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Plot sizes used for phytosociological sampling of European vegetation

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Abstract. In European phytosociology, variable plot sizes are traditionally used for sampling different vegetation types. This practice may generate problems in current vegetation or habitat survey projects based on large data sets, which include relevés made by many authors at different times. In order to determine the extent of variation in plot sizes used in European phytosociology, we collected a data set of 41 174 relevés with an indication of plot size, published in six major European journals focusing on phytosociology from 1970 to 2000. As an additional data set, we took 27 365 relevés from the Czech National Phytosociological Database. From each data set, we calculated basic statistical figures for plot sizes used to sample vegetation of various phytosociological classes.

The results show that in Europe the traditionally used size of vegetation plots is roughly proportional to vegetation height; however, there is a large variation in plot size, both within and among vegetation classes. The effect of variable plot sizes on vegetation analysis and classification is not sufficiently known, but use of standardized plot sizes would be desirable in future projects of vegetation or habitat survey. Based on our analysis, we suggest four plot sizes as possible standards. They are 4 m^2 for sampling aquatic vegetation and low-grown herbaceous vegetation, 16 m^2 for most grassland, heathland and other herbaceous or low-scrub vegetation types, 50 m^2 for scrub, and 200 m^2 for woodlands. It has been pointed out that in some situations, sampling in either small or large plots may result in assignment of relevés to different phytosociological classes or habitat types. Therefore defining vegetation and habitat types as scale-dependent concepts is needed.

Keywords: Braun-Blanquet approach; Class; Database; Data quality; Ecological scale; Habitat survey; Plant community; Relevé; Vegetation classification.

Introduction

Vegetation varies over a wide range of spatial scales, which are imposed arbitrarily in vegetation studies by the size of sample plots. Quite different patterns may be detected in a single vegetation stand if we change the scale of observation by sampling in plots of different size. Various studies have shown that the plot size influences the analysis of spatial patterns of plant populations (Greig-Smith 1964), correlations between species occurrences or performances (Greig-Smith 1964; Bouxin & La Boulengé 1983; Juhász-Nagy & Podani 1983; Hauser 1993), and vegetation-environment correlations (Palmer 1990; Reed et al. 1993). However, there is no single 'correct' scale to describe vegetation pattern (Allen & Starr 1982; Palmer 1988; Levin 1992; Juhász-Nagy 1993).

The scale-dependence of vegetation attributes has far-reaching consequences for phytosociological vegetation classification and associated projects of habitat classification (Ostermann 1998; Rodwell et al. 2002). As the correlation among species may appear and disappear or shift from positive to negative by changing the plot size, vegetation sampling in differently sized plots may yield different classifications (Fekete & Szöcs 1974). Strictly speaking, only comparisons among plots of equal size would therefore be valid for classification purposes.

During the 20th century, European followers of the Braun-Blanquet approach (Westhoff & van der Maarel 1978) accumulated invaluable data sets consisting of hundreds of thousands relevés (Rodwell 1995; Ewald 2001). This wealth of information on European vegetation challenges synthetic endeavours on local, national, and continental scales (Mucina et al. 1993; Rodwell et al. 1995, 1997; Lawesson et al. 1997; Bruelheide & Chytrý 2000; Hennekens & Schaminée 2001). However, a serious problem associated with the analysis of existing phytosociological data sets is the considerable variation in relevé plot sizes.

The objective of this paper is to review the variation in plot sizes used in European phytosociology, both within and among broad vegetation types, and to explore possibilities of standardization. To meet this objective, we analysed two representative data sets taken from the European phytosociological literature and from the Czech National Phytosociological Database.

Material and Methods

We assembled two phytosociological data sets covering the range of vegetation classes sampled in the whole of Europe and the Czech Republic, respectively. We followed Mucina (1997) for nomenclature and delimitation of classes, but included the class of thermophilous oak woodlands (*Quercetea pubescentis*) in the class of deciduous woodlands (*Querco-Fagetea*), because of the ambiguous assignment of many associations and alliances to either class.

