In the Name of God
Unit 9: Range Management

Vegetation survey and sampling

Whatever our aim, approach and scale of observation, **vegetation**, whether loosely defined or approached as a **phytocoenosis** or a unit on a higher level of integration, should be described and measured. Vegetation characteristics are either derived from **plant morphological characters**, usually called structure, or from the **plant species** recognized, the **floristic composition**. Our description or analysis will only include a relatively small piece of vegetation which is considered representative of a larger unit. This leads to the issue of **sampling**.

In statistics the members of the universe can usually be identified without problems, e.g. the individuals of a crop and the trees in a **plantation**. In **vegetation ecology** this is much less simple. Moreover, the variables we measure and compare are partly composite and difficult to measure, notably the species composition, or only measurable through **destructive sampling**, notably **above-ground biomass** (and most below-ground characteristics as well).

Our universe to be sampled is the total area occupied by a certain type of vegetation. However, (i) it is difficult to identify this type, even if we have some previous knowledge about it; and (ii) this total area can be too large to be encompassed in one sampling. The first problem can be approached as follows - partly following the classical textbook by Cain & Castro (1959): sampling is preceded by reconnaissance, an inspection of a local area where the vegetation pattern with its **dominant species** and species combinations is recognized and related to topography and other apparent environmental conditions. The second problem can be solved by restricting ourselves to a 'local universe'.

The reconnaissance is followed by a **primary survey**, including a brief description of the dominant vegetation types. Of course the areal extent and amount of detail will depend on the specific objective of the study. Amongst the many different objectives four common ones are:

1. **Phytosociological,** with the intention to analyse phytocoenoses for a subsequent **community classification**, either of one particular type, or, preferably, of the all the types locally recognized;
2. **Ecological,** with the intention to correlate the local variation in vegetation composition with variation in environmental factors; ideally ecological and phytosociological sampling are integrated;
3. **Dynamical,** with the intention to establish or revisit pieces of vegetation for describing vegetation changes;
4. **Applied,** for instance to investigate the effect of a management measure.

The next phase in the analysis is an intensive survey, usually including a more complete description and measurement of the structure and species composition of the vegetation, and analysis of soil and **microclimate** characteristics.

In any case a unit of investigation has to be located and delimited. Since this is usually a well-delineated piece of vegetation the indication plot or sample plot is obvious. Other terms in use include stand, site and quadrat, a sample area within a frame, usually a square. For time series of observations the terms **permanent plot** or **permanent quadrat** are in use. Often terms for the analysis of the plot – analysis itself, sample, record, releve - are used as equivalent to the sample plot. We better stick to the terms plot and sample, while adding the term releve (French

for record) for the special case it was originally meant for: a phytosociological record of a phytocoenosis for classification purposes.

As to the phytosociological sampling objective, the Braun-Blanquet approach has often been criticized for a neglect of the primary survey and a 'subjective' selection of sample plots which are recognized as representative **stands of a plant community type** from which releves have been taken elsewhere. The problem with selective sampling is not so much that the sample is not representative but rather that other, related stands of vegetation are not sampled. However, the personal bias of phytosociologists and the lack of representative samples will be compensated for if larger numbers of samples of a certain type are available. This is the case in most European countries. For example, the survey of British plant communities was based on 35,000 samples.

In the survey of plant communities of The Netherlands lower units are documented by up to several hundreds of releves, and higher units by several thousands. The database behind this survey, which is still growing, contained 350,000 samples in 2001, and software to handle such huge data sets has been developed. If **vegetation analysis** proceeds on the basis of sample plots the plot is usually analysed completely, at least regarding species composition ('**single-plot analysis**'). In certain cases and in certain traditions **multiple-plot analysis** is preferred on the basis of systematically or randomly located small squares. In cases where the delineation of a sample plot is not possible - or not desired - so-called **plotless sampling** can be applied. This proceeds along lines where contacts with vegetation are recorded at regular distances, or with networks of points, or with small quadrats. Lines, points or quadrats can be laid out at random, in a systematical way, or in a combination (stratified random sampling). The formerly practised vegetation analysis in Northern Europe can be considered as a transition between multiple-plot **analysis s.s.** and plotless sampling.

