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Vegetation and stand development of mesic forest after prescribed burning

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SELOSTE: KASVILLISUUDEN JA PUUSTON KEHITYS TUOREELLA KANKAALLA KULOTUKSEN JÄLKEEN

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This study deals with the succession of vegetation and tree stand in 16 mesic *Myrtillus* site type Scots pine plantations after prescribed burning in Evo, southern Finland. The oldest tree stands studied were about 30-years-old. The growth of trees followed the height site index of *Myrtillus* site type. The vegetation was first mesic, dominated by grasses and herbs, turning more xeric after four years. This change was accelerated by treatment with herbicides. After the closure of tree stand, vegetation became more characteristic of forest vegetation, but pioneer species and composition disappeared slowly. The basic characters of vegetation succession could be clearly described by DCA ordination and TWINSPAN classification. The study confirmed that *Myrtillus* site type has succession phases which are typical for each age phases as Cajander's forest site type theory has proposed. However, differences in primary and secondary site factors have their own effects on the vegetation of the succession phases.

Tutkimuksessa käsiteltiin kulotettujen mustikkatyypin männynviljelyalojen kehitystä Evolla. Puuston kehitys ja kasvillisuus kuvattiin 16 alalta kulotuskesäisistä n. 30 vuotta vanhoihin aloihin. Puuston kasvu noudatti MT:n pituusboniteettikäyrää. Kasvillisuudessa havaittiin ensin rehevän kasvillisuuden piirteitä. Herbisidikäsittelyjen jälkeen kulotetut alat muuttuivat karumman näköisiksi. Puuston sulkeutuessa kasvillisuus jälleen rehevöityi saaden metsäisemmät piirteet. Pioneerilajit säilyivät silti kasvillisuudessa pitkään. Kasvillisuussukkession peruspiirteet saatiin selkeästi kuvattua DCA-ordinaatiolla ja TWINSPAN-luokittelulla. Tutkimus osoitti, että Cajanderin metsätyyppijärjestelmää voidaan mainiosti selventää sukkessiosarjoilla. Ne on järkevintä perustaa sekä puuston kehitykseen että kullekin ikävaiheelle ominaisiin kasviyhdyskuntiin. Lisäksi on otettava huomioon maaperän ja ilmaston sekä metsänkäsittelyn aiheuttamat erityispiirteet.

Keywords: prescribed burning, succession, forest site types, boreal zone
ODC 434+182.2+568+54+114.521.7

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1. Introduction

Before silviculture was widely practiced in Finland Scots pine (*Pinus sylvestris*) was mostly regenerated after forest fires. Especially xeric coniferous forests are known to have burnt rather often (e.g. Högbom 1934, Haapanen & Siitonen 1978). It has been estimated that almost all pine stands encountered during the 19th century in Finland were situated on burned or slashed and burned areas (Heikinheimo 1915, Saari 1923, Kalela 1937). Due to fire suppression forest fires are rare today.

Prescribed burning is no longer widely carried out as a method to facilitate artificial regeneration and growth of new tree stands, being replaced by mechanical site preparation. Prescribed burning was most common in the 1950s, when the area burned annually was some 30000 ha. Today only some 1000s of ha are burnt.

The succession after prescribed burning consists not only of the growth of planted or seeded trees but also of naturally regenerated trees and herbs, the importance of which may be significant to the forester.

The aim of this study was to investigate the early succession of vegetation and development of tree stands after prescribed burning in mesic sites. The study was carried out in southern Finland and is part of a project looking into the ecology and structure of plant communities after prescribed burning (Ruuhijärvi et al. 1983, 1986).

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2. Study area

The study was carried out at Evo in the Lammi commune (61°12'N, 25°07'E, 140–180 m a.s.l.). The area is mostly covered by coniferous forests (*Pinus sylvestris* and *Picea abies*) representing forest types from *Vaccinium* site type (VT) to *Oxalis – Myrtillus* site type (OMT) (Cajander 1949) of different ages. The soils in the area are developed partly on till rich in boulders and partly on esker gravel deposits.

The Evo area lies in the southern boreal coniferous forest zone (Ahti et al. 1968) The climate is, in general, moderately continental (Tuhkanen 1980), but slightly hygric due to the relative altitude of the area. The yearly precipitation is 611 mm of which 313 mm falls during May-September (mean for 1931–1960, Helimäki 1967). The effective temperature sum (over +5°C) is 1150 d.d. °C (mean for 1931–1960, Kolkki 1966).

The Evo area was chosen because of its long tradition with prescribed burning. It was also possible to restrict the study sites to a small area in which the macroclimate does not vary much and the soil is rather homogenous among the sites.

3. Material

Sixteen *Myrtillus* site type (MT, see Cajander 1909, 1949) sites on till textured soil were chosen (Fig. 1, Table 1). According to forest management maps, MT site type cover approximately a quarter of the total forest area in the Evo area. The age of the burns ranged from less the 1-year to 27 years, with one site being 120-years-old. Prescribed burning is usually conducted one year after clear felling. For the burnings older than eight years there were no data available about the time lag. At the Iso Keltajärvi site (IK0) the time lag was two years.

After burning artificial regeneration (planting or sowing) with Scots pine was carried out at all but one site, Iso Keltajärvi B, where Norway spruce (*Picea abies*) was planted instead. The development of vegetation after burning was not undisturbed. The growth of seedlings was in most cases facilitated by mechanical and/or chemical control of grass and bush swards. Later the seedling stands had usually been cleaned and thinned (Table 1).

The vegetation of one mature spruce stand burned over 100 years ago on a mesic site representing typical MT vegetation near Lake Nimetön (61°13'N 25°11'E, 145 m a.s.l.) is described in Table 2.

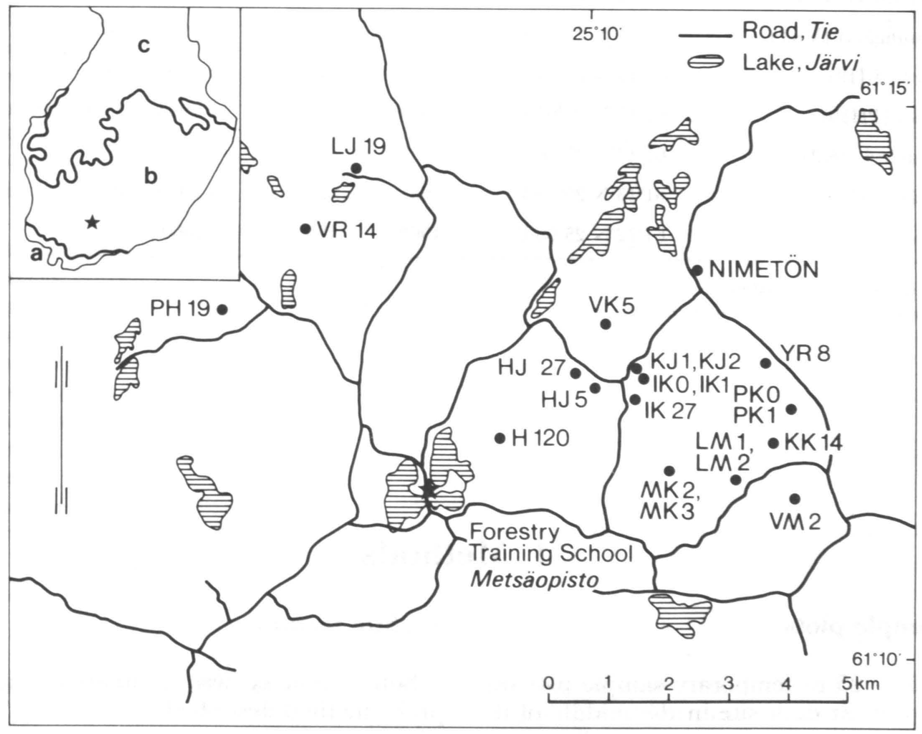

Figure 1. The location of the study areas. Forest vegetation zones: a) hemiboreal, b) southern boreal, c) middle boreal (Ahti et al. 1968).

