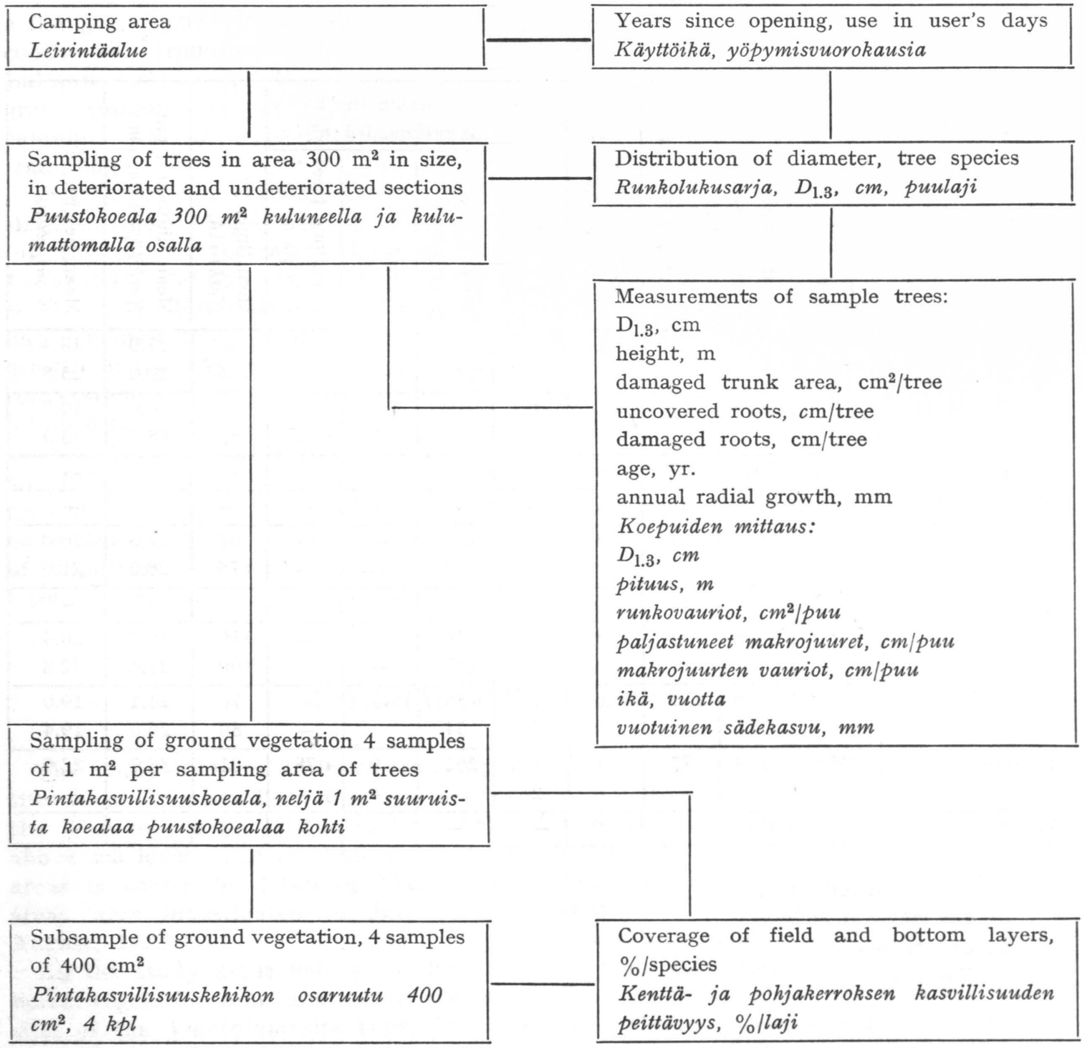

Fig. 2. Sampling, measurements and observations made in the study areas.
Kuva 2. Otanta sekä tehdyt mittaukset ja havainnot.

determined on the sample trees; tree species, height, diameter at breast height, total length of exposed roots thicker than 2 cm within a 2 m radius around the sample tree, the total length of damaged macro roots within the same area and damaged trunk area of the sample tree. In addition, the age of the sample tree at breast height was determined with the help of an increment borer. These cores were utilized in determining the retrospective annual radial growth of the sample trees.

