

# A COMPARISON OF DIFFERENT SAMPLING METHODS OF QUANTITATIVE VEGETATION ANALYSIS

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*Seloste*

*KVANTITATIVISESSA KASVILLISUUSANALYYSISSÄ KÄYTETTYJEN NÄYTTEENOTTOMENETELMIEN VERTAILU*

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Different sampling methods (the Percentage Cover Scale, the Graphical Method, two Point Quadrat Methods, the Five, Nine and Twelve-Class Cover Scales and the Biomass Harvesting) were used in estimating abundances of ground vegetation in clear-cut areas and on an abandoned field in southern and central Finland. The results are examined with the help of DCA ordinations. In addition, the species numbers and diversity indices obtained by different sampling methods are compared.

There were no large differences in DCA configurations between the sampling methods. According to all the sampling methods, a complex soil fertility-moisture gradient (a forest site type) was interpreted as the main ordination gradient in the vegetation data for clear-cut areas. However, different sampling methods did not give similar estimates of species numbers and diversity indices.

## 1. INTRODUCTION

Few comparative studies have been carried out on the sampling methods used in the quantitative analysis of ground vegetation. However, choosing the appropriate sampling method is an acute problem in vegetation ecology (Knapp 1984a). The criteria used in choosing the method are objectivity, accuracy and repeatability of the information obtained with the method. One has to consider whether increasing the accuracy of the method produces more essential information about the plant community under study. Furthermore, it is necessary to know how well different sampling methods describe the species composition of the community and estimate the species number. In general, a compromise has to be made between the extensiveness of the material (time consumed

working in the field) and sampling errors. Finally, the optimal choice of method depends on the goal of the study, the type of vegetation analysed and the statistical methods applied in the data-processing stage.

The purpose of this study is to determine whether different sampling methods give consistent estimates of the abundance relationships between plant species. The comparison is primarily done with the help of an ordination analysis. In addition, the species numbers and diversity indices obtained by different sampling methods are compared. The study material is part of a larger project dealing with the succession and dynamics of vegetation on abandoned fields (Jukola-Sulonen 1983) and clear-cut areas.

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## 2. MATERIALS AND METHODS

### 2.1. The clear-cut areas

The material used for comparing the sampling methods was collected from clear-cut areas in Janakkala and Tuulos (southern Finland, 61°00' N, 24°47' E) in late July and early August in 1981 and 1982. The data analysed here were collected from a total of 13 sample quadrats of 1 m<sup>2</sup> each. Two of these represent the *Oxalis-Myrtillus* (OMT), four the *Myrtillus* (MT), three the *Vaccinium* (VT) and four the *Calluna* (CT) forest site type (as defined in the field, see Cajander 1926). The stand on the CT sample plot had been cut in 1978, and the other stands in 1980. The sample plots had been scarified with a disc harrow, and pine seedlings (*Pinus sylvestris* L.) planted on the exposed mineral soil during the year following clear-cutting.

The current material consists of ground vegetation analyses (vascular plants, bryophytes, lichens) made with different sampling methods on the same sample quadrats in two successive years ( $n = 7 + 6$ ). However, one quadrat of the VT site type was analysed in 1981 only. The average cover percentages of the plant species found in the four forest site types are listed in Table 1. Abundance values of the other sampling methods are available from the authors.

Sample plots (100×50 m<sup>2</sup>) were chosen subjectively to represent each forest site type. The distance between the sample plot and the edge of the nearest tree stand was always at least 30 m, and an attempt was made to select an area with as homogeneous a plant cover as possible. A sub-plot, 10×10 m<sup>2</sup> in size, was randomly laid out within each sample plot. About 20 sample quadrats were chosen for a study of vegetation succession within each

sub-plot. The quadrats were placed systematically in such a way that a planted pine seedling was growing in the middle of each quadrat. The 13 sample quadrats analysed in this paper were selected randomly from these quadrats ( $n=80$ ).

The following 7 sampling methods were used in analysing the 13 sample quadrats in the field:

(1) Coverages were assessed visually using the Direct Percentage Cover Scale. Assessment was facilitated by limiting the quadrat with a wooden frame, which had been divided into 20×20 cm<sup>2</sup> small quadrats using metal rods.

(2) In the Graphical Method a map of the species coverages in each quadrat was drawn to a scale of 1:5. This task was made easier by the use of small quadrats in the same way as in the previous method. The coverage maps were transformed into surface areas using a coordinate reader (digitizer) interfaced to a computer. Percentage covers were calculated from the species-specific areas.

(3) In the Point Quadrat (PQ) Method a frame with a moving metal needle (type 'Rejmánek', see eg. Kubíková & Rejmánek 1973) was used to record the presence or absence of plant species. Using the frame the needle (tip diameter < 1 mm) was lowered vertically at one hundred points, spaced evenly at distances of 10 cm. Touches between the needle tip and the plant species were counted. The proportion of points where each species was present out of all the points in the quadrat gave the measure of percentage cover.

Percentage Cover = 100 × the number of points where the needle hits species A at least once / total number of points.

Table 1. Visually estimated cover percentages (averages) of plant species, litter, humus and exposed ground in the clear-cut areas of different forest site types.