The European data set was compiled from relevés included in phytosociological papers between 1970-2000 as published in *Colloques Phytosociologiques* (1971-1997), *Documents Phytosociologiques* (1972-1999), *Folia Geobotanica* (*et Phytotaxonomica*) (1970-2000), *Phytocoenologia* (1973-2000), *Tuexenia* (1981-2000) and *Vegetatio* (1970-1996). Earlier work was not included because the size of sample plots was perhaps less standardized before the 1970s (Chytrý 2001). These papers provided a reasonable cover of all the regions with an established phytosociological tradition, including central, western and southern Europe. Other regions of Europe were covered in several papers. The assignment of relevés to particular phytosociological classes followed the original author's opinion. We omitted relevés not assigned to higher syntaxa (ca. 5% of all relevés, especially those from southern and southeastern Europe) and relevés with missing plot size indication (ca. 10% of all relevés). We did not find any suitable relevés for the classes *Oryzetea sativae*, *Pulsatillo-Pinetea sylvestris*, *Festucetea indigestae*, *Rumici-Astragaletea siculi* and *Artemisietea lerchianae*, and excluded classes for which we found less than 50 relevés: *Ruppietea maritimae, Zosteretea, Spartinetea maritimae, Honckenyo-Elymetea, Adiantetea, Junipero sabinae-Pinetea, Daphno-Festucetea, Cytisetea scopario-striati,* and *Nerio-Tamaricetea*. The resulting European data set included 41 174 relevés.

A separate data set was taken from the Czech National Phytosociological Database (Chytrý & Rafajová 2003) to compare variation in plot sizes used within a single country. All available relevés, sampled from 1970 to 2000, assigned to vegetation classes by their original authors, and with a plot size indication were used except those assigned to classes represented by less than 50 relevés (*Charetea fragilis, Puccinellio-Salicornietea* and *Erico-Pinetea*). The resulting data set contained 27365 relevés.

Descriptive statistics for each data set were calculated using the SPSS package (Anon. 1998). Plot sizes used in more than 10% of the relevés assigned to a particular class were considered as frequently used.

Results

Basic statistics of plot sizes used in Europe and the Czech Republic are summarized in Tables 1 and 2. In spite of the considerable variation, both data sets show that larger plot sizes are generally used in taller vegetation. In accordance with plot size recommended in phytosociological handbooks (Westhoff & van der Maarel 1978; Dierschke 1994), the largest plots are usually used for woodlands: 100-200 m^2, and scrub: 25-100 m^2. Most types of grasslands and low-scrub vegetation are sampled in plots of 10-50 m^2. Plot sizes smaller than 5 - 10 m^2 are used either in vegetation with a typical stand height not exceeding a few cm or in vegetation types frequently developed in small patches of a few m^2, such as pleustonic vegetation (*Lemnetea*), stonewort vegetation (*Charetea fragilis*), vegetation of oligotrophic waters (*Isoëto-Littorelletea*), annual amphibious vegetation (*Isoëto-Nanojuncetea*), vegetation of springs (*Montio-Cardaminetea*), ephemeral vegetation of coastal salt-sprayed habitats (*Saginetea maritimae*), and vegetation of trampled habitats (*Polygono arenastri-Poëtea annuae*). Compared with average plot sizes used for herbaceous or low-scrub vegetation, relatively large plots are frequently used for sampling species-poor or very open vegetation types, such as the vegetation of screes (*Thlaspietea rotundifolii*) and heathlands (*Calluno-Ulicetea*). However, this does not hold true for the Czech data, as the vegetation of these two classes rarely occurs in extensive stands in the Czech Republic.

The largest variation in plot size, as quantified as the variation coefficient, was detected in classes of species-poor vegetation, which is often developed in small patches but occasionally forms quite extensive stands, e.g. pleustonic vegetation (*Lemnetea*), vegetation of oligotrophic waters (*Isoëto-Littorelletea*), annual amphibious vegetation (*Isoëto-Nanojuncetea*), salt-marsh vegetation with annual succulents (*Thero-Salicornietea*), maritime salt-marsh grasslands (*Juncetea maritimi*), and vegetation of trampled habitats (*Polygono arenastri-Poëtea annuae*). This large variation indicates that researchers tend to use large plots in these vegetation types, but they are frequently limited by the total size of

Table 1. Summary statistics of plot sizes in the European data set. Vegetation classes and groups of classes are according to Mucina (1997). *N* – number of relevés; SD – standard deviation; V – variation coefficient; Min, Max – minimum and maximum plot size found. The most frequent plot sizes are ranked by decreasing frequency.

