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COURSE

Methods for the Study and Inventory of Plant and Animal Communities

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Academic Year 2025/ 2026

Preface

This document serves as a course support and is proposed for teaching the subject "Methods for the study and inventory of plant and animal communities". The handout complies with the teaching program approved by the Ministry of Higher Education and Scientific Research. This course support is dedicated to students enrolled in the 3rd year of the Bachelor's degree specializing in Ecology and Environment. In this handout, after an introduction on fauna and flora inventory, this course presents the general principles of sampling and the different types of sampling (Subjective and probabilistic). This is followed by an explanation of the three methods of plant sampling (Physiognomic, dynamic, and phytosociological) and the methods of fauna sampling (Mammals, Birds, Amphibians, Reptiles, and Arthropods, particularly terrestrial and aquatic insects). The last part of the course is dedicated to the presentation of observation and collection (sampling) data in the field, as well as the ecological indices and statistical tests necessary for the analysis of results.

Degree / Master: Bachelor's 3rd Year

Subject: Methods for the Study and Inventory of Plant and Animal Communities

Domain: Ecology and Environment

Stream: Ecology and Environment

Semester: 5, **Academic Year:** 2024/2025

Coefficient: 2

Credit: 5

Teaching Unit: UE Methodology

Teaching Objective

Through this subject, students will have the capacity to master the different sampling methods for plant and animal communities in different natural biotopes of the Jijel region. It is necessary for students to carry out field trips to deepen all the theoretical data to be evaluated in the field.

Recommended prior knowledge: Different techniques and methods used for sampling flora and fauna in different types of ecosystems.

Course Content:

I. General Principles
I.1. Plant and Animal Material
I.2. The Environment
I.3. Structure and Homogeneity of Communities

II. Quality and Types of Sampling

III. Hierarchization and Classification of Communities

III.1. Qualitative Methods
III.1.1. Signatist Method and Phytosociological Nomenclature
III.1.2. Statistical Floristic Methods
III.1.3. Concept of Ecological Groups
III.1.4. Phytoecological Approaches (Inventory form for different types of ecological groups)
III.1.5. Different Zoocenoses Depending on Plant Formations

III.2. Quantitative Methods

- Linear Analysis
- Point Quadrat

Assessment Method:
Final Exam 60%
Practical Work 40%

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CHAPTER 1: GENERAL PRINCIPLES

The study of the flora of each region is useful in mastering ecological problems such as biological protection and the management of natural resources. The biological forms of plants depend on genetic characteristics as well as environmental factors, because the environment can have undeniable effects on the formation of different critical forms of plants. The diverse topography, geology, and spatial and temporal variability of the climate in Africa have created a mosaic of distinct vegetation types. Understanding the response of plant communities to changes in environmental conditions can therefore predict the consequences of these changes on processes such as primary productivity. This can be of great interest in terms of environmental management, as these processes influence the services provided by ecosystems environmentally.

I. General Principles

Flora is the set of plant species present in a defined geographical space or ecosystem.

The term "flora" also refers to the set of microorganisms (excluding viruses which are not "living") present in a given place. By extension, it also designates works inventorying and describing these species, and serving to determine plants (to identify them). The number of species to describe being very important, floras intended for the general public are often limited to vascular plants or seed plants and their main species.

Collections of specimens used to define the different species are preserved in herbaria. This network of herbaria around the world is very important. It is the reference that allows botanists to find their way and take stock between old names and discoveries and current identifications.

The **fauna corresponds to the set of animal species living in the same** geographical space at a given time. It is opposed to flora.

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Fauna is a collective term for animal life. In zoology, fauna is the set of animal species listed for a region or an environment, in the faunistic sense. They are characteristic of a geological period or an ecosystem.

Therefore, fauna consists of animal life present in a given place or substrate at a certain time. Its equivalent in botany is flora.

A sample is a fragment of a whole taken to judge that whole. Numerous observation and measurement methods applied to such fragments can be proposed, adapted to each particular case to obtain a satisfactory representation of the object studied.

Sampling must be adapted to test the hypothesis made, at a given spatial and temporal scale, on the structure or dynamics of the biological system studied. It is imperative to take the time to plan one's sampling (Durand, 2009).

In this perspective, it is essential to recognize some basic notions:

♦ **Protocol:** A detailed study plan explaining how data should be collected, organized, and analyzed.

- **Method** (of collection): A collection method is a set of techniques, know-how, and/or specific tools mobilized logically (rules, steps, and principles) to collect data associated with a parameter to observe or an ecological factor to consider.
- **Inventory:** This is a set of quantitative and qualitative observations and measurements using standardized protocols, carried out in a limited period of time.
- **Monitoring:** This is a series of data collections (series of inventories) repeated over time.
- **Tracking:** Faced with a well-identified problem, tracking relies on a series of data collections repeated over time.
- **A study:** Under the term "study," we will group the notions of inventories, monitoring, and tracking.
- **Research:** A research program is the collection of data under very specific conditions to verify the initial hypotheses, after statistical processing of the data and analysis of the results (Adam et al., 2015).

I.1. Plant and Animal Material

I.1.1. Plant Material

Flora is a fundamental element for assessing the quality of a natural environment. Indeed, considering plant species allows describing natural habitats, characterizing prevailing ecological conditions, or detecting species of heritage interest. Due to its integrating character, synthesizing environmental conditions and ecosystem functioning, vegetation is considered a good indicator and therefore allows characterizing the habitat. A floristic inventory, both quantitative and qualitative, quickly provides valuable information on the different components of the ecosystem, even before knowing the results of the various analyses performed in the laboratory.

For any vegetation study, it would be necessary to first establish a sampling plan which may differ depending on the study envisaged or the objectives. Then, samples must be taken following a method or technique that will also differ depending on the requested study. Once the samples are taken, the statistical processing of the results and their interpretation is carried out (Bouzillé, 2007).

I.1.1.1. Concept of Species

In 1583, Césalpin, philosopher, physician, botanist, and naturalist, used the concept of species to classify his plants. For him, plants that resemble each other in their entirety generally belong to the same species.

Charles Bonnet, a Swiss naturalist, in 1740, defined a species by a combination of morphological (= related to appearance), physiological (= related to the functioning of the organism), and ethological (= related to behavior) characteristics.

In 1798, Georges Cuvier proposed his definition of species: "is the collection of all individuals descended from common parents and all those who resemble them as much as they resemble each other".

According to Mayr (1942), The species consists of groups of natural populations that are potentially or actually interbreeding and reproductively isolated from any other similar group. According to Mayr, species are groups of current populations capable of inter-crossing and that are reproductively isolated from other similar groups.

Cuénot specifies that the species is a union of related individuals, having the same hereditary morphology, the same physiognomic character, a common way of life, a definable geographical area, separated from neighboring groups by a barrier generally of a sexual nature".

The species is the collection of all organized beings descended from one another or from common parents and become extinct in relation to the succession process or with the arrival of new disturbances. The definition of the species is based essentially on the comparison of morphological characters, on characters related to interfertility, on the hereditary characters of forms, and on the relationships of species with environmental conditions.

The main difficulty lies in the limit of character variations that differentiate individual characters from hereditary characters. Therefore, the concept of species can be defined at two levels:

- **Biological sense:** a set of populations effectively or potentially interbreeding under natural conditions and sexually isolated from other populations;
- **Taxonomic sense:** fundamental unit in taxonomic classification that distinguishes the following major units: kingdom, phylum, class, order, family, genus, and species.

These two notions overlap most of the time.

I.1.1.2. Concept of Flora

I.1.1.2.1. Definition

Flora corresponds to the set of plant species living in the same geographical space at a given time. The term should not be confused with vegetation. Vegetation is one of the major characteristics of biogeography and is defined as the set of plant communities containing the flora, which consists of a list of all plant species in a given region. "It is the plant mass, the set of plants considered in their relationships with the environment, climate, soil, and living beings including man".

The flora of a region is the list of taxonomic units, taxa, species that compose that region. Flora thus mainly expresses the current result

of the history of taxa, their variation, and their movement across the globe.