	OMT		MT		VT		CT	
	1981	1982	1981	1982	1981	1982	1981	1982
Field layer								
<i>Rubus saxatilis</i>	0.9	1.9						
<i>Linnaea borealis</i>	0.9	1.0						
<i>Carex digitata</i>	2.8	5.1						
<i>Hierochloë odorata</i>	0.9	5.1						
<i>Anemone nemorosa</i>	0.0	1.3						
<i>Calamagrostis arundinacea</i>	6.4	12.6	2.3	10.4				
<i>Veronica officinalis</i>		3.2		0.4				
<i>Luzula pilosa</i>	0.0	2.5		1.1				
<i>Melampyrum sylvaticum</i>		1.9		0.4				
<i>Maianthemum bifolium</i>	0.5		1.5	0.4				
<i>Vaccinium myrtillus</i>	0.5	1.0	3.2	2.3	1.6		0.5	0.0
<i>Vaccinium vitis-idaea</i>	0.0	0.3	0.6	1.1	16.3	20.8	5.1	3.9
<i>Empetrum nigrum</i>					3.1	0.0		
<i>Calluna vulgaris</i>					0.2		5.1	10.4
<i>Pinus sylvestris</i>			0.5	0.4	0.2	0.8	8.7	10.9
<i>Betula pendula</i>							1.7	5.2
<i>Betula pubescens</i>							4.8	5.5
Others	0.0	1.3	0.1	0.6	0.0	0.0	0.2	0.3
Ground layer								
<i>Polytrichum juniperinum</i>	1.0		0.4					0.6
<i>Dicranum polysetum</i>		0.0	1.5	2.9	2.7	6.7	1.5	5.2
<i>Dicranum scoparium</i>			1.0	0.0	3.3			0.5
<i>Pleurozium schreberi</i>	0.0	0.0	0.5	1.5	22.8	10.0	6.4	6.7
<i>Pohlia nutans</i>				0.0			6.8	2.3
<i>Cladonia arbuscula</i>					2.5	5.8		
<i>Cladonia rangiferina</i>					5.0	18.3	0.4	0.0
<i>Polytrichum commune</i>							10.7	5.2
Others		0.0	0.2				0.3	0.3
Litter	73.4	53.0	53.5	60.4	28.1	36.7	23.3	40.8
Humus		1.3	4.3	11.1	3.9			
Exposed area	13.8	8.8	25.7	7.0	10.3	0.8	23.8	2.4

(4) In the Point Quadrat All Touches (PQAT) Method all the hits in a vertical direction between the needle and parts of the plant species were counted. This gave an approximate value of the species-specific percentage cover weighted with size, and the vertical arrangement of each species.

Weighted Percentage Cover = all touches between the needle and species A / total number of touches.

Five persons performed the vegetational analyses in the field with the four methods mentioned above. Care was

taken to ensure that the same person did not survey the same quadrats with different sampling methods.

(5)–(7) Values of the Direct Percentage Cover Scale were later converted into three different cover-classes. The scales applied were the so-called (5) Scandinavian (Hult-Sernander) Five-Class Scale, (6) the Nine-Class Scale (cf. J. Oksanen 1981; Pakarinen 1984, p.38) and (7) the Twelve-Class Scale (L. Oksanen 1976).

## 2.2. The abandoned field

The data were collected in Suonenjoki (Central Finland 62° 36' N, 27° 5' E) on 26. 6. 1981 and 20. 7. 1982. The field had been abandoned since 1970 when it had been ploughed for the last time. The field had become partly covered with shrubs, but most of it was still open. The study area has been described in detail by Jukola-Sulonen (1983).

In the first year the 1 m<sup>2</sup> sample quadrat was subjectively chosen and the following year another quadrat was placed adjacent to it. Herbs and grasses grew mixed together in the quadrats. The average plant height was 60 cm.

The following 8 sampling methods were used in analysing the 2 quadrats:

- (1) Direct Percentage Covers were estimated visually. In 1981 two persons assessed the coverages in the same quadrat.
- (2) The Graphical Method
- (3) The Point Quadrat Method
- (4) The Point Quadrat All Touches Method
- (5)–(7) Direct Percentage Covers were transformed according to the (5) Five, (6) Nine and (7) Twelve-Class Cover Scales.
- (8) The Biomass Harvesting Method

The first seven sampling methods were carried out in the same way as in the clear-cut areas. In 1981 three persons made the vegetation analyses, but in 1982 the surveys were made by only one person. In the Harvesting Method all the above-ground plant parts were cut off. Each sample was sealed in a plastic bag and stored in a freezer until species identification. Dead and living biomass was separated. The species-specific samples were dried for 24 hours at 105 °C and then weighed. The dry weights of the species are listed in Table 2.

## 2.3. DCA ordination

In ordination analysis information about the primary community data is summarized and simplified in order to reveal the relation-

Table 2. Biomass values (dry weight g/m<sup>2</sup>) of plant species in the abandoned field (Central Finland, see Jukola-Sulonen 1983).

Species	g/m <sup>2</sup>	
	1981	1982
<i>Ranunculus repens</i>	0.0	
<i>Ranunculus acris</i>	2.3	5.0
<i>Alchemilla vulgaris</i> coll.	13.2	19.1
<i>Vicia sepium</i>	8.6	
<i>Epilobium angustifolium</i>	162.2	208.1
<i>Epilobium montanum</i>	1.2	0.0
<i>Veronica chamaedrys</i>	1.0	0.2
<i>Cirsium arvense</i>		2.8
<i>Taraxacum officinale</i>	127.6	132.3
<i>Poa trivialis</i>	0.0	3.0
<i>Poa pratensis</i>	16.0	4.2
<i>Elymus repens</i>	15.9	96.7
<i>Deschampsia cespitosa</i>		3.1
<i>Agrostis tenuis</i>	94.7	94.7
<i>Phleum pratense</i>	0.8	2.0
Total	443.5	571.2
Litter	448.9	421.6

ships between community variation and the environment. Ordination shows up the most important patterns or gradients in the vegetational data. Samples and species are arranged into low-dimensional space (usually one to three dimensions), ecologically similar species or samples being placed close together and dissimilar ones far apart. An ordination configuration can usually be interpreted on the basis of environmental variables (Gauch 1982a).