Kuva 1. Tutkimusalojen sijainti. Metsäkasvillisuusvyöhykkeet: a) hemiboreaalinen, b) eteläboreaalinen, c) keskiboreaalinen (Ahti ym. 1968).

Table 1. Study areas and the works done on them. The numbers after abbreviations refer to years since burning. Other treatments: a = planting of pine, b = sowing of pine, c = planting of spruce, d = supplementary planting, e = thinning and cleaning of the stand, f = chemical treatment of the stand, g = chemical and mechanical treatment of the grass sward, h = fertilization, i = natural pine regeneration after burning.

Taulukko 1. Tutkimuskohteet ja niillä tehdyt toimenpiteet. Numero lyhenteen perässä ilmaisee kulotuksesta kuluneen ajan. Muut käsittelyt: a = männyn istutus, b = männyn kylvö, c = kuusen istutus, d = täydennysistutus, e = taimikon hoito, f = taimikon kemiallinen hoito, g = heiniminen, h = lannoitus, i = luonnonkulon jälkeen luontaisesti syntynyt mäntytaimikko.

Name of the site *Alueen nimi*	Location *Sijainti*	A)	B)	Other treatments *Muut käsittelyt*
Perikulma (PK0, PK1)	61°12'N 25°14'E	1982	0	a, b 1982, h 1969.
Iso Keltajärvi A (IK0, IK1)	61°13'N 25°11'E	1982	0	a 1982.
Iso Keltajärvi B (KJ1, KJ2)	— " —	1981	1	c 1981.
Latomäenmaa (LM1, LM2)	61°11'N 25°11'E	1981	1	a, b 1981.
Myllykorvenmaa (MK2, MK3)	61°11'N 25°11'E	1980	2	b 1980, f 1981.
Vahtermäki (VM2)	61°11'N 25°13'E	1980	2	a 1980, h 1969.
Vähä Keltajärvi (VK5)	61°13'N 25°10'E	1977	5	b 1977, d, g 1981.
Hankajärvi (HJ5)	61°12'N 25°10'E	1977	5	b 1977, d 1979, g 1980, h 1971.
Yliset Rajajärvet (YR8)	61°13'N 25°13'E	1974	8	b 1974, f 1976, e 1980.
Kuulakivenmaa (KK14)	61°12'N 25°13'E	1968	14	a 1968, d 1974.
Vähä Ruuhijärvi (VR14)	61°14'N 25°04'E	1968	14	a 1968, f 1972, e 1975.
Lapinjärvi (LJ19)	61°15'N 25°05'E	1963	19	a 1963, e 1968, f 1972.
Palohonka (PH19)	61°13'N 25°03'E	1963	19	a 1963, e, f 1970, 1979.
Iso Keltajärvi (IK27)	61°12'N 25°10'E	1955	27	a 1955, e 1977.
Horkkajärvi (HJ27)	61°13'N 25°10'E	1955	27	a 1955, e 1977.
Havinniitty (H120)	61°12'N 25°08'E	1960	120	i 1860

A) year of prescribed burning, *kulotusvuosi*
B) years since burning in 1982, *vuosia kulotuksesta 1982*

4. Methods

41. Sample plots

A 25 × 25 m temporary sample plot was established at each site in the middle of the site on a representative area avoiding moist paludified depressions, dry hillock tops and boulder-fields. The following measurements and observations were carried out on these plots.

42. Site factors

Soil stoniness was estimated using the probe method described by Viro (1952) from 64 systematic points in each plot. The bouldery indices were calculated and the plots were classified accordingly. Two of the plots represented bouldery index 2, where the stoniness is 30.1–60 %. In the other 14 plots the

Table 2. The cover of plant species in a mesic spruce stand at Evo. Mean of 30 one square meter relevés.
Taulukko 2. Evolaisen tuoreen kankaan kuusikon kasvilajisto peittävyyksineen. Keskiarvo 30:n 1 m²:n näytealasta.

Species *Laji*	Cover *Peittävyys*	Species *Laji*	Cover *Peittävyys*
Field layer – *Kenttäkerros*		Groud layer – *Pohjakerros*	
Betula pubescens	+	*Brachythecium* spp.	2
Calamagrostis arundinacea	10	*Bryum* spp.	+
Calluna vulgaris	+	*Ceratodon purpureus*	+
Carex digitata	+	*Cladonia* spp.	+
Convallaria majalis	2	*Dicranum fuscescens*	+
Deschampsia flexuosa	1	*D. majus*	2
Epilobium angustifolium	+	*D. polysetum*	2
Geranium sylvaticum	+	*D. scoparium*	3
Goodyera repens	+	*Hepaticae*	1
Gymnocarpium dryopteris	+	*Hylocomium splendens*	6
Hieracium vulgatum	+	*Hypnum cupressiforme*	+
Hypocoeris maculata	+	*Plagiothecium* spp.	+
Lathyrys pratensis	+	*Pleurozium schreberi*	50
Linnaea borealis	2	*Pohlia nutans*	+
Luzula pilosa	+	*Polytrichum commune*	+
Lycopodium clavatum	+	*P. juniperinum*	+
Maianthemum bifolium	4	*Ptilium crista-castrensis*	+
Melampyrym pratense	+	*Rhodobryum roseum*	+
M. sylvaticum	3	*Rhytidiadelphus triquetrus*	+
Melica nutans	+	*R. squarrosus*	+
Orthilia secunda	1	*Sanionia uncinata*	+
Oxalis acetosella	+		
Picea abies	1		
Platanthera bifolia	+		
Populus tremula	+		
Pteridium aquilinum	+		
Rubus saxatilis	1		
Salix phylicifolia	+		
Solidago virgaurea	+		
Sorbus aucuparia	+		
Trientalis europaea	1		
Vaccinium myrtillus	20		
V. vitis-idaea	7		
Vicia sepium	+		
Viola riviniana	+		

stoniness was 60.1–100 % (bouldery index 3).

Particle size analysis of mineral soil was made in nine of the plots. The soil represented gravel till to gravelly fine-sand till (SrMr – srHtMr, Virkkala 1969).

The intensity of burning could be estimated only on those sites where prescribed burning had been carried out within the last few years. It was estimated visually by a) the percentage of slash burned, b) the proportion of needles and humus burned, and c) the proportion of perennial vegetation burned. In cases where the amount of slash burned was under 50 % the intensity of the burn was considered low (less than 300 kW/m). In cases where the amount of slash burned was approximately 70 % the intensity of the burn was considered high (more than 1000 kW/m) (Vasander & Lindholm 1985: tables 1, 3).

The herbicides used on the sites were glyfosate (trade-mark Round-up) and terbutylatzine (trade-mark Cardoprim). Cardoprim is used against grasses and herbs and Round-up also against bushes e.g. on areas with abundant poplar (*Populus tremula*) saplings.

43. Tree stands and seedlings

The tree stands on those sites where the prescribed burning was carried out more than ten years ago were described. Crown cover on a scale: 0, 10, 20, . . . , 90, 100 where 0 is open and 100 fully stocked was estimated. Breast height diameter (D1.3) was measured with calipers from all trees at least 2 m high. Stem frequency distribution series were drawn, and based on them three average trees were chosen for further measurements. The total volume of the tree stand was estimated according to the volume of the average trees (Ilvessalo 1947).

The mean height of the stands was based on the average trees. As the development of stands is often expressed by dominant height (Vuokila & Väliaho 1980), also the relationship between mean height and dominant height was estimated by Kallio's (1960: table 2) data. The form of the relationship was for trees shorter than five metres:

$$y = 1.16 + 0.90x, r = 0.998, P \leq 0.001, n = 3 \qquad (1)$$

and for trees longer than five metres:

$$y = 2.03 + 1.00x, r = 0.989, P \leq 0.001, n = 73 \qquad (2)$$

where y is dominant height and x mean height.