The flora of a region includes species considered indigenous (or native or autochthonous) and introduced species (or foreign or exotic). Introduced plants are of four categories: naturalized, adventure, sub-spontaneous, and cultivated (Daget et al., 2010).

I.1.1.2.2. Floristic Assemblage

This is the set of species characterizing a given territory: Mediterranean assemblage...; it can be broken down into elements: eastern Mediterranean element, western element.

The correlation between the ranges of species constituting a floristic assemblage is due to ecological and paleoecological reasons: thus, Mediterranean species are united because they have a common adaptation to the same climate on one hand and on the other hand because they come from a floristic background existing for a long time in this region.

Gaussen proposed to call Mediterranean assemblage or element: the set of species adapted to the Mediterranean climate and which cannot exceed its limits and conversely Mesogean assemblage or element: the set of species of Mediterranean geographical stock but having acquired a wider range and are likely to exist in sub-Mediterranean or even temperate "Central European" conditions among others.

Ex: Mediterranean assemblage: holm oak, pistachio, carob, strawberry tree, juniper, Aleppo pine, rosemary... (Dajoz, 2006).

I.1.1.2.3. Main Types of Floras

A. Indigenous or Native Plant

Indigenous plants are plant species that develop naturally in the wild, without intentional human intervention on the considered territory (= that grow by themselves). The spontaneity of a species in certain stations is difficult to determine: it sometimes remains uncertain and is a source of confusion. Indigenous plants constitute the "foundation of the flora" of the considered territory. They can colonize natural, semi-natural, or secondary (man-made) environments (Delassus, 2015).

B. Naturalized Plant

Is a foreign plant, introduced fortuitously or voluntarily, but well established, meaning spreading like an indigenous plant and persistent in several of its stations. Among the naturalized species of a territory, those that, "by their proliferation in natural or semi-natural environments, produce significant changes in the composition, structure, and/or functioning of ecosystems" are considered invasive (or invasives). Biological invasions would be the third cause of biodiversity impoverishment, the first two causes being climate modification and habitat destruction.

- Species naturalized long ago introduced: Archaeophyte.
- Species naturalized newly introduced: Neophyte.

C. Adventure Plant

Plant species foreign to the indigenous flora of a territory into which it is accidentally introduced and can establish itself. Otherwise, an Adventure is a plant that grows spontaneously

D. Sub-spontaneous Plant

Is a foreign plant, first cultivated in gardens, parks, or fields, then escaping from these spaces but hardly mingling with the indigenous flora and generally persisting only for a short time. Its establishment in natural environments is still precarious.

E. Cultivated Plant

Is a plant that is the subject of intentional cultivation, for various purposes: agriculture, horticulture, wood production, ornament, medicinal or beekeeping interests, soil protection... These plants are voluntarily introduced into fields, gardens, artificial meadows and forests, cities, roadsides...

F. Cosmopolitan Plant

Plants with wide geographical distribution; reed, nettle, black nightshade, shepherd's purse also, the vegetation of continental "fresh and brackish" waters is cosmopolitan because these environments are homogeneous and aquatic species have a great multiplication power.

G. Ubiquitous Plant

Species capable of occupying very different environments from an ecological point of view.

H. Endemic Plant

Species whose distribution area is entirely contained within territorial limits; they are not distributed randomly but exist in regions whose flora has been relatively isolated (islands, desert, high mountain peaks); thus, geographical isolation "sudden variation in environmental conditions" leading to a fragmentation of the overall area, and each part of this area then has its own conditions triggering different adaptations; in addition, following geographical isolation, barriers to interfertility and genetic mixing are established, instituting genetic isolation.

I.1.1.3. Concept of Vegetation

I.1.1.3.1. Definition

Vegetation is perceived as a mosaic of units at different stages of evolution and/or occupying different habitats ... Species successively colonize these units, settle there more or less permanently, and become extinct in relation to the succession process or with the arrival of new disturbances.

Vegetation is one of the major characteristics of biogeography and is defined as the set of plant communities containing the flora, which consists of a list of all plant species in a given region.

Characterizing vegetation allows to "paint the aspect given to a country by the distribution, habit, abundance, or rarity of the plants that cover the soil". "It is the plant mass, the set of plants considered in their relationships with the environment, climate, soil, and living beings including man".

Vegetation is largely independent of the systematic nature of the plants that compose it. On the other hand, it is the faithful reflection of the environment in which it lives. Two equivalent vegetation, growing in an analogous climate, may have no species in common. They will nonetheless be related and capable of mutually replacing each other.

Vegetation can therefore be characterized in multiple ways, since it involves considering structured sets of plants. The respective proportions of the different species are only one aspect. The mode of association, spatial distribution, but also size, morphology of organs and individuals are other criteria that can be just as important to consider (Duvigneaud, 1984).

The organization and functioning of vegetations can be apprehended at different hierarchical levels (Figure 1):

- **The individual:** in meadows, the definition of the physiological individual is not always easy. It is generally constituted by an assemblage of basic modules or tillers for grasses. The common term "plant" fairly well accounts for the notion of an individual, except for stoloniferous or rhizomatous plants for which the real "individuals" are hardly distinguishable.
- **The population:** it is "the set of individuals of the same species living in a given territory".
- **The community:** it is "the set of plants gathered on the same surface". It is therefore made up of individuals of different species living in interaction in the same ecological environment. The terms phytocoenosis, grouping, which we do not use, have similar meanings (El Bouhissi et al., 2021).

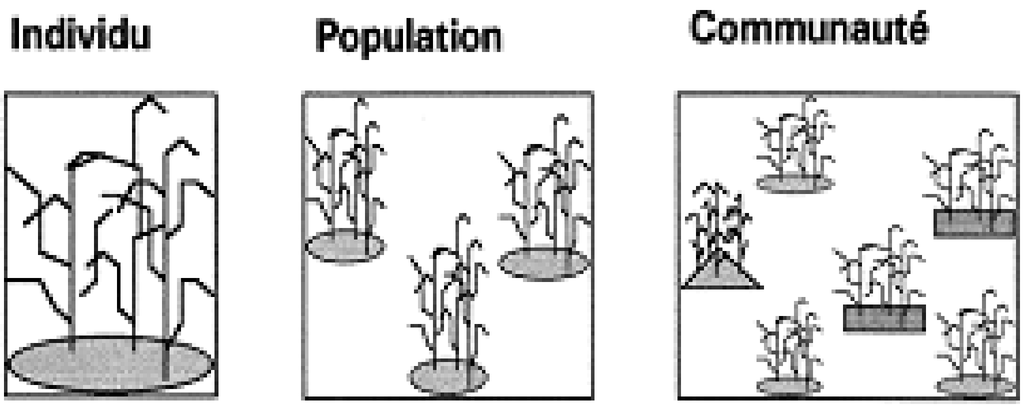


Figure 1. Different hierarchical levels of vegetation

I.1.1.3.2. Types and Biological Spectra

Several criteria can be used to classify plants according to their type of morphological and biological organization:

❖ According to **the living environment:** we distinguish aerial plants (epiphytes), terrestrial plants, living in mud (helophytes), or aquatic plants (hydrophytes).

❖ According to carbon nutrition: we distinguish autotrophic plants, hemiparasites, parasites, saprophytes, or symbiotic plants.

❖ According to **the lifespan of the plant:** we distinguish annual plants (therophytes), biennial or perennial plants (vivacious).

❖ According to the height of the renewal buds in the unfavorable season (Gaudin, 1997).

I.1.1.3.2.1. Definition of Biological Types

Raunkiaër's biological types constitute one of the very interesting characteristics of vegetation.

Biological types or life forms which designate the adaptive behavior of the species. They provide information on the type of plant formation, its origin, and its transformations. According to Raunkiaer (1934), the biological type of a plant species is defined by the position of the buds that survive the unfavorable season, relative to the ground level.