Detrended correspondence analysis (DCA) (Hill 1979, Hill & Gauch 1980) has been used in this study for ordinating the vegetation data. The abundance values of the Five, Nine and Twelve-Class Scales are used in the ordinations without any transformations. In the other sampling methods the abundance values for each sample plot were standardized to correspond to 100 per cent, and lg(x+1) transformation then performed on them. The default value of 26 segments was used in the detrending procedure of the DCA axes, except for the analysis of the MT quadrats where the number was 10.

## 3. RESULTS

### 3.1. DCA ordination

#### *The clear-cut areas*

The data of the 7 sampling methods applied in the 13 sample quadrats were ordinated by DCA (Fig. 1). The sample scores form clearly separated clusters in the DCA configuration. Each cluster of points represents one of the 13 sample quadrats. The 1st axis (eigenvalue = 0.735) can be interpreted

as a complex soil fertility-moisture gradient or a forest site type gradient (the lowest scores in CT, the highest scores in OMT). The information content of the 2nd axis (eigenvalue = 0.118) is probably mostly due to random variation (noise) in the data, but it may express successional change in the vegetation. If the 2nd axis is read as a time dimension, then time in the CT quadrats runs opposite to that in the other forest site types.

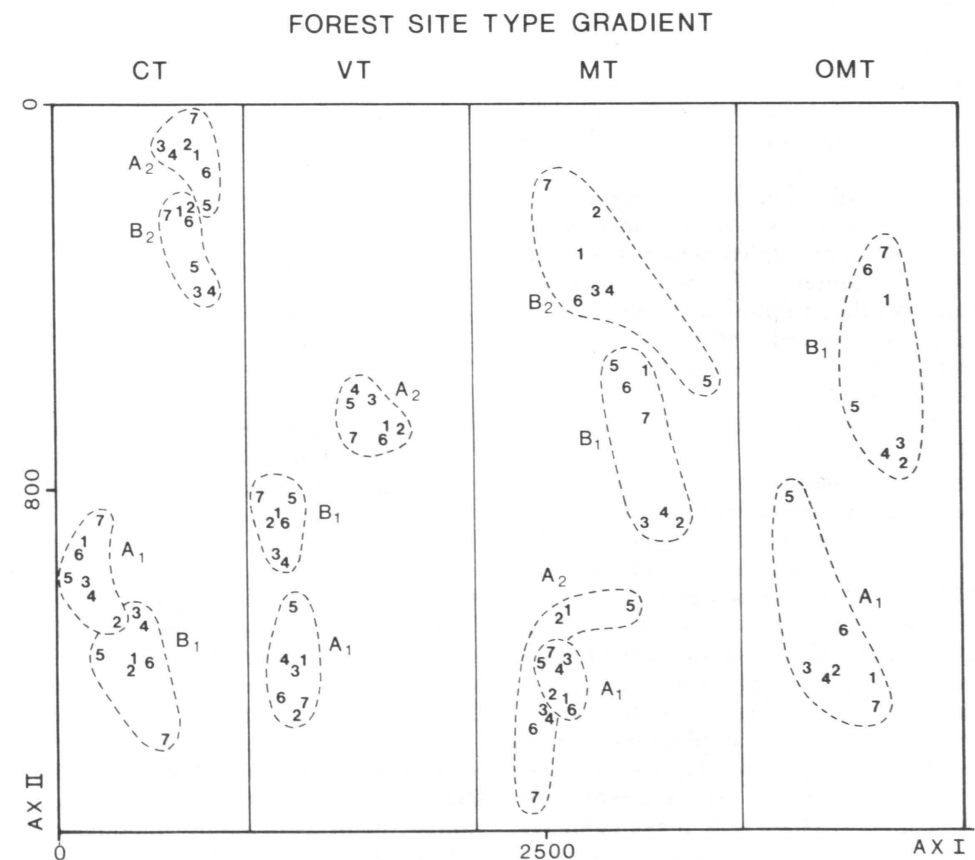


Fig. 1. Detrended correspondence analysis (DCA) ordination of vegetation in the clear-cut areas. Results of different sampling methods (1–7) in the 13 sample quadrats are presented. The first axis expresses the fertility-moisture gradient (the forest site type). A and B represent the same quadrat in 1981 and 1982 respectively, sub-indices 1 and 2 refer to the quadrat. 1 = the Cover Percentage Method, 2 = the Graphical Method, 3 = the Point Quadrat Method, 4 = the Point Quadrat All Touches Method, 5 = the Five-Class Scale, 6 = the Nine-Class Scale, 7 = the Twelve-Class Scale.

Table 3. Spearman rank correlations between different sampling methods in the clear-cut areas. Correlations based on the order of the 13 sample quadrats on the 1st DCA axes (lower left) and on the 2nd DCA axes (upper right).  $\circ = P < 0.10$ ,  $* = P < 0.05$ ,  $** = P < 0.01$ ,  $*** = P < 0.001$ .  $n = 13$ .

	Cover %	Graphical	PQ	PQAT	5-Class	9-Class	12-Class
Cover %							
Graphical	1.00***	0.20	-0.31	0.13	-0.16	-0.23	-0.09
PQ	0.63*	0.63*		0.14	-0.59*	0.16	0.21
PQAT	0.80**	0.80**	0.86***		0.42	-0.19	-0.18
5-Class	0.28	0.28	0.64*	0.50°		-0.49°	-0.03
9-Class	0.99***	0.99***	0.66*	0.80**	0.30		0.09
12-Class	0.99***	0.99***	0.66*	0.80**	0.30	1.00***	-0.13

In many cases the location of the Five-Class Scale score lies outside the cluster of ordination scores for the other methods. The scores for the Point Quadrat and the Point Quadrat All Touches Methods are close together in all the cases. No trend where the sample scores of different sampling methods would be arranged systematically in the clusters can be observed.

The DCA ordination of the vegetation data for the clear-cut areas (Fig. 1) suggests that there are no large differences between the information content of the 7 sampling methods. All the sampling methods show the same successional order of the sample quadrats within any forest site type in this ordination.