RESULTS AND DISCUSSION

Deterioration of ground vegetation

For the analysis, the ground cover plant species were grouped into dwarf shrubs, grasses, herbs, lichens and mosses. The mean values of each group in the deteriorated and undeteriorated sections are presented in Table 2. As expected, the field layer vegetation appeared to be more resistant to trampling than vegetation in the bottom layer (cf. Kellomäki and Saastamoinen 1975). In the field layer herbs and grasses are the most tolerant to trampling. They even seem to have colonized the trampled area even though they did not belong to the original vegetation of the camping area. Especially in partially deteriorated sections these species may replace dwarf shrubs which are easily damaged. These findings suggest that the renewal rate of a plant species plays a dominant role in trampling tolerance, not the structural properties of the stand crop (cf. Kellomäki and Saastamoinen 1975, Kellomäki 1977).

The frequency of occurence of the most common species is presented in Table 3. The comparisons between deteriorated and the undeteriorated section are based on the ratio between frequency values respectively. The original vegetation is characterized by a low number of different species. The number of species seems to increase in trampled areas. In the field layer, the maximum is reached in the partially deteriorated sections. The total coverage in such sections is, however, considerably lower than that in the original ground cover. For example, Holmström (1970) has suggested that there is an increase in the number of species in areas subjected to moderate trampling. This is in accordance with our findings.

Vaccinium vitis-idaea tolerated moderate and heavy trampling better than other dwarf shrub species. The trampling tolerance of *Vaccinium myrtillus* is a little lower but it exceeds that of *Calluna vulgaris.* This ranking is in accordance with the results of Kellomäki and Saastamoinen (1975). The ranking seems to be partly associated with the morphological and growth differences between these species. Especially the tolerance of *Vaccinium vitis-idaea* is determined by the morphology of this species.

The trampling tolerance among herbs and grasses is also variable. *Trientalis europaea* and *Melampyrum* spp. are common only in undeteriorated sections. *Maianthemum bifolium, Convallaria majalis* and *Rubus saxatilis* are still common in partially deteriorated sections but not in severely deteriorated ones. Some herb and grass species may even become more common as a result of trampling, *e.g. Agrostis* spp., *Poa pratensis, Poa annua, Festuca ovina, Chamaenerion angustifolium, Fragaria vesca* and *Veronica* spp. In general, grasses are relatively tolerant except for *Calamagrostis* spp. and *Deschampsia flexuosa.* The ranking does not seem to be due to any particular plant characteristic. Among grasses, the ability to regenerate sexually seems, however, to be advantagenous and to increase the trampling tolerance.

In general, the trampling tolerance of mosses was low. However, they show considerable variation between species as regards tolerance. As demonstrated by Kellomäki and Saastamoinen (1975), the trampling tolerance of *Pleurozium schreberi, Dicranum* spp. and *Polytrichum* spp. exceeded that of *Hylocomium splendens.* The role of lichens in the study areas was negligible.

Carrying capacity of ground vegetation

The carrying capacity of ground vegetation is determined as the rate of deterioration under a particular level of trampling. The following formulae were used for estimating its values as presented by Kellomäki and Saastamoinen (1975)

$$(1) \quad y_i = P^j x_i + e_i,$$

where x_i is coverage before trampling, y_i coverage after trampling, j amount of trampling, P a parameter and e_i the amount of uncontrolled variance. The parameter P

Table 2. Share of horizontal layer and groups of plant species out of total coverage [a]) in each camping area.
Taulukko 2. Suhteelliset peittävyydet osakasvustoittain ja lajiryhmittäin eri leirintäalueilla.

