# Phytosociology

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## Introduction

Phytosociology is a subset of vegetation science, in which it stands out by focusing on extant (vs. fossil), taxonomic (vs. physiognomic or functional) plant assemblages at the scale of vegetation stands (vs. landscapes or biomes). Its principal goal is the definition and functional characterization of vegetation types based on the total floristic composition of stands. Phytosociology distinguishes between concrete vegetation stand (phytocoenosis), which can be represented by a plot record (relevé), and abstract vegetation type (syntaxon), representing a group of all stands sharing certain attributes. The classification framework (syntaxonomy) is designed in close analogy to plant taxonomy, with association as the basic unit.

The fundamental concepts of phytosociology were developed by Josias Braun-Blanquet in the 1920s. He combined a standardized protocol for plot sampling, sorting of species-by-plot matrices, demarcation of community types, and their hierarchical ordering into a practical and efficient framework for the study of vegetation. In this article, we use the term phytosociology for the Braun-Blanquet approach and its modern extensions.

Phytosociology is the mainstream vegetation classification scheme in Europe, as well as in several countries outside Europe, and has become increasingly popular worldwide from the 1990s onward. Within modern ecology, phytosociology represents the most comprehensive and consistent methodology for vegetation classification. Relevés are the most widely used standardized protocol for sampling plant species co-occurrences at the stand scale. Being derived from the vast body of relevé data, syntaxonomy provides a comprehensive yet open system of vegetation types, which are indispensable in land-use management and nature conservation. Consisting of abundance data on individual plant species, relevés and vegetation types organized in large phytosociological databases are an enormous source of fine-scale biodiversity information. If linked to the growing body of plant trait or indicator value data or environmental information in geographical information systems (GISs), phytosociological data open new avenues for exploring large-scale ecological patterns and processes, and provide spatially explicit information necessary for environmental management.

## Phytosociological Data

### Data Records

In phytosociology, the data of a single plot are called a relevé (French for record, see **Table 1**), which consists of 'header' and species data. The 'header' comprises plot identification, methodological information, and metric, ordinal, or categorical data on geographic position, environmental conditions, and overall vegetation structure. Some of these data are essential, others optional, depending on the purpose and resources of a project (**Table 2**).

The species data are composed of a list of plant taxa (species and infraspecific taxa; further referred to as 'species') and their attributes. A full relevé lists all plant species occurring in the plot and growing on soil, including bryophytes, lichens, and macroalgae. Additional recording of species growing on substrata other than soil, such as on living plants (epiphytes), rocks (saxicolous plants), or dead wood (lignicolous plants), is desirable, but not standard in phytosociology. Every species observation is assigned to a vertical stratum (e.g., tree layer, shrub layer, herb layer, and cryptogam layer). Woody species occurring in different layers are recorded separately for each layer. For each species observation in a layer, an importance value is estimated and usually expressed on a simplified scale of abundance (number of individuals/ramets) and/or cover (area of the vertical projection of all aerial parts of a species relative to the total plot area) (**Table 3**). As mixed cover-abundance scales pose problems in data analysis, pure cover scales are preferred when precise quantitative estimates are required, for

**Table 1** Example of a forest relevé with five vegetation layers distinguished: upper tree layer (T1), lower tree layer (T2), shrub layer (S), herb layer (H), and cryptogam layer (C)

| | |
|---|---|
| *Plot ID/methodology* | |
| Field number | 291 |
| Author | J Ewald |
| Plot size (m$^2$) | 144 |
| Plot shape | square |
| Sampling date | 3 June 1997 |
| Preliminary syntaxon | Galio-Fagetum adenostyletosum |
| *Geographic data* | |
| UTM coordinates | 32 U 4434393 E – 5272800 N |
| Locality | Ettaler Manndl, Höllenstein, 3 km W from Eschenlohe, Garmisch-Partenkirchen, Bavaria, Germany |
| *Environmental data* | |
| Elevation (m a.s.l.) | 1300 |
| Slope aspect (°) | 35 |
| Slope inclination (°) | 32 |
| Soil type | Cambisol |
| Parent material | Cretaceous sandstone |
| Management | Protective forest |
| Stand age (year) | 140 |
| *Structural data* | |
| Height upper tree layer (m) | 30 |
| Height lower tree layer (m) | 6 |
| Height shrub layer (m) | 3 |
| Cover upper tree layer (%) | 75 |
| Cover lower tree layer (%) | 3 |
| Cover shrub layer (%) | 1 |
| Cover herb layer (%) | 20 |
| Cover cryptogam layer (%) | 3 |