	N	Mean plot size	SD	V	Most frequent plot sizes	Min	Max
Aquatic vegetation							
Pleustonic vegetation (*Lemnetea*)	446	12	32	2.7	2; 1; 4	0.01	300
Stonewort vegetation (*Charetea fragilis*)	53	4	4	0.9	5; 2; 1; 3	1	20
Vegetation of mesotrophic and eutrophic waters (*Potametea*)	1039	23	37	1.6	10; 5; 2	0.5	400
Vegetation of fresh-water marshes and fens							
Vegetation of oligotrophic waters (*Isoëto-Littorelletea*)	579	11	33	2.9	1; 2; 3; 5	0.1	400
Annual amphibious vegetation (*Isoëto-Nanojuncetea*)	274	13	41	3.1	2; 3; 1	0.05	400
Vegetation of springs (*Montio-Cardaminetea*)	320	4	7	1.6	4; 0.1	0.04	80
Reed beds and tall-sedge vegetation (*Phragmito-Magnocaricetea*)	1880	25	34	1.4	10; 20	0.5	500
Fens and transitional mires (*Scheuchzerio-Caricetea fuscae*)	1141	18	27	1.5	10; 2	0.25	200
Bogs (*Oxycocco-Sphagnetea*)	662	24	47	2.0	4; 10	0.5	500
Coastal vegetation							
Nitrophilous strandline vegetation (*Cakiletea maritimae*)	647	16	28	1.7	10; 4	0.5	300
Ephemeral vegetation of coastal salt-sprayed habitats (*Saginetea maritimae*)	336	3	5	2.0	1; 2; 0.25	0.06	50
Vegetation of coastal salt-sprayed rocks (*Crithmo-Staticetea*)	932	13	14	1.1	10; 5; 20	0.1	100
Salt-marsh vegetation with annual succulents (*Thero-Salicornietea*)	592	16	49	3.1	1; 10; 2	0.5	1000
Saltmarsh vegetation of succulent scrub (*Salicornietea fruticosae*)	219	28	63	2.2	10; 20	1	500
Maritime salt-marsh grassland (*Juncetea maritimi*)	320	21	65	3.0	10; 5; 20	1	1000
Vegetation of coastal sand dunes (*Ammophiletea*)	1500	31	47	1.5	10; 20	1	800
Chasmophytic vegetation							
Vegetation of rocks and walls (*Asplenietea trichomanis*)	872	21	35	1.7	10	0.1	200
Vegetation of screes (*Thlaspietea rotundifolii*)	703	40	50	1.3	100; 10	0.5	500
Arctic and alpine vegetation							
Subalpine and subarctic heathlands (*Loiseleurio-Vaccinietea*)	68	22	36	1.7	2; 1; 9	0.5	200
Snow-bed vegetation (*Salicetea herbaceae*)	167	13	19	1.5	4; 10; 20; 2	0.06	100
Siliceous alpine and boreal grasslands (*Juncetea trifidi*)	224	23	32	1.4	4; 10; 100; 25	0.5	200
Tundra grasslands and dwarf heathlands (*Carici rupestris-Kobresietea bellardii*)	78	7	6	0.8	4; 6; 16; 2	1	25
Calcareous alpine grasslands (*Elyno-Seslerietea*)	331	45	46	1.0	100; 25; 20	1	225
Subalpine deciduous scrub and tall-forb vegetation (*Mulgedio-Aconitetea*)	338	51	54	1.1	100; 25; 50	2	400
Synanthropic vegetation							
Annual hygrophilous ruderal vegetation (*Bidentetea tripartiti*)	353	11	16	1.5	10; 5; 4	1	150
Vegetation of trampled habitats (*Polygono arenastri-Poëtea annuae*)	907	9	19	2.1	2; 1; 4	0.1	300
