Plant Functional Types (PFTs)

- Recently, the earlier physiognomic concepts of Raunkiaer, Dansereau, Kuchler and others have been modified to be more useful with respect to many ongoing global modeling efforts. These approaches have been loosely grouped under the name of **plant functional types.**
- It is not feasible to develop *global models* that include every ecosystem or every species. Therefore, various approaches are being used to group the multitude of plant species into more manageable units that are considered important with respect to ecosystem function.
- These groups are based on a variety of plant characteristics, including growth forms, life forms, taxonomic groups or other characteristics depending on the application.
- Numerous PFT methods including: Solomon and Shugart 1993; Box 1996, Noble and Gitay 1996; Woodward and Cramer 1996; Smith et al. 1997.

Response to the Global Change in Terrestrial Ecosystems' (GCTE) need for a smaller group of "functional types" for global modeling efforts

Plant Functional Types of Box (1981)

Table 14.1 The plant functional types defined by E. O. Box

[illegible]

- Partial list of the plant functional types developed by Eugene Box.
- Widely accepted as perhaps the best statement to date of a consistent approach to describing plant and community physiognomy.
- However, it is still quite a long list and not particularly useful for global modeling efforts because of its complexity.

Vegetation types based on the plant functional types of Box

Plant functional type	Vegetation	Traits
1. Tropical evergreen broad-leaved trees	Tropical rain forest	Tall, determinate branching, leurophyll
2. Tropical deciduous broad-leaved trees	Raingreen forest, woodland, and scrub	Various, determinate, malacophyll or leurophyll
3. Extra-tropical evergreen broad-leaved trees	Evergreen broad-leaved forest, temperate rain forest	Tall, determinate, malacophyll or leurophyll
4. Temperate deciduous broad-leaved trees	Summergreen broad-leaved forest and woodland	Various, determinate, winter-dormant, malacophyll
5. Temperate/boreal needle-leaved evergreen trees	Needle-leaved forest and woodland	Various, monopodial, winter-dormant, coriaceous
6. Boreal/cool temperate deciduous needle-leaved trees	Deciduous boreal needle-leaved forest and woodland	Various, monopodial, winter-dormant, malacophyll
7. Sclerophyllous trees	Subtropical woodland and scrub	Short, determinate, evergreen, sclerophyll, light-demanding
8. Sclerophyll/coriaceous shrubs and subshrubs	Scrubland (chaparral, semidesert, heath)	Short, basally determinate, evergreen, sclerophyll or coriaceous, light demanding
9. Deciduous shrubs and dwarf shrubs	Scrubland, krummholz, semidesert	Short, basally determinate, seasonally dormant, malacophyll or coriaceous
10. Short-season broad-leaved dwarf shrubs	Tundra	Short, basally ramifying, winter-dormant, evergreen or deciduous, malacophyll or coriaceous or sclerophyll
11. Diurnally active tufted arborescents and herbs	Tropical alpine	Various, monopodial rosettes, evergreen, coriaceous or sclerophyll
12. Grasses and graminoids	Grassland	Short herbs, usually perennial, malacophyll
13. Stress-tolerant succulents	Semidesert scrub	Various, perennial, evergreen, succophyll
14. Ephemeral herbs	Semidesert scrub	Short, annual to perennial but short growing season, malacophyll
15. Stress-tolerant mosses and lichens	Tundra, cold desert	Short, winter-dormant

- **15 global vegetation types is derived from the PFTs of Box**

BIOME model (Prentice et al. 1992)

- Goal is to *find the simplest possible model with the smallest number of plant functional types, constraints and driving variables that could still simulate broad features of present vegetation of the Earth…*
- This model then could be used to help predict the vegetation under altered climate scenarios, either in the past or in the future.

Bioclimatic indices derived from climatic data in the Biome model

Table 14.3 Derivation of bioclimatic indices from interpolated climatic data in the BIOME model

Tolerance/requirement	Ecophysiological mechanism	Bioclimatic index	Climatic variable used (monthly means)
Cold tolerance	killing temperature during coldest period of the year	T_{min}: temperature of the coldest month (lower limit)	temperature
Chilling requirement	winter chilling period required for budburst of woody plants	T_{min}: temperature of the coldest month (upper limit)	temperature
Heat requirement	annual growth respiration requirement	GDD: growing degree days above 0 °C and 5 °C	temperature
Moisture requirement/drought tolerance	soil moisture availability	AET/PET: annual actual evapotranspiration/annual potential evapotranspiration	temperature, precipitation, cloudiness

Source: Prentice et al. (1992).

