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RADIAL GROWTH OF SCOTS PINE AND SOIL CONDITIONS AT SOME CAMPING SITES IN SOUTHERN FINLAND

LIISA NYLUND, MARKKU NYLUND, SEPPO KELLOMÄKI and ANTTI HAAPANEN

SELOSTE:

MÄNNYN SÄDEKASVU JA MAAPERÄMUUTOKSET ERÄILLÄ ETELÄ-SUOMEN LEIRINTÄALUEILLA

Saapunut toimitukseen 1979-10-05

Radial growth of Scots pine *(Pinus sylvestris* L.) was investigated in seven camping areas located in southern Finland. Radial growth reduction of 20—40 % was found. The magnitude of the reduction was related to the amount of damage in the trees, and the age of the trees. A loss of humus, exposure of the roots and soil compaction were associated with the use of the areas but not related to the reduction in growth.

INTRODUCTION

NYLUND, M. *et al.* (1979) have demonstrated a considerable decrease in the radial growth of Scots pine at several camping sites in southern Finland. Similar phenomena are also described by LAPAGE (1962) and FRISSEL and DUNCAN (1965). According to MAGILL and NORD (1963), the trampling of forest ground cover seems to give rise to serious problems in tree growth. In the most popular areas special measures are needed to protect trees and shrubs from damage due to too heavy trampling.

NYLUND, M. *et al.* (1979) have emphasized the abruptness of the decrease in tree growth on camping sites. On the other hand, the decreasing trend in the growth rate is still detectable several years after opening a camping site to the public. The different phases of the growth reduction interpreted as being caused by two separate processes. The short-term but abrupt decrease during the first couple of years is assumed to be due to the destruction of the root systems as emphasized for example by MAGILL and NORD (1963). The long-term reduction is assumed to originate from a change in the environment, especially in the soil as suggested by, for example, LUTZ (1945) and DÜGGELI (1945).

On untrampled areas both root systems and the soil are protected by the ground vegetation. Hence the deterioration of the ground vegetation is the driving force for both the short and long-term decline in growth (cf. FRISSEL and DUNCAN 1965). An assumption is made that both the short and long term changes in tree growth

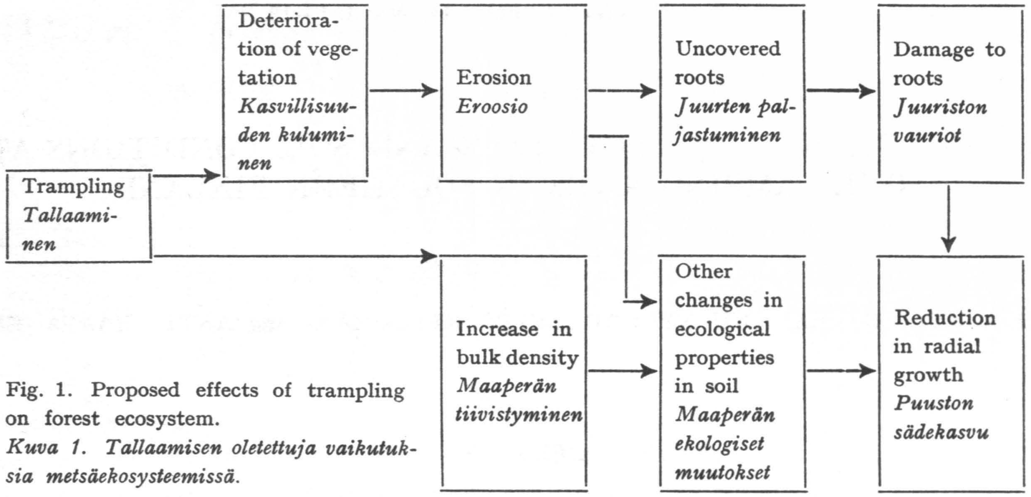

Fig. 1. Proposed effects of trampling on forest ecosystem.
Kuva 1. Tallaamisen oletettuja vaikutuksia metsäekosysteemissä.

appear after the removal of the protection given by the ground vegetation and humus layer caused by trampling. Such an approach is supported, for example, by studies carried out by Frissel and Duncan (1965), McCool *et al.* (1969) and Merriam *et al.* (1971) and Liddle and Greig-Smith (1975).

The aim of the present study is to investigate the effect of trampling on the radial growth of Scots pine *(Pinus sylvestris* L.) by applying the approach presented in Fig. 1. Factors affecting tree growth through the root systems and soil properties are included in the study.

This paper belongs to a series of studies concerning the ecological effects of recreation and tourism on forest ecosystems. The total 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 of Man and Biosphere (MAB) Project. We acknowledge the financial support.

MATERIAL AND METHODS

The material consists of seven camping sites in southern Finland lying between the 60th and 62nd latitudes at a height of 100–200 m above sea level (see Fig. 2). The areas are representative of the south boreal vegetation zone, and most are located on sites of the *Vaccinium* type, *i.e.* medium fertility. Sand was the main characteristic of soils on the selected areas (cf. also Table 1–2). The areas had been in use for camping from five to fifteen years. The investigation was carried out from July through September, 1974.