Annual weed vegetation (*Stellarietea mediae*)	2604	74	138	1.9	10	0.1	800
Perennial xerophilous ruderal vegetation (*Artemisietea vulgaris*)	1455	29	36	1.3	10	0.5	400
Perennial mesophilous ruderal vegetation (*Galio-Urticetea*)	669	26	39	1.5	20; 10	1	800
Vegetation of woodland clearings (*Epilobietea angustifolii*)	182	37	46	1.3	12	2	350
Temperate heathlands and grasslands							
Heathlands and acidophilous grasslands (*Calluno-Ulicetea*)	2037	46	102	2.2	25; 10; 100	0.05	2500
Temperate sand grasslands and therophyte swards (*Koelerio-Corynephoretea*)	1110	11	17	1.6	10	0.01	200
Hay meadows and pastures (*Molinio-Arrhenatheretea*)	5474	34	46	1.3	20; 25	0.2	500
Woodland fringe vegetation (*Trifolio-Geranietea*)	784	14	15	1.1	10; 5	0.1	100
Dry grasslands and steppes (*Festuco-Brometea*)	2663	29	45	1.6	10	0.5	800
Inland halophilous grasslands (*Puccinellio-Salicornietea*)	503	11	14	1.3	10; 1; 9	0.5	200
Temperate and boreal woodlands and scrub							
Temperate mesophilous and xerophilous scrub (*Rhamno-Prunetea*)	764	76	64	0.8	100; 30	2	400
Willow and poplar riverine woodlands and scrub (*Salicetea purpureae*)	113	128	111	0.9	200	5	420
Alder and willow carrs (*Alnetea glutinosae*)	437	128	104	0.8	100; 50; 200	1	600
Deciduous woodlands (*Querco-Fagetea*)	3232	252	294	1.2	100; 200; 400	1	10000
Montane calcareous pine woodlands (*Erico-Pinetea*)	77	147	93	0.6	100; 150	35	400
Coniferous woodlands (*Vaccinio-Piceetea*)	221	120	128	1.1	100; 150	1	1440
Oromediterranean grasslands and scrub							
Cyrno-Sardean oromediterranean grasslands (*Saginetea piliferae*)	223	114	62	0.5	100; 200; 50	9	200
Southwest European oromediterranean calcareous grasslands and scrub (*Festuco hystricis-Ononidetea striatae*)	135	51	28	0.5	50; 100; 20	4	100
Cyrno-Sardean mountainous garrigue (*Carici-Genistetea lobelii*)	110	102	72	0.7	100; 200; 50	10	300
Mediterranean vegetation							
Mediterranean annual vegetation (*Helianthemetea guttati*)	883	13	20	1.5	4; 10	0.05	100
Mediterranean pseudo-steppes (*Lygeo sparti-Stipetea tenacissimae*)	409	59	36	0.6	100; 50; 10	0.1	200
Mediterranean siliceous low scrub (*Cisto-Lavanduletea*)	96	105	101	1.0	100	1	500
Mediterranean calcareous low scrub (*Cisto-Micromerietea julianae*)	899	55	59	1.1	50; 20; 100	3	400
Mediterranean evergreen woodlands and macchia (*Quercetea ilicis*)	937	121	166	1.4	100; 200; 50	2	2000
Semideserts							
Mediterranean semidesert scrub (*Pegano harmalae-Salsoletea vermiculatae*)	176	50	80	1.6	20; 10; 15	1	400