I.1.1.3.2.2. Standard Typology

Plants are classified according to their biological types determined by the general morphology of the species, which expresses its adaptation to the environment. The five biological types of terrestrial plants:

A) Phanerophytes

for which the persistent vegetative buds are located at the end of woody stems quite far from the ground; according to height, we distinguish:

- **Megaphanerophytes** whose woody stems exceed 32 meters.
- **Macrophanerophytes** woody stems from 16 to 32 meters.
- **Mesophanerophytes** woody stems from 8 to 16 meters.
- **Microphanerophytes** woody stems from 2 to 8 meters.
- **Nanophanerophytes** woody stems from 0.5 to 2 meters.

The subdivisions of Phanerophytes are based on the degree of protection of tender organs against the bad season. Among the characters considered as such, Raunkiaer successively mentions the following:

o Protection of buds;
o Leaf fall before the unfavorable season;
o Decrease in plant size;
o Xerophytic adaptations in general.

B) Chamaephytes

include plants whose buds or tips of perennial shoots are located near the ground less than 0.5 m, on creeping or erect branches.

The low position of persistent organs is considered favorable for ensuring the protection of perennial organs, by a layer of snow in cold countries, by plant debris covering the soil in temperate or warm countries. In the savannas of tropical regions, this arrangement is also advantageous, as it ensures effective protection between the more or less dense clumps of grasses. This situation constitutes, in any case, an advantage, because there prevails, near the ground, even in the dry season, a microclimate more favorable than in the biosphere exposed to winds and evaporation accentuated by drought (Crosaz, 1994).

Raunkiaer divides chamaephytes into five main subtypes:

- Suffrutescent Chamaephytes or Annual Herbs, with diffuse and erect branching.
- Creeping Chamaephytes, decumbent branches hardly rising above the ground.
- Cespitose Chamaephytes, forming dense clumps or rosettes.
- Cushion Chamaephytes, very compact growth.
- Bryoid Chamaephytes, mosses and lichens.

C) Hemicryptophytes

are perennial rooted plants whose replacement shoots or buds are located at the soil surface. Normally, in the most perfect hemicryptophytes, the aerial shoot dries up completely or almost completely during the unfavorable period. The perennial organs of these plants are thus protected in the soil and their renewal organs are sheltered in the Ao horizon of pedologists, i.e., in the layer of organic matter undergoing humification.

The hemicryptophyte type also presents great diversity.

Braun-Blanquet (1928), in turn, divides hemicryptophytes into the following subtypes:

- Cespitose Hemicryptophytes, the buds and shoots are protected by tunics or real carapaces formed by leaves persisting wholly or in part and forming a sheath around the buds and young replacement axes.
- Rosette Hemicryptophytes, plants with leaves spread out on the soil surface, forming rosettes, at least temporary, with often continuous assimilation.
- Scapose Hemicryptophytes, in this type, leafy aerial shoots are produced which are destroyed more or less completely during the bad season.
- Climbing Hemicryptophytes, these are scapose hemicryptophytes, but with aerial shoots lacking rigidity and clinging to a support.

D) Cryptophytes

For which these buds are located inside the soil, and according to the type of soil the following subdivisions are recognized:

D-1) Geophytes

Are plants with shoots or persistent buds entirely sheltered, during the unfavorable season, under a layer of earth of variable thickness.

Raunkiaer made a distinction between geophytes proper and helophytes. Geophytes are land plants, while helophytes are marsh cryptophytes, with persistent buds developed in waterlogged soil and often covered by a more or less deep water table.

Braun-Blanquet (1928) divides, in turn, geophytes as follows:

- **Eugeophytes:**
  - Bulbous or tuberous Geophytes;
  - Rhizomatous Geophytes;
  - Root-bud Geophytes.
- **Parasitic Geophytes.** Parasitic plants of roots whose persistence organs are underground.

D-2) Helophytes

when they are in very wet terrestrial soil like mud. Helophytes are plants that end up developing totally aerial vegetative and reproductive apparatus, but keeping their underground apparatus in a waterlogged muddy substrate. Some begin their cycle in a submerged state while others start immediately as a land plant (Albert C. H., 2009).

D-3) Hydrophytes

Include aquatic plants whose persistent buds are located at the bottom of the water.

Braun-Blanquet (1928) divides this biological type into two groups:

¬ **Swimming Hydrophytes:** floating aquatic plants or weakly rooted.

¬ **Fixed Hydrophytes:** aquatic plants fixed to the substrate.

This subtype is in turn divided by Koch (1928), as follows:

➢ **Hydrogeophytes:** Aquatic plants with rhizome.
➢ **Hydrohemicryptophytes:** Aquatic plants with buds located level with the mud, at the bottom of the water.
➢ **Hydrotherophytes:** Annual aquatic plants.

E) Therophytes

Annual herbaceous plants that pass the unfavorable season in the form of seeds and which complete their entire cycle in one year at most. A great diversity of behavior of these "annual plants". Some germinate as early as autumn in temperate regions, spend the winter as seedlings, take active development during spring and die during the summer drought. Others only germinate in spring and their vegetative cycle ends in summer. Still others germinate and develop at any time and only disappear during the unfavorable seasons. Many are, among annual plants, those that develop several generations during the year (Alzieu, 2003).

Braun-Blanquet classifies therophytes according to the behavior of the aerial shoot. He distinguishes the following categories:

✓ **Erect Therophytes.**
✓ **Prostrate Therophytes.**
✓ **Climbing Therophytes.**
✓ Müller (1933 in Albert National Park) adds a fourth category, that of rosette therophytes.

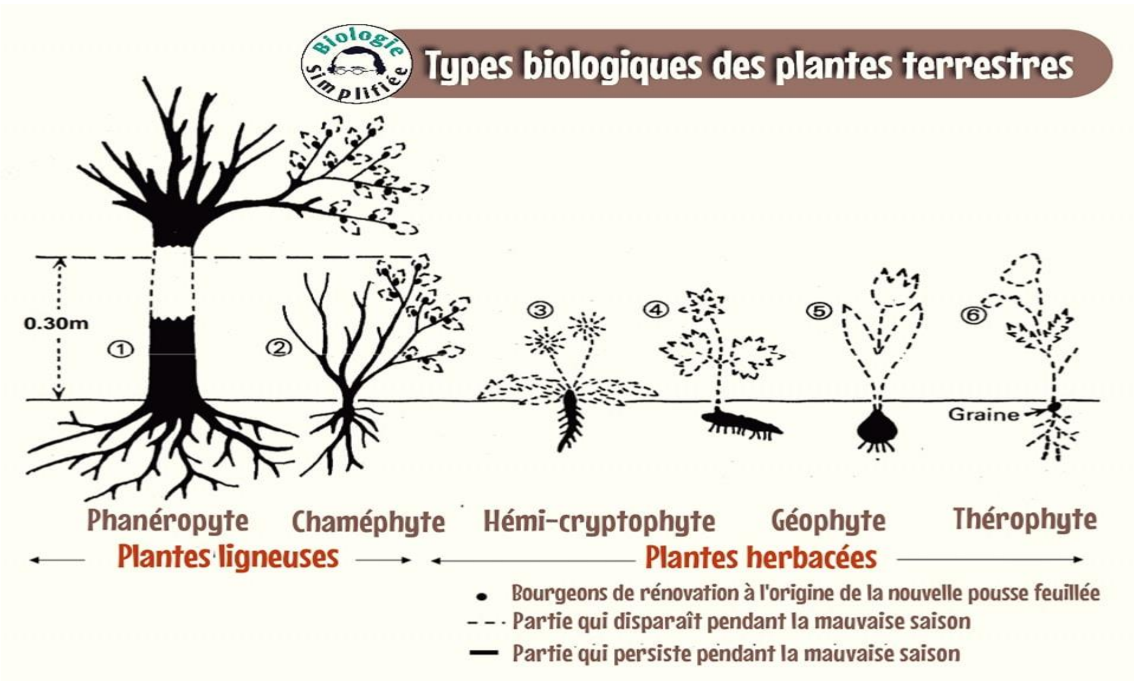


Figure 2. The different biological types

Table 1. Summary table of different biological types

Biological Types	Characteristics
Phanerophytes	Woody plant, buds up to more than 50 cm from the ground. Trees, shrubs, small trees, epiphytes.
Chamaephytes	Woody plant, buds between 0 and 50 cm from the ground. Trees, creeping dwarf shrubs, sub-shrubs.
Hemicryptophytes	No woody plant, buds at ground level. Biennial and perennial herbaceous plants.
Cryptophytes (geophytes)	No woody plant, buds below the soil surface. Perennial herbaceous plants with bulbs, rhizomes, tubers, ….
Therophytes	No woody plant, no winter buds. Annual herbaceous plants.