An alternative explanation for the results described above is that the forest site type gradient is so strong that it hides all the variation due to the sampling methods. In order to minimize the obvious variation due to the forest site type gradient (Fig. 1), only the MT quadrats were selected for detailed comparison. Fig. 2 shows the DCA ordination for the data of the 7 sampling methods in the four MT quadrats. However, the result is the same even with these data: the sample scores for the different sampling methods in the same sample quadrats form clearly distinct clusters. Only the 1st axis, which expresses temporal change, is meaningful (eigenvalue = 0.351). The information content of the 2nd axis (eigenvalue = 0.061) is probably only due to random variation.

The abundance values obtained with the different sampling methods were ordinated separately. A comparison of the sample scores on the 1st DCA axes given by different

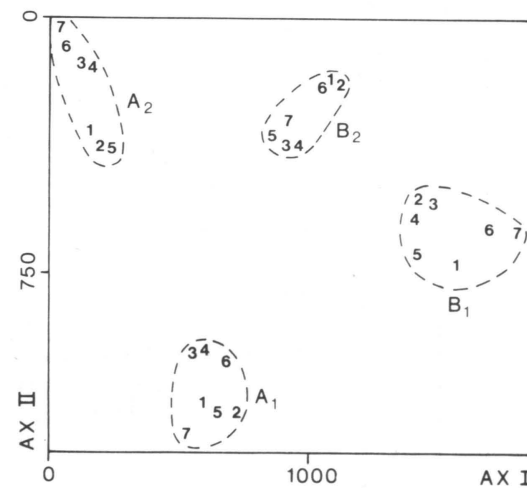


Fig. 2. DCA ordination of forest floor vegetation in the clear-cut MT type site. Results of the 7 sampling methods in the 4 sample quadrats. Symbols as in Fig. 1.

sampling methods is shown in Fig. 3. The forest site type can be interpreted as the strongest ordination gradient (the eigenvalues of the 1st axes range from 0.724 to 0.847 in the ordinations of different methods) in all the sampling methods. The Spearman rank correlations show (excluding the Five-Class Scale) that the methods arrange the sample quadrats in almost the same order on the 1st axes (Table 3). When the order of the sample quadrats on the 1st axes of all the 7 methods are compared simultaneously using the Kendall coefficient of concordance (Siegel 1956), it appears that there are no differences between the methods ( $W = 0.746$ ,  $X^2 = 62.66$ ,  $P < 0.001$ ,  $df = 12$ ).

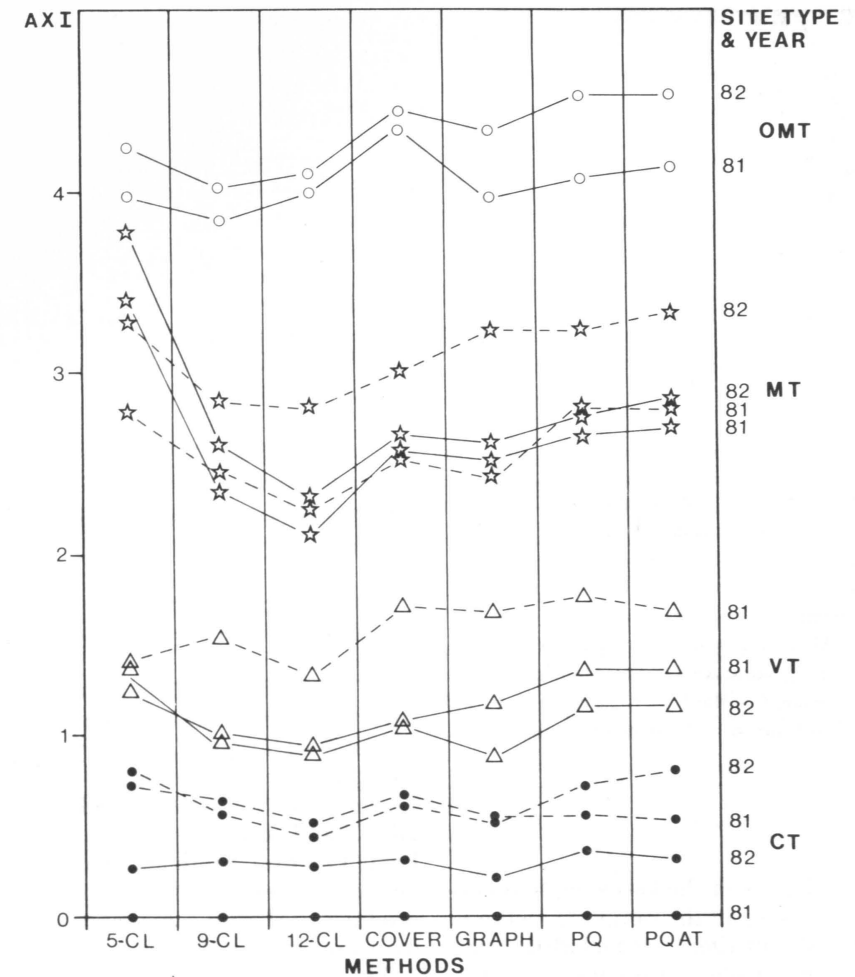


Fig. 3. Comparison of sample scores of the first DCA axes between different sampling methods in the clear-cut areas. The data collected with each method are ordinated separately. The first axis goes from a site type poor in nutrients (CT) to more fertile conditions (OMT). The scores of the same quadrat in both sampling years are connected with lines of similar type. All sample scores are divided by 1000.