- **The limits of vegetation types are defined by various tolerance limits or climatic requirements of the dominant plant functional types in each vegetation unit.**
- **The various tolerance or plant requirements were related to ecophysiological mechanisms.**
- **Bioclimatic indices that were tied to these ecophysiological requirements were identified.**
- **And the element(s) in the climate data base that could be used to calculate the bioclimatic index were identified.**

Environmental constraints of the PFT's in the BIOME model

Table 14.4 *Environmental constraints for each plant functional type in the BIOME model*

	Plant functional type	No.	T_{c} min	T_{c} max	GDD_0 min	GDD_5 min	T_{w} min	AET/PET min	AET/PET max
Trees	tropical evergreen	1	15.5	—	—	—	—	0.80	—
	tropical raingreen	2	15.5	—	—	—	—	0.45	0.95
	warm-temperate evergreen	3	5.0	—	—	—	—	0.65	—
	temperate summergreen	4	−15.0	15.5	—	1200	—	0.65	—
	cool-temperate conifer	5	−19.0	5.0	—	900	—	0.65	—
	boreal evergreen conifer	6	−35.0	−2.0	—	350	—	0.75	—
	boreal summergreen	7	—	5.0	—	350	—	0.65	—
Non-trees	sclerophyll/succulent	8	5.0	—	—	—	—	0.28	—
	warm grass/shrub	9	—	—	—	—	22.0	0.18	—
	cool grass/shrub	10	—	—	—	500	—	0.33	—
	cold grass/shrub	11	—	—	100	—	—	0.33	—
	hot desert shrub	12	—	—	—	—	22.0	—	—
	cold desert shrub	13	—	—	100	—	—	—	—
No plants	(dummy type)	14	—	—	—	—	—	—	—

Source: Prentice *et al.* (1992).

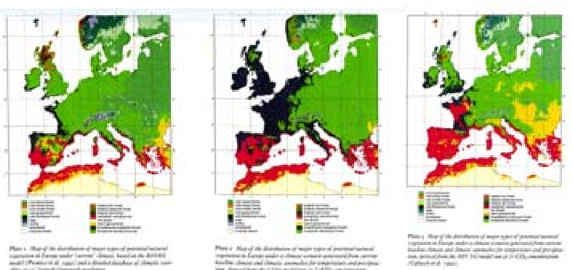
Assembling "vegetation types" from PFTs

Table 14.5 *Combinations of plant functional types in biomes, resulting from the BIOME model*

Biome type	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tropical rainforest	x													
Tropical seasonal forest	x	x												
Tropical dry forest/savanna		x												
Broad-leaved evergreen forest			x											
Temperate deciduous forest				x	x		x							
Cool mixed forest				x	x	x	x							
Cool conifer forest					x	x	x							
Boreal forest (taiga)						x	x							
Cold mixed forest					x		x							
Cold deciduous forest							x							
Xerophytic woods/shrub								x						
Warm grass/shrub									x					
Cool grass/shrub										x	x			
Tundra											x			
Hot desert												x		
Semidesert													x	
Ice/polar desert														x

Source: Prentice *et al.* (1992).

Vegetation redistribution of Europe under a changed climate as predicted by the BIOME model using two different climate models as drivers



Current | **2x CO_2 (GISS model)** | **3x CO_2 (MPI T42 model)**

Species richness, evenness, and diversity

- **Richness:** the number of species per unit area.
- **Evenness:** the distribution of individuals among the species. This is maximized when all the species have the same number of individuals.
- **Diversity:** A combination of richness and evenness, i.e. richness weighted by evenness.

For example: If community A has 5 species with uneven numbers of individuals, and community B has 4 species with equal numbers of individuals, A will have higher species richness, but B may have a higher diversity.

Simpson's and Shannon-Wiener's indices of diversity

- **The Simpson index (*C*)** is calculated:

  $$C = \Sigma (p_i)^2$$

  where p_i is the proportion of all individuals in the sample that belong to species *i*.

  The Simpson index weights the most abundant species more heavily than rare species
- **The Shannon-Wiener index (*H'*)** is an index of the total amount of information in a sample.

  $$H' = - \Sigma (p_i)(\ln p_i),$$

  where p_i is the proportion of all individuals in the sample that belong to species *i*.

  The Shannon-Wiener index varies from 0, for a community with one species only, to values of 7 or more in rich forests.

Examples of how the diversity indices vary with different abundance of species

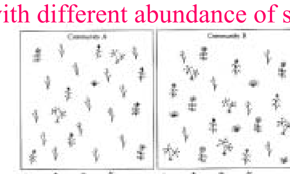


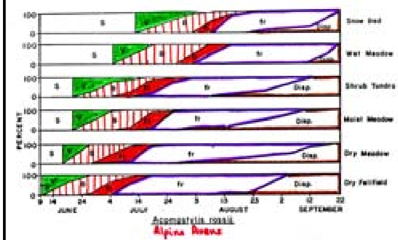
Table 8-4 Diversity indices calculated for community samples A and B in Figure 8-5. Note that only the Simpson index (C) shows community A to be the more diverse, reflecting that index's high sensitivity to dominance by one species and insensitivity to low numbers of other species.

Index	A	B
Simpson (C)	0.36	0.20
Shannon-Wiener (H')	1.70	2.31

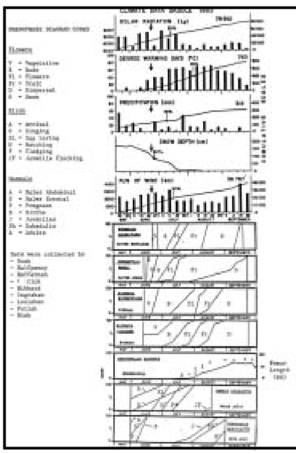
Phenology

- The study of the time of appearance of characteristic periodic events in the life cycles of organisms and how these events are influenced by factors, such as temperature, latitude, and altitude.
- For example, the timing of flowering and leaf fall in plants.