The development of naturally regenerated bushes and tree seedlings or saplings was analyzed on sub-sample plots (10×10 m) inside the tree stand sample plot. The cover of bush and tree species 0.3–2 m high was estimated. Lower seedlings and sprouts were analyzed as part of the field layer. Measuring of the tree stands and seedlings was made in July 1982.

44. Vegetation

The percentage cover of species in ten 2 × 2 m relevés was estimated randomizing by dividing the circle centred on the middle of the plot into 50 sectors. Ten sectors were chosen randomly and the relevé was placed at the distance of ten meters from the centre of the circle. If stones covered more than 50 % of the area of the relevé then it was moved two meters further along the same sector. The following percentages were used: + (present), 1, 2, 3, 5, 10, 15, 20, . . . , 80, 85, 90, 95, 97, 98, 99 and 100. The data from the relevés on each plot were combined for further analyses. Vegetation analyses were made in July 1982 and repeated for the youngest plots (0, 1 and 2 years from burning) in July 1983.

Detrended correspondence analysis (DCA) was used to ordinate the vegetation data (Hill 1979a, Hill & Gauch 1980, Gauch 1982). Species occurring three times or less were omitted. TWINSPAN (Hill 1979b) was used to classify the plant species and relevés. Species occurring only once were omitted. The percentage cover values were transformed to 9 pseudospecies in logarithmic scale with the following cut levels: 0, 0.41, 0.83, 1.56, 3.13, 6.25, 12.6, 26, and 51.

The diversity of species composition was calculated by the Shannon-Wiener formula (Shannon & Weaver 1949):

$$H' = \sum_{i=1}^{S} p_i \ln p_i \qquad (3)$$

where H' is the diversity index, S the number of species and p_i the proportional cover of each species.

The nomenclature follows Hämet-Ahti et al. (1984) for vascular plants, Koponen et al. (1977) for mosses and Ahti (1979) for lichens.

5. Results

51. Tree stand

The height of trees increased evenly. In the age of 14 years the height was 3.5–4 m, in 19 years 6.5–7 m and in 27 years 9–11 m (Fig. 2). Thus the mean annual height increment had been approximately 40 cm to the age of 27 years. After ten first years the mean annual height increment had been approximately 50 cm.

In the age of 14 years the stand volume was 10–17 m^3/ha, five years later 48–60 m^3/ha and again eight years later 118–121 m^3/ha (Fig. 2). The mean annual increase in stem volume had thus been approximately 4.5 m^3/ha calculated from the oldest stands studied.

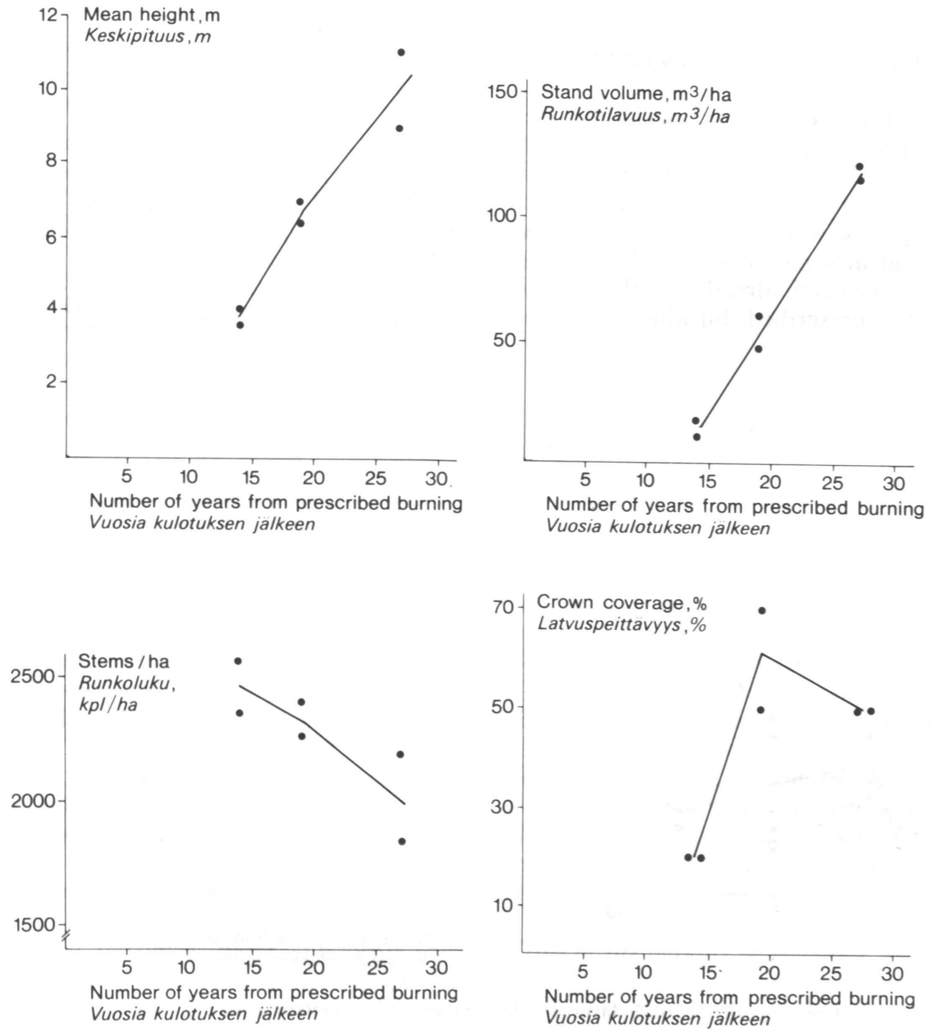

Figure 2. Mean height, volume, stem number, and crown coverage of the tree stands at the studied areas.

Kuva 2. Puuston keskipituus, runkotilavuus, runkolukumäärä ja latvuspeittävyys tutkituilla aloilla.

In Kuulakivi plot (KK14) there was 1 m^3/ha and in Iso Keltajärvi plot (IK27) 16.5 m^3/ha birch (mainly *Betula pendula*) among pine. This represented, however, rather small amount of the total volume (10 and 14 % respectively).

After 14 years from planting the canopy density was still low (Fig. 2). It increased during the succession but due to thinnings lowered again at the age of 27 years (Fig. 2). The amount of stems decreased also from approximately 2500/ha on 14-year-old plots to 2000/ha on 27-year-old plots (Fig. 2).

52. Development of seedlings and bushes

The naturally regenerated deciduous tree seedling species encountered in the study plots were: *Sorbus aucuparia, Betula pendula, B. pubescens, Populus tremula* and *Salix caprea*. Coniferous species were: *Picea abies, Juniperus communis* and in some areas also *Pinus sylvestris*. *Sorbus* occurred already in the second season after prescribed burning. In some areas this was also the case with *Betula pendula, B. pubescens* and *Populus tremula*. After eight years *Picea abies* was a constant component in the seedling layer. *Pinus sylvestris* and *Salix caprea* usually occurred after ten years. However, they were not constant species.

During the three first years after prescribed burning there was a rapid increase in the cover of seedling and bush layer. The further development was limited by mechanical or chemical treatments. The total cover was about 10 % at the age of 27 years (Fig. 3).