	Asikkala 1)	2)	3)		Eno 1)	2)	3)
Field layer — *Kenttäkerros*	41.5	17.3	41.7	Field layer — *Kenttäkerros*	34.6	4.8	14.0
Dwarf shrubs — *Varvut*	26.5	9.6	36.4	Dwarf shrubs — *Varvut*	30.9	4.4	14.2
Herbs — *Ruohot*	9.6	4.3	44.8	Herbs — *Ruohot*	2.3	0.4	17.8
Grasses — *Heinät*	5.5	2.8	52.0	Grasses — *Heinät*	1.9	0.3	16.0
Bottom layer — *Pohjakerros*	50.6	10.3	20.4	Bottom layer — *Pohjakerros*	35.0	8.8	25.2
Lichens — *Jäkälät*	0.0	0.1	> 100	Lichens — *Jäkälät*	0.7	0.0	5.6
Mosses — *Sammalet*	50.8	10.2	20.0	Mosses — *Sammalet*	34.5	8.9	25.7
	Hämeenlinna 1)	**2)**	**3)**		**Juva 1)**	**2)**	**3)**
Field layer — *Kenttäkerros*	31.4	11.0	35.1	Field layer — *Kenttäkerros*	66.6	19.7	29.6
Dwarf shrubs — *Varvut*	17.5	6.1	35.0	Dwarf sbrubs — *Varvut*	61.1	8.5	13.9
Herbs — *Ruohot*	11.9	3.3	28.1	Herbs — *Ruohot*	4.8	3.6	75.4
Grasses — *Heinät*	2.5	1.3	51.8	Grasses — *Heinät*	1.7	7.7	> 100
Bottom layer — *Pohjakerros*	4.8	1.0	20.2	Bottom layer — *Pohjakerros*	4.2	1.6	36.9
Lichens — *Jäkälät*	0.0	0.0	—	Lichens — *Jäkälät*	0.0	0.0	—
Mosses — *Sammalet*	5.1	1.0	20.2	Mosses — *Sammalet*	4.3	1.6	37.3
	Kesälahti 1)	**2)**	**3)**		**Kuopio 1)**	**2)**	**3)**
Field layer — *Kenttäkerros*	11.0	15.6	> 100	Field layer — *Kenttäkerros*	26.0	15.0	57.8
Dwarf shrubs — *Varvut*	10.7	15.7	> 100	Dwarf shrubs — *Varvut*	22.9	12.4	54.2
Herbs — *Ruohot*	0.0	0.0	> 100	Herbs — *Ruohot*	0.2	0.5	> 100
Grasses — *Heinät*	0.2	0.0	0.0	Grasses — *Heinät*	2.8	1.3	47.2
Bottom layer — *Pohjakerros*	66.6	31.4	47.2	Bottom layer — *Pohjakerros*	12.1	7.3	60.0
Lichens — *Jäkälät*	0.0	0.4	> 100	Lichens — *Jäkälät*	10.4	3.7	35.4
Mosses — *Sammalet*	66.7	31.1	46.7	Mosses — *Sammalet*	3.6	3.9	> 100
	Rautalampi 1)	**2)**	**3)**		**Saarijärvi 1)**	**2)**	**3)**
Field layer — *Kenttäkerros*	14.8	7.0	47.5	Field layer — *Kenttäkerros*	12.8	2.4	18.9
Dwarf shrubs — *Varvut*	14.8	7.1	47.6	Dwarf shrubs — *Varvut*	12.8	2.4	18.6
Herbs — *Ruohot*	0.1	0.0	50.0	Herbs — *Ruohot*	0.0	0.0	—
Grasses — *Heinät*	0.1	0.0	0.0	Grasses — *Heinät*	0.0	0.1	> 100
Bottom layer — *Pohjakerros*	60.9	22.9	37.6	Bottom layer — *Pohjakerros*	78.2	8.3	10.6
Lichens — *Jäkälät*	0.8	2.8	> 100	Lichens — *Jäkälät*	4.3	0.1	2.6
Mosses — *Sammalet*	60.2	20.6	34.2	Mosses — *Sammalet*	74.1	8.4	11.3
	Virrat 1)	**2)**	**3)**		**Total — *Yhteensä* 1)**	**2)**	**3)**
Field layer — *Kenttäkerros*	10.6	6.6	62.4	Field layer — *Kenttäkerros*	27.7	11.1	40.0
Dwarf shrubs — *Varvut*	10.5	5.2	49.7	Dwarf shrubs — *Varvut*	23.1	7.9	34.4
Herbs — *Ruohot*	0.0	1.0	> 100	Herbs — *Ruohot*	3.2	1.5	46.0
Grasses — *Heinät*	0.0	0.2	> 100	Grasses — *Heinät*	1.6	1.4	84.8
Bottom layer — *Pohjakerros*	32.2	9.5	29.5	Bottom layer — *Pohjakerros*	38.3	11.2	29.3
Lichens — *Jäkälät*	0.6	0.2	33.9	Lichens — *Jäkälät*	1.9	0.8	43.6
Mosses — *Sammalet*	31.8	9.5	29.8	Mosses — *Sammalet*	36.8	10.6	28.8

[a]) Camping site in Tammela was not including to the study of the ground cover.
Tammelan alue ei sisälly pintakasvillisuustutkimukseen.
1) Undeteriorated section — *Täysin kulumaton vyöhyke*
2) Deteriorated sections — *Lievästi ja voimakkaasti kuluneet vyöhykkeet*
3) 2/1 × 100

Table 3. Frequency of plant species as a percentage of the total number of species in the camping areas.
Taulukko 3. Kasvilajien frekvenssi prosentteina kokonaismäärästä leirintäalueilla.