the stand. Unlike in the European data set, the highest variation in the Czech data set was found in mire vegetation. In bogs (*Oxycocco-Sphagnetea*) it is obviously due to the considerable structural complexity of the vegetation assigned to this class, which comprises small treeless hummocks surrounded by transitional mires, fens or pools on the one hand, and extensive stands of forested bogs on the other.

Although the major trends are common to the European and the Czech data set, there are some interesting differences. Plot sizes are more standardized in the Czech Republic (variation coefficient rarely exceeds 1.5) than in Europe (variation coefficient is often higher than 2). This difference obviously results from lower variation in different approaches and methodological schools existing in a single country. In Europe, more popular plot sizes are those derived as multiplication products of number 10 (e.g. 5, 10, 20, 50, and 100 m^2), while in the Czech Republic there is a clear preference of sizes derived from quadratic shape of plots, namely 16, 25, 100 m^2. Compared with European averages, Czech phytosociologists tend to use smaller plots for sampling chasmophytic and alpine vegetation and some types of grassland and synanthropic vegetation, and larger plots for sampling aquatic vegetation, mires and woodlands.

Discussion

Historical causes of variation in plot size

Current analysis revealed a considerable variation in the relevé plot sizes used by European phytosociologists. The origin of this variation may be traced back to the early theory of vegetation science, notably to the minimum area concept (Braun-Blanquet 1913, 1928; Du Rietz 1921). This concept postulated that every vegetation stand inherently possesses some threshold plot size (i.e. the minimum area), which includes all the important properties of the vegetation type. During the history of phytosociology, several attempts have been made to provide a formal definition of the minimum area, and to develop a method for its exact measurement (e.g. Barkman 1968, 1989; Tüxen 1970; Moravec 1973; Dietvorst et al. 1982). All these methods attempted to find a ‘correct’ plot size by measuring change in some vegetation parameter as a function of plot size, but there was no theoretical reason to expect that such ‘correct’ plot size does exist. Current ecology stresses the principle that any scale (e.g. any plot size) can be used to study plant communities and different patterns can be recognized at different scales (Allen & Starr 1982; Allen & Hoekstra 1992; Levin 1992; Peterson & Parker 1998).

Although the minimum area concept used to be frequently mentioned in phytosociological papers, it was apparently circular (Feoli 1984). Its circularity can be demonstrated using the definition by Toman (1990), which we believe to be rather close to the intuitive understanding of the concept by earlier generations of European phytosociologists: (Minimum area is) “... the smallest possible area, which already shows a representative species combination, so that a reliable syntaxonomical classification of the stand is possible” (translated from German). This definition implies that the minimum area can only be determined if the properties of the vegetation type are already known. It is satisfactory if the relevés are used merely for documentation of intuitively recognized vegetation types, however, it is useless if relevés are intended to be used as primary data for delimitation of vegetation types.

Rough standardization of plot sizes used for sampling different vegetation types was achieved among European phytosociologists during the 1930s, mainly through personal contacts with the leading centre in Braun-Blanquet’s institute in Montpellier. Most of the pioneer phytosociologists possibly believed that the plot sizes used by their predecessors were based on objectively determined minimum areas, and did not recognize these plot sizes to be purely conventional. As demonstrated in the case of Czech grassland vegetation (Chytrý 2001), standardization of conventional plot sizes for some vegetation types could be achieved even later, e.g. in the 1960s.

However, as shown in the current analysis, and as evident from the rather broad ranges of recommended plot sizes published in standard handbooks (Westhoff & van der Maarel 1978; Dierschke 1994), the standardization has been rather loose. Even in a single community type, the plot sizes reported in the literature may vary considerably. Small plots are usually used when the entire size of the vegetation stand is smaller than the conventionally accepted plot size. By contrast, some phytosociologists tend to use large plots when vegetation is species-poor, apparently in order to increase the number of species in the relevés (Chytrý 2001).

More strict standardizations of plot sizes used in large areas and broad spectra of vegetation types are exceptional in Europe. Perhaps only in Great Britain, where the phytosociological method was introduced rather late, the project of the National Vegetation Classification (Rodwell 1991-2000) could avoid the historically established lack of uniformity among continental researchers. This project used a standardized sampling design with four plot sizes to sample different vegetation types, 2 m × 2 m, 4 m × 4 m, 10 m × 10 m, and 50 m × 50 m, or sampling the whole stand when it was smaller than the standard plot size.

Table 2. Summary statistics of the plot sizes in the Czech data set. Vegetation classes and groups of classes are according to Mucina (1997). *N* – number of relevés; SD – standard deviation; V – variation coefficient; Min, Max – minimum and maximum plot size found. The most frequent plot sizes are ranked by decreasing frequency.