Size of the sample plot; minimal area

When an intensive survey is carried out in a sample plot the size of this plot has to be determined. Usually the entire local phytocoenosis (according to its definition) is inspected as to uniform environment, floristic composition and structure, as distinct from the surrounding vegetation. Depending on the type of vegetation the area covered may vary from a few m^2 to several ha. If species composition is one of the descriptors, the sample plot should not be too small because only a few species would then be included. This leads to a discussion of the concept of **minimal area**, defined as a 'representative area, as an adequate sample of species of regular occurrence', which is related to the total number of species in the stand. A definition such as that of Mueller-Dombois & Ellenberg (1974): 'the smallest area on which the species composition of the community in question is adequately represented' is what Westhoff & van der Maarel called a '**synthetic minimal area**'. Such an area cannot be determined without previous knowledge of the community sampled; this can have been acquainted during the successive approximation.

To this end the determination of a **species-area relationship** has been recommended, both in classical phytosociology and in Anglo-American textbooks of vegetation analysis. The usual way of determining this relation is to start with a very small quadrat, count the number of species, enlarge the quadrat, usually with a factor 2, count the number of additional species, etc. until the boundaries of the local stand are reached. Instead of such a series of **nested plots** randomly located plots of increasing size are theoretically preferred and, still better, several such series should be analysed. The species-area relation is usually plotted as number of species

against area. The resulting curve is quasi-asymptotic and the suggestion was to consider as minimal area an area beyond which the curve levels off.

Although this procedure has been long criticized as it is subjective, i.e. dependent on the choice of the ratio of the y-axis to the x-axis, it has remained standard practice in phytosociology, partly under the influence of Tiixen (1970) who collected many species-area curves from the literature and spoke of a **'saturated community'** if the minimal area had been reached. It is curious that the decisive arguments against this approach had already been provided by the Swedes O. Arrhenius, L.G. Romell and H. Kylin before Braun-Blanquet had published the first edition of his textbook. They had developed three models of species-area relationships, in graphical terms the log-log, the linear-log and the linear-linear relation, respectively. The third relation, the real saturation curve was only found in species-poor communities, while the first was fully developed by Preston (1962) and the second is well-known as the basis for the a-diversity of Fisher, as elaborated by Williams (1964). Braun-Blanquet (1932) mentioned these models but he was only vaguely aware of the repercussions for the minimal area approach by confirming that Kylin's model of a linear-linear species-area relation was appropriate for the minimal area approach but by not realizing that the other two models, which are much more commonly applicable to natural communities, question the validity of the species-area based determination of the minimal area.

While these considerations on minimal area refer to numbers of species represented, the area to be sampled should also be large enough to represent the abundance relations of the participating species. This idea was expressed for the first time by E. Meijer Drees in 1954, who distinguished between qualitative (species-area based) and quantitative minimal area. In his case the latter concept referred to the area where most of the timber species in tropical rain forest stands were represented with trees of more than 100 cm circumference.

Another quantitative approach had already been proposed by G.E. Du Rietz in the 1920s: the frequency of species in series of quadrats of increasing size is determined and the number of 'constant' species (with frequency of at least 90%) is plotted against area. M. Gounot, C. Roux and other French investigators calculated the floristic similarity between quadrats of increasing size. However, none of these more sophisticated methods produced saturation curves in most cases. Dietvorst *ef al.* (1982) elaborated the similarity approach by comparing values with the maximum similarity values obtained in models with 5000 cells with varying numbers of species and mean cover. Critical quantitative similarity levels varied from more than 90% in salt marsh to 50-80% in open sand dune vegetation; qualitative levels from 50% in *Calluna* heath to 80% in salt marsh. The highest of the two corresponding minimal area levels was chosen as minimal area. These values were within the range indicated by Westhoff & van der Maarel (1978). It was also shown that the sizes of the two minimal areas are related to species richness and amount of dominance.

Barkman (1989) advocated an additional method by plotting the increase in species number against log area (based on large numbers of replicates). If the increase is zero over short trajectories this would be an indication that the size of some within-community pattern is exceeded. Following E. Meijer Drees and others, he also emphasized the concept of **'biological minimal area',** the area needed for a local phytocoenosis to maintain itself, including patch dynamics. For forests this area could be several ha. The species richness of the total vegetation stand is the same as what nowadays is called the community species pool. In conclusion, a 'minimal area' to be sampled, related to species richness, canopy height and species dominance relations, remains difficult to determine. Instead a 'representative' sampling area should be

selected the size of which can be chosen on the basis of field experience with different vegetation types as represented in various textbooks.