Phenology diagram for *Acomastylis rossii* in different habitats on Niwot Ridge, Colorado



- Shows the *timing* of various events in the life history of a species.
- The example shows how snow affects the timing of growth in one species.
- Early season events are shifted about one month later, but seed dispersal is initiated at about the same time.



Phenophase diagrams for plants, birds, mammals, and insects, and comparison with climate data, 1983, Niwot Ridge, Colorado

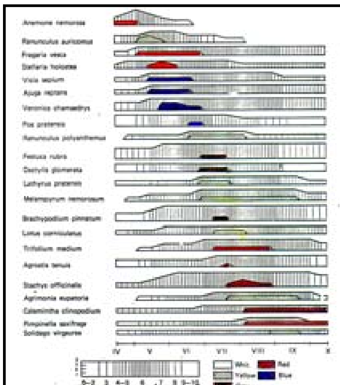


FIGURE 8.5. Phenological diagram of selected species in a permanent relevé of the Trifolium-Melampyrum nemorosum community near Göttingen, Germany. Explanation in text. [From DIERSCHKE 1972.]

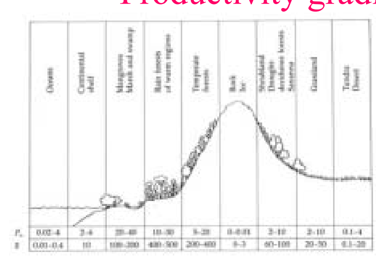
Phenological diagrams of several species in a *Trifolium-Melampryum* community, Göttingen, Germany

- Dierschke diagram portrays timing, cover-abundance, phenological stage, and flower color.

Indices of biomass

- Total Biomass
  - Clip harvest
  - Harvest and regression method for trees
- Productivity: amount of biomass produced during the growing season
- Percentage cover
  - Scalar estimates
  - Measurement
- Leaf area index
- Vegetation indices (e.g. NDVI, normalized difference vegetation index)

Productivity gradients



- Example of variation of productivity and biomass along an elevation-climate gradient.
- Note 100-1000 fold increase in productivity and biomass.

Summary

- In the "**Association-unit**" view of plant communities are repeating assemblages of plants that can be found in similar habitats. These assemblages can be classified according to the total floristic composition of the communities. Major proponents included Braun-Blanquet, Clements, Daubenmire.
- In the "**Continuum view"** species have individualistic responses along an environmental gradients. Major proponents included Gleason, Curtis, and Whittaker.
- A modern synthesis of the continuum and association views recognizes that both view have validity and application for different aspects of community analysis
- Some characteristics of vegetation:
  - **Species composition** (Braun-Blanquet)
  - **Physiognomy** (Davis, Richards, Dansereau, Kuchler, Raunkaier, Box, Plant Functional Types)
  - **Species richness, evenness, and diversity** (Simpson and Shannon-Wiener indices)
  - **Phenology** (phenology and phenophase diagrams)
  - **Biomass and productivity** (harvests, productivity, cover, LAI, NDVI, etc.)

Literature for Lesson 13

Cramer, W. 1997. Using plant functional types in a global vegetation model. Pages 271-288 in Smith, T.M., H.H. Shugart, and F.I. Woodward. 1997. *Plant Functional Types.* Cambridge, Cambridge University Press.

Noy-Meir, I. And E. van der Maarel. 1988. Relations between community theory and community analysis in vegetation science: some historical perspectives. *Vegetatio* 69: 5-15.

Lesson 14: Sampling methods

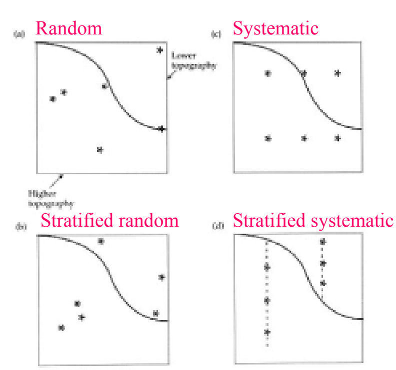
- Subjective vs. objective sampling
- Centralized replicate, random, and systematic sampling approaches
- The relevé method
- Cover
  - Cover estimates
  - Measuring cover, point sampling, line intercept
- Density
- Frequency
- Basal area
- Count-plot method
- Distance methods

Subjective vs. objective sampling

- ***Subjective sampling***
  - **Sample sites are consciously chosen as representative of predetermined vegetation classes.**
  - **Most flexible sampling scheme**
  - **Allows for experience and decision making ability of the investigator**
  - **Best used in areas where there are clear boundaries between plant communities**
  - **Good approach for vegetation classification**
- ***Objective sampling***
  - **Sample sites are chosen according to chance (i.e. random sampling)**
  - **Essential if probability statistics are to be used to back up the conclusions**
  - **Best used in areas where boundaries between communities are indistinct or where the objective is to determine the causes of variation within a single plant community**
  - **Good approach for ordination methods**