Most of the areas represented mature

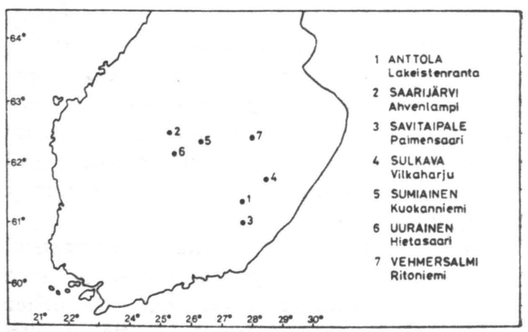

Fig. 2. Location of study areas.
Kuva 2. Tutkimusalueiden sijainti.

Table 1. Some main features of the camping areas.
Taulukko 1. Eräitä leirintäalueiden yleistietoja.

Area *Alue*	Year opened *Perustamisvuosi*	Years since opening *Käyttöikä tutkimusvuonna, v.*	Area, ha *Pinta-ala, ha*	User days per year *Yöpymisvuorokausia keskimäärin vuodessa*	Site type *Metsätyyppi*	Share of soil fraction *Maalajitteiden % osuudet*		
						Gravel *Sora*	Fine sand *Hieno sora*	Silt and other fine fractions *Hieta ja hiesu*
Anttola	1965	8	2.5	2 362	VT	0.56	1.11	98.03
Saarijärvi	1959	15	26.0	14 328	CT	3.59	6.77	89.64
Savitaipale	1961	12	3.0	2 789	MT	6.14	8.42	85.44
Sulkava	1962	11	27.0	10 355	VT	3.92	9.06	87.02
Sumiainen	1964	9	1.7	989	VT	0.00	0.07	99.93
Uurainen	1960	13	2.6	1 564	VT	0.00	0.77	99.23
Vehmersalmi	1968	5	12.0	18 157	VT	0.00	0.70	99.30

Scots pine *(Pinus sylvestris* L.) stands, *i.e* mean age between 60–110 years (Table 2). Moderate thinning had been carried out in most areas. Fertilization and other measures had also been carried out but to a more limited degree than thinning. The assumption is made that these measures do not interfere with the analysis and the areas are comparable in the data processing.

For the sampling, each camping area was divided into two sections: undeteriorated and deteriorated. In the undeteriorated section the ground vegetation had not been affected by trampling as it had in the deteriorated section. In the sampling procedure (cf. Fig. 3) six sample plots, 300 m² in size, were selected from the deteriorated sections for more detailed study. There were three sample plots in each undeterriorated section. Seven sample trees were selected to represent the tree stratum on each sample plot. The frequency distribution of stem diameter was taken into account in the sampling of the tree stratum. Sampling of the ground vegetation and soil was also carried out on these sample plots, as presented in Fig. 3.

The following measurements were made on the sample trees: diameter at breast height (1.3 m above soil level), height, area of damaged trunk, amount of uncovered roots, amount of damaged roots, age and radial growth during a corresponding period before and after the construction of the camping areas (cf. Fig. 2). Description of the ground vegetation was limited to the total coverage of the field and ground layers. In describing the soil the proportion of uncovered mineral soil and humus-covered soil and the depth of the humus layer, were measured. In addition, mineral soil samples were taken for determination of the basic density and particle-size distribution. The sampling was carried out with the help of a cylindrical water volumeter. The bulk density of the soil was calculated on the dry mass basis.

Table 2. Main features of tree stratum in the camping areas.
Taulukko 2. Leirintäalueiden puuston kuvaus.

Area[1] *Alue*		Volume, m^3/ha *Kuutiomäärä, m^3/ha*	Mean age, yr *Keski-ikä, v*	Mean height, m *Keskipituus, m*	Mean diameter, cm $D_{1.3}$, *cm*	Number of sample trees *Koepuiden määrä, kpl*	Additional information *Hoitotoimenpiteet*
Anttola	1	288	59	21.2	24.6	35	Thinning, amount of removed trees 25 % from original number *Harvennus poistettu ≥ 1/4 alkuperäisestä puustosta*
	2	224	54	17.6	21.3	7	
Saarijärvi	1	156	76	18.9	26.2	42	Fertilized *Metsälannoitus* Sowing of grass *Ruohikon kylvö*
	2	161	80	19.9	26.9	21	
Savitaipale	1	266	93	24.3	31.3	42	Thinning, amount of removed trees 25 % from original number *Harvennus poistettu ≥ 1/4 alkuperäisestä puustosta*
	2	279	101	24.5	36.1	14	
Sulkava	1	363	111	22.7	33.8	42	Thinning, amount of removed trees 25 % from original number *Harvennus poistettu ≥ 1/4 alkuperäisestä puutosta*
	2	241	111	24.8	32.3	21	
Sumiainen	1	267	79	22.4	31.2	42	Thinning, amount of removed trees 25 % from original number *Harvennus poistettu ≥ 1/4 alkuperäisestä puustosta*
	2	254	87	22.2	33.1	21	
Uurainen	1	163	66	17.2	25.3	42	No treatment *Ei käsittelyä*
	2	208	54	20.3	26.1	14	
Vehmersalmi	1	150	96	17.5	26.8	42	Thinning, amount of removed trees 25 % from original number *Harvennus poistettu ≥ 1/4 alkuperäisestä puustosta*
	2	131	98	19.2	25.7	21	