Sampling of vegetation characteristics

Vegetation structure and floristic composition are usually measured or estimated on a plant community basis. Barkrnan (1979) distinguished between texture, the composition of morphological elements, and structure s.s., the spatial arrangement of these elements - the temporal arrangement, including **phenology**, can be included here. However, most ecologists still use structure as a general term. Four overall measurements, some of them more widely used than others, may be mentioned:

1. **Stratification:** the arrangement of phytomass in layers. Usually a tall tree, low tree, tall shrub, low shrub, dwarf-shrub, tall herb, low herb and moss layer are distinguished if separated from each other.
2. **Cover:** Percentage cover is the relative area occupied by the vertical projection of all aerial parts of plants, as a percentage of the surface area of the sample plot. This can be determined for the vegetation as a whole or for separate layers. Cover is usually estimated by eye, but can also be determined more accurately through the line-intercept method - in **sparse vegetation** - where contacts between the line and plant parts are counted, or the point-intercept method - in **dense short vegetation** - where contacts with a cross-wire grid are counted, or the cover pin frame - in dense taller vegetation - where pins are moved vertically downwards and contacts with plant parts are counted (because pins can hit plants at several heights total cover can exceed 100%).
3. **Phytomass:** Total phytomass (= plant biomass) in the plant community, is expressed as dry-weight $g.m^2$, $kg.m^2$ or t.ha ($t.ha^{-1}$ = 10 kgm^2). Phytomass is usually determined by removing the standing crop, the above-ground phytomass during the period of maximal development. The standing crop is related to, but by no means identical to, what is produced during the growing season - which varies from weeks in arctic to 12 months in moist tropical environments. Plant production, i.e. production by **autotrophic plants**, also called primary production - to distinguish it from secondary production, which is the transformation of phytomass by **heterotrophic organisms**, animals and saprobes - is usually expressed in terms of productivity, production per time unit, usually g m^2 y. The destructive sampling necessary for phytomass measurements usually requires an adapted sampling scheme so that a sufficient area of the same vegetation remains undisturbed. Phytomass can be determined per layer so that a vertical phytomass profile can be obtained and interpreted in terms of species interactions and light climate. Barkman (1988) developed a method and apparatus to determine phytomass denseness, and its horizontal and vertical distribution. This method is also destructive, but only small sections of plant mass are cut. Such profiles can be fruitfully linked to measurements of microclimate.
4. **Leaf Area Index:** The total area of leaf surface (actually photosynthetic surface) expressed in m^2 per m^2 surface area is known as leaf area index, LAI; it can be determined per layer and can thus also be used for a refined description of the architecture of vegetation. A derivate characteristic is specific leaf area, SLA = leaf (lamina) area per unit leaf (lamina) dry mass. **LAI** and cover are related, but no studies of the correlation between the two characteristics for individual species are known to the author. Next, structural-physiognomic characteristics can be determined. Typical textural characters, as mentioned by Barkman (1979), are leaf size, leaf consistency, leaf

orientation, leaf longevity and plant growth form. The consistent analysis (rather the detailed description) of such characters as developed by P. Dansereau, F.R. Fosberg and A.W. Iciichler, and life-form categories based on, or elaborated from, C. Raunkiaer's system is usually related to the respective classification systems developed. The description of the characteristics and spatial position of organs, as in textural descriptions, including drawings of vegetation profiles, has not become a standard procedure. Structural research rather proceeds via the species composition combined with the allocation of species to life form or other categories. Structural analysis of above-ground plant parts should be (but is seldom) completed with an analysis of the below-ground parts.