	N	Mean plot size	SD	V	Most frequent plot sizes	Min	Max
Aquatic vegetation							
Pleustonic vegetation (*Lemnetea*)	547	28	41	1.4	25; 16; 100	1	400
Vegetation of mesotrophic and eutrophic waters (*Potametea*)	1119	33	49	1.5	25; 16	1	900
Vegetation of fresh-water marshes and fens							
Vegetation of oligotrophic waters (*Isoëto-Littorelletea*)	113	9	8	0.9	4; 9; 25	0.3	40
Annual amphibious vegetation (*Isoëto-Nanojuncetea*)	244	13	15	1.2	25	0.2	100
Vegetation of springs (*Montio-Cardaminetea*)	290	13	23	1.8	9; 1	1	300
Reed beds and tall-sedge vegetation (*Phragmito-Magnocaricetea*)	3257	22	22	1.0	25; 16	0.6	400
Fens and transitional mires (*Scheuchzerio-Caricetea fuscae*)	615	25	51	2.1	25; 16	0.1	900
Bogs (*Oxycocco-Sphagnetea*)	273	72	130	1.8	100; 25	0.2	1000
Chasmophytic vegetation							
Vegetation of rocks and walls (*Asplenietea trichomanis*)	212	6	5	0.9	4; 10; 5	0.2	30
Vegetation of screes (*Thlaspietea rotundifolii*)	69	12	6	0.5	10; 25	2	30
Arctic and alpine vegetation							
Siliceous alpine and boreal grasslands (*Juncetea trifidi*)	105	16	14	0.9	16; 25	0.1	100
Subalpine deciduous scrub and tall-forb vegetation (*Mulgedio-Aconitetea*)	440	26	26	1.0	25; 16	2	225
Synanthropic vegetation							
Annual hygrophilous ruderal vegetation (*Bidentetea tripartiti*)	326	22	29	1.3	25; 16	2	400
Vegetation of trampled habitats (*Polygono arenastri-Poëtea annuae*)	1050	10	11	1.1	10; 2	0.5	100
Annual weed vegetation (*Stellarietea mediae*)	1214	20	20	1.0	16; 20; 10	0.8	100
Perennial xerophilous ruderal vegetation (*Artemisietea vulgaris*)	473	15	12	0.8	10; 20	1	100
Perennial mesophilous ruderal vegetation (*Galio-Urticetea*)	1282	18	26	1.4	10; 20; 25; 15; 16	1	400
Vegetation of woodland clearings (*Epilobietea angustifolii*)	453	37	30	0.8	25	0.3	300
Temperate heathlands and grasslands							
Heathlands and acidophilous grasslands (*Calluno-Ulicetea*)	892	22	17	0.8	16; 25	0.3	200
Temperate sand grasslands and therophyte swards (*Koelerio-Corynephoretea*)	399	11	12	1.1	25; 2; 1; 16	1	100
Hay meadows and pastures (*Molinio-Arrhenatheretea*)	4965	21	22	1.1	25; 16	1	400
Woodland fringe vegetation (*Trifolio-Geranietea*)	219	28	33	1.2	25	2	300
Dry grasslands and steppes (*Festuco-Brometea*)	3127	24	19	0.8	25; 16	0.1	300
Temperate and boreal woodlands and scrub							
Temperate mesophilous and xerophilous scrub (*Rhamno-Prunetea*)	134	52	57	1.1	100	0.5	400
Willow and poplar riverine woodlands and scrub (*Salicetea purpureae*)	111	180	87	0.5	200; 150; 100; 300; 250	25	400
Alder and willow carrs (*Alnetea glutinosae*)	180	174	114	0.7	100; 225; 200	4	625
Deciduous woodlands (*Querco-Fagetea*)	4337	284	135	0.5	400; 200; 300; 100	1	2500
Coniferous woodlands (*Vaccinio-Piceetea*)	918	200	158	0.8	100; 400; 25	4	1600

Making use of relevés with varying plot sizes

Electronic databases of phytosociological relevés are currently being developed in many institutions across Europe (Ewald 2001; Hennekens & Schaminée 2001). Our analysis has shown that the data stored in these databases are quite heterogeneous with respect to plot size. For the analysis of these data, however, uniformity of plot sizes may be required in order to avoid possible negative effects of the scale-dependence of inter-specific correlations.

In a strict sense, existing data sets should be divided into subsets of identical plot sizes, and these subsets should be analysed separately. However, the effect of variable plot size on vegetation classification (Fekete & Szöcs 1974) is little known. It may be important in some vegetation types but negligible in other types. We presume that in most vegetation types, relevés falling into a certain range of the most frequent plot sizes can perhaps be analysed together in a single data set, without introducing severe error. Such a moderate departure from stringent demands for a uniform plot size is pragmatic, as it reduces the loss of available data. However, we propose that every data analysis should be preceded by deleting the relevés from the tails of frequency distribution of plot sizes.