[1] 1: Deteriorated section — *Kulunut osite*
2: Undeteriorated section — *Kulumaton osite*

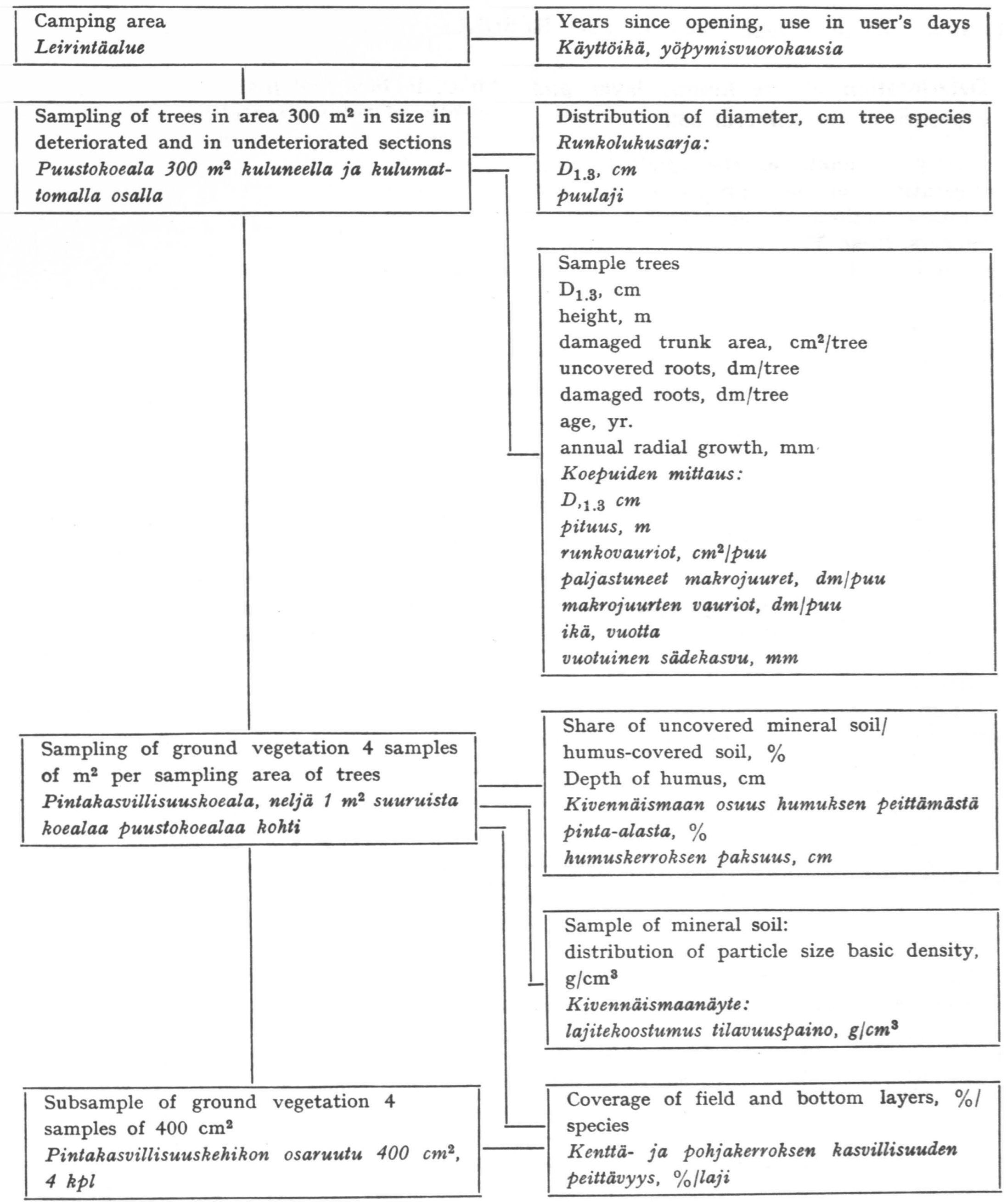

Fig. 3. Description of measuring procedure.
Kuva 3. Tutkimusmenetelmän kuvaus.

RESULTS

Deterioration of the humus layer and exposure of the mineral soil

Only remnants of the original ground vegetation were still present on the deteriorated sections of the camping areas as appears from Table 3. The reduction of ground cover was of the same magnitude both in field and bottom layers. Independently of the horizontal layer the coverage of ground vegetation was only a few per cents, *i.e.* in all cases lower than 10.

Due to the deterioration of ground cover it was evident that the humus layer had become exposed to trampling to a considerable extent. In most areas, the thickness of the humus layer in deteriorated sections was only half that of the undeteriorated sections as appears from Table 4. The loss in humus thickness is associated with exposure of the mineral soil. On the average one third of the soil area of the deteriorated sections was uncovered. The exposure of mineral soil was, however, not strongly correlated with the loss of humus. For example, near to trees and large stones the reduction in humus was negligible and hence the reduction does not correlate with the exposure of mineral soil as well as was expected.

Loss of humus and exposure of the mineral soil were related to the amount of use as indicated by the age of the camping area (Figs. 4 and 5). Both regressions are linear and suggest that a further loss of humus and uncovering of mineral soil will take place in the future in the studied areas. In general, no considerable regeneration of the ground vegetation and humus layer seems to be characteristic of recreation areas subjected to heavy trampling. In other words, the root systems of the trees and the mineral soil are exposed to increasing pressure due to trampling.