Sampling of species characteristics

The species composition of a plant community, the key element in its definition, is described in its simplest form by a list of species occurring in the sample plot. The list is mostly restricted to vascular plants, and almost always to their above-ground parts; often easily recognizable mosses, liverworts and lichens are included. The quantity a species attains can be called its performance, but often the term abundance is used, even if this is only one of the following quantitative measures:

1. **Abundance:** the number of individuals on the sample plot. Because individuality in many (clonal) plant species is difficult to determine, the concept of plant unit, a plant or part of a plant (notably a shoot) behaving like an individual, is needed, if only for a quantitative approach of **species diversity** based on the distribution of plant units over species. Density is a derivate variable, being the abundance per unit area.
2. **Frequency:** is the number of times a species occurs in subplots within the sample plot - or within an undelimited phytocoenosis (formally plottless sampling).
3. **Cover:** can be measured species-wise (see section 1.1.8); it is usually estimated along a cover scale. Many scales have been proposed, some of which more or less linear (e.g. with 10% intervals), some geometrical, e.g. the stillused five-point geometrical Hult-Sernander-Du Rietz scale developed during the 1910s by the so-called Uppsala school.
4. **Cover-abundance:** is a combined parameter of cover - in case the cover exceeds a certain level, e.g. 5% - and abundance. This 'total estimate' has been both criticized as a wrong combination of two independently varying parameters and praised as a brilliant integrative approach. It reminds us of the importance value developed by Curtis (1959), the product of density, frequency and cover, which has been popular in the US for some decades. Several proponents of a combined cover-abundance estimation have nevertheless found it realistic to convert the abundance categories in the combined scale into approximate cover values. The two combined scales still in use are the Domin or Domin-Krajina scale the Braun-Blanquet scale which, in several variants, has been in use since the 1920s. Van der Maarel (1979) suggested an 'ordinal transform' (OTV) scale replacing the modern nine-point Braun-Blanquet scale by the values 1-9, which could be used, if not as arithmetic at least as ordinal values. This scale was also included in Westhoff &van der Maarel (1978) and has found wide acceptance.
5. **Basal area:** the area outline of a plant near the surface, is of particular interest for trees and can be used for tree volume estimations. A related measure is **tree diameter at breast height** (DBH; at 1.30 m), which is more often used in standard forest descriptions.

6. **Phytomass:** can be measured per species, even if this is a very tedious work. These data can be used to accurately relate species performances to each other and to follow species performances in time series of observations and experiments.
7. **Sociability:** the gregariousness of plant units of a species, has been a standard parameter included in phytosociological releve's. Five degrees are distinguished, varying from 1 = plant units growing singly to 5 = growing in great crowds over most of the sample plot. However, this parameter has seldom been used in the comparison of releve's, mainly because sociability is species-specific for many species and also because there is no numerical way to treat the data.

Species data should not only be collected **above-ground** but also below-ground. Dierschke (1994) presented examples of **root:shoot ratio** differentiation within a plant community. Titlyanova et al. (1999) showed how in steppes the below-ground phytomass (which can store 70% of the net primary production) is more homogeneously distributed, both over the area and over the species. The dominance-diversity curves of 19 species in **steppe vegetation** based on percentage dry weight contributions of species to green phytomass and **below-ground organs** are quite different. Where in both cases the top species are *Stipa krylovii* and *Potentilla acaulis*, the other species have different sequences and the below-ground curve is much less steep. The main use of data on species characteristics is in the classification and ecology of communities, but these data also form the basis for the analysis of vegetation dynamics. For this purpose permanent sample plots can be established which are regularly, preferably annually, investigated. In order to interpret changes in species characteristics the data should be more accurate than in a spatial context. In relevis of permanent plots and in the analysis of **chronosequences** a more detailed cover scale can be used. However, to reduce the effects of subjectivity more exact data, notably on phytomass, are preferred.

Top 25 scientific journals publishing vegetation-related articles

1. ***Journal of Vegetation Science***
2. ***Vegetatio***
3. ***plant Ecology***
4. ***Journal of Ecology***
5. ***Ecological Monograph***
6. ***American Naturalists***
7. ***Journal of Applied Ecology***
8. ***Oikos***
9. ***Grass and Forage***
10. ***Canadian Journal of Plant Science***
11. ***Oecologia***
12. ***New Zealand Journal of Ecology***
13. ***Journal of Range Management***
14. ***Rangelands***
15. ***Biological Conservation***
16. ***Ecosystems***
17. ***Ecological Modelling***
18. ***American Midland Naturalist***
19. ***Australian Journal of Botany***
20. ***Forest Ecology and Management***
21. ***Journal of Forestry***
22. ***Journal of Experimental Botany***
23. ***African Journal of Ecology***
24. ***Forest Science***
25. ***Canadian Journal of Forest Research***