Standardization proposal

Sampling procedures in current projects of vegetation survey move towards standardization (Mucina et al. 2000), and there is also a chance to standardize plot sizes. Nevertheless, it is difficult to propose standard plot sizes for the whole of Europe due to the high diversity of vegetation types across the continent and variable field methods traditionally used in different countries. Using the results of our analysis, four plot sizes, which seem to fit closest to the established tradition, may be proposed as standards:

4 m^2 – All types of aquatic vegetation and low terrestrial vegetation, including:
- Vegetation of oligotrophic waters (*Isoëto-Littorelletea*);
- Annual amphibious vegetation (*Isoëto-Nanojuncetea*);
- Vegetation of springs (*Montio-Cardaminetea*);
- Ephemeral vegetation of coastal salt-sprayed habitats (*Saginetea maritimae*);
- Vegetation of rocks and walls (*Asplenietea trichomanis*);
- Mediterranean and Atlantic vegetation of water-splashed rocks (*Adiantetea*);
- Annual hygrophilous ruderal vegetation (*Bidentetea tripartiti*);
- Vegetation of trampled habitats (*Polygono arenastri-Poëtea annuae*).

16 m^2 – Most types of herbaceous vegetation:
- Reed beds and tall-sedge vegetation (*Phragmito-Magnocaricetea*);
- Fens and transitional mires (*Scheuchzerio-Caricetea fuscae*);
- Bogs (*Oxycocco-Sphagnetea*);
- Coastal vegetation (except *Saginetea maritimae*);
- Vegetation of screes (*Thlaspietea rotundifolii*);
- Arctic and alpine herbaceous vegetation;
- Synanthropic vegetation (except annual hygrophilous ruderal vegetation of the *Bidentetea tripartiti,* vegetation of trampled habitats of the *Polygono arenastri-Poëtea annuae* and woodland clearing scrub of the *Epilobietea angustifolii*);
- Temperate heathlands and grasslands (all types);
- Oromediterranean grasslands and scrub (all types);
- Mediterranean pseudo-steppes (*Lygeo sparti-Stipetea tenacissimae*);
- Mediterranean semidesert scrub (*Pegano harmalae-Salsoletea vermiculatae*).

50 m^2 – Shrub vegetation:
- Bogs (*Oxycocco-Sphagnetea*);
- Subalpine deciduous scrub (*Mulgedio-Aconitetea*);
- Vegetation of woodland clearings (*Epilobietea angustifolii*);
- Temperate mesophilous and xerophilous scrub (*Rhamno-Prunetea*);
- Willow riverine scrub (*Salicetea purpureae*);
- Willow carrs (*Alnetea glutinosae*);
- Mediterranean low scrub (*Cisto-Lavanduletea* and *Cisto-Micromerietea julianae*);
- Mediterranean riverine scrub (*Nerio-Tamaricetea*);
- Mediterranean macchia (*Quercetea ilicis*).

Herbaceous or woodland vegetation included in these classes should be sampled in plots of 16 or 200 m^2, respectively.

200 m^2 – Boreal, temperate and Mediterranean woodlands.

This standardization proposal cannot be followed where an entire stand of vegetation is smaller than the proposed size, while no larger patch is available nearby. In such situations, it may be advisable to take a relevé in a smaller plot than given above, rather than to refrain from sampling. However, when there are no problems in using the proposed plot sizes in sufficiently large vegetation stands, the above standards are recommended.

Plot size variation among broadly defined vegetation types

Variation in plot size within individual vegetation types is only one aspect of the plot size issue. It is particularly important if relevés from differently sized plots are to be analysed together. Another aspect is variation in plot size among broadly defined vegetation types, such as phytosociological classes. There is rarely a need for joint analysis of data from different classes, especially from structurally dissimilar ones. However, this latter aspect indicates that a phytosociological system of vegetation units, as well as related systems of habitat classification, consist of phenomena defined at different spatial scales.