Table 3. Deterioration of ground cover in the camping sites.
Taulukko 3. Pintakasvillisuuden kuluminen leirintäalueilla.

Area *Alue*	Coverage of vegetation, % *Kasvillisuuden peittävyys*				Reduction of ground cover, deteriorated section % of undeteriorated section *Pintakasvillisuuden vähennys, kulunut alue % vertailualueen arvosta*	
	Deteriorated section *Kulunut alue*		Undeteriorated section *Vertailualue*			
	Field layer *Kenttäkerros*	Bottom layer *Pohjakerros*	Field layer *Kenttäkerros*	Bottom layer *Pohjakerros*	Field layer *Kenttäkerros*	Bottom layer *Pohjakerros*
Anttola	0.2	0.1	23.5	20.6	0.9	0.5
Saarijärvi	0.0	0.2	25.2	73.2	0.0	0.3
Savitaipale	0.4	0.2	39.1	16.2	1.0	1.2
Sulkava	0.0	1.1	15.5	60.7	0.0	1.8
Sumiainen	0.9	0.2	36.5	33.9	2.5	0.6
Uurainen	0.8	0.8	43.7	12.2	1.8	6.6
Vehmersalmi	0.3	0.4	25.7	26.9	1.2	1.5

Table 4. Deterioration of humus layer in the camping areas.
Taulukko 4. Humuskerroksen kuluminen leirintäalueilla.

Area *Alue*	Depth of humus, cm *Humuksen paksuus, cm*		Reduction of humus, % *Humuksen oheneminen,* %	Uncovered soil, % *Maaperän paljastuminen,* %
	Deteriorated section *Kulunut alue*	Undeteriorated section *Vertailualue*		
Anttola	2.1	3.8	44.7	4.8
Saarijärvi	0.7	2.4	70.8	54.6
Savitaipale	1.0	2.8	64.3	35.5
Sulkava	1.5	3.0	50.0	38.4
Sumiainen	0.9	3.4	73.5	21.7
Uurainen	0.9	3.0	70.0	38.3
Vahmersalmi	1.7	2.3	26.1	22.2

Increase in basic density of the mineral soil

Basic density in the upper parts (0–10 cm) of the mineral soil increased in all the areas as appeas from Table 5. On the average, the increase in the deteriorated sections was 12–36 % compared with the undeteriorated sections. In absolute terms, the increase was 0.43 g/cm³ at its greatest. The increase was related to the age of the area as well as to the loss in humus as appears from Figs. 6 and 7. The particle-size distriction of the soil had no clear effect on this increase. In principle, coarse fractions and sandy soils are more resistant to the effects of trampling than other types of soil. More detailed studies are, however, needed to verify this assumption.

Exposure of root systems and damage to roots and stems

Part of the root systems of nearly all the sample trees in the deteriorated sections were uncovered as appears from Table 6. The exposure of the root systems was

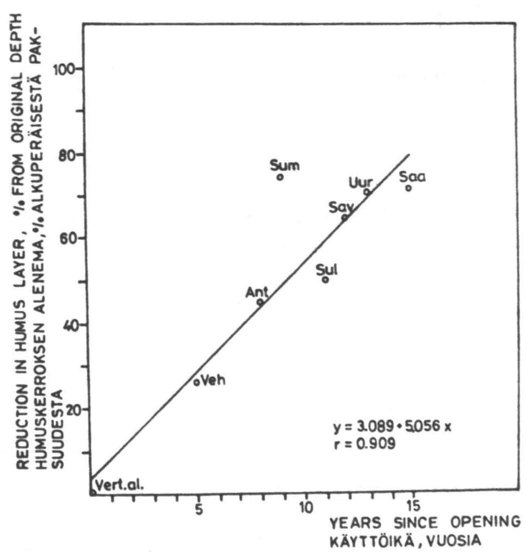

Fig. 4. Reduction of humus layer.
Kuva 4. Humuskerroksen aleneminen.

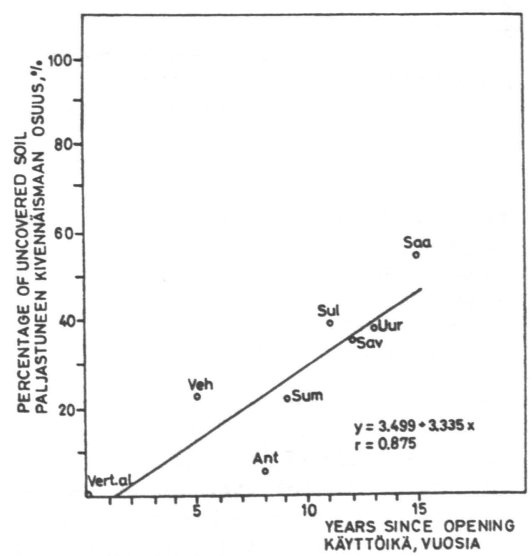

Fig. 5. Uncovering of mineral soil.
Kuva 5. Kivennäismaan paljastuminen.

Table 5. Change in bulk density of mineral soil.
Taulukko 5. Kivennäismaan tilavuuspainon muutos.