FIELD LAYER — *KENTTÄKERROS*					
Dwarf shrubs — *Varvut*	1)	2)	3)	4)	5)
Calluna vulgaris (L.) Hull	45.4	27.6	0.61	10.7	0.24
Vaccinium vitis-idaea L.	86.4	74.7	0.86	31.0	0.36
Vaccinium myrtillus L.	61.4	47.7	0.78	20.8	0.34
Arctostaphylos uva-ursi Spr.	4.9	8.2	> 1	0.2	0.04
Empetrum nigrum L.	3.3	6.2	> 1	4.2	> 1
Linnaea borealis L.	11.7	6.5	0.56	1.6	0.14
Pyrola L. spp.	2.4	2.8	> 1	0.0	0.00
Herbs — *Ruohot*					
Eupteris aquilina (L.) Newm.	2.2	3.7	> 1	0.9	0.41
Maianthemum bifolium L.	7.3	12.5	> 1	0.0	0.00
Convallaria majalis L.	0.8	3.1	> 1	0.0	0.00
Fragaria vesca L.	1.9	6.5	> 1	0.4	0.21
Rubus saxatilis L.	3.3	2.0	0.61	0.0	0.00
Chamaenerion angustifolium L.	0.8	1.7	> 1	0.9	> 1
Trientalis europaea L.	17.4	6.0	0.34	0.4	0.02
Veronica L. spp.	0.8	0.9	> 1	1.1	> 1
Melampyrum L. spp.	17.4	6.8	0.39	0.9	0.05
Grasses — *Heinät*					
Luzula pilosa (L.) Willd.	5.7	8.5	> 1	1.3	0.23
Carex digitata L.	2.7	1.4	0.52	0.0	0.00
Agrostis L. spp.	4.3	5.1	> 1	3.3	0.77
Calamagrostis L. spp.	24.2	12.2	0.50	6.0	0.25
Deschampsia flexuosa L.	21.7	11.4	0.53	0.4	0.02
Poa pratensis L.	0.3	1.7	> 1	1.3	> 1
Poa annua L.	0.0	2.3	> 1	3.6	> 1
Festuca ovina L.	0.8	4.8	> 1	0.9	> 1
BOTTOM LAYER — *POHJAKERROS*					
Mosses — *Sammalet*	1)	2)	3)	4)	5)
Hylocomium splendens B. S.	21.2	9.4	0.44	2.0	0.09
Pleurozium Schreberi Mitt.	70.7	64.8	0.92	21.9	0.31
Dicranum Hed. spp.	47.6	36.9	0.78	21.2	0.45
Polytrichum Dill. spp.	11.6	8.8	0.76	4.9	0.42

1) Undeteriorated section — *Täysin kulumaton vyöhyke*
2) Partially deteriorated section — *Lievästi kulunut vyöhyke*
3) 2/1
4) Severely deteriorated section — *Voimakkaasti kulunut vyöhyke*
5) 4/1

determines the rate of deterioration and is used as a measure of the carrying capacity (cf. KELLOMÄKI and SAASTAMOINEN 1975). The observations shown in Table 2 were used in estimating the values of the parameter P. The estimation was carried out separately for field and bottom layers and the whole ground cover. The amount of trampling was described by the cumulative number of user days. The minimization of the following square sum gave the values of the parameter P

$$(2) \quad \sum_{i=1}^{n} (P^j x_i - y_i)^2 = \sum_{i=1}^{n} e_i^2.$$

The value of the parameter was 0.70 for the field layer, 0.53 for the bottom layer and 0.55 for the whole ground vegetation. The values of this parameter are lower than those presented by KELLOMÄKI and SAASTAMOINEN (1975) and KELLOMÄKI (1977) which were obtained by means of artificial trampling with the same type of vegetation.

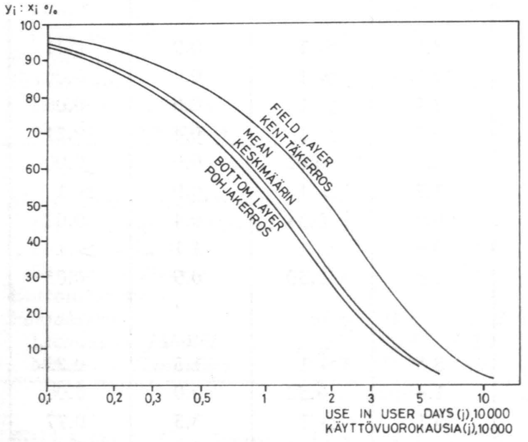

Fig. 3. Estimated ground cover as a function of amount of use.
Kuva 3. Pintakasvillisuuden arvioitu peittävyys kulutusmäärän funktiona.