1.1.1.3.2.3. The Biological Spectrum

1 -The notion of biological spectrum

- The biological spectrum represents the proportion of each biological type constituting the plant cover.
- This proportion is calculated as a percentage
- The biological spectrum of a formation specifies its physiognomy and structure.
- It also allows knowing the characteristics of the climate.
- The study of the biological spectrum is one of the methods for studying vegetation.
- It allows knowing the relative importance of each biological type in the flora.

To calculate the biological spectrum of a type of vegetation, we use a vegetation table listing the species, the biological type of each species, and its abundance-dominance coefficient.

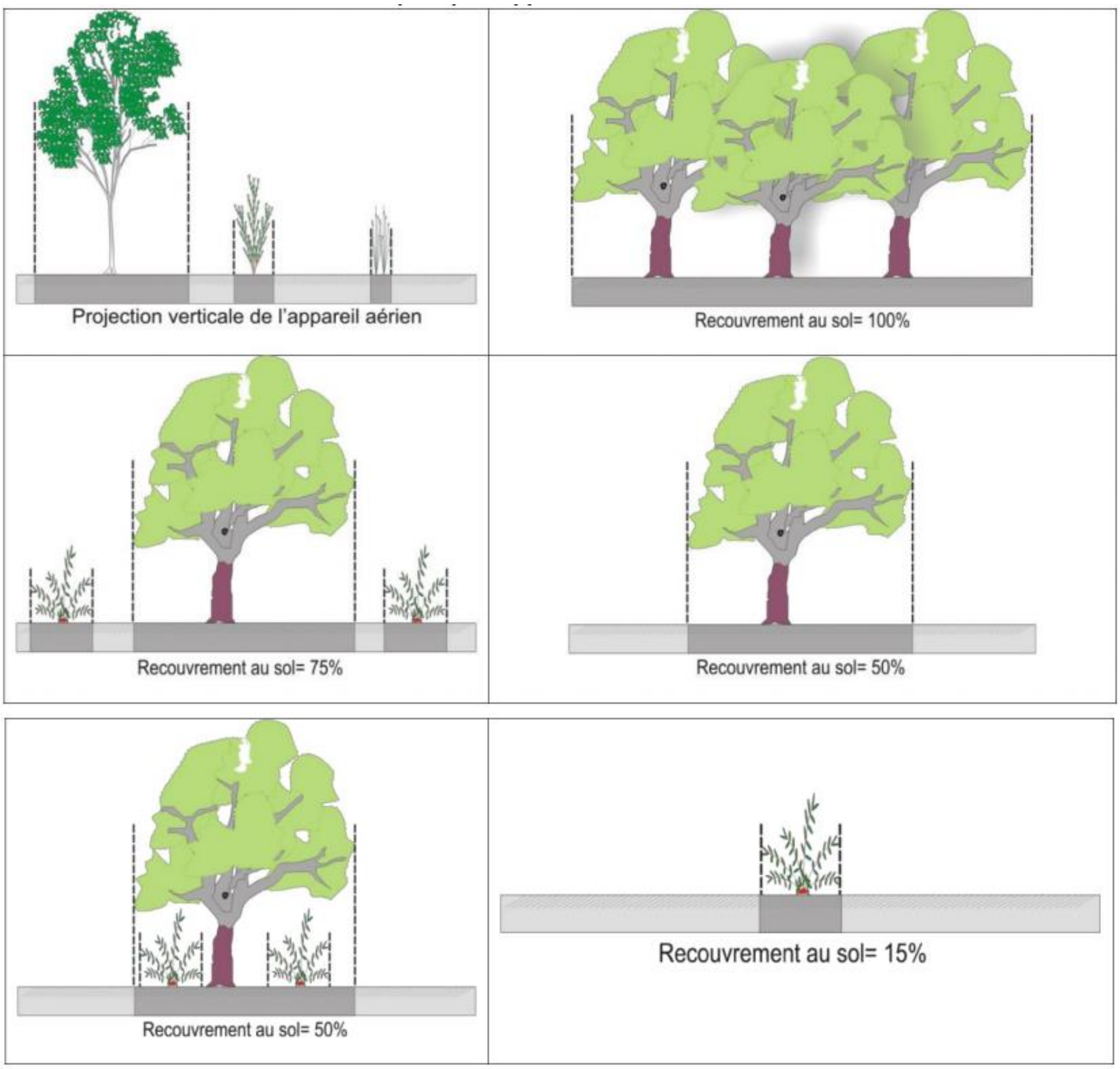
These vegetation tables come from vegetation surveys carried out in specific sectors within a plant formation (Laporte et al., 2009).

2 – The Abundance-Dominance Coefficient:

- Plant species are not distributed identically in the survey.
- Some species are more abundant and cover an important part of the ground, others are relatively rare.

Abundance is the relative proportion of individuals of a plant species (evaluation of the number of individuals), and dominance is the area covered by this species (the degree of cover). The two notions are very close and complementary.

The cover rate of a plant species: It is the space occupied by the vertical projection of the aerial apparatus of all individuals of the same species relative to the total considered area (Ramade, 2009).



Vertical projection of the aerial apparatus
Ground cover = 100%; Ground cover = 75%; Ground cover = 50%; Ground cover = 50%; Ground cover = 15%.

Figure 3. Cover of a plant species

I.1.1.3.2.3.1. Raw Biological Spectrum

The raw biological spectrum is the floristic richness of a population. It expresses the percentage of the number of species belonging to the various biological types relative to the total number of species of the studied ecosystem.

It is expressed by the following formula:

$$SB = Fi / N \times 100$$

Where

- SB= Raw spectrum of a given biological form;
- Fi: Number of times the species of a given biological form are in the set of surveys;
- N: Total number of species.

I.1.1.3.2.3.2. Net Biological Spectrum

The net biological spectrum corrects the raw biological spectrum since it uses the abundance-dominance coefficients (A.D.C.). The sum of the A.D.C. is calculated for each biological type and then the percentages of the biological types are calculated from the total sum of the A.D.C.

I.1.1.3.3. Plant Formation

I.1.1.3.3.1. Definition

A plant formation designates a classification of plant species characterized by a particular aspect which, in turn, determines a characteristic landscape. This physiognomy, called vegetation, allows an overview on a very large scale, which depends on the species in a plant growth environment where it develops.

Plant formations are groups of plants sharing a common environment that interact with each other, with animal populations, and with the physical environment. Some plant communities are often found together in the landscape due to common environmental requirements.

Plant formations may require a plant association in all these major categories; for most plant formations, it is necessary to concretely consider the ecological systems that characterize them (Chermat S., 2013).

In biogeography, a plant formation specifies the nature of the set of plants that possess a similar habitus and form a homogeneous plant unit. A plant formation specialized in a plant species usually has a specific name like a reed bed, a rush bed, a sedge bed, a rush bed, a hedge, a wood, a forest, a mangrove, a steppe, a garrigue, a heathland, etc. Conversely, some formations are inhabited by a multitude of plant species, promoting good biodiversity.

An anemogenous area qualifies a plant formation whose characteristics of floristic composition, location, and evolution are conditioned by the wind.

Some floristic, herbaceous formations, composed of perennials, require regular maintenance by mowing, carding, weed cutting for aquatic plants, etc.

With the progress made regarding chorology and phytosociology, the classification of plant formations (deciduous, pine forests, xerothermic, compact forests, open forests, thick scrub, heaths, herbaceous vegetation...) tends to be replaced by a more precise plant set, to account for the dominant species that compose a community and the environment to which they are associated in their biome (Bournerias et al., 2002).

A chaparral qualifies a xerophytic plant formation in Texas, California, and Northern Mexico, composed of dense thorny scrub about 2 m high.