Area *Alue*	Bulk density, g/cm³ *Maan tilavuuspaino, g/cm³* Deteriorated section *Kulunut alue* a	Undeteriorated section *Vertailualue* b	Change in bulk density *Maan tiivistymisaste* 100 . a/b
Anttola	1.22	1.09	112
Saarijärvi	1.63	1.28	127
Savitaipale	1.24	1.02	122
Sulkava	1.50	1.18	127
Sumiainen	1.37	1.11	123
Uurainen	1.61	1.18	136
Vehmersalmi	1.32	1.17	113

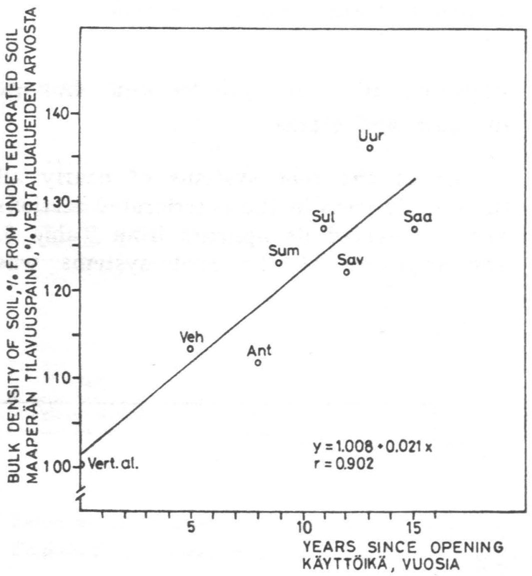

Fig. 6. Bulk density of mineral soil as a function of age of area.
Kuva 6. Kivennäismaan tiivistyminen alueen iän funktiona.

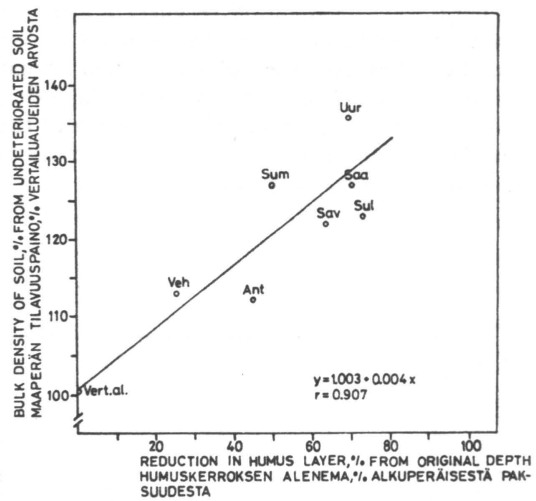

Fig. 7. Bulk density of mineral soil as a function of reduction of humus layer.
Kuva 7. Kivennäismaan tiivistyminen humuskerroksen aleneman funktiona.

closely associated with the loss of the humus layer as presented in Fig. 8. As one would expect, the age of the camping area was also related to the exposure of the root systems as appear from Fig. 9. The extent of exposure of the root systems seems to be linearly increasing as regards the age of the camping area.

The degree of exposure seems to indicate rather well the extent to which the root system is damaged as appears from Fig. 10. Consequently, the amount of root damage is closely related to the age of the camping areas as shown in Fig. 11. Nearly all the trees in camping areas seem to be damaged after 15—20 years of use, *i.e.* some damage

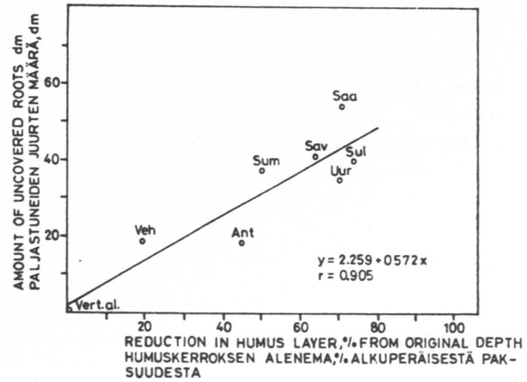

Fig. 8. Amount of uncovered roots as a function of reduction of humus layer.
Kuva 8. Juurten paljastuminen humuskerroksen alenemisen funktiona.

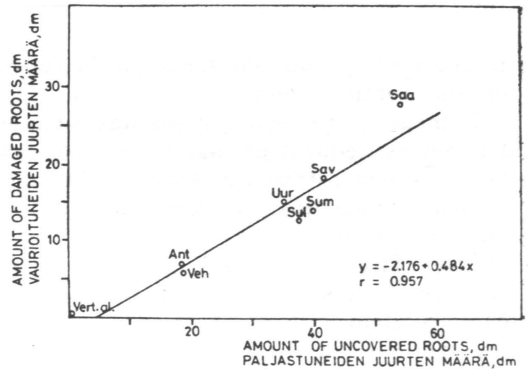

Fig. 10. Amount of damaged roots as a function of amount of uncovered roots.
Kuva 10. Vaurioituneiden juurten määrä paljastuneiden juurten määrän funktiona.