The difference in the field layer and in the bottom layer is pronounced as can be seen in Table 4. The quality of trampling affects, however, the values of the parameter P. Consequently, the comparison is not valid in every respect. Especially, the much higher level of trampling in camping areas than that produced artificially must be considered in the comparison.

The correlation between field observations and model-based values for actual coverage was 0.670 in the field layer, 0.853 in the bottom layer and 0.816 in the whole ground cover. The discrepancy between the observed and calculated values in the field layer is due to the fact that growth was omitted from the calculations. In the bottom layer, growth is negligible and results in no bias in calculations as indicated by the high correlation coefficient (cf. KELLOMÄKI 1977).

The model (1) was used to study the coverage of ground vegetation when subjected to particular levels of trampling. The ground cover in a trampled area calculated as the percentage of that in an untrampled one is presented in Fig. 3 as a function of the number of user days. In the field layer, 10 000—15 000 user days appear to be the threshold value for a rapid decrease in coverage. In the bottom layer, the threshold value is lower. In this case 3 000—5 000 user days seems to be sufficient to start a rapid decrease in coverage. On the other

Table 4. Values of parameter P and its comparison with those obtained in earlier studies.
Taulukko 4. Parametrin P arvot ja sen vertailu aiemmin esitettyihin lukuihin.

Horizontal layer *Osakasvusto*	P	r	r²	Values of P in earlier studies *P arvot aiemmissa töissä*	
				by[1])	by[2])
Field layer .... *Kenttäkerros*	0.70	0.670	0.449	.99	.96
Bottom layer .... *Pohjakerros*	0.53	0.853	0.728	.97	.92
Mean .... *Keskimäärin*	0.55	0.816	0.667		

[1]) KELLOMÄKI and SAASTAMOINEN (1975)
[2]) KELLOMÄKI (1977)

hand, trampling of 50 000—100 000 user days is sufficient to destroy thoroughly the ground vegetation. A coverage value of 40 was suggested by BEARSLEY and WAGAR (1972) as being aesthetically sufficient. This value falls within the trampling range 15 000—25 000 user days. Earlier, KELLOMÄKI (1977) has given estimates of the same magnitude for the carrying capacity of the ground cover of the same site type. The amount of user days is not, however, related to the area of the camping site which obscures the interpretation of the results (cf. Table 1).

Deterioration of the root system of the tree stratum

The deterioration of the tree stratum was studied in six camping areas (cf. Table 1). The degree of deterioration of the root systems is presented in Table 5. On the average, the root system was partially or greatly exposed in 77 % of the total number of sample trees. The unprotected root system suffered in most cases from damage to the cambial system of the roots.

Damage to the root system was found in 66 % of the total number of sample trees. On the average one third of the total length of uncovered roots was damaged. Damage to the root systems was limited to the severely deteriorated sections of the areas in which the protective humus layer had been destroyed (cf. KALELA 1949).

Deterioration of the root systems is irreversible and increases according to an increasing amount of trampling as depicted in Fig. 4. The length of uncovered and damaged roots per sample tree appears to increase linearly as a function of the age of the sampling area. The deterioration of the root systems in camping areas has earlier been documented by, for example, MAGILL and NORD (1963) and FRISSEL and DUNCAN (1965). Low physiological activity and insect and fungus damage are consequences of this phenomen (cf. KANGAS 1955, KÄRKKÄINEN 1971, ISOMÄKI and KALLIO 1974). Deterioration of the root systems also decreases the aesthetic value and suitability of the areas for camping.

Table 5. Damaged root systems of trees.
Taulukko 5. Puiden juurten vaurioituminen.

Camping area *Leirintäalue*	Number of sample trees *Koepuita, kpl*	Amount of uncovered roots *Makrojuuriston paljastuminen*			Amount of deteriorated root system *Makrojuuriston vaurioituminen*			Amount of damages as a percentage from area of uncovered root system *Vaurioituneen juuriston osuus paljastuneiden juurten määrästä, %*
		Frequency *Määrä, kpl*	Percentage from sample trees *Osuus koepuista, %*	cm/tree *cm/puu*	Frequency *Määrä, kpl*	Percentage from sample trees *Osuus koepuista, %*	cm/tree *cm/puu*	
Asikkala	19	18	95	453	17	89	—x)	—x)
Eno	26	20	77	147	20	77	34	23
Kesälahti	19	7	37	83	4	21	34	41
Rautalampi	21	15	71	200	14	67	63	32
Saarijärvi	39	33	85	259	21	64	122	47
Tammela	21	19	90	223	19	90	78	35
Total *Yhteensä*	145	112	77	228	95	66	73	32