53. Vegetation and flora

Ordination of species and sites

Axis 1 of the DCA species ordination (Table 3) is interpreted as a succession age gradient and axis 2 as a moisture (mesophilic-xerophilic) gradient. *Marchantia polymorpha, Epilobium collinum, Viola rupestris, Rubus idaeus* and *Ceratodon purpureus* were in the higher end of the first axis while *Hylocomium*

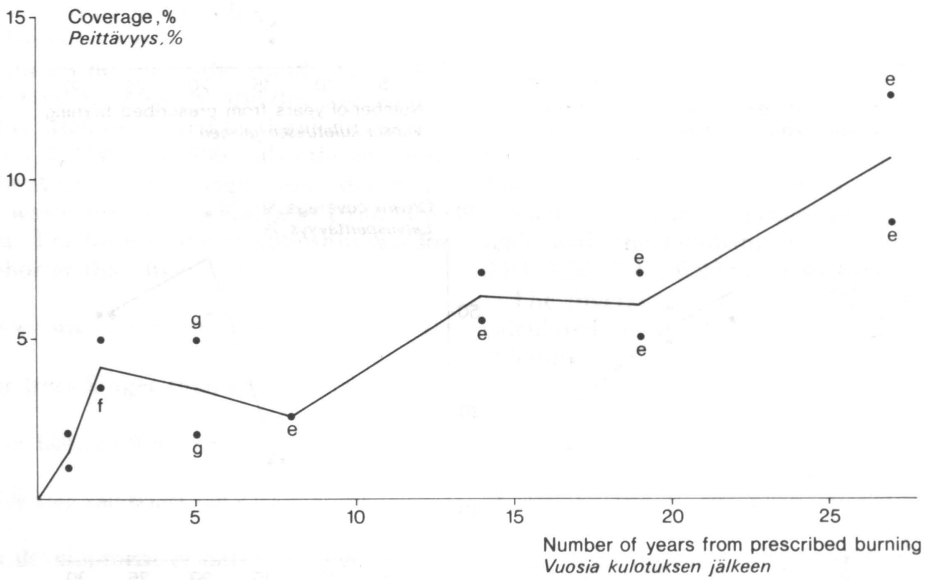

Figure 3. Coverage of the bush layer on the studied areas. Letters denote to the following treatments: e) thinning and cleaning of the stand, f) chemical treatment, g) chemical and mechanical treatment, (cf. Table 1).

Kuva 3. Pensaskerroksen peittävyys tutkituilla aloilla. Kirjaimet viittaavat seuraaviin toimenpiteisiin aloilla: e) taimikon hoito, f) taimikon kemiallinen hoito, g) heiniminen, (vrt. Taul. 1).

Table 3: Ranked DCA scores for ten species with the highest and lowest score values on the first two ordination axes. The species included in the analysis numbered 68. No logarithmic transformation of the data or downweighting of rare species performed.

Taulukko 3: Kymmenen korkeinta ja alhaisinta DCA-latausarvoa saanutta lajia kahdella ensimmäisellä DCA-akselilla. Aineiston logaritmimuunnosta tai harvinaisten lajien painon vähentämistä ei ole tehty.

Axis 1 – *Akseli 1* (eigenvalue, *ominaisarvo* 0.297)	Score *Lataus*	Axis 2 – *Akseli 2* (eigenvalue, *ominaisarvo* 0.090)	Score *Lataus*
Marchantia polymorpha	4451	*Pinus sylvestris*	4144
Epilobium collinum	4265	*Pteridium aquilinum*	3632
Viola rupestris ssp. *rupestris*	4089	*Cladonia coniocrea*	3416
Salix spp.	3792	*Lycopodium annotinum*	3202
Rubus idaeus	3586	*Calluna vulgaris*	2821
Vicia sylvatica	2781	*Diphasiastrum complanatum* spp. *complanatum*	2670
Rumex acetosa	2725	*Cladonia cenotea*	2571
Ceratodon purpureus	2648	*Taraxacum* spp.	2491
Carex digitata	2564	*Cladonia botrytes*	2442
Luzula pilosa	2405	*Cladonia arbuscula*	2270
Cladonia furcata	– 751	*Sorbus aucuparia*	–1400
Pleurozium schreberi	– 757	*Epilobium collinum*	–1608
Diphasiastrum complanatum ssp. *complanatum*	– 778	*Pyrola* spp.	–1805
Hieracium vulgatum	– 818	*Geranium sylvaticum*	–2328
Dicranum polysetum	– 872	*Hypocoeris maculata*	–2348
Cladonia arbuscula	– 923	*Hieracium sylvaticum*	–2493
Platanthera bifolia	– 981	*Goodyera repens*	–2498
Goodyera repens	–1409	*Fragaria vesca*	–2673
Pyrola spp.	–1455	*Marchantia polymorpha*	–2810
Hylocomium splendens	–1475	*Rhodobryum roseum*	–3759

splendens, Pyrola spp., Goodyera repens, and *Platanthera bifolia* were in the lower end. *Rhodobryum roseum, Marchantia polymorpha, Fragaria vesca* and *Goodyera repens* were in the lower end of axis 2 while such species as *Pinus sylvestris, Lycopodium annotinum, Pteridium aquilinum,* and *Cladonia coniocrea* were in the higher end.

Age elapsed since burning was the main factor in separating sites in the site DCA ordination (Fig. 4). TWINSPAN analysis divided the sites into four groups: young (0–3 years from burning), older still open (5–8 years from burning), young forested (14–27 years from burning) and mature (120 years from burning) sites (Figs. 4, 5). In the first group, typical species were those in the higher end of the first DCA-axis. The second TWINSPAN group was characterized by xerophilic vegetation. Characteristic species were *Calluna vulgaris, Vaccinium vitis-idaea* and *Cladonia* spp. In the vegetation of the third TWINSPAN class the proportion of grasses and herbs again increased and also some plants of mature forest thrived, for example, *Vaccinium myrtillus, Dicranum polysetum* and *Pleurozium schreberi*. The fourth TWINSPAN class was characterized by typical species of mature mesic forests.

Effect of fire intensity on vegetation

The Perikulma site (PK0) burned with low fire intensity. Thus many of the forest species were left immediately after burning. It received a relatively high score value along the first DCA axis compared to the other young

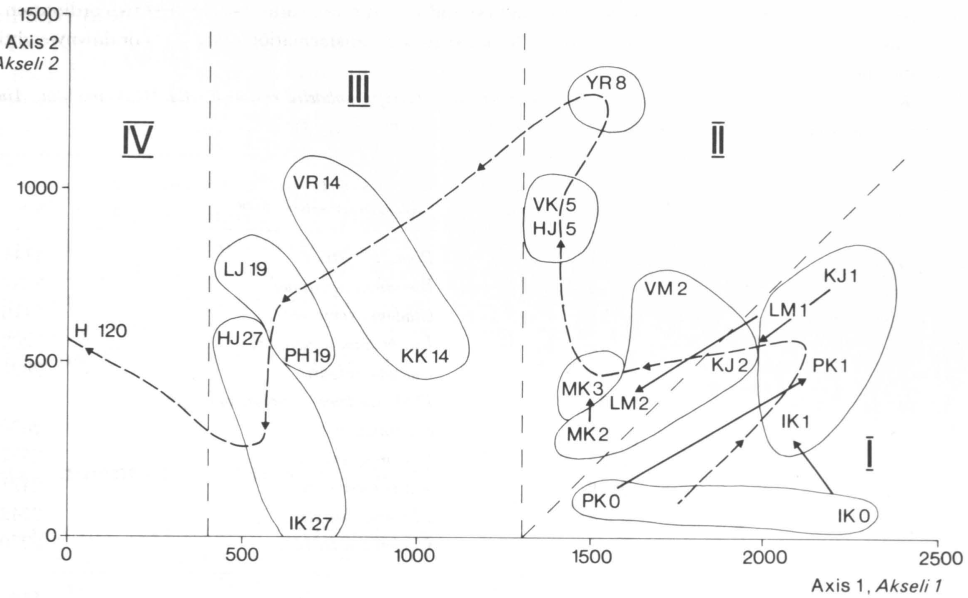

Figure 4. A DCA ordination of the study material (two first axes of the ordination) based on the abundance of field and ground layer plant species. Also the classes created by TWINSPAN (I–IV) are marked. Areas representing the same number of years from burning are separated inside lines. Areas analyzed during succeeding years are marked by arrows. A dashed line with arrows unites the areas in increasing age from the prescribed burning.

Kuva 4. Tutkimuskohteiden DCA-ordinaatio (analyysin kaksi ensimmäistä akselia) kenttä- ja pohjakerroksen lajistopeittävyyksien perusteella. Myös TWINSPAN-luokat (I–IV) on merkitty. Samanikäiset kulotusalat on yhdistetty viivoituksen sisään. Peräkkäisinä vuosina analysoidut alat yhdistetty nuolin. Paksunnettu katkoviiva nuolineen yhdistää alat kasvavassa ikäjärjestyksessä kulotuksesta lähtien.

sites (Fig. 4). The Iso Keltajärvi A site (IK0) burned with high fire intensity and thus the amount of forest species is low (Fig. 4).