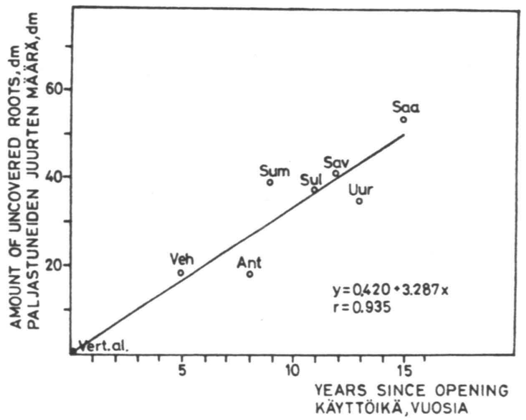

Fig. 9. Amount of uncovered roots as a function of age of area.
Kuva 9. Juurten paljastuminen alueen iän funktiona.

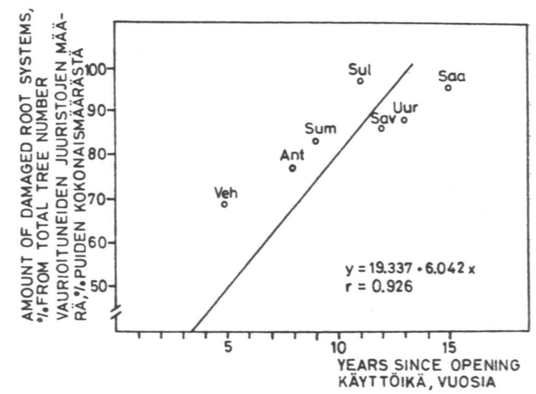

Fig. 11. Amount of damaged root systems as a function of age of area.
Kuva 11. Vahingoittuneiden juuristojen määrä alueen iän funktiona.

Table 6. Damages in roots and stems.
Taulukko 6. Puiden juuristojen ja runkojen vaurioituminen.

Area *Alue*	Number of sample trees *Koe-puita kpl*	Uncovered roots *Juurten paljastuminen* dm/tree *dm/puu*	Uncovered roots trees *puita* %	Damages in roots *Juurten vauriot* dm/tree *dm/puu*	Damages in roots trees *puita* %	Damages in stems *Runkojen vauriot* cm²/n/tree *cm²/puu*	Damages in stems trees *puita* %	Damages in roots and stems *Rungoista ja/tai juurista vaurioituneita puita* number *kpl*	Damages in roots and stems %
Anttola	35	18.4	85.7	6.8	77.1	6.1	17.1	29	82.8
Saarijärvi	42	53.6	100.0	28.0	95.2	21.2	33.3	40	95.2
Savitaipale	42	41.1	92.9	18.3	35.7	20.7	21.4	39	92.9
Sulkava	42	37.3	97.6	12.7	97.6	0.6	7.1	41	97.6
Sumiainen	42	39.6	88.1	14.0	83.3	0.0	0.0	35	83.3
Uurainen	42	34.8	95.2	14.8	88.1	1.7	4.8	38	90.5
Vehmersalmi	42	18.6	61.0	5.8	69.0	22.9	26.2	33	78.6

to the root system was found in 70–90 % of the sample trees.

Damage to the stem systems was common but not as frequent as that to the root systems, as demonstrated in Table 6. The rate of stem damage was not comparable with the amount of root damage nor with the amount of use. The assumption is therefore made that recreational use is not the primary cause of stem damage. It is suggested that the construction of facilities in the camping area causes such damage and they can be avoided through proper planning and construction techniques.

Decrease of radial growth of the tree stratum

Radial growth of the trees was studied using the same procedure as that utilized by NYLUND, M. *et al.* (1979). The total growth during a period of the same duration before and after the opening of the camping area was pooled. The annual values of radial growth were related to this summed value in order to eliminate the effect of genetic and other internal factors on the results. The role of climatic factors was excluded by carrying out computations in which the radial growth of trees in the deteriorated sections was related to that of trees in the undeteriorated sections. The growth trends before and after the opening of the areas were studied by regression analysis. Comparisons of these trends gave the criteria for detecting the general effect of trampling on growth. The procedure was comparable to that applied by JONSSON and SUNDBERG (1972).

The growth trends in different study areas are presented in Fig. 12. Decreasing growth is characteristic of all the areas, as was expected. The growth trends were increasing on nearly all the areas before trampling. Thus the effect of trampling on radial growth is further magnified, indicating its abruptness and magnitude.