In the DCA ordinations of each sampling method the 1st axes contain the most important information, while the eigenvalues of the 2nd axes are much lower (0.061 to 0.200). The Spearman rank correlation based on the order of the sample quadrats on the 2nd axes is statistically significant ( $P < 0.05$ ) only between the Graphical Method and the Five-Class Scale (Table 3). Furthermore, the Kendall coefficient of concordance ( $W = 0.068$ )

shows that the sequence of the sample quadrats varies ( $X^2 = 5.69$ , NS,  $df = 12$ ) on the 2nd axes between the different sampling methods.

#### The abandoned field

The DCA ordination of the abandoned field data is shown in Fig. 4. The plant

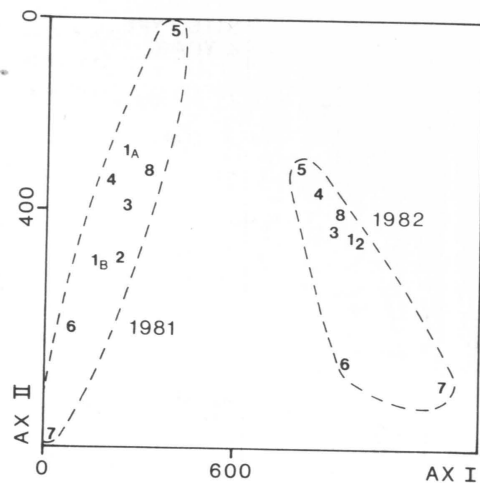


Fig. 4. The abandoned field data ordinated by DCA. The analysis consists of abundance values of different sampling methods (1-8) in the two sample quadrats (1981 and 1982). 1 = the Cover Percentage Method (in 1981 estimates of two persons A and B), 2 = the Graphical Method, 3 = the Point Quadrat Method, 4 = the Point Quadrat All Touches Method, 5 = the Five-Class Scale, 6 = the Nine-Class Scale, 7 = the Twelve-Class Scale, 8 = the Biomass Method.

species abundances of the two sample quadrats obtained using all the sampling methods (9 in 1981 and 8 in 1982) are included in the analysis. The variance explained by the analysis remained low (eigenvalues: the 1st axis = 0.191, the 2nd axis = 0.008). The 1st axis distinguishes the two quadrats from each other. In spite of the insignificant information content of the 2nd axis, the order of the

sample scores of the different sampling methods are almost the same in both clusters.

The sample scores of the Cover-Class Scales for the 1981 sample quadrat are isolated from those for the other sampling methods. The sample scores of the two Point Quadrat Methods and one of the two estimates for the Cover Percentages are closest to the sample score of the Biomass Method (which can be regarded as the most objective sampling method). All the sample scores for the 1982 sample quadrat, excluding the Nine and Twelve-Class Scales, are located in the cluster (Fig. 4).

### 3.2. Species numbers and diversity indices

The species numbers obtained by the 7 sampling methods in the clear-cut areas are compared by means of the paired-sample t test (Table 4). Both Point Quadrat Methods naturally give an identical number of species. The species number given by the Graphical and the Cover Percentage Methods (and the Cover-Class Scales) are similar, too. On the other hand, these two methods and the two Point Quadrat Methods give unequal numbers of species. The Point Quadrat Methods produce a slightly smaller species number than the other methods.

The highest species numbers in the data of the abandoned field (Table 5) are given by the Biomass and the lowest ones by the Point Quadrat Methods.

Diversities were estimated using the Shannon (Shannon & Weaver 1949) and the

Table 4. Comparison of species numbers as recorded by different sampling methods in the clear-cut areas using the paired-sample t test. Lower left: t statistics, upper right: statistical significances. NS = not significant. \*\*\* =  $P < 0.001$ .  $df = 12$ .

	Cover %	Graphical	PQ	PQAT
Cover %		NS	***	***
Graphical	0.29		***	***
PQ	-5.16	-4.39		NS
PQAT	-5.16	-4.39	0.00	

Table 5. Species numbers and Shannon and Lamont diversity indices as recorded by different sampling methods in the abandoned field.

Method	Species number		Shannon index		Lamont index	
	1981	1982	1981	1982	1981	1982
Cover % <sub>1</sub>	10	14	1.583	1.709	2.606	1.292
Cover % <sub>2</sub>	9		1.397		1.390	
Graphical	10	13	1.739	1.584	2.693	2.563
PQ	9	10	1.678	1.788	1.958	2.244
PQAT	9	10	1.626	1.646	1.999	2.003
Biomass	13	14	1.544	1.607	1.499	2.369

Table 6. Comparison of Shannon (lower left) and Lamont (upper right) diversity indices between different sampling methods in the clear-cut areas (the paired-sample t test). The upper figures are t values and the lower ones statistical significances. NS = not significant.  $df = 12$ .

		Lamont indices			
		Cover %	Graphical	PQ	PQAT
Shannon indices	Cover %		0.91 NS	1.80 P=0.10	1.09 NS
	Graphical	-0.72 NS		2.15 P=0.05	1.55 NS
	PQ	2.76 P=0.02	1.16 NS		2.52 P=0.03
	PQAT	-0.85 NS	-1.54 NS	2.81 P=0.02	

Lamont (Lamont et al 1977) indices. The diversity indices obtained by different sampling methods (the Cover-Class Scales excluded) in the clear-cut areas are compared by means of the paired-sample t test (Table 6). In most cases the Point Quadrat Method gives values for the Shannon diversities which are to some extent larger than the Point Quadrat All Touches and the Cover Percentage Methods. The Point Quadrat Method differs from the other methods with respect to the Lamont indices, too.

There is variation in both diversity indices for 1981 among the sampling methods in the abandoned field data (Table 5). The largest indices are received by the Graphical Method and the smallest ones by the other estimate of the Cover Percentage Scale. The Shannon indices for 1982 are of the same order of magnitude, but the Lamont indices vary between different sampling methods.