| *Layer* | *Species* | *Importance* |
|---|---|---|
| T1 | *Fagus sylvatica* | 3 |
| | *Picea abies* | 3 |
| T2 | *Picea abies* | 1 |
| S | *Picea abies* | 1 |
| H | *Acer pseudoplatanus* | + |
| | *Aconitum vulparia* | + |
| | *Adenostyles alliariae* | 1 |
| | *Adoxa moschatellina* | + |
| | *Athyrium filix-femina* | + |
| | *Cardamine flexuosa* | + |
| | *Chaerophyllum hirsutum* | + |
| | *Chrysosplenium alternifolium* | + |
| | *Cicerbita alpina* | + |
| | *Deschampsia cespitosa* | + |
| | *Dryopteris dilatata* | + |
| | *Dryopteris filix-mas* | + |
| | *Epilobium montanum* | + |
| | *Galeopsis tetrahit* | + |
| | *Galium odoratum* | + |
| | *Geranium robertianum* | + |
| | *Gymnocarpium dryopteris* | + |
| | *Impatiens noli-tangere* | + |
| | *Lamiastrum montanum* | 1 |
| | *Luzula sylvatica* subsp. *sieberi* | + |
| | *Lysimachia nemorum* | 1 |
| | *Mercurialis perennis* | + |
| | *Mycelis muralis* | 1 |
| | *Myosotis sylvatica* | + |
| H | *Oxalis acetosella* | 2 |
| | *Paris quadrifolia* | + |
| | *Polypodium vulgare* | + |
| | *Prenanthes purpurea* | + |
| | *Primula elatior* | + |
| | *Ranunculus lanuginosus* | 1 |
| | *Rumex alpestris* | + |
| | *Salvia glutinosa* | 1 |
| | *Sanicula europaea* | + |
| | *Saxifraga rotundifolia* | 1 |
| | *Senecio fuchsii* | 1 |
| | *Stellaria nemorum* | 2 |
| | *Thelypteris limbosperma* | + |
| | *Veronica urticifolia* | + |
| | *Viola biflora* | + |
| C | *Atrichum undulatum* | 1 |
| | *Brachythecium rutabulum* | + |
| | *Conocephalum conicum* | + |
| | *Ctenidium molluscum* | + |
| | *Dicranella heteromalla* | + |
| | *Dicranum scoparium* | + |
| | *Fissidens taxifolius* | + |
| | *Mnium spinosum* | + |
| | *Plagiochila porelloides* | + |
| | *Plagiomnium undulatum* | + |
| | *Plagiothecium curvifolium* | + |
| | *Polytrichum formosum* | + |
| | *Rhizomnium punctatum* | + |
| | *Thuidium tamariscinum* | + |

**Table 2** Essential (*) and selected optional data to be included in the 'header' of a phytosociological relevé

| *Group* | *Data* | *Comment* |
|---|---|---|
| ID/methodology | Field number* | |
| | Author(s)* | |
| | Plot size* | |
| | Plot shape | |
| | Sampling date* | |
| | Preliminary assignment to a syntaxon | |
| Geographic data | Geographic coordinates* | For example, Greenwich coordinates, UTM including political and/or natural geographic units |
| | Locality in textual form* | |
| Environmental data | Elevation (m a.s.l.)* | |
| | Slope aspect* | |
| | Inclination* | |
| | Soil | For example, type, texture, depth, pH, humus form, humus content, C/N ratio |
| | Geology (parent material) | |
| | Management | |
| Structural data | Height of vegetation layers (m) | For example, tree layer, shrub layer, herb layer, cryptogam layer |
| | Cover of vegetation layers (%)* | Cover of each layer and total cover |
| | Cover of other surfaces (%) | For example, bare soil, litter, woody debris, rocks, open water |

**Table 3** Customary version of an extended Braun-Blanquet cover-abundance scale with ordinal values, which are often used for numerical interpretation. In the original Braun-Blanquet scale, 2m, 2a, and 2b were joined under the symbol '2'

| *Symbol* | *Abundance (number of individuals/ramets)* | *Cover interval (%)* | *Ordinal value* |
|---|---|---|---|
| r | 1 | 0–5 | 1 |
| + | 2–5 | 0–5 | 2 |
| 1 | 6–50 | 0–5 | 3 |
| 2m | More than 50 | 0–5 | 4 |
| 2a | Any | 5–12.5 | 5 |
| 2b | Any | 12.5–25 | 6 |
| 3 | Any | 25–50 | 7 |
| 4 | Any | 50–75 | 8 |
| 5 | Any | 75–100 | 9 |

example, in studies of vegetation change in permanent plots. Sometimes, additional characteristics of the species – such as sociability (degree of clustering of the individuals), vitality, fertility, age class (e.g., seedling or juvenile), and phenological status – are recorded, but these are of little or no importance for standard analyses.

### Selection and Size of Plots

Plot sites in the field are positioned in vegetation stands that are relatively homogeneous in terms of structure, species composition, and environment, so that variation is minimized within and maximized between plots.