The fire intensity at the Iso Keltajärvi B site (KJ1) was high. Two years after prescribed burning the site was dominated by *Epilobium angustifolium* and *Rubus idaeus*, and other species typical for young succession phases were also present (Fig. 4). However, later in the succession differences caused by fire intensity diminish due to different silvicultural treatments (Table 1) and tree stand development.

Effect of herbicides on the vegetation pattern

On recently treated sites the vegetation had a xerophilic pattern. The five-year-old sites (HJ5, VK5) and the eight-year-old site (YR8) were thus located at the higher (drier) end of DCA axis 2 (Fig. 4). The vegetation cover was also more open as the abundance of grasses and herbs had decreased (Figs. 6, 7). Herbicide treatment did not affect the cover of dwarf shrubs (Fig. 8). The cover of small akrocarpous mosses (*Ceratodon purpureus, Polytrichum strictum*) increased after prescribed burning and was highest in recently treated sites. However, the variation between the sites was great (Fig. 9).

Changes in diversity

Total number of plant species in all sites was 85; 59 vascular plants and 26 bryophytes and lichens. The number of species was lowest (10–15) just after prescribed burning (Fig. 10). The number of species increased

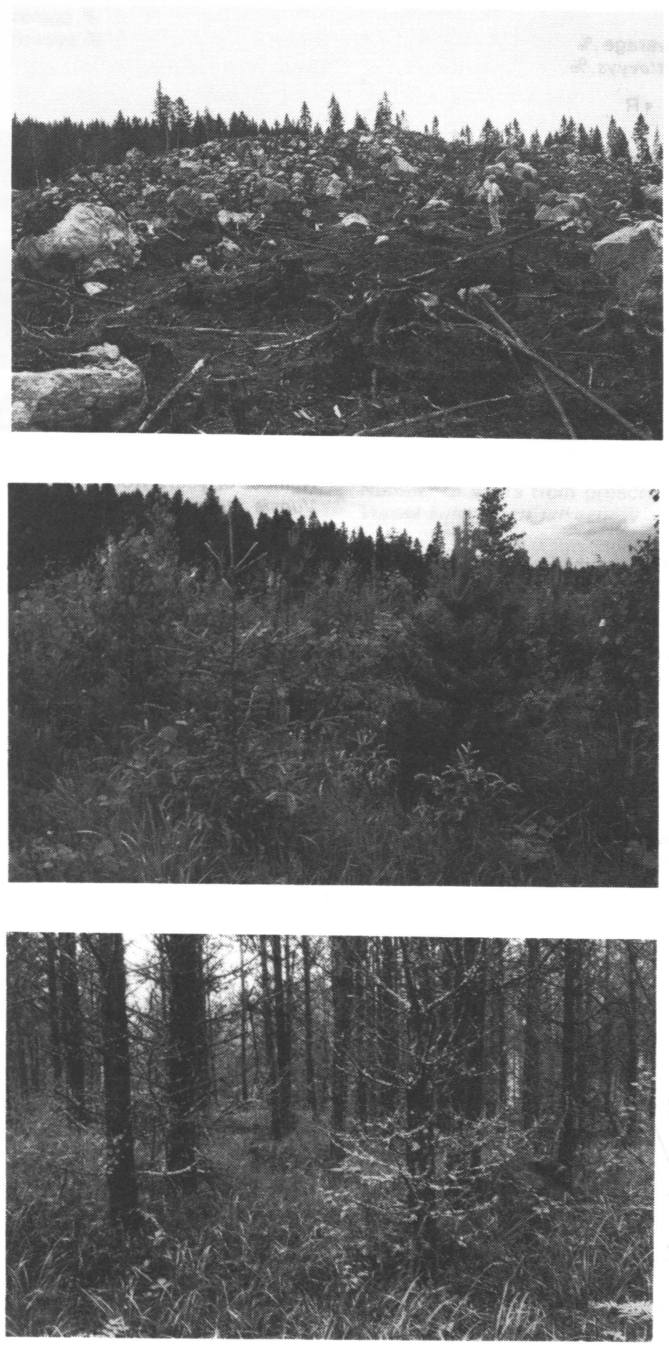

Figure 5. Typical examples of areas representing the three first TWINSPAN groups: IK0, YR8 and HJ27. Photos: Markku Nironen, July 1982.

Kuva 5. Kolmen ensimmäisen TWINSPAN-luokan edustajat: IK0, YR8 ja HJ27. Kuvat: Markku Nironen, heinäkuu 1982.

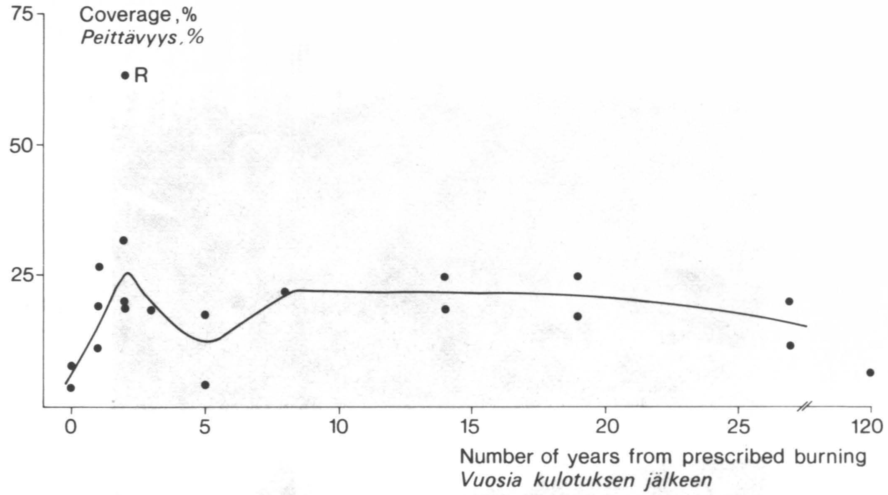

Figure 6. The summed coverage of herbs on the studied areas. Line uniting the areas has been fitted by eye. The plot with a dense cover of *Rubus idaeus* (R) has not been included in this fitting.

Kuva 6. Ruohojen kokonaispeittävyys tutkituilla kulotusaloilla. Aloja yhdistävä käyrä piirretty silmävaraisesti huomioimatta alaa, jossa vadelma muodosti peittävän kasvuston (R).

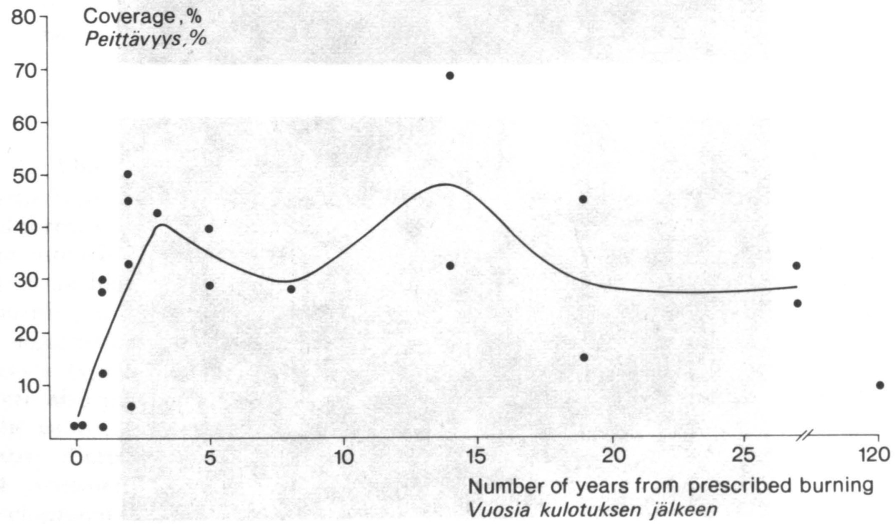

Figure 7. The summed coverage of grasses on the studied areas. Line uniting the areas has been fitted by eye.