Centralized replicate, random, and systematic sampling approaches

- **Centralized replicate**
  - Sample sites are chosen subjectively and centrally located within representative homogeneous areas of predetermined vegetation types.
  - This method is used in the relevé approach (more on this later).
- **Random**
  - Sample sites are chosen according some randomizing method (e.g., dice, random numbers). Any point is a possible sample point.
  - In a **complete random** method plots are chosen completely randomly.
  - In a **stratified random** approach, the research areas is first divided into relatively similar classes based on some criteria, for example, landscape units (floodplains, hills, mountains) or mapped vegetation units. Sample sites are then randomly chosen in the various classes. This ensures that the most common units are not over-sampled and the uncommon units under sampled. The samples are dispersed throughout the entire survey area.
- **Systematic**
  - Plots are located according to a regular system such as a grid or regular intervals along a line. A **stratified systematic** approach is similar to the stratified random approach except the sample sites are chosen according to a systematic method (grids or linear transects) within each stratified class.



The relevé method

- French term meaning a collection of data. Often used in terms of surveys.
- Developed by Josias Braun-Blanquet as a standard method of sampling for vegetation classification according to the Zurich-Montpellier School of phytosociology.
- Recently has gained popularity in North America (e.g., Nature Conservancy, California Department of Fish and Game, Talbot and Talbot 1994, Walker et al. 1994, Komárková 1978, Rivas-Martinez 1997, Miyawaki et al. 1994, Klinka et al. 1996)
- The quickest way to obtain detailed community information.
- Does not necessarily involve sampling other components of the site such as soils and site factors, although these are often collected if environmental gradient analysis is part of the research.
- Subjective sampling (centralized replicate).
- Qualitative in the sense that species cover is estimated instead of measured.
- Quantitative in the sense that it gives a complete list of species for the plot.

Entitation and requirements of a relevé

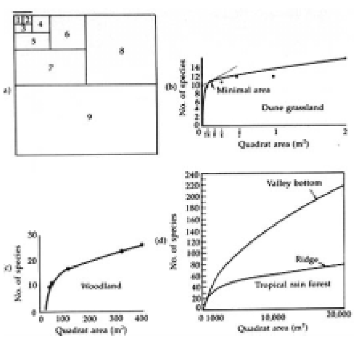
Entitation

- The process of subdividing the vegetation into recognizable entities or preliminary vegetation types
- Reconnaissance essential (cannot be overemphasized) The better your initial knowledge of an area, the better will be the subsequent sampling.
- Important to avoid sampling ecotones or breaks between distinct communities
- Iterative process that may take several years to develop a good concept of the communities.

Requirements of a sample site for a relevé

- 1. HOMOGENEITY of the vegetation canopy
- 2. Homogeneity of the soil and other site factors
- 3. Large enough to contain all the species in the community
- 4. Should be recognizable as unit that is repeated in other areas of the landscape, i.e. a repeating assemblage of species.

Size of plots: Minimal Area Method

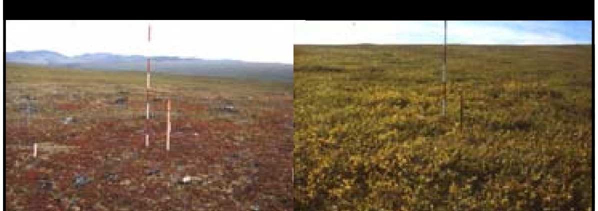


Minimum area for common vegetation types

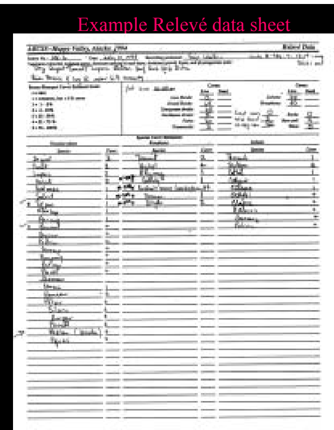
Table 9-1 Minimal areas for various vegetation types. From *Aims and Methods of Vegetation Ecology*. Mueller-Dombois and Ellenberg. Copyright © 1974 John Wiley and Sons, Inc. Reprinted by permission.

Type	Minimal area (m²)
Tropical rain forest	1000–50,000
Temperate forest:	
Overstory	200–500
Undergrowth	50–200
Dry temperate grassland	50–100
Heath	10–25
Wet meadow	5–10
Moss and lichen communities	0.1–4

Relevé sites



Example Relevé data sheet



Cover-abundance classes

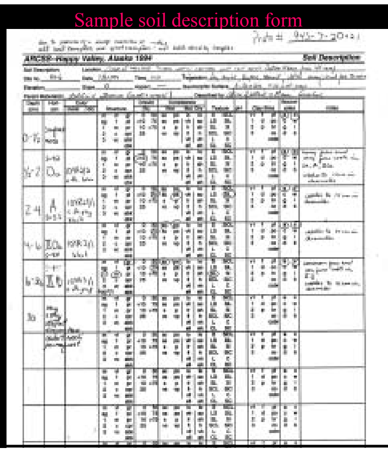
Table 9-2 Cover classes of Braun-Blanquet, Domin-Krajina, and Daubenmire. From *Aims and Methods of Vegetation Ecology*. Mueller-Dombois and Ellenberg. Copyright © 1974 by John Wiley and Sons, Inc. Reprinted by permission.