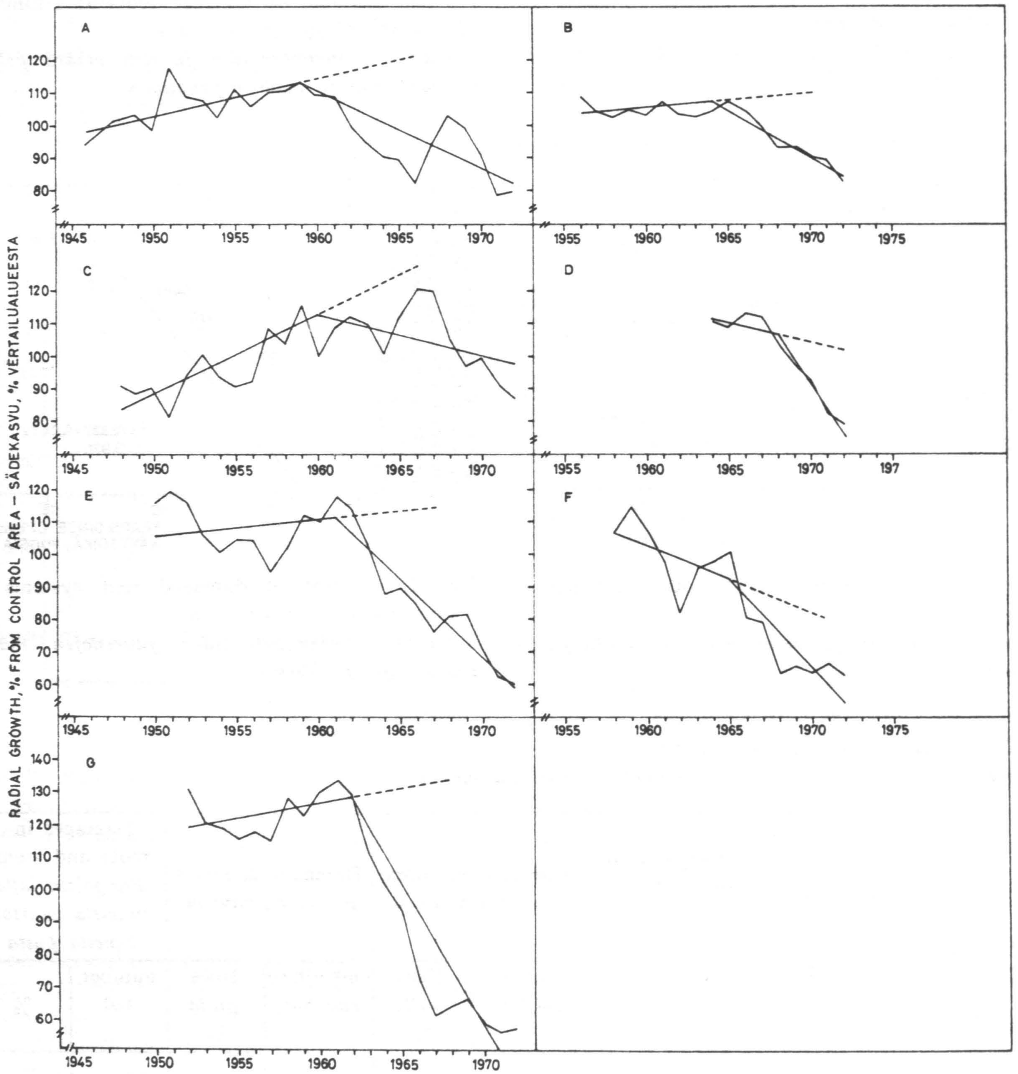

Fig. 12. Growth of trees in camping areas. A: Saarijärvi, B: Sumiainen, C: Uurainen, D: Vehmersalmi, E: Savitaipale, F: Anttola, G: Sulkava.
Kuva 12. Puiden sädekasvu leirintäalueilla. A: Saarijärvi, B: Sumiainen, C: Uurainen, D: Vehmersalmi, E: Savitaipale, F: Anttola, G: Sulkava.

The decreasing trend seems, however, to level off within 8–10 years. The new growth level remains considerably low *i.e.* 60–80 % of that before the opening of the area.

The reduction in the radial growth was not directly comparable with the number of users nor with the age of the area. The amount of use had, however, an indirect effect on the amount of reduction as presented in Fig. 13. It appears that the number of damaged trees in the camping area is correlated with the reduction in radial growth. As demostrated earlier the number of damaged trees was closely associated with the total amount of damage to the trees of the camping area. The number of damaged points per sample tree had, however, no recognizable effect on the reduction in radial growth. The assumption is thus made that even a small amount of damage per tree is important and may reduce the trampling tolerance of the trees through changes in their physiological status. This assumption is supported by the regression between the age of the trees and reduction in growth rate as shown in Fig. 14. It appears that young trees are more resistant to trampling than old trees. The low tolerance of old trees is assumed to be a consequence of their low physiological activity.

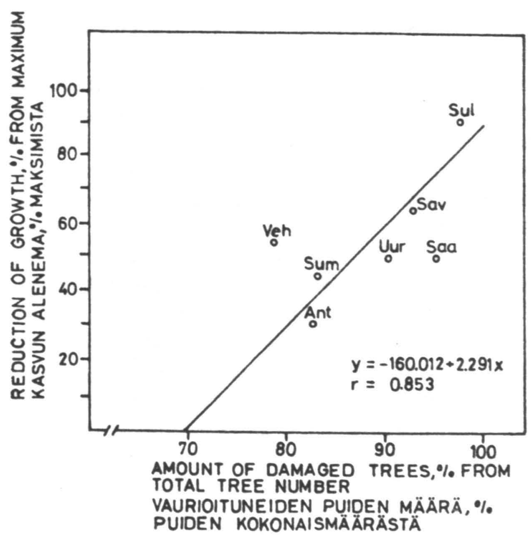

Fig. 13. Reduction of growth as a function of amount of damaged trees.
Kuva 13. Kasvun alenema vaurioituneiden puiden määrän funktiona.