x) No measurements — *Ei mitattu*

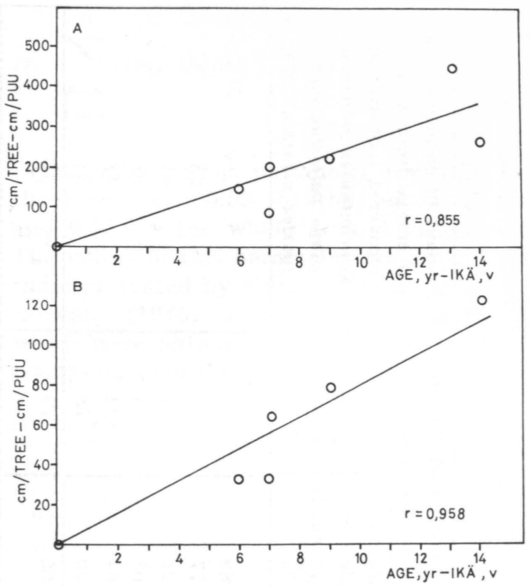

Fig. 4. The amount of exposed roots per tree (a) and the amount of damaged roots per tree (b) as a function of age of camping area.
Kuva 4. Puuta kohti paljastuneen juurten (a) ja vaurioituneiden juurten (b) määrä leirintäalueen iän funktiona.

Damage to aerial parts of the tree stratum

Damage to the trunks and other aerial parts of the trees is not directly associated with trampling but is rather due to construction work, service and the passage of vehicles in the areas. Campers' behaviour also causes damage. Such type of damages are, however, common in severely deteriorated sections as presented in Table 6. The number of damaged trees exceeds one fourth of the total number of sample trees. The proportion of damaged trees increases as a function of the age of the camping area as presented in Fig. 5. Trunk damage is also a source of decreasing physiological activity and may result in secondary damages.

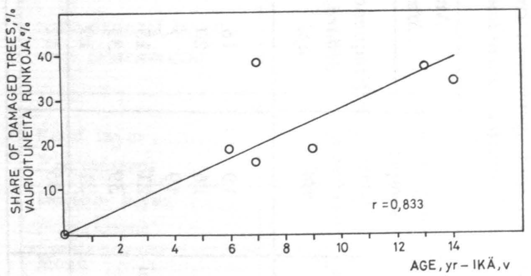

Fig. 5. Share of damaged trees as a function of age of camping area.
Kuva 5. Vaurioituneiden puiden määrä leirintäalueen iän funktiona.

Table 6. Deterioration of stems.
Taulukko 6 Runkojen vaurioituminen.

Camping area *Leirintäalue*	Number of sample trees *Koepuita, kpl*	Amount of deteriorated trees *Vaurioituneita runkoja*: Frequency *Määrä, kpl*	Percentage from sample trees *Osuus koepuista, %*	Number of damages *Vaurioita, kpl*	Damaged area, cm² *Vaurioiden yhteispinta-ala, cm²*	Mean area damaged, cm² *Vaurion keskikoko, cm²*	Damaged area per damaged tree, cm² *Vauriopinta-ala/runko, cm²*
Asikkala	19	7	37	15	351	24	50
Eno	26	5	19	5	25	5	5
Kesälahti	19	3	16	3	46	15	15
Rautalampi	21	8	38	16	762	48	95
Saarijärvi	47	16	34	28	1 496	53	94
Tammela	21	4	19	6	941	157	235
Mean *Keskimäärin*	152	43	28	73	3 621	50	84