Braun-Blanquet			Domin-Krajina			Daubenmire		
Class	Range of cover (%)	Mean	Class	Range of cover (%)	Mean	Class	Range of cover (%)	Mean
5	75–100	87.5	10	100	100.0	6	95–100	97.5
4	50–75	62.5	9	75–99	87.0	5	75–95	85.0
3	25–50	37.5	8	50–75	62.5	4	50–75	62.5
2	5–25	15.0	7	33–50	41.5	3	25–50	37.5
1	1–5	2.5	6	25–33	29.0	2	5–25	15.0
+	<1	0.1	5	10–25	17.5	1	0–5	2.5
r	<<1	*	4	5–10	7.5			
			3	1–5	2.5			
			2	<1	0.5			
			1	<<1	*			
			+	<<<1	*			

*Individuals occurring seldom or only once; cover ignored and assumed to be insignificant.

Sample site-factor data form

Sample soil description form

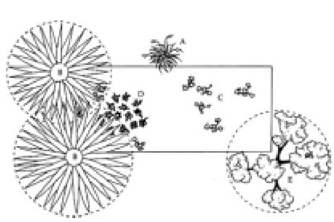


Cover

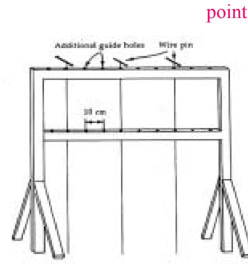
The area of ground covered by the vertical projection of the aerial parts of plants of one or more species.

- An easily obtained index of plant biomass.
- **Estimates** of cover can be obtained by using cover-abundance scores.
- **Measures** of cover can be made using point sampling methods, line transect method, or photos and planimeter or other direct measure of cover.

Estimating percentage cover



Point sampling methods to determine percentage cover: point frame



The frame is set up over the vegetation and the needles are lowered down through the plant canopy. Every time the point of a needle touches a plant, a "hit" is recorded with the species name. The needle can touch several plants before it eventually touches the ground surface.

% cover of species A =

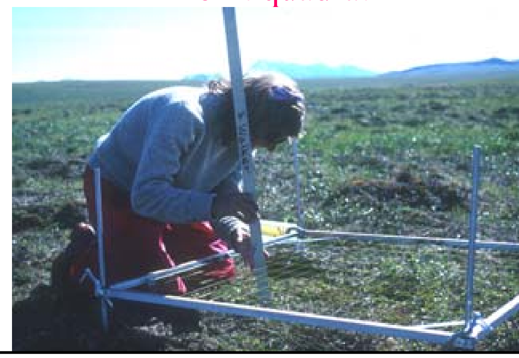
(No. of hits that intercept species A)/ (No. of points)

This is the only point sampling method that can give an accurate estimate of absolute cover of each species in multistratose vegetation, and hence an estimate of total leaf area for each species. All other methods give relative percentage cover.

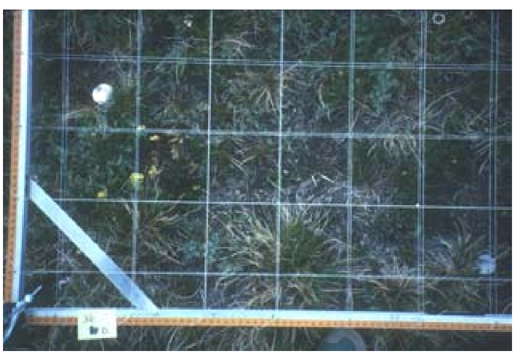
It is, however, a very time consuming method.

Electronic inclined point frame

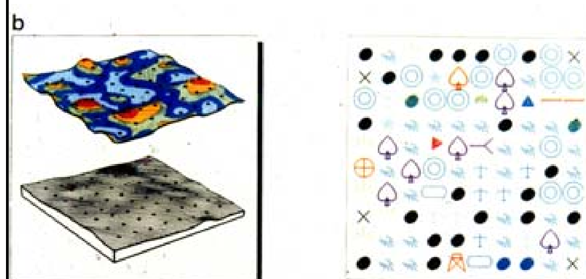
Point quadrat



Point quadrat grid



Map from point-quadrat data

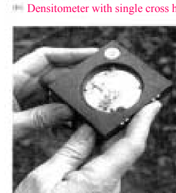


Buckner sampler: Optical device for measuring cover

Methods of determining tree-canopy cover

(a) Moosehorn crow-cover estimator

(b) Densitometer with single cross hairs

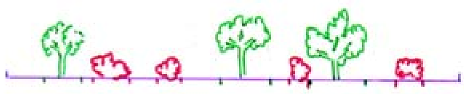


(c) Spherical densiometer

Figure 9-6 Several devices for estimated overstory tree cover. (a) Crown-closure estimator (moosehorn) with a grid of dots in the view. (b) Densitometer with a single point created by two cross-hairs in the field of view. (c) Spherical densiometer with 24 squares etched into the reflective surface.