#### 4. DISCUSSION

The type of sampling method used had little effect on the results of ordinations with the present data. The DCA configurations for the different sampling methods closely resemble each other in the material for the clear-cut areas. There are no large differences between the sampling methods in the DCA ordination of the abandoned field data, either. (Note the different scales of the axes when comparing the ordinations of these two data sets, Figs. 1 and 4). On the other hand, different sampling methods do not give completely equivalent estimates for species numbers and diversity indices.

Although there are differences in the absolute abundances obtained by different sampling methods, it seems that all these sampling methods produce similar qualitative abundance relationships between the plant species. This is often sufficient for the input data of multivariate analyses in community ecology (Sarvala 1984). Since the ordinations are affected only slightly by even severe rounding-off the input data (Gauch 1982b), more accurate field measurements are of only marginal value.

Logarithmic transformations have often been recommended for the cover percentages and biomass values in ordinations and clusterings (e.g. Sarvala 1984). Transformation of this kind normalizes biased distributions and gives a relative weight to the less abundant species. The information content of the Cover-Class Scales corresponds almost exactly to the logarithmic transformation of the Direct Cover Percentages (Pakarinen 1984).

Different sampling methods emphasize the different features of the plant community under study. Each method has its advantages and disadvantages in the field work. Numerical methods set certain limitations, too.

The Biomass Harvesting Method gives reliable and exact data concerning the abundance ratios between species, subjective errors being insignificant. The method has been widely used in production ecological research since the late 1960s. However, it is laborious, time consuming and expensive to carry out determinations of the dry matter of the plant species. The method is useful only for collecting relative small data sets. It is not the most appropriate method for succession studies,

which involve the monitoring of temporal changes in the plant community, because the same quadrats cannot be surveyed year after year. Several methods attempt to assess the biomass indirectly.

The most general method for estimating plant species abundances is to study the coverage relationships. Direct estimation of percentage covers is the most widely used method in Finland (Pakarinen 1984). Kellomäki (1974, 1975) has shown that there appears to be significant positive correlations between the coverages of the ground vegetation and the biomass values of the corresponding species in boreal forests.

The Coverage Method is rapid, but it contains a large number of subjective sources of errors. Visual assessment of cover percentages is a highly subjective method for many species (e.g. grasses and low-creeping plants). The person doing the survey often tends to assess small coverages larger and large coverages smaller than they really are. The error variance increases if more than one person performs the analyses. Extensive practice in visual assessment improves the objectivity of the results.

Attempts have been made to minimize subjective biases in coverage estimation by means of Cover-Class Scales. It is easier to set the coverage of the species correctly into wide class ranges than to determine an exact percentage value. The use of Cover-Classes thus increases the objectivity of the assessment, although simultaneously decreasing the information content of the data (L. Oksanen 1976). The field work will be made easier and speeded up, thus making it possible to analyse more sample plots or quadrats. During data-processing the Cover-Class Scale matrices take less space in the computer register than the values of the Direct Cover Percentages.

According to Pakarinen (1984), the Five or at least the Nine-Class Cover Scales generally produce sufficient information for the delimitation and typification of boreal plant communities. Class Scales may not give adequately accurate information in studies of community change (e.g. succession). With the present data for the clear-cut areas, however, the temporal changes in the vegetation

were also recorded by all the Cover-Classes studied. Cover-Class values must be transformed into a percentage scale when calculating diversity indices.

A map of the outlines of individual species gives more precise cover estimates than visual ones. This Graphical Method is suitable for monitoring succession and phenology in permanent sample quadrats. Furthermore, it enables the growth of an individual plant or a clone to be studied in detail. Sarukhán and Harper (1973) have used the Graphical Method in studies on plant demography. The drawbacks of the method are its slowness and laboriousness. Mapping can be facilitated by using small quadrats or a pantograph.

As the abundances of species are determined in the methods described above by means of estimation, the data are exposed to subjective sources of errors. With the Point Quadrat Methods, cover percentages are measured and the information that is obtained is purely quantitative if there is a sufficiently high number of points (Knapp 1984b). The Point Quadrat results are affected by the thickness of the needle (Goodall 1952) and a modified method has been developed incorporating an optical device (Winkworth & Goodall 1962).

The Point Quadrat Method is perhaps the most suitable for studying low vegetation. It has been used in Australia in surveying

grass and heathlands (Goodall 1952, Winkworth 1955) and in Czechoslovakia in succession studies of cultural grasslands. Kubíková & Rejmánek (1973) have demonstrated that the results obtained with a thin needle (0.1 mm) and an adequate number of points are directly proportional to the dry matter content and the leaf area of the plant species studied. Prach et al (1985) obtained the same result when studying vegetation in a summer-drained fishpond. We found no clear relationships of this kind in the analysis of the abandoned field data.

The previous remarks can be summarized as follows. The appropriate accuracy to which vegetation data is collected depends on the general objectives of the study and the type of vegetation analysed. It is essential to apply the right qualitative relationships between plant species abundances in clustering and typifying vegetation communities with the help of multivariate analyses (e.g. ordination). It is thus more preferable to use large sample quadrats or to make many repeated surveys with smaller quadrats applying a crude scale, than to analyse few small quadrats with a very accurate scale. In contrast, a more accurate sampling method should be used when monitoring temporal changes of individual plants or clones in population studies.

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Total of 23 references

## SELOSTE

### KVANTITATIIVISESSA KASVILLISUUSANALYYSISSÄ KÄYTETTYJEN NÄYTTEENOTTOMENETELMIEN VERTAILU

Tutkimuksessa vertaillaan pintakasvillisuuden kvantitatiivisessa analysoinnissa käytettävien näytteenottomenetelmien antamia tuloksia. Eri menetelmillä saatuja kasvilajien runsauksien (abundanssien) estimaatteja tutkitaan vastinkeskiarvo-ordinaation (DCA) avulla. Lisäksi tarkastellaan eri menetelmillä saatuja lajimääriä ja diversiteetti-indeksejä.