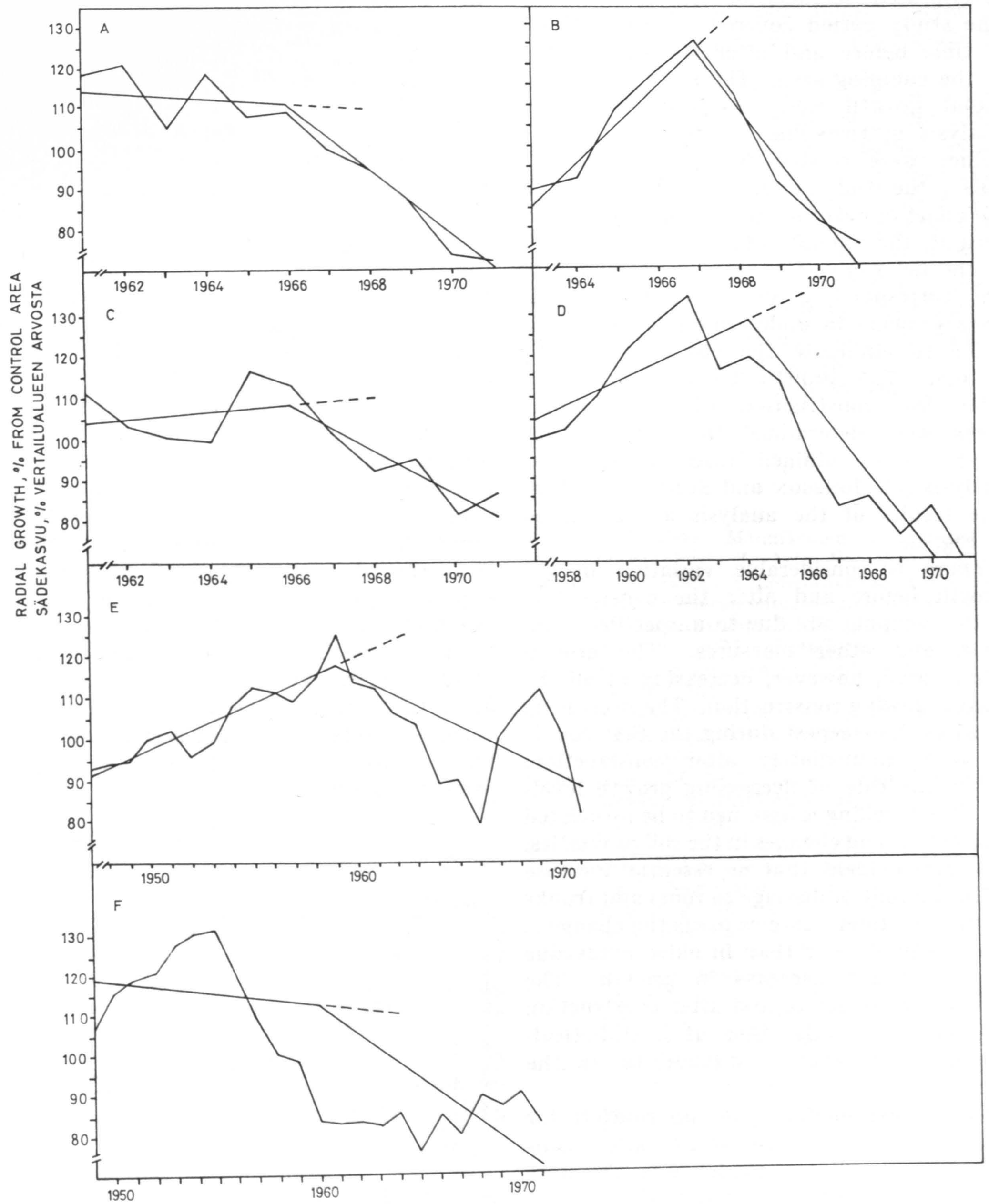

Fig. 6. Growth of trees in camping areas: a: Rautalampi, b: Eno, c: Kesälahti, d: Tammela, e: Saarijärvi, f: Asikkala.
Kuva 6. Puiden sädekasvu leirintäalueilla: a Rautalampi, b: Eno, c: Kesälahti, d: Tammela, e: Saarijärvi, f: Asikkala.

Changes in radial growth in the tree stratum

The changes in radial growth were studied only in sample trees located in severely deteriorated sections of the study areas. The study period covered the same length of time before and after the construction of the camping area. The annual values of radial growth were transformed for the analysis in two phases. First, the annual values were related to the total growth during the study period in order to eliminate the effect of natural variation in tree growth. Second, the annual values of radial growth in the deteriorated sections were related to the corresponding values of the sample trees growing in undeteriorated sections in order to eliminate the effect of climatic factors. The growth trends before and after the construction of the camping areas were determined from transformed observations obtained through regression analysis (cf. JONSSON and SUNDBERG 1972). The results of the analysis are presented in Fig. 6.

There is considerable variation in the growth before and after the construction of the camping site due to unspecified thinnings and other measures. The growth trends were, however, decreasing in all the areas following construction. The decreasing trend is the steepest during the first couple of years immediately after construction. Later, the rate of decreasing growth levels off. The levelling is assumed to be associated with decreasing changes in the soil properties. It is also evident that no essential increase in the amount of damage to roots and trunks takes place later. In new areas the change is apparently greater than in older areas due to the abrupt decrease in growth. The growth trends before and after construction differed from each other at a statistically significant level ($p < 0.001$) in all the areas.