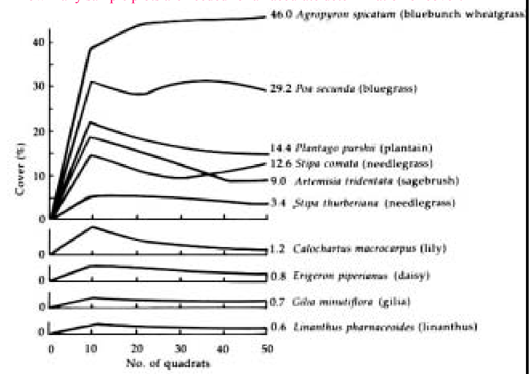
Line intercept method for determining plant cover

- Generally used for tree and shrub cover or for measuring cover of clearly defined vegetation types
- A line is laid out along the ground and the line segments for each species or vegetation type is recorded. Percent cover for each species is the total length of line segments for each species divided by the total length of the transect.

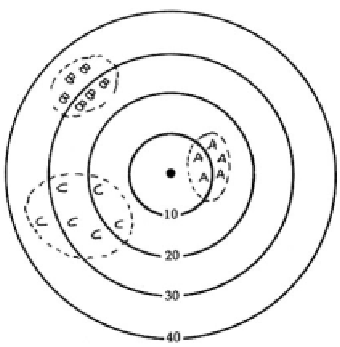


Sample size:

How many sample plots are needed for an accurate determination of cover?



Precision vs. Accuracy



Common parameters from plant community analysis

- Species composition (total species list)
- Cover
- Density
- Frequency
- Basal area

Cover

The area of ground covered by the vertical projection of the aerial parts of plants of one or more species.

- An easily obtained index of plant biomass.
- **Estimates** of cover can be obtained by using cover-abundance scores.
- **Measures** of cover can be made using point sampling methods, line transect method, or photos and planimeter or other direct measure of cover.

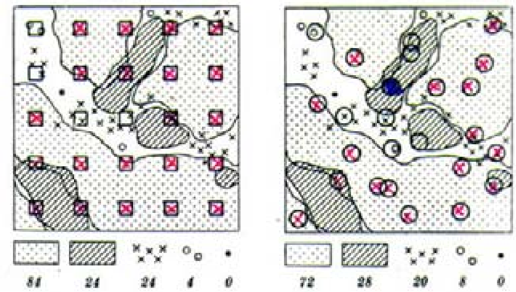
Density

- The number of plants per unit area. Expressed as number/square meter, stems/acre, etc.
- Most often used for trees or large plants.
- An an easy concept to grasp, but very difficult to perform in some types of vegetation because of:
  - (1) the difficulty of defining an individual (e.g. caespitose growth forms, plants with underground rhizomes, plants in peaty landscapes often have complicated stems just beneath the surface of the moss layer)
  - (2) quadrat size affects density size because of problem of counting large individuals near the boundary of the quadrat
  - (3) it is very time-consuming in graminoid dominated systems and low-growing vegetation.

Frequency

- Expressed as a percentage of plots (quadrats) of equal size in which at least one individual of the species occurs in a stand.
- It is a measure of the degree of uniformity with which individuals of a species are distributed in an area, and more specifically a stand.
- Generally frequency quadrats are much smaller than quadrats used to determine species composition in plant communities (relevés). Rule of thumb is that the frequency plot size should be at least twice the size of the largest individual.

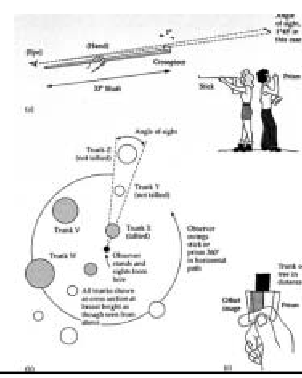
Frequency plots



Basal area

- A measure of dominance. Generally used for trees.
- The cross-sectional area of tree stems at breast height per unit of ground area (e.g., m^2/ha)
- Methods of determining basal area
  - Measure tree diameters at breast height with a biltmore stick or diameter tape. Area = $\pi(dbh/2)^2$. This approach is used in count-plot and distance methods (e.g., point-centered quarter method).
  - Bitterlich stick, or angle gauge

Bitterlich Stick method for determining basal area



Count-plot method

- Species are counted and measured within a specifically defined area (belt transect or quadrat).
- Used for determining density and basal area of trees.
- Widely used method for forest inventory and long-term studies.
- The main reason for doing a plot as opposed to a plotless methods are:
  - It can also be used to sample the understory, and thus is useful for vegetation classification
  - Record a wide variety of other properties, such as soils, site factors, and the plot can be mapped for spatial studies
- Useful for long-term studies where the same plot will be revisited in future years.