Kuva 7. Heinien yhteispeittävyys tutkituilla kulotusaloilla. Aloja yhdistävä käyrä piirretty silmävaraisesti.

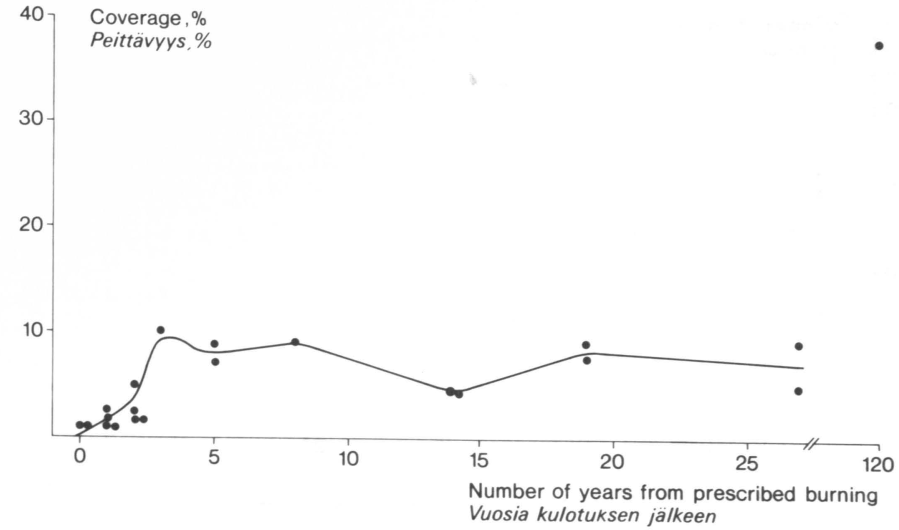

Figure 8. The summed coverage of dwarf shrubs on the studied areas. Line uniting the areas has been fitted by eye.

Kuva 8. Varpujen kokonaispeittävyys tutkituilla kulotusaloilla. Aloja yhdistävä käyrä piirretty silmävaraisesti.

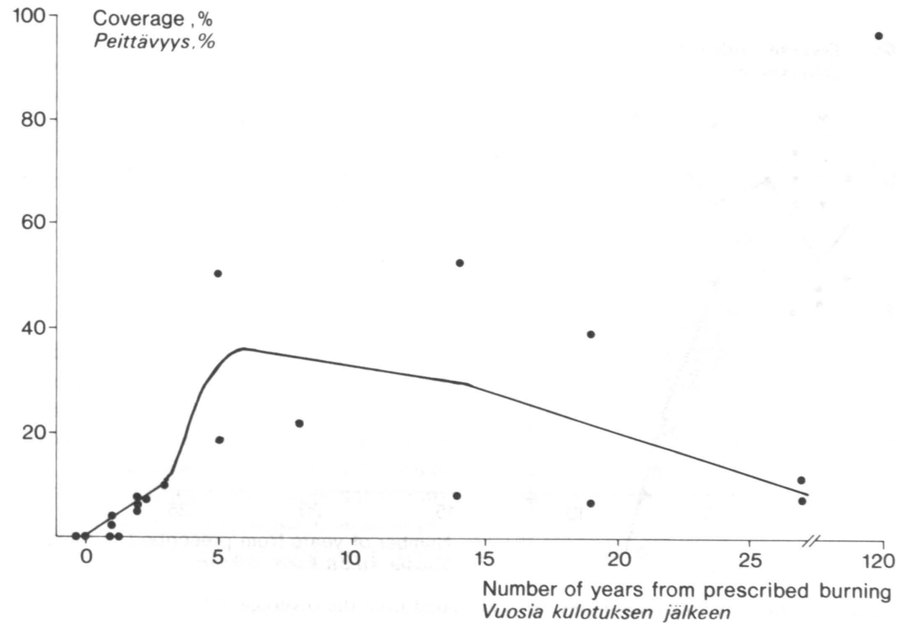

Figure 9. The summed coverage of mosses on the studied areas. Line uniting the areas has been fitted by eye.

Kuva 9. Sammalten yhteispeittävyys tutkituilla kulotusaloilla. Aloja yhdistävä käyrä piirretty silmävaraisesti.

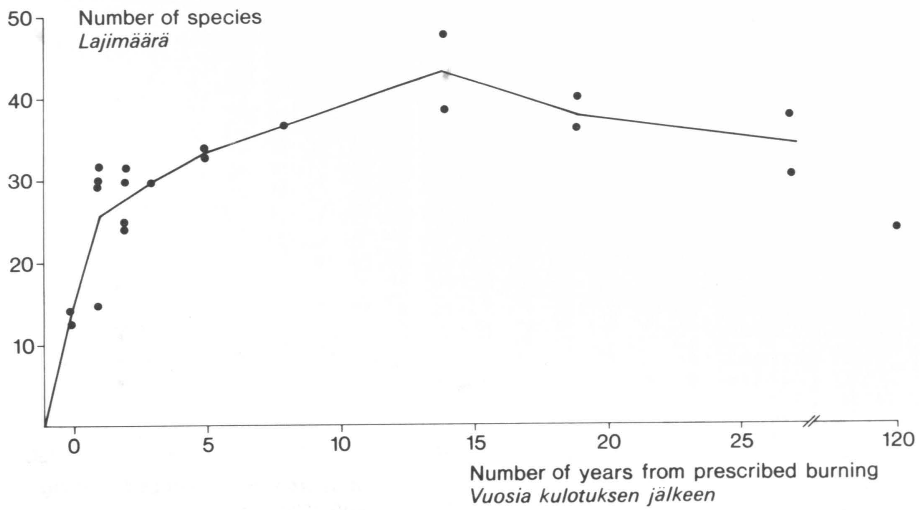

Figure 10. Number of plant species in the field and ground layers of the studied areas (measured on an area of 10 × 4 m^2). Line uniting the areas has been fitted by eye.

Kuva 10. Kenttä- ja pohjakerroksen yhteenlaskettu lajimäärä tutkituilla aloilla (mitattu 10 × 4 m^2:n alalta). Aloja yhdistävä käyrä piirretty silmävaraisesti.

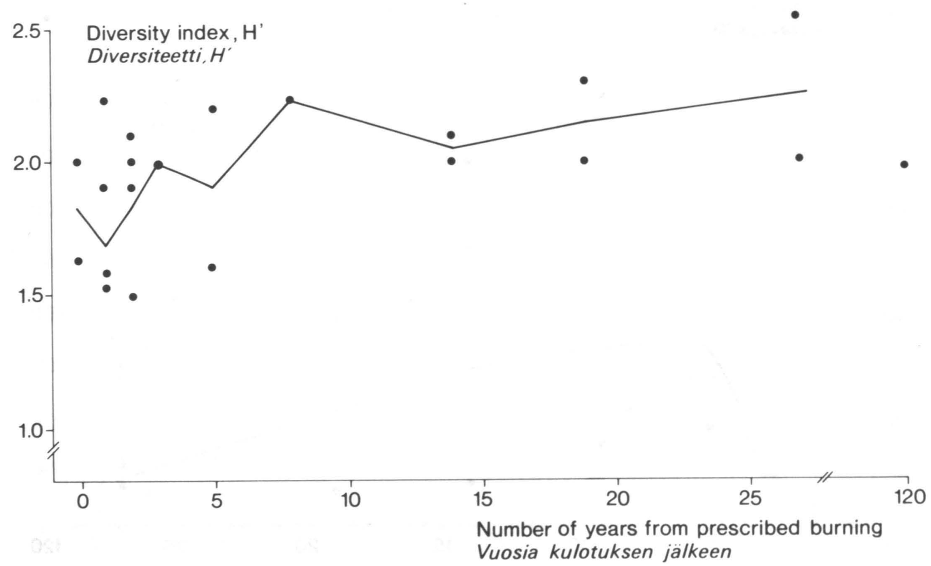

Figure 11. Diversity (Shannon-index, H') calculated from the coverage of field and ground layer species. Line uniting the areas has been fitted by eye.