Vegetation types sampled in small plots, e.g. 4 m^2, can be often recognized as synusiae within vegetation types sampled in larger plots. The example in Fig. 1 shows that at least three phytosociological classes can be distinguished in a series of nested plots of different size: thermophilous oak woodland (*Quercetea pubescentis*) in large plots, dry grassland (*Festuco-Brometea*) or woodland fringe vegetation (*Trifolio-Geranietea*) in medium plots, and therophyte swards on rock outcrops

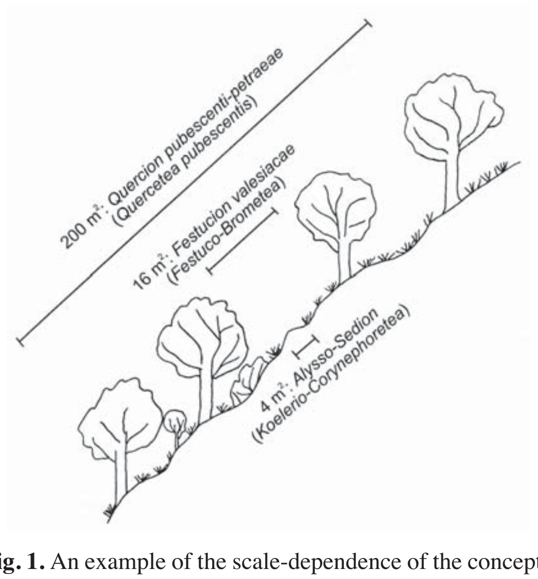

Fig. 1. An example of the scale-dependence of the concept of vegetation units and habitat types. In a series of nested plots, relevés taken in the large plot can be assigned to the class of thermophilous oak woodlands (*Quercetea pubescentis*), relevés taken in smaller plots in canopy openings to the class of dry grasslands (*Festuco-Brometea*), and relevés from the smallest plots on rock outcrops with vernal therophytes to the class of temperate sand grasslands and therophyte swards (*Koelerio-Corynephoretea*).

(*Koelerio-Corynephoretea*) in small plots. Similar relationships can be found in many pairs of different vegetation types, such as Mediterranean low scrub (*Cisto-Lavanduletea, Cisto-Micromerietea julianae*) and Mediterranean annual vegetation (*Helianthemetea guttati*), or hygrophilous deciduous woodlands (*Alnion incanae, Querco-Fagetea*) and shade-tolerant spring vegetation (*Caricion remotae, Montio-Cardaminetea*). A striking feature in the phytosociological tradition is that, especially on finer scales, vegetation is only sampled in a few specific habitats while other habitats are neglected. Examples are patches with vernal therophytes (*Koelerio-Corynephoretea*) in dry grasslands or moist patches in woodlands (*Montio-Cardaminetea*), which are preferentially sampled in smaller plots than the adjacent vegetation. Contrary to the moist patches, mesic habitats of the woodland floor are almost never sampled in small plots (but see the discussion on synusial communities in Barkman 1968 and also Gillet et al. 1991, Gillet & Gallandat 1996, Freléchoux et al. 2000, Decocq 2002 for alternative approaches).

These examples clearly show that the present phytosociological system of syntaxa and related systems of habitat classification consist of a mixture of phenomena manifested on different spatial scales, which are not directly comparable. On every scale, and notably on the finest scales, only certain phenomena are being described as vegetation types while other phenomena are neglected. It is therefore useful to define phytosociological syntaxa as scale-dependent concepts. Being the highest syntaxon, the phytosociological class is perhaps most suitable for this purpose, because once a class is defined as a phenomenon on a specific scale, all the lower-rank syntaxa are also defined on that scale.

The definition of the phytosociological class suggested by Pignatti et al. (1995) postulates that vegetation types included in one class have a common ecology (habitat) and a common set of character taxa which are coherent in their geographical distribution. In this definition, common physiognomy is considered as an auxiliary criterion unless it is discrepant with habitat, character taxa and phytogeographical affinities. We suggest to complete this definition by a requirement that the class should be defined on a uniform scale. This definition would imply, for example, that small-sized relevés of synusial vegetation types in a woodland herb layer cannot be assigned to the same class as the relevés of the same woodland sampled in large plots, i.e. comprising trees.

Pignatti et al. (1995) also distinguished 'bad' and 'good' classes, based on their criteria. Considering the criterion of scale, their evaluation would have to be slightly modified. For example, the class of bog vegetation (*Oxycocco-Sphagnetea*) is a well-defined class with respect to character species, ecology, and chorology, but it is a 'bad' class in terms of scale. The same holds true for most classes, which combine scrub and woodland vegetation.

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