Aineisto on kerätty kesinä 1981 ja 1982 Etelä-Hämeen avohakkuualueilta (13 yhden m<sup>2</sup>:n pintakasvillisuusruutua neljältä metsätyypiltä) ja Keski-Suomesta viljelemättä jätetyltä pellolta (2 yhden m<sup>2</sup>:n näyteruutua).

Tutkimuksen kohteena ovat seuraavat näytteenottomenetelmät: (1) peittävyysprosentit arvioituna silmävaraisesti, (2) piirtämällä saadut peittävyysarviot, (3) Point Quadrat -menetelmä, (4) Point Quadrat All Touches -menetelmä, (5) 5-luokkainen peittävyysasteikko, (6) 9-luokkainen peittävyysasteikko, (7) 12-luokkainen peittävyysasteikko ja (8) biomassan korjuumenetelmä (sovellettiin vain peltoaineistoon).

#### Tärkeimmät tulokset ovat seuraavat:

(1) Kaikilla näytteenottomenetelmillä saatujen runsausarvojen ordinaatiokuvaot muistuttavat selvästi toisiaan. Avohakkuualueiden aineistossa kaikkien menetelmien ordinaatioissa I akseleilla ilmenee voimak-

kaimpana vaihtelu suuntana ravinteisuus-kosteus (metsätyyppi) -gradientti. Sen sijaan II akseleilla, joiden selitysasteet ovat huomattavasti pienemmät kuin I akseleiden, eri menetelmien ordinaatiot poikkeavat jossain määrin toisistaan. Peltoaineistossa 9- ja 12-luokkaisten peittävyysasteikkojen ordinaatiopisteet sijaitsevat hieman erillään muista menetelmistä. Vuoden 1981 näyteruudussa myös 5-luokkainen asteikko antaa muista menetelmistä poikkeavan tuloksen.

Saadun tuloksen perusteella todetaan, että eri näytteenottomenetelmien informaatioisällöt eivät ratkaisevasti poikkea toisistaan. Myös luokka-asteikoilla saadut runsausarvot ovat riittävän tarkkoja yhteisöekologisten monimuuttuja-analyysien lähtöaineistoksi ainakin avohakkuualueiden aineistossa. Tämä johtuu siitä, että kaikki tutkitut menetelmät arvioivat kasvilajien väliset runsaussuhteet suurinpiirtein samantavaisesti, vaikka eri menetelmät saattavat tuottaa erilaisia kvantitatiivisia runsausarvoja.

(2) Eri menetelmät antavat erilaisia arvioita lajimäärästä ja diversiteeteistä. Esim. Point Quadrat -menetelmillä saadut lajimäärät ovat hiukan pienemmät kuin muilla menetelmillä.

Optimaalisen näytteenottomenetelmän valintaan vaikuttavat viimekädessä tutkimuksen tavoitteet, kasvillisuustyyppi sekä aineiston jatkokäsittelyssä käytettävät numeeriset menetelmät.

ODC 5--015+946.2

ISSN 0037-5330

Metsien inventoinnin tilastolliset menetelmät. Statistical methods in forest inventories. 1985. *Silva Fenn.* 19 (3): 211-243.

At a joint meeting of the Finnish Statistical Society and the Society of Forestry in Finland on 17. 10. 1984, papers were presented on the history and mathematical foundations of statistical method used in forest inventories in Finland. The advantages and applicability of Bayesian methods and methods of spatial statistics were also discussed. In two papers, forest inventories were examined as part of a forest information system, and the information demands of the user were discussed.

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ODC 237+174.7 *Pinus sylvestris*+ (480.99)

ISSN 0037-5330

POHTILA, E. & POHJOLA, T. 1985. Maan kunnostus männyn viljelyssä Lapissa. Summary: Soil preparation in reforestation of Scots pine in Lapland. *Silva Fenn.* 19 (3): 245-270.

The study deals with the interaction of various soil preparation and reforestation methods. The most favourable time of the year for broadcast sowing and the effect of stabilization after soil preparation on restocking were studied as special problems.

Prescribed burning, scalping and disc ploughing made a better combination with sowing than planting, and ploughing a better combination with planting than sowing. The longer the period was between sowing and germination the fewer seedlings emerged. The best stocking was clearly resulted from sowing in June. Stabilization of soil after preparation had a negative effect on reforestation results.

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ODC 641+624+76

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LAPPI, J. & SIITONEN M. 1985. A utility model for timber production based on different interest rates for loans and savings. *Seloste: Säästö- ja lainakorkoon perustuva puuntuotannon hyötymalli.* *Silva Fenn.* 19 (3): 271-280.

The evaluation of timber production policies with different income (timber drain) schedules is discussed. Special attention is given to the temporal smoothness of the income flow. A utility model is formulated in which the objective is to maximize a fixed consumption pattern, and money can be saved and borrowed at different interest rates. We thus have smoothness requirements only for consumption, the capital market then determines the smoothness of the optimal income flow. Present discounted value and maximization of even income flow criteria are special cases of the utility model. Consumption can be maximized by linear programming. A sample problem is presented.

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ODC 142+151+(480.9)+(480.99)

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HELLE, P. & MUONA, J. 1985. Invertebrate numbers in edges between clear-fellings and mature forests in Northern Finland. *Seloste: Selkarangattomien runsaustuhteista avohakkuualueiden ja metsien reuna-alueilla Pohjois-Suomessa.* *Silva Fenn.* 19(3): 281-294.

The abundance of invertebrates in edges between forests and clear-fellings was studied by pitfall and window traps in Northern Finland. Most invertebrate groups were more abundant in edges than in the interior parts of forests or clear-fellings. *Arachnida* showed the clearest edge preference.