Kuva 11. Tutkittujen alojen kenttä- ja pohjakerroslajien peittävyyksistä laskettu diversiteetti (Shannon-indeksi, H'). Aloja yhdistävä käyrä piirretty silmävaraisesti.

with the number of years since prescribed burning and was highest (40–50) on 15-year-old sites; afterwards the number of species started gradually to decline (Fig. 10).

The diversity (H') index was 1.5–2.0 immediately after prescribed burning and increased during the first ten years after burning (Fig. 11). Variation between plots was, however, great. The change in H' was greatest during the first years and later no major changes occurred (Fig. 11).

6. Discussion

61. Development of the tree stand

Although the number of studied stands was small, it can be noticed that the early height development had been fast. Evo area is stony and relatively humid. The site index (H_{100}) of the stands studied was between H_{100}=27 m and H_{100}=30 m which are usually considered to be index values for *Myrtillus* (MT) and *Oxalis – Myrtillus* (OMT) site types (Vuokila & Väliaho 1980). The early height development was comparable to that measured for pine stands on burnt-over land in Vesijako near Evo already by Vuori (1913) as also to more thorough analyses of young Scots pine stands conducted in southern and eastern Finland (Fig. 12). The other inventories presented in figure 12 were conducted on MT except Varmola's (1982) study which concerned *Vaccinium* site type (VT). However, half of his pine stands were established on burnt-over land. He concluded that prescribed burning, which has been found to improve the properties of the soil (e.g. Viro 1969), may be the reason for the fast early development of the seedlings. In that study

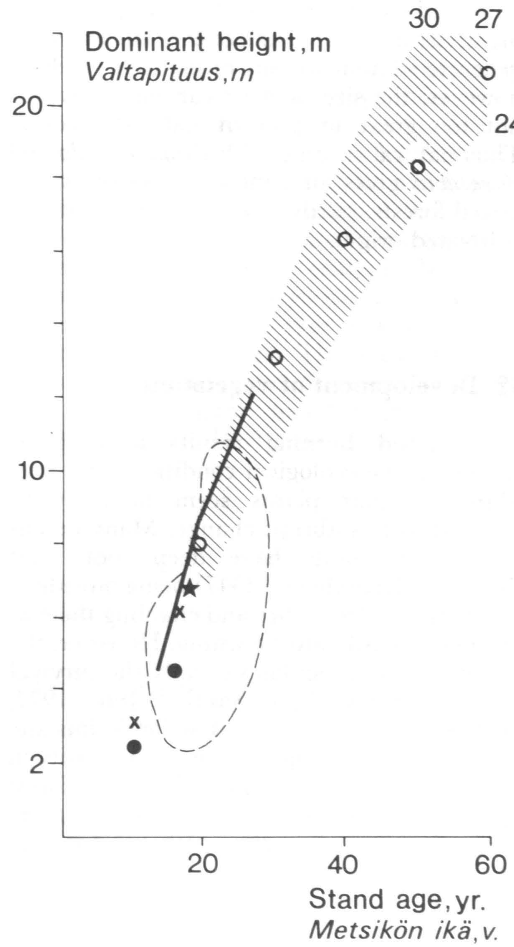

Figure 12. Height bonity of the studied pine stands (black line) compared to the height bonity classes of Vuokila & Väliaho (1980, shadowed area) and some earlier inventories: o = Kallio (1960), x = Leikola et al. (1977), ★ = Parviainen (1979), ● = Rautiainen & Räsänen (1980), area inside the broken line = Varmola (1982). The relationship between mean height and dominant height calculated according to equations 1 and 2.

Kuva 12. Tutkittujen kulotusaloille perustettujen mäntymetsiköiden pituusboniteetit (musta viiva) verrattuna Vuokilan & Väliahon (1980) pituusboniteettiluokkiin (varjostus) sekä muutamiin aiempiin tutkimuksiin: o = Kallio (1960), x = Leikola ym. (1977), ★ = Parviainen (1979), ● = Rautiainen & Räsänen (1980), katkoviivoitettu alue = Varmola (1982). Keskipituudet muutettu valtapituuksiksi yhtälöiden 1 ja 2 perusteella.

the VT sites (H_{100}=24 m, Vuokila & Väliaho 1980) obtained site indices H_{100}=27 m and even H_{100}=30 m (Fig. 12).

Huss and Sinko (1969) noted that the benefits of prescribed burning on height development diminish when the time lag between burning and stand establishment increases. On the sites they studied the benefits of prescribed burning on early height growth were observed even though seeding had been conducted five years after burning. On dry and poor sites the effect of burning has always been negative on account of burning the thin humus layer (Uggla 1967).

The burnt-over areas at Evo had many of naturally regenerated seedlings. Burnt-over areas are known to be good regeneration sites for seeds (Sarvas 1937, 1950, Lehto 1956, Yli-Vakkuri 1961). However, as the effective distance of tree seed dispersal is only some times the height of the trees (Kotisaari 1982, Lindholm & Tiainen 1982), wide prescribed burning areas may not satisfactorily naturally regenerate without seeding or planting. At Evo, however, the size of the clear-cut areas was not too great to prevent natural seeding. Thus natural seeding with *Betula pendula* and *Picea abies* gives an option in silviculture for mixed forests, partly of natural and partly of cultivated origin.

62. Development of vegetation

Prescribed burning results in a great change in the ecological conditions of a site. Many vascular plants seem to be well-adapted to this abrupt change. Many perennial forest plants have deep roots and rhizomes (Kivenheimo 1947) being outside of the thermal effect of fire and enabling them to regenerate easily after burning. However, the intensity of fire regulates greatly the survival of plants (Kujala 1926, Smith & Jones 1972, Shafi & Yarranton 1973). The Perikulma site (PK0) was an example of low fire intensity in our data. The proportion of mature forest species was thus high after burning and in the ordination this site received "old" loading. Within a site there is also variation in fire intensity causing also variation in the vegetation (Vasander & Lindholm 1985; Table 1).

The other component of vegetation on burned sites are invading species (e.g. *Epilobium collinum, E. angustifolium, Viola canina* ssp. *montana* and *V. rupestris*). Some of these species may also arise from the germination of old subsoil seeds (e.g. Kellman 1970, Archibold 1978). Examples of these at Evo were *Rubus idaeus, Rumex acetosella* and *Luzula pilosa* (Kujala 1926, Graber & Thompson 1978, Granström 1982). *Calluna vulgaris* seedlings were numerous one and two years after prescribed burning. These probably arose also from viable seeds lingering in the surface humus layer. In mature mesic forests in the Evo area *Calluna* seldom thrives but the viability of its seeds is promoted by heating (Whittaker & Gimingham 1962).

Herbicides killed certain species giving the impression of a xerophilic environment. It has been noted that herbicides have no or a very small effect on bryophytes and lichens (Moilanen 1976, Raatikainen & Mustonen 1977, Sieppi 1986). Moilanen (1976) even found that the growth of lichens increased after herbicide treatment when field layer species decreased in abundance. Some dwarf shrubs (e.g. *Vaccinium vitis-idaea*, Raatikainen 1978) may also benefit when the amount of light reaching the ground increases after a decrease in herbs and grasses. The general xerophilic vegetation character of burned areas (e.g. Lehto 1969, Kujala 1979) was thus accelerated by grass and herb control.

Changes in diversity measured either as changes in species number or Shannon's H' were small. The small peak in species number encountered on the areas of 14–19 years after prescribed burning is due to the occurrence of both pioneer species colonizing after burning and climax species occurring on the site. Shading by developing pine stands suppresses the dominants in floor vegetation and the heterogenic light environment makes it possible for both pioneer and climax species to establish themselves (Linkola 1916, Cajander 1925, Keltikangas 1959, Whittaker 1972, Bazzaz 1975).