The traditional sampling strategy in phytosociology, preferential sampling, in which the researcher selects stands that are considered as representative of some vegetation units, has several disadvantages: it is not repeatable by other researchers, tends to neglect some vegetation types and oversample others, and produces a nonrepresentative sample of vegetation diversity in the study area. In spite of these disadvantages, probabilistic sampling strategies, such as random or systematic sampling, have never received wider acceptance in phytosociology. While providing reliable estimates of vegetation attributes, probabilistic sampling is less suited to phytosociology's goal of representing maximum variation in vegetation diversity across a study area, as it tends to undersample or even miss rare types. GIS and global positioning system (GPS) technology have made stratified-random sampling schemes increasingly popular in phytosociology. Based on the overlay of digital maps in a GIS, the study area can be stratified into patches with certain combinations of land-cover types and environmental variables that are supposed to correlate with plant distribution. Within each of these strata, plot positions are randomly placed and subsequently found in the field with a GPS receiver. A related sampling strategy is a gradient-oriented transect or gradsect, which establishes plot sites along a landscape transect that runs parallel to an important environmental gradient.

Phytosociological plots are usually squares or rectangles, which, as a rule of thumb, are roughly as large in square meters as the vegetation is high in decimeters (e.g., 200 $m^2$ for a forest of 20 m height). Despite this rule and other suggestions in textbooks, actual plot sizes used may

span more than one order of magnitude within the same vegetation type. Standardization of plot sizes is hindered by the vague and misleading concept of 'minimal area', which is thought to be a certain plot size specific for each vegetation type, beyond which any further enlargement has negligible effects on species richness and composition. However, plot size strongly influences estimates of species richness and other vegetation parameters. Joint use of differently sized relevés in a single analysis may thus produce artifacts in classification, ordination, and calculation of fidelity of species to vegetation units. To safeguard data compatibility, standard plot sizes have been proposed for use within certain structural formations, for example, 200 $m^2$ in forest vegetation; 50 $m^2$ in scrub vegetation; 16 $m^2$ in grassland, heathland, and other herbaceous vegetation; and 4 $m^2$ in aquatic and low-growing herbaceous vegetation.

### Vegetation Databanks

Phytosociology has a long tradition of publishing, archiving, and re-analyzing relevés as its basic primary data. Many phytosociological journals print full tables including all relevant relevés, thus making data accessible for future compilation and analysis, which was traditionally performed as synoptic tables on paper. The limitations of manual data management were overcome by using table editing and databank software, which allows seizing, storing, managing, filtering, and analyzing relevé data in multiple ways.

Compilation in a databank requires that all information obeys stringent formal and technical rules laid down in reference lists, meta-data and data models. Databanks of different formats and complexity were established, ranging from simple spreadsheets to relational and object-based data models that allow flexible definitions and comprehensive documentation of meta-data. Simple databanks are able to exchange data freely if the same standards, database formats, definitions, and reference lists are used. The success of phytosociological databanks is so far due to rather simple management software packages such as TURBOVEG, which is currently the most widespread program in Europe and beyond, distributed free of charge or at small cost along with taxonomic reference lists and tools to create, edit, and analyze phytosociological tables.

While early databank development revolved around fixing standards for data types and references for plant taxon concepts and names, modern ecoinformatics provides tools to exchange data of different formats and taxonomic reference and, ultimately, link up databanks of any format in networks. Rather than enforcing standard formats, these systems require that data are recovered and stored with as much original information as possible, including meta-data on sampling design and methods, cover-abundance scales, definition of layers, taxonomic references, and original data sources.

## Classification of Vegetation

### Aims and Criteria

Vegetation classifications are performed with three fundamental goals: (1) delimiting and naming parts of the vegetation continuum to enable communication about them; (2) predicting a multitude of ecosystem attributes (e.g., species composition, site conditions, and ecological processes) from the assignment of a particular stand to a vegetation unit; and (3) making multispecies co-occurrence patterns representable by verbal descriptions, tables, diagrams, and maps. Floristically defined vegetation types are thus suitable reference entities for ecological research, bioindication, and nature conservation.

Reaching these aims requires of the classification approach:

1. coherence of units with respect to major ecosystem properties;
2. simple and clear discernability of units;
3. completeness of the system (i.e., coverage of all vegetation types of the given area);
4. robustness (i.e., minor changes of the data should not considerably change the classification);
5. tolerance against varying data quality;
6. supra-regional applicability;
7. applicability for a range of different purposes;
8. hierarchical structure, allowing for different degrees of generalization;
9. equivalence of units of the same hierarchical level; and
10. adequate number of units with respect to practical use.

As no single classification can ideally meet all of these criteria at the same time, and their relative importance depends on the purposes, competing classifications of the same objects and data are a reality. Thus, the interpretation of local data will change with scaling up from local to regional and supra-regional context. However, there is also a practical requirement to have a unified supra-regional classification to enable communication among scientists, managers, and authorities between regions.

### Braun-Blanquet Approach

The 'Braun-Blanquet approach' provides a methodological framework for vegetation classification that seeks an optimal combination of the above criteria and that reconciles conflicting requirements of different scales and