The catches of different invertebrate groups at study sites were correlated to the vegetation characteristics. Of the eight variables used the distance to the forest edge and the density of saplings best explained the variations in invertebrate numbers.

The results support the assumption that the often high breeding bird density at forest edges may depend on high prey density there.

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KÄRKKÄINEN, M. & HALINEN, M. 1985. Mäntysahatukkien minimivaatimusten täsmäntäminen. Summary: Reappraisal of minimum requirements of pine sawlogs. *Silva Fenn.* 19 (3): 295–324.

A test sawing was made of 807 pine sawlogs of varying size and quality. The most important knot characteristic affecting the value of sawn goods was the diameter of the thickest dry knot. The new minimum requirements for pine logs were proposed on the basis of top diameter of the log and the diameters of the thickest dry and living knots.

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JUKOLA-SULONEN, E.-L. & SALEMAA, M. 1985. A comparison of different sampling methods of quantitative vegetation analysis. Seloste: Kvantitatiivisessa kasvillisuusanalyysissä käytettyjen näytteenottomenetelmien vertailu. *Silva Fenn.* 19(3): 325–337.

Different sampling methods (the Percentage Cover Scale, the Graphical Method, two Point Quadrat Methods, the Five, Nine and Twelve-Class Cover Scales and the Biomass Harvesting) were used in estimating abundances of ground vegetation in clear-cut areas and on an abandoned field in southern and central Finland. The results are examined with the help of DCA ordinations. In addition, the species numbers and diversity indices obtained by different sampling methods are compared.

There were no large differences in DCA configurations between the sampling methods. However, different sampling methods did not give similar estimates of species numbers and diversity indices.

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## KIRJOITUSTEN LAATIMISOHJEET

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Kirjoitusten laadinnassa noudatetaan Silva Fennica 4 (3):ssa (1970) annettuja sekä toimittajan erikseen antamia ohjeita. Suureissa, yksiköissä, symboleissa ja kaavoissa sekä oikoluvussa noudatetaan suomalaisia standardeja SFS 2300, 3100, 3101 ja 2324.

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Kuvat on laadittava mieluiten yhdelle palstalle sopiviksi (lev. n. 6,5 cm). Kuvien sisällä olevat tekstit on kirjoitettava siirtokirjaimin, tekstityslaitteella tai muuten siististi. Useita osakuvia sisältävät kuvat tai monen kuvan sarjat on suunniteltava siten, ettei taitto vaikeudu. Kuvaoriginaalien tulee olla korkeintaan kokoa A4. Mikäli isompia kuvia joudutaan käyttämään, on asiasta sovittava toimittajan kanssa. Valokuvien on oltava teknisesti moitteettomia, kiiltävälle paperille vedostettuja. Värikuvia ei yleensä hyväksytä. Kuvien otsikko-tekstejä ei missään tapauksessa saa kirjoittaa kuvaoriginaaleihin, vaan ne kirjoitetaan erilliselle liuskalle. Taulukkoktestit kirjoitetaan kuitenkin ao. taulukon yläosaan, eikä niistä erillistä luetteloa tarvita.

Taulukot laaditaan mahdollisimman paljon lopullista painatusasuaan muistuttaviksi. Taulukoiden viivituksen on oltava yhdenmukainen ja harkittu, yleensä pari johtoviivaa riittää. Vain pienet, yhdelle palstalle sopivat asetelmat ovat sallittuja, suuremmista tulee tehdä taulukko. Taulukot ja kuvat numeroidaan juoksevasti ja sijoitetaan tekstiosasta erilleen kukin omalle liuskalleen. Kuvien ja taulukoiden toivotut paikat merkitään käsikirjoituksen marginaaleihin. Jos vieraskielisessä summaryssä viitataan kuviin ja taulukoihin, tulee viitatuissa kuvissa ja taulukoissa olla vieraskieliset otsikot ja selitykset. Muut kuvat ja taulukot saavat olla yksikieliset.

Matemaattiset kaavat, ylä- ja alaindeksit sekä erikoismerkit on kirjoitettava selkeästi, niin että jokainen merkki on yksiselitteinen. Matemaattiset kaavat on muokattava sellaisiksi, että ne mahtuvat palstan leveydelle (n. 6,5 cm). Leveämmät kaavat on katkaistava soveltuvasta kohdasta ja jatkettava seuraavalle riville.

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Kirjallisuusluettelossa julkaisujen tekijät kirjoitetaan isoin kirjaimin, milloin tekijänä on henkilö. Jos tekijöitä on useita, nimet erotetaan pilkulla, paitsi kaksi viimeistä, jotka erotetaan &-merkillä. Tekijäin etunimistä käytetään vain alkukirjaimia. Mikäli sama ensimmäinen tekijä on kirjoittanut useampia julkaisuja, nimeä ei toisteta vaan se korvataan yhtäläisyysmerkillä. Toisen tekijän suhteen ei näin kuitenkaan tehdä. Tutkimusten nimet kirjoitetaan lyhentämättä. Tavallisista julkaisusarjoista käytetään lyhenteitä, jotka on painettu Silva Fennica 5(2):ssa (1971). Harvinaisia tai poikkeuksellisia sarjoja ei lyhennetä. Julkaisun numeron yhteydessä ei mainita vol.- tai n:o -sanoja. Sivunumerot erotetaan kaksoispisteellä volyymistä tai julkaisun numerosta. Esimerkkejä:

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Smolander, H., Räsänen, P. K. & Kostamo, J. 1981. Maan tiivyyden vaikutus männyntaimien haihduntaan ja pituuskasvuun istutuksen jälkeen. Summary: Effect of soil compaction on transpiration and height increment on planted Scots pine seedlings. Silva Fenn. 15(3): 256–266.  
Sääsähkeohjeet 1982. Ilmatieteen laitos. Helsinki.

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