Data obtained in the plot-count method

In the United States this is usually done in plots or belt transects (e.g., a 10 x 20-m plot.

Sampling often includes:

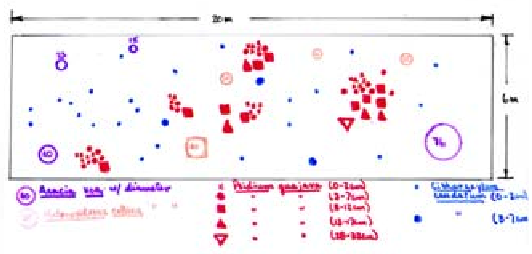
(1) ***Number of individuals for each tree species*** above a predetermined minimum diameter. From these data **density** of each species is determined.

(2) ***Tree diameters*** at breast height (dbh) using a Biltmore stick or diameter tape and grouped in diameter classes. From these data **basal area (cross-sectional area of tree stems at breast height/ha)** for each species is determined.

(3) ***Tree heights*** (e.g., with an inclinometer).

(4) Trees less than the minimum diameter are classed as ***seedlings or saplings*** and grouped into 1 ft (30 cm) height classes.

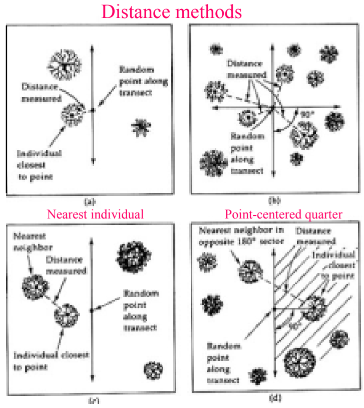
Example of plot to determine density and basal area



Distance Methods

- Developed by Cottam and Curtis in the 1950s to describe the forests of Wisconsin.
- **Density** can be determined by first finding the average distance between trees, and then squaring this distance to find the average area per tree. To find the number of trees per unit area, divide the unit area (m^2) by the area per tree.
- **Frequency** is determined by counting the number of points (sample sites) at which a tree occurs (not the percentage of the total number of trees).
- **Dominance** is calculated by first determining the mean basal area per tree species and then multiplying by the density of that species.

Distance methods



Nearest individual — Point-centered quarter — Nearest neighbor — Random pairs

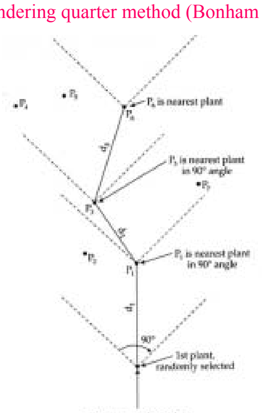
Four plotless methods: methods of determining distance

- **Nearest individual** - measure distance to the nearest tree at each point (correction factor = 2).
- **Nearest neighbor** - the nearest tree is selected and the distance between it and its nearest neighbor is measured. (correction factor = 1.47).
- **Random pairs** - a line from a random point to the nearest tree is made and a 90˚ exclusion is erected on either side of the line. The distance to the nearest tree outside the exclusion angle is measured. (Correction factor = 0.8)
- **Pont-centered quarter** - a pair of perpendicular lines are erected at the random point, forming a cross with four quadrants. The distances to the nearest tree in each quadrant are measured. This method can also yield a measure of frequency (the number of sample points (not quadrants!) at which a species occurs).

Notes:

1. The distances are calculated separately for each tree species.
2. The squared distances are the areas occupied by each tree.
3. If the average area per tree is divided into a unit of area (e.g. ha), this will give the **density** of the trees.

Wandering quarter method (Bonham 1989)



Importance Value

$$IV_i = Dr_i + Fr_i + Br_i$$

IV = importance value

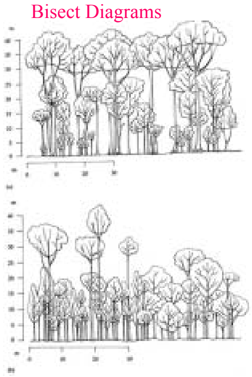
i = species i

Dr_i = relative density of species *i* = (density of species *i)/* (density of all species)

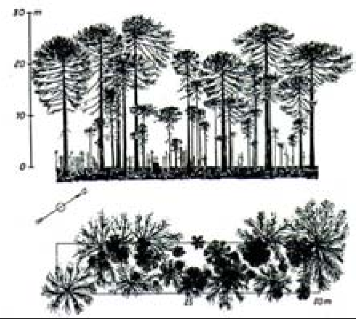
Fr_i = relative frequency of species *i* = (frequency of species *i)/* (frequency of all species)

Br_i = relative dominance of species *i* = (dominance of species *i)/* (dominance of all species)