A halopsammous biological area determines an open plant formation on sandy and salty soil according to the classification of Allorge and Jovert. The plants there are generally halophilic (Bouzidi, et al., 2009).

The plant formation can be easily recognized by looking at a landscape, without in-depth analysis, according to the importance and size of the types of plants that compose it: grasses, bushes, shrubs, trees... Thus, among the most common types of formation, we distinguish prairie, forest, savanna, mangrove, taiga, steppe... A closed plant formation entirely covers the ground (forest), contrary to an open formation (steppe) (Nentwing et al., 2009).

I.1.1.3.3.3. Type of Formations

1- Tundra

Located at the level of the Arctic polar circle, it is an environment without trees; the vegetation is reduced to low shrubs. Similar communities, called alpine tundra, are found in mountains above the tree line.

In the Arctic tundra, the climate is very cold and the winter days are short. The deep layers of the soil are permanently frozen; only a superficial layer about 1 m thick thaws during the summer. Consequently, plant roots cannot penetrate deeply. Precipitation is as low in the tundra as in some deserts. The tundra is dotted with dwarf shrubs, herbaceous plants, mosses, and lichens. Plant growth and reproduction occur suddenly during the short summers, during which sunlight is almost continuous.

Animals of the Arctic tundra are protected against the cold by their fat and fur, and many of them take refuge in burrows. As many bird species migrate, and particularly waterfowl, the fauna proves to be much richer in summer than in winter. The Arctic tundra is home to many herbivorous mammals, such as the musk ox and caribou in North America and the reindeer in Europe and Asia. The most widespread predators are the Arctic fox, the wolf, and, near the coasts, the polar bear.

Figure 4. Tundra

2- Taiga

Also called Coniferous Forest or boreal forest, it covers a wide band that extends in North America, Europe, and Asia, up to the southern limit of the Arctic tundra. Taiga is also found at more temperate latitudes, in cold high-altitude zones, particularly in the mountainous region of western North America. The taiga is characterized by long, cold winters and short, rainy summers, sometimes hot. Precipitation can be considerable and mainly takes the form of snow. The soil of the taiga is generally thin, poor, and acidic. It forms slowly, as it is exposed to cold and covered with conifer needles that decompose slowly.

Nevertheless, vegetation grows rapidly during the long summer days (up to 18 hours of sunlight at these latitudes).

Conifer stands typically consist of a single species or a few at most, such as Pines, Firs…, and they are so dense that little vegetation grows in the understory. Rare deciduous trees like Willow, Alder, and Poplar grow in particularly wet or disturbed habitats.

Snow accumulations, which can reach several meters each winter, have important ecological consequences. The snow insulates the soil before the extreme cold and thus prevents it from freezing permanently. Mice and other small mammals dig tunnels in the snow at ground level; they remain active all winter and continue to feed on plant debris.

Animal populations of the taiga mainly include granivores like squirrels, jays, and nutcrackers, herbivores like insects that eat leaves and wood, and large herbivores like deer, caribou, hare,…. Among the predators of the taiga are the grizzly bear, wolf, lynx, and wolverine. Many mammals of the taiga have thick winter fur that protects them from the cold; some hibernate until spring.

Figure 5. Taiga

3- Temperate Forests

Temperate forests are located in mid-latitude regions where humidity is sufficient for the growth of large trees, in most of the eastern United States, Central Europe, and eastern Asia. Temperate forests are characterized by the presence of deciduous trees.

In temperate forests, temperatures are very cold in winter and warm in summer (from -30 to 30 'C), and the growing season lasts from five to six months. The precipitation is relatively heavy and distributed uniformly throughout the year, but the soil water freezes temporarily at the worst of winter. Temperate forests experience an annual cycle: trees lose their leaves in autumn, go dormant in winter, and bud in spring. The relatively rich soils of temperate regions provide the nutrients necessary for spring leafing. Decomposition rates are slower in temperate forests than in tropical forests; the soil of temperate forests is therefore covered with a thick layer of dead leaves that contain a good part of the biome's nutrients.

More open and less high than the tropical forest, the temperate forest comprises several layers of vegetation, including one or two tree layers, an understory of shrubs, and a herbaceous layer. The species composition of temperate forests varies from one part of the world to another; among the dominant trees are Oak, Beech, and Maple….

Given the diversity and abundance of food resources and habitats it contains, the temperate forest hosts a multitude of animal species. Microorganisms, Insects, and Spiders live in large numbers in the soil or in the leaf layer, or feed on the leaves and shrubs of the understory. The forest also hosts many species of birds and small mammals and, where human encroachment has not eliminated them, wolves, lynxes, foxes, bears.

Figure 6. Temperate Forests

4- Temperate Grasslands

Have some characteristics in common with the tropical savanna, but they are located in regions where winters are relatively cold. Temperate grasslands include the veldts of South Africa, the pusztas of Hungary, the pampas of Argentina and Uruguay, the steppes of Russia, and the plains of central North America.

The persistence of all grasslands relies on seasonal droughts, occasional fires. These factors prevent the establishment of shrubs and woody trees. The soil of grasslands is greasy and rich in nutrients, and the roots of perennial herbaceous plants often penetrate very deeply. The amount of annual precipitation influences the height of the vegetation; in North America, a "tall grass prairie" is found in humid regions and a "short grass prairie" in dry regions.

The area of grasslands expanded after the retreat of the glaciers, at the end of the last glaciation, when climates warmed and dried worldwide. This expansion was accompanied by the proliferation of large herbivorous mammals like the Bison of North America, the Gazelles, Zebras, and Rhinoceroses of the African veldt, and the Wild Horses and Antelopes of the Asian steppes. Herbivores are chased by large carnivores such as Lions and Wolves (Daget et al., 2010).

Figure 7. Temperate Grasslands

5- Mediterranean Forest

Coastal regions located near cool marine currents are often characterized by mild and rainy winters and long, hot, and dry summers.

The plant formation of these regions is the Mediterranean forest, and it consists of dense stands of thorny evergreen shrubs. It is found in the Mediterranean region (where it was first described) as well as along the coasts of California, Chile, southwestern Africa, and southwestern Australia. The Plants of these various regions are not related but, such as the Eucalyptus of Australia and the Holm Oak of California, they present morphological and physiological similarities.

In the Mediterranean forest, annual plants abound during winter and early spring, periods when precipitation is heaviest.

The Mediterranean forest is adapted to periodic fires. Among the typical Animals of the Mediterranean forest are Deer, frugivorous Birds, Lizards, Snakes, and Rodents that eat the seeds of Annual Plants (Carles J., 1948).

Figure 8. Mediterranean Forest

6- Deserts

Are the driest of terrestrial biomes, they are characterized by low and unpredictable precipitation (less than 30 cm per year). There are cold deserts and hot deserts (with temperatures over 60° C at the soil surface during the day).

Hot deserts are found in the southwestern United States, on the west coast of South America, in North Africa, and the Middle East. Cold deserts are located west of the Rockies, in eastern Argentina, and Central Asia. The driest deserts, where average annual precipitation is less than 2 cm (precipitation is zero some years) are the Atacama in Chile, the Sahara in Africa, and the deserts of central Australia.

The density of desert vegetation is largely determined by the frequency and amount of precipitation. In less arid deserts, the dominant vegetation is sparse, and it consists of shrubs and drought-resistant Cacti and Plants that store water in their tissues. Periods of precipitation (like the end of winter in the Sonoran Desert in the southwestern United States) are marked by sudden and spectacular flowering of Annual Plants.

Granivorous Animals, such as Ants, Birds, and Rodents, are found in abundance in deserts, and they feed on the small seeds produced in large quantities by Vegetation. Reptiles such as Lizards and Snakes are important predators of granivores. Like desert Plants, most Animals of the desert are well adapted to drought and extreme temperatures.

Figure 9. Desert

7-Savanna

A vast grassy expanse where scattered trees are found. The savanna covers immense tropical and subtropical regions of central South America, central and southern Africa, and Australia. There are generally three distinct seasons in these regions: a cool and dry season, a hot and dry season, and a hot and rainy season, in that order. Despite its apparent simplicity, the savanna proves rich in species. Trees and shrubs are scattered in the open landscape, as frequent fires and large herbivorous mammals destroy a good part of the young plants.