As a linear model is not appropriate for describing the growth trend after construction, the linear model was therefore replaced by the following formula

$$(3) \quad y_i = a \cdot \frac{1}{x_i + b} + c + e_i,$$

where y_i is the relative growth level, x_i the age of the camping area and a and c parameters describing the shape of the function. The value of parameter b was estimated through minimizing the formula (4)

$$(4) \quad \sum_{i=1}^{n} \left(a \cdot \frac{1}{x_i + b} + c - y_i\right)^2 = \sum_{i=1}^{n} e_i^2.$$

The values of parameters a and c were determined through the formula (5)

$$(5) \quad y_i = a \cdot (x_i + b) + c,$$

where inverse values of $x_i + b$ were utilized.

The value for parameter a was 91.4, for b 2.0 and for c 53.3. The obtained model explained 97 % of the variance in growth after construction as presented in Fig. 7. The decreasing growth trend is greatest during the first 3–4 year period after construction and levels off after about 10 years. The growth level is then about 35 % lower than that in undeteriorated sections. A further decrease in growth is, however, expected judging by the values of the parameter c. It suggests that the growth level may decline to a level only one half of that before construction of the camping area. LaPAGE (1962) has documented similar trends in trees on forested recreation areas, but not as severe as those found in the present material.

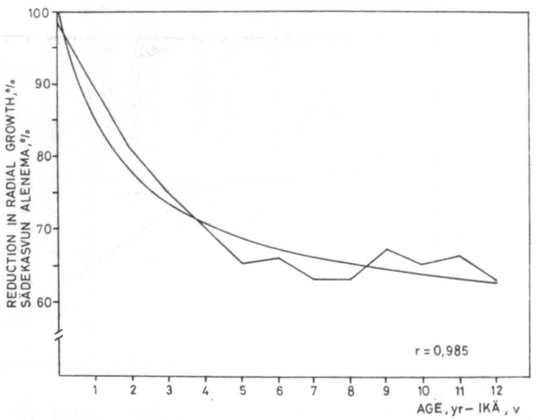

Fig. 7. Reduction in growth as a function of age of camping area.
Kuva 7. Sädekasvun alenema alueen iän funktiona.

CONCLUSIONS

The deterioration of ground vegetation is unavoidable in forested camping areas. Our results suggest that only certain grass species can survive in these areas. In forested areas their share out of the ground vegetation can be increased through proper thinning and fertilizing treatments (cf. for example BEARSLEY and WAGAR 1972, KELLOMÄKI 1977). The replacement of dwarf shrubs and mosses is recommended immediately after construction in the most frequented sites such as around toilets and cooking places. Sowing of *Poa* species may accelerate stabilization of the ground cover on such areas.

Trampling can also be limited to constructed paths and other areas. Such guidance has a great potential in protecting forest recreation areas as found in many cases. Gravel paths and other protective measures also have a more important role as regards tree protection than the ground vegetation can ever have. Conserving the ground vegetation and humus layer is important for the avoidance of damage to the root systems.

The abrupt decrease in growth in trampled areas suggests that only intensive measures can prevent changes in the physiological status of the trees. In fact, the fine roots may play the crucial role in the damaging process of trees. Damage to macro roots only indicates the main lines of the role of soil in the damaging process. Further studies are therefore needed to verify this assumption. On the other hand, tree species other than Scots pine should also be included in further studies.

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SELOSTE:

LEIRINNÄN VAIKUTUS METSÄN ALUSKASVILLISUUTEEN JA PUIDEN KASVUUN

Pintakasvillisuuden tilaa ja puiden sädekasvua tutkittiin kymmenellä Etelä-Suomen leirintäalueella. Alkuperäisen pintakasvillisuuden tuhoutuminen oli yleistä tutkituilla alueilla. Ainoastaan eräät heinälajit näyttivät sietävän leirintäalueiden voimakasta kulutusta. Kuluminen pysyi kohtuullisena, jos alueen käyttö ei ylittänyt 10 000—15 000 käyttövuorokautta. Käytön ylitettyä 100 000 käyttövuorokautta ei alkuperäisestä kasvipeitteestä ollut jäljellä muuta kuin rippeet. Tällaisilla alueilla havaittiin puiden sädekasvun alentuneen voimakkaasti. Kasvun aleneminen oli voimakkainta välittömästi alueen käyttöönoton jälkeen, mutta sen havaittiin jatkuvan vielä kymmenen vuotta käyttöönoton jälkeen. Tässä vaiheessa puiden sädekasvu kuluneilla alueilla oli 65 % kulumattomien alueiden sädekasvusta. Sädekasvun aleneminen näyttää jatkuvan tulevaisuudessa.