Due to the lower seedlings density, planted pine stand canopies close-up some 15 years later than naturally seeded ones (Hari et al. 1982). Thus light conditions enable some heliophilous plant species to survive much longer than in natural pine stands and spruce forests where their amount is drastically decreased after 20 years from clear felling (Kellomäki et al. 1977). The ground vegetation in later phases of the succession is also heavily dependent on the dominant tree species (pine – spruce) on sites representing the same site type (Kuusipalo 1985). So a forest plant community reaches its maximum diversity in the early forest stage when both shade-tolerant and light-demanding species and many kinds of physiognomical groups are present in the same plant community (Margalef 1969, Jukola-Sulonen 1983).

63. Succession and forest site type theory

The succession of vegetation on mesic sites after prescribed burning studied is relevant to the Finnish forest site type theory because the Finnish concept *Myrtillus* site type was developed according to the vegetation in these same forests at Evo some 80 years ago (Cajander 1909: 103–105) but also because of the need for information concerning forest plant associations in young silviculturally treated forests representing different forest site types (Cajander 1925, Keltikangas 1959).

Our limited data of vegetation and stand development indicate a clear vegetation pattern in each phase of the succession and that age classes can be identified based on that pattern. In the beginning of the succession the vegetation may resemble a better site type with the abundance of grasses and herbs (Cajander 1925: 71–78). After herbicide treatments the vegetation may resemble that of poorer site types. The primary site factors remain unaltered and areas can be identified as original site type according to the vegetation. Exceptions to this may be e.g. heavy burns on xeric coniferous forests (Cajander 1909: 174).

The distinction between the concepts of forest site type and forest plant association type must also be kept in mind. The same stand in different stages of growth e.g. sapling, thicket and saw timber stage represents different plant association types (Cajander 1949). Different plant association types should also be separated in stands of different tree species and in stands with different silvicultural history (Cajander 1949) as, for example, prescribed burning, herbicide treatment and change of cultivated tree species. The differences in primary site factors due to the differences in soil characters and climatic conditions may lead to differences in succession pattern (Keltikangas 1959). Thus differences in succession between different stands described as *Myrtillus* site type may occur (e.g. Sirén 1955, Keltikangas 1959). At Evo the relative elevation may be a local ecological character that is often forgotten in Finnish site type research (Keltikangas 1959).

The growth of trees is also characteristic to the site as measured, for example, by height classes. Tree stand development is heavily dependent on the site type but it does not determine the site type. The optimal way in forest site type determination is to use vegetation and tree stand together (Keltikangas 1959, Kuusipalo 1985).

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Total of 65 references

Seloste

KASVILLISUUDEN JA PUUSTON KEHITYS TUOREELLA KANKAALLA KULOTUKSEN JÄLKEEN

Lammin kunnassa sijaitsevalla Evon metsäalueella on pitkät perinteet metsien taloudellisessa hyödyntämisessä. Siellä on myös pitkään yhtäjatkoisesti harjoitettu kulotusta silloinkin, kun sen suosio on ollut vähimmillään.

Tässä Suomen Luonnonvarain Tutkimussäätiön rahoittamassa tutkimuksessa on tutkittu Cajanderin tuoreen kankaan mustikkatyypiä (MT) vastaavien kulotettujen alojen kasvillisuuden sekä niille perustettujen männiköiden kehitystä vasta kulotetuista aloista 30-vuotisiin metsiköihin. Tutkitut kohteet sijaitsivat Evon valtionpuistossa suhteellisen suppealla alueella. Tiedot aloilla suoritetuista toimenpiteistä saatiin metsähallituksen Hämeenlinnan hoitoalueen arkistoista.

Kaikki kohteet olivat kivisiä. Viron (1952) kivisyysindeksillä mitattuna suurin osa edusti kivisintä luokkaa. Pohjamaan raekoko vaihteli soramoreenista soraiseen hietamoreeniin. Äskettäin kulotettujen alojen kulotustehokkuus arvioitiin humuskerroksen paksuuden ja palaneiden hakkuutähteiden perusteella. Eräitä aloja oli suhteellisen äskettäin käsitelty glyfosaatilla (Round-up) ja terbutylatsiinilla (Cardoprim).

Puusto mitattiin eri ikäisiltä kuloaloilta 25×25 m:n kokoiselta kertakoealalta. Puustosta mitattiin runkopuun kuutiomäärä, runkoluku, latvuspeittävyys ja keskipituus, joka vertailun suorittamiseksi muunnettiin myös valtapituudeksi. Pensaat ja luontaisesti uudistuneet puuntaimet mitattiin 10×25 m:n kertakoealalta. Kasvillisuus tutkittiin prosenttipeittävyytenä kymmeneltä 2×2 m:n kertakoealalta, joiden tiedot yhdistettiin analyysejä varten. Kasvillisuustiedot analysoitiin DCA-ordinaatio- ja TWINSPAN-luokitteluohjelmilla. Kavillisuuden diversiteetti esitettiin lajimäärän ja Shannon-Wiener -indeksin avulla.

Puuston kasvu oli tasaista eri aloilla ja kulotuksesta kulunut aika oli määräävin tekijä eri alojen puustojen välillä. Pituuden mukaan arvioituina Evon alat edustavat hyvin hoidettua MT:n männikköä. Luontaisesti syntynyttä puustoa muodostui myös aloille, mutta harvennusten ja vesakontorjunnan ansiosta sen määrä jäi pieneksi. Paikoin oli kuitenkin n. 10 %:n koivusekoitus männikössä.

Kasvillisuus käy 30:n ensimmäisen kulotuksenjälkeisen vuoden aikana läpi suuren muutoksen. Alojen välillä oli eroja palotehokkuuden, herbisidikäsittelyjen, taimikonhoidon kuten myös alojen omien piirteiden suhteen. Kuitenkin selkeimmäksi alojen kasvillisuuden luonnetta selittäväksi tekijäksi osoittautui niiden ikä suhteessa kulotukseen. Ryhmittelyssä alat jakaantuivat selviin sukkessioluokkiin. Nuorimmilla aloilla näkyi selvästi myös palotehokkuuden vaikutus (kuva 4). Kulotus ei koskaan tuhoa kaikkea kasvillisuutta, mutta monivuotisten metsäkasvien runsaus aivan kulotuksen jälkeen on suhteessa palotehokkuuteen.

Sukkession alkuvaiheessa kasvillisuutta leimaavat monet pioneerilajit, ruohot ja sammalet. Ne väistyvät kasvillisuudesta vähittäin puuston sulkeutuessa. Metsäsammalet yleistyvät vasta puuston sulkeutuessa. Kasvillisuuden monimuotoisuus, mitataan sitä lajimääränä tai diversiteetti-indeksillä, oli suurimmillaan n. 15 vuotta kulotuksesta. Tällöin on paikalla vielä ensivaiheen kasvistoa, mutta metsälajitkin ovat saaneet jo jalansijaa.

Tutkimus osoitti, että kuloalojen kasvillisuudella on selvä sukkessionsa, jossa oleellisena vaikuttavana tekijänä on kulotuksen aiheuttama ekologinen tilanne. Kehittyvä puusto muovaa myös kasvillisuuden piirteitä. Herbisidikäsittely aiheuttaa kasvillisuusmuutoksia, jotka eivät kuitenkaan ole niin suuria, että alojen tyypittely estyisi.

Cajanderin metsätyyppijärjestelmää voidaan tämän tutkimuksen antamien osviittojen perusteella mainiosti täydentää eri ikävaiheiden sukkessiotilanteilla. Tällöin tulisi kuitenkin pitää primäärisesti erilaiset ekologiset tilanteet, variantit, erillään. Kasvillisuuden, puuston ja puulajin antamia tietoja tulisi käyttää toisiaan täydentävinä, ei toistensa vaihtoehtoina. Tämä olisi myös metsätyyppiteorian hengen mukaista.