The predominant vegetation consists of herbaceous Plants including several Grasses. The tropical savannas of the different continents host some of the largest herbivores in the world, including the giraffe, zebra, antelope, buffalo, and kangaroo. Burrowing Animals, which nest and shelter in burrows, are also found in abundance and include mice, moles, snakes…. The Animals of the savanna are most active during the rainy season and many of them are nocturnal.

The term savanna also designates the regions of overlap between forest and grassland. For example, a savanna is found in North America, in the zone of interpenetration between the forest and the temperate grassland, in a band that extends roughly from

Minnesota to eastern Texas. There, the climatic conditions and characteristics of the communities are halfway between those of the forest and those of the grassland (Cámara Artigas, 2009).

Figure 10. Savanna

8- Tropical Forests

The average temperature (about 23°C) and photoperiod (about 12 hours) vary little throughout the year. Precipitation, on the other hand, is variable and determines, more than temperature and photoperiod, the vegetation.

The lush tropical rainforest grows in regions near the equator, where precipitation is abundant (greater than 250 cm per year) and where the dry season lasts only a few months.

The tropical rainforest is the community with the greatest biological diversity; it contains as many plant and animal species as all other terrestrial biomes combined. Indeed, up to 300 species of trees can be counted in one hectare, some of which reach 50 to 60 m in height. Given the size and density of the trees, competition for light constitutes strong selection pressure in the plant communities of the tropical rainforest.

Animals are mostly arboreal; monkeys, birds, insects, snakes, bats, and even frogs find shelter and food in the trees. The heat is conducive to the presence of numerous ectothermic (poikilothermic) Animals; there are more species of Amphibians and Reptiles in the tropical rainforest than in any other biome.

The effects of human activity on the tropical rainforest are currently causing much concern. The destruction of the tropical forest is progressing at an alarming rate. The forest has already disappeared by more than half and, according to estimates, nothing will remain by the end of the century.

Figure 11. Tropical Forests

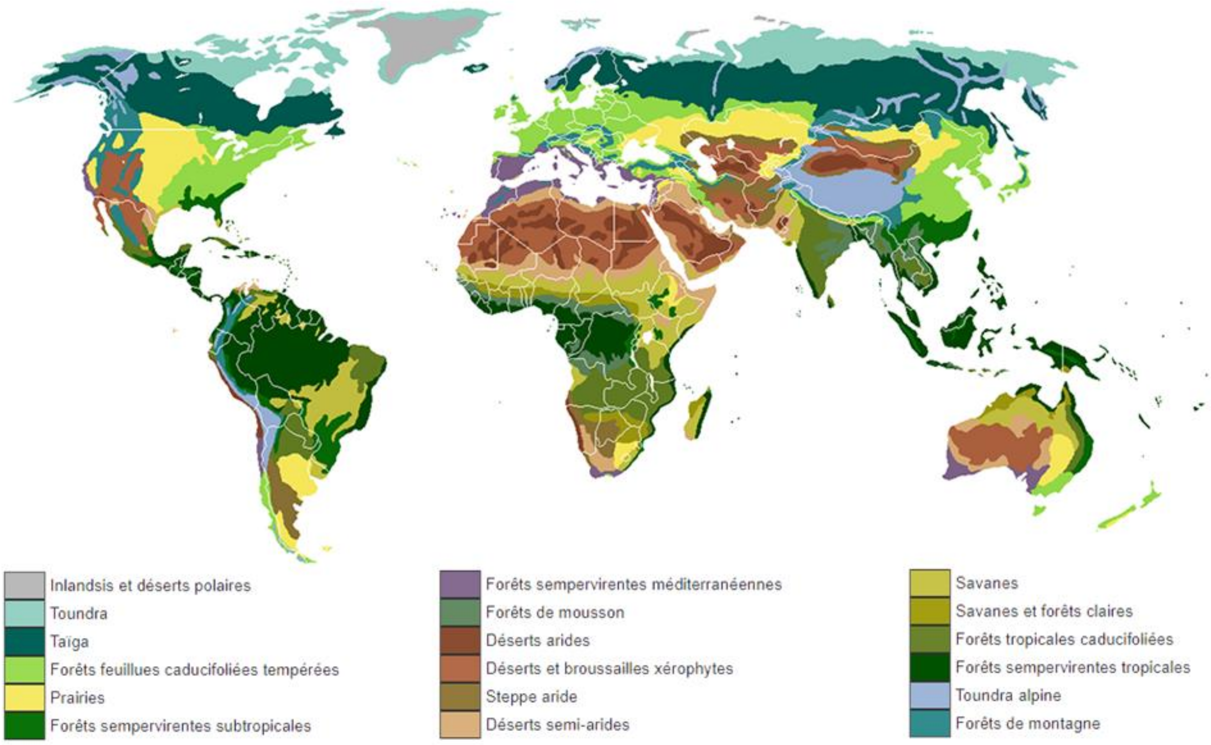


Figure 12. Main Biomes

- Irish and polar deserts
- Tundra
- Taiga
- Temperate deciduous broadleaf forests
- Grasslands
- Subtropical evergreen forests

- Mediterranean evergreen forests
- Monsoon forests
- Arid deserts
- Xerophytic deserts and scrub
- Arid steppe
- Semi-arid deserts
- Savannas
- Savannas and open forests
- Tropical deciduous forests
- Tropical evergreen forests
- Alpine tundra
- Mountain forests

I.1.1.2. Animal Material

The vagile fauna, i.e., not fixed, has the advantage over plants of being able to move. Consequently, if it is easy to approach flora from a quantitative point of view, it will not be the same for animals. It is relatively easier to consider the qualitative aspect.

The only means of studying the animal community are based on direct observation, with the naked eye, with binoculars, on video, by hearing, or thanks to capture and recapture techniques after marking. Modern means put at the service of field technicians even allow, with the help of sophisticated transmitters placed on animals before release, to locate and follow them in their wild behavior without too much disturbance.

I.1.2. The Environment

Whatever the level of organization at which one places oneself, one will always be led to study the effects of the ecological factors specific to each environment, which are physicochemical or biological parameters likely to act directly on living beings. However, it must be kept in mind that, whatever the level of organization at which one places oneself, these factors never act in isolation because living beings are always exposed simultaneously to the combined action of a large number of ecological factors, many of which are not constant, but present significant spatio-temporal variations.

There are several modalities for classifying ecological factors:

We can distinguish abiotic factors, of a physical or chemical nature (climatic factors ex: chemical composition of a soil) and biotic factors (parasitism, predation, feeding, etc.).

Some ecological factors are said to be density-independent because they exert their effects on individuals taken in isolation, independently of the density of the population to which they belong. Almost all physicochemical factors can be classified in this category. Conversely, there are density-dependent factors, which have an action whose intensity increases with the abundance of individuals. These are almost always biotic factors like competition or predation (Figure 13).

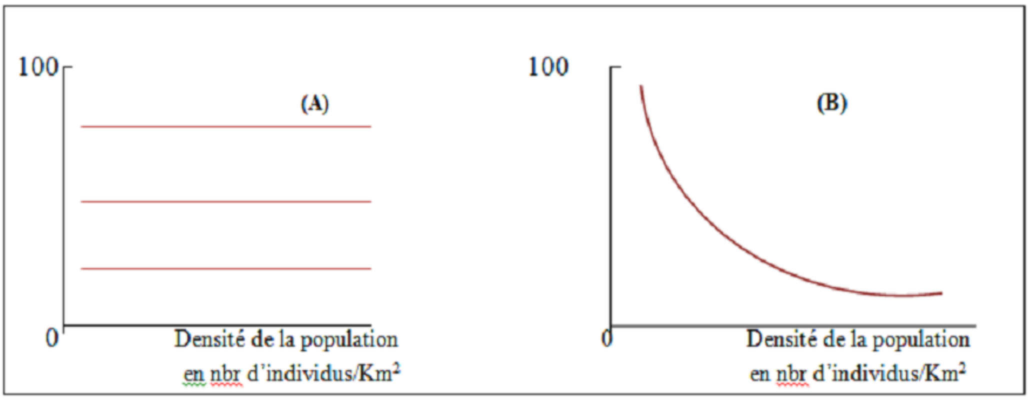


Figure 1 : Diagramme schématisant le mode d'action des facteurs indépendants de la densité (A) et dépendant de la densité (B).