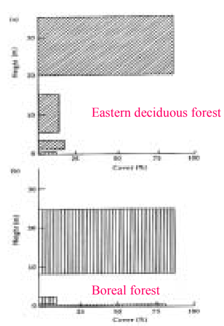
Bisect Diagrams



Bisect transect: *Aracaria* forest, Rio Negro, Argentina



Canopy profiles



Summary Lesson 14: sampling

- **Subjective vs. objective sampling**
- **Centralized replicate, random, and systematic sampling approaches**
- **The relevé method**
  - Used for vegetation classification
  - Entitation: the process of subdividing the vegetation cover into recognizable entities or vegetation types
  - Requirements of a sample site for a relevé (homogeneity, size, repeating assemblage of species)
  - Sampling protocol (species list, site factors, soil description)
- **Cover**
  - An easily obtained indicator of a plant's importance
  - The area of ground covered by the vertical projection of the aerial parts of plants of one or more species
  - Estimating cover: cover-abundance classes
  - Measuring cover
    - Point sampling (point frame, point quadrat, Buckner sampler, densiometers, moose-horn cover estimator)
    - Line intercept method
- **Precision vs. accuracy**
- **Density**
  - The number of plants of a species per unit area (e.g., individuals/m^2, or individuals/ha)
  - Measuring density
    - count-plot method,
    - plotless methods (e.g., point centered quarter method))
- **Frequency**
  - A measure of the degree of uniformity with which individuals of a species are distributed in an area.
  - The percentage of plots (quadrats) of equal size in which at least one individual of the species occurs.
- **Basal area**
  - A measure of dominance
  - $\pi(dbh/2)^2$
  - Methods of measuring basal area
    - Dbh in count-plot and plotless methods
    - Bitterlich stick, or angle gauges
- **Count-plot method** for determining density and basal area of trees
  - Widely used method for forest inventory and long-term studies.
  - Species are counted and measured within a specifically defined area (belt transect or quadrat)
  - Data obtained: no. of individuals of each species (density), dbh (basal area and size classes), heights, seedling abundance, frequency can be obtained from subsamples within the larger quadrat.
- **Bisect transect** (graphic portrayal of vertical and planar structure of sample transects)
- **Distance Methods**
  - Plotless methods of determining density and basal area of trees
  - Density is determined by measuring the average distance between trees and dividing area/tree into a unit of ground area
  - Basal area is determined by finding average basal area per tree for each species and multiplying times the density of trees
  - Five approaches (nearest neighbor, nearest individual, point-centered quarter, random pairs, wandering quarter)

Literature for Lesson 14

Bonham, C.D. 1989. *Measurement for terrestrial vegetation.* New York: Wiley-Interscience.

Cottom, G. and J.T. Curtis. 1956. The use of distance measures in phytosociological sampling. *Ecology* 37:451-460.

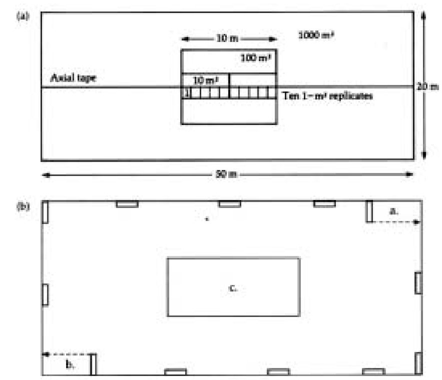
Westhoff. V. and van der Maarel, E. 1978. The Braun-Blanquet approach. In: Whittaker, R.H. *Classification of Plant Communities.* The Netherlands: Junk, p. 289-312 (Introduction, History, General Concepts, and Analytical Research Phase)

Table 9-3 Absolute and relative cover and density, based on the 0.1 m^2 quadrat shown in Figure 9-5.

Species	Absolute cover (%)	Relative cover (%)	Absolute density		Relative density (%)
			Per quadrat	Per ha	
A	0.2	0.4	0	<1	<1
B	33.2	63.6	1	100,000	4.2
C	4.7	9.0	9	900,000	37.5
D	6.2	11.9	14	1,400,000	58.3
E	7.9	15.1	0	<1	<1
Total	52.2	100.0	24	2,400,000	100.0
Overlap	5.3	—	—	—	—
Bare ground	53.1	—	—	—	—

Table 9-4 Calculation of importance value (IV) for an open tropical rain forest at 450 m elevation near Honolulu, Hawaii. Only the four most abundant overstory trees are summarized below. "Cover" here is the total basal area of all stems >3 cm dbh. From *Aims and Methods of Vegetation Ecology*. Mueller-Dombois and Ellenberg. Copyright © 1974 John Wiley and Sons, Inc. Reprinted by permission.

Species	Relative density	Relative cover	Relative frequency	IV	IV rank
Koa tree (*Acacia koa*)	30.0	78.4	30.8	139.2	1
Ohia lehua (*Metrosideros collina*)	20.0	13.9	23.1	57.0	3
Ohia (*M. tremuloides*)	5.0	5.8	7.7	18.5	4
Guava (*Psidium guajava*)	45.0	1.9	38.5	85.4	2



Example using 1994 Flagstaff Mountain data

- North-facing slope of Flagstaff Mountain, Colorado
- *Pinus ponderosa* - *Pseudotsuga menzeisii* forest
- Sampled using point-centered quarter method