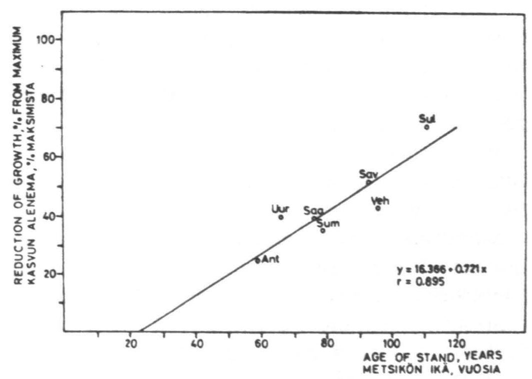

Fig. 14. Reduction of growth as a function of age of stand.
Kuva 14. Kasvun alenema metsikön iän funktiona.

DISCUSSION

Deterioration of the ground vegetation and the humus layer and increasing bulk density of the mineral soil seem to be unavoidable consequences of the intensive use of forest areas for recreation as suggested earlier, for example, by FRISSEL and DUNCAN (1965), McCOOL *et al.* (1969) and MERRIAM *et al.* (1971). Increasing soil density and other ecological effects, and a reduction in tree growth, are associated with these changes. The reduction in recreational potential is an evident consequence of these processes as demonstrated, for example, by BEARSLEY and WAGAR (1972).

A decrease in the thickness of the humus layer was linearly correlated with the age of the camping area. The total destruction of the humus layer seems to be an unavoidable consequence of intensive and long-lasting trampling (cf. MAGILL and NORD 1963). Also the size of the area of exposed mineral soil was increasing. Both processes expose the roots of the trees to increasing pressure through trampling. Therefore the survival of trees in camping areas may be limited, as indicated by the reduction in the radial growth of threes (cf. LAPAGE 1962, MAGILL and NORD 1963).

The change in ecological conditions also has an effect on tree growth in camping areas. LAPAGE (1962) assumes that the increase in the basic density of mineral soil is the most important factor as regards tree growth (cf. also SETTERGREN and COLE 1970, LIDDLE and MOORE 1974). In the present study no correlation between growth reduction and basic density was, however, found. The assumption is made that changes in the humus layer are sufficient to induce a reduction in growth. Soil compaction takes place only when the humus layer has been destroyed, and therefore its contribution to growth reduction remains negligible as compared with other factors (cf. GRABLE and SIEMER 1968, KEMPER *et al.* 1971, WHISLER 1965). Especially, the role of fine roots is assumed to be of importance in tree growth. The reduction of fine roots is closely associated with the loss of humus (cf. MAGILL and NORD 1963).

The growth reduction was directly associated with the rate of damage in the tree stratum. Even a negligible amount of damage had an effect on tree growth. The sensitivity of trees may indicate a loss of fine roots but also damage caused by insects and fungi (cf. NUORTEVA and LAINE 1968). For example, MAGILL and NORD (1963) have emphasized the role of insects in damaging trees on camping areas. The sensitivity of old trees to trampling may increase the insect and fungus damage problem on camping areas.

The reduction in radial growth was most rapid during the first couple of years following the opening of the camping area. Within ten years the reduction levelled off and the new growth level was 20–40 % lower than that before trampling. Only the reduction in radial growth was investigated but reduction in height growth may also occur. According to LAPAGE (1962), height growth is, however, not as sensitive to trampling as radial growth and hence its role in growth reduction may be negligible.

The capacity of the original forest vegetation seems to be too low to withstand the level of trampling prevailing in intensively used areas. Therefore proper planning and the carrying out of protective measures are necessary if the loss of the recreational value of a selected area is to be avoided. Trails, especially, are of importance (cf. KELLOMÄKI 1977). New camping areas should also be located in young stands and on coarse soils to avoid the high reduction in tree growth as suggested by the present results. On the other hand the trampling tolerance of fertile sites is higher than those investigated now, and thus their potential for minimizing the effects of trampling should be considered in the planning of new areas (cf. KELLOMÄKI and SAASTAMOINEN 1975, KELLOMÄKI 1977). The trampling tolerance of forest vegetation is, however, always lower than that of cultivated vegetation. Fertilization and other measures are not as widely applicable to forest ground cover as to cultivated vegetation (cf. CORDELL and TALHELM 1969, BEARSLEY and WAGAR 1971, KELLOMÄKI and SAASTAMOINEN 1975).

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SELOSTE:

MÄNNYN SÄDEKASVU JA MAAPERÄMUUTOKSET ERÄILLÄ ETELÄ-SUOMEN LEIRINTÄALUEILLA

Männyn sädekasvun suuruutta tutkittiin seitsemällä Etelä-Suomen leirintäalueella. Alueiden käyttöönoton jälkeen oli kasvussa tapahtunut selvää vähenemistä. Kymmenen vuoden kuluessa aleneminen oli keskimäärin 20–40 % kulumattomiin alueisiin verrattuna. Kasvun alenema korreloitui vaurioituneiden puiden määrän ja puiden keskimääräisen iän kanssa, ja se oli sitä suurempi mitä yleisempää vaurioituminen oli ja mitä vanhempaa puusto oli. Myös pintakasvillisuuden ja humuskerroksen tuhoutuminen sekä puiden juurten ja kivennäismaan paljastuminen olivat yleisiä, mutta ne eivät korreloituneet puiden kasvun alenemaan. Myös voimakasta kivennäismaan tiivistymistä havaittiin, mutta sen suora vaikutus kasvun alenemaan jäi epäselväksi.