Diagram schematizing the mode of action of density-independent (A) and density-dependent (B) factors.

Figure 13. Factor Dependency Diagram.

An ecological factor is any physicochemical or biological parameter likely to act directly on living beings during at least one phase of their life cycle. This definition does not consider elements such as altitude and depth because they do not act directly. Indeed, altitude acts through temperature, sunlight, and atmospheric pressure atmospheric. Similarly, depth acts on aquatic animals and plants through increased pressure and decreased light.

Ecological factors act differently on living beings:

- They intervene in the **geographical distribution of living beings** by eliminating certain species from territories whose characteristics are not favorable to them.
- They influence the density of populations in their environment by modifying the birth and death rates of various species (action on the development cycle and on animal migrations).
- They favor the appearance of **adaptive modifications** in certain living beings.

In general, we distinguish abiotic factors and biotic factors.

- Abiotic factors

These are physicochemical factors of the environment, such as climate elements, soil, etc. that exert an influence on living beings. They do not depend on living organisms. They are of a chemical or physical, climatic, hydrological, and edaphic nature.

- *Biotic factors*

These are ecological factors that manifest within populations and influence their demography: group and mass effects, intra- or interspecific competitions, predation, parasitism. They therefore depend on living organisms. These are all the interactions that exist between the living beings present in a given ecosystem.

Another classification distinguishes density-independent factors (factors that exert their effects on individuals taken in isolation, independently of density) and density-dependent factors.

I.1.3. Structure and Homogeneity of Communities

I.1.3.1. Physiognomy and Structure of Plant Communities

The plant community is characterized by its physiognomy or appearance (ex: the appearance of the forest is different from that of fields), its structure, its floristic composition, and its ecology.

The physiognomy, or appearance of plant communities, depends primarily on the type of formation (forest, fields) but also on their structures. It also depends on the scale of observation at which one places oneself, particularly for aerial photographs.

It may appear homogeneous on a small scale, but heterogeneous on a large scale, for the same community. The physiognomy of the community can be variable throughout the seasons due to a more or less marked phenological periodicity of the biological spectrum, i.e., the relative proportion of various life forms.

These life forms or biological types are based on the general morphology of the plant and notably on the position of the renewal buds relative to the ground. These buds are the organisms that allow surviving the unfavorable season.

ϖ **Phanerophytes (Tree Stratum)**

Phanerophytes and nanophanerophytes are represented by plants (trees, shrubs, small trees, and lianas) exceeding 25cm in height.

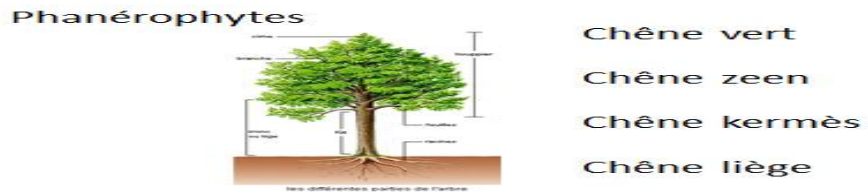


Figure 14. Phanerophytes

ϖ **Chamaephytes (Shrub Stratum)**

Chamaephytes are formed of sub-shrubs, herbs, and sub-woody plants not exceeding 25 cm in height.

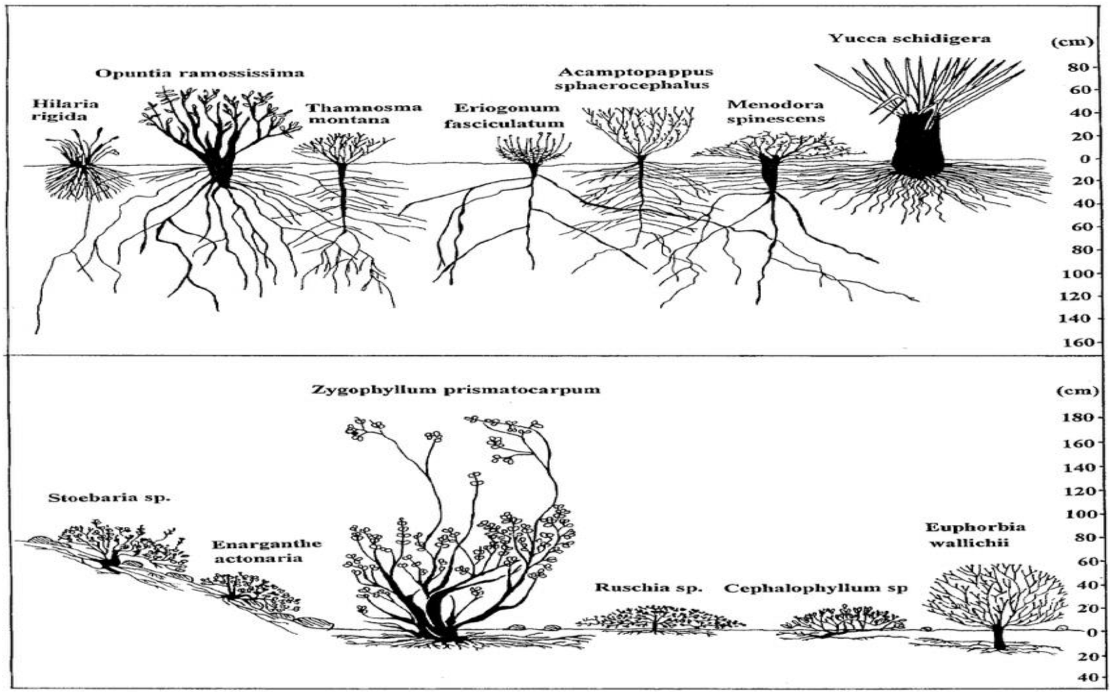


Figure 15. Chamaephytes

Hemi-cryptophytes (Herbaceous Stratum)

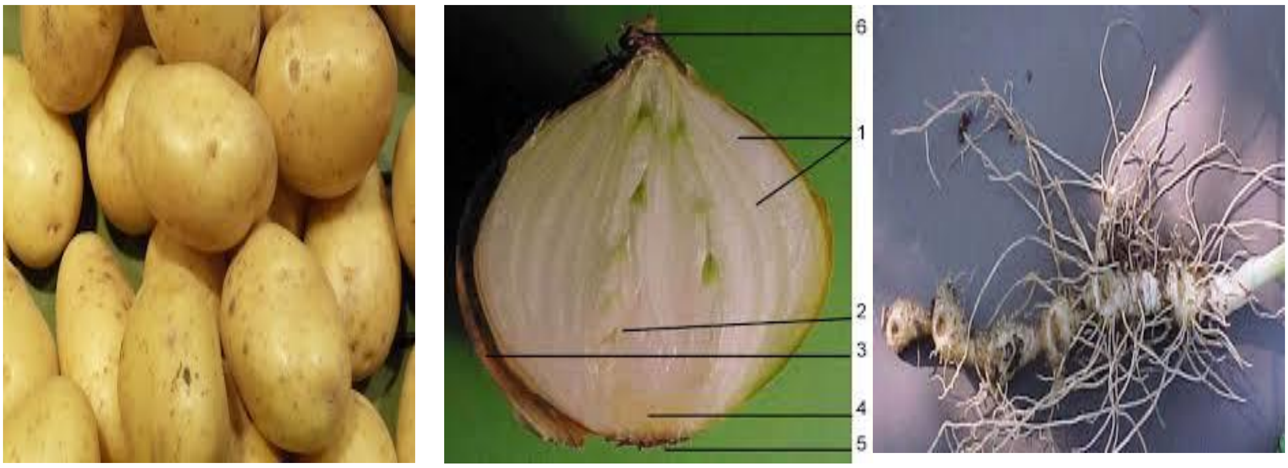
Hemi-cryptophytes group low plants with perennial buds located at ground level. These species have basal leaves in rosettes.

Berardia subacaulis Convolvulus arvensis

Figure 16. Hemi-cryptophytes

✿Geophytes (Herbaceous Stratum)

Geophytes constitute plants whose storage organs are underground (rhizomes, bulbs, tubers).



Tubers Bulbs Rhizomes

Figure 17. Geophytes

✿Therophytes (Annual Herbaceous Stratum)

Therophytes or annual plants pass the unfavorable season in the form of seeds.

Figure 18. Calcioclous lawns dominated by annual Therophytes

. Structure

There is a horizontal and vertical

of the community:

-The horizontal structure

The horizontal structure is at the origin of the physiognomy of a plant community. It corresponds to the distribution, or mode of distribution of individuals on the soil surface.

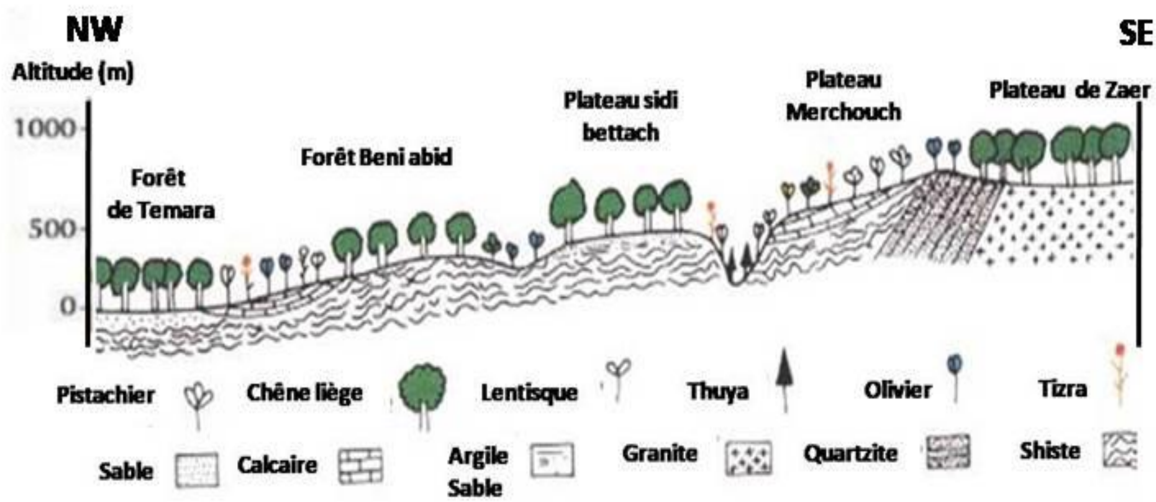


Figure 19. The horizontal structure

-The vertical structure

Distribution of individuals in levels or strata of different heights

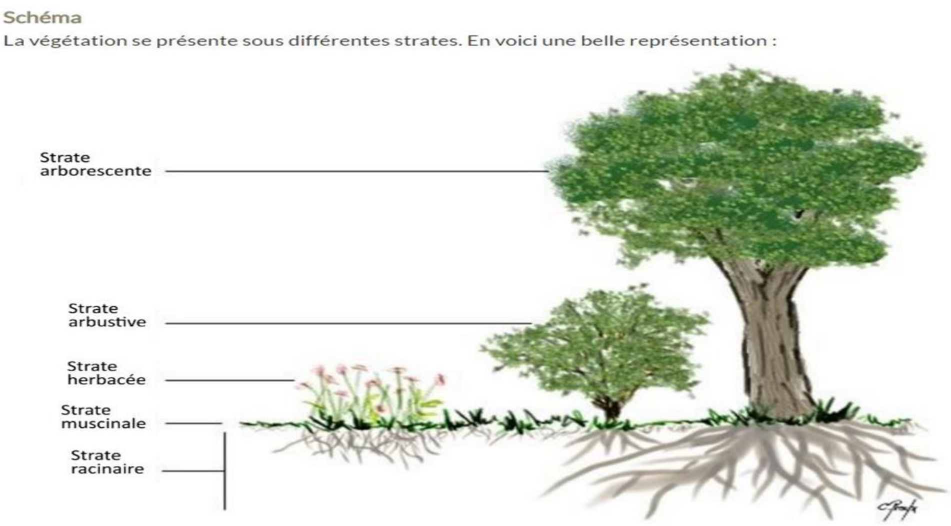


Figure 20. Vertical structure

-Cryptogamic stratum (bryophytes, lichens)

Figure 21. Lichens

-Herbaceous stratum

Figure 22. Herbaceous Stratum

-Shrub Stratum

Figure 23. Shrub Stratum.

-Tree Stratum or Arborous

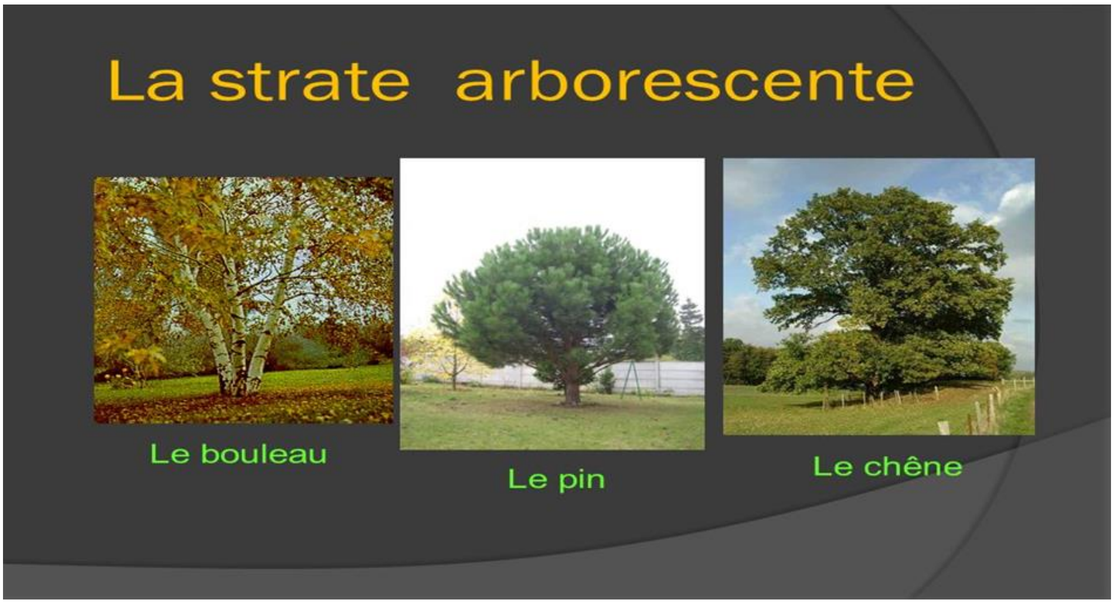


Figure 24. Tree Stratum

1.1.3.2. Spatial Structure of Animal Communities

The different organisms that make up a community do not live "in bulk" in space: they occupy locations that are often well defined, while being variable in time if they are mobile animals.

The existence of this localization plays an essential role in the life of the community, since it allows or prevents the meeting of the various species and, more generally, governs their relationships. It is notably at the origin of the trophic relationships that exist between the organisms, and therefore of the very functioning of the ecosystem to which they belong.

The spatial distribution of living beings can be considered on one hand on a horizontal plane, on the other hand along a vertical axis.

1.1.3.2.1. Distribution on a Horizontal Plane

On a horizontal plane, various types of distribution are possible for individuals of the same species.

❖ **Uniform (regular)** distribution is rare and reserved for territorial animal species, it means that individuals tend to keep an equal distance from each other. It corresponds to a maximum avoidance of individual contacts and therefore reflects the importance of intraspecific competition.

❖ **Random distribution implies,** on the contrary, a rarity of interactions between individuals at the same time as a homogeneity of environmental factors.

❖ **Aggregated (contagious)** distribution is the most frequent. It is due to the heterogeneity of the environment or to the behavior of individuals who tend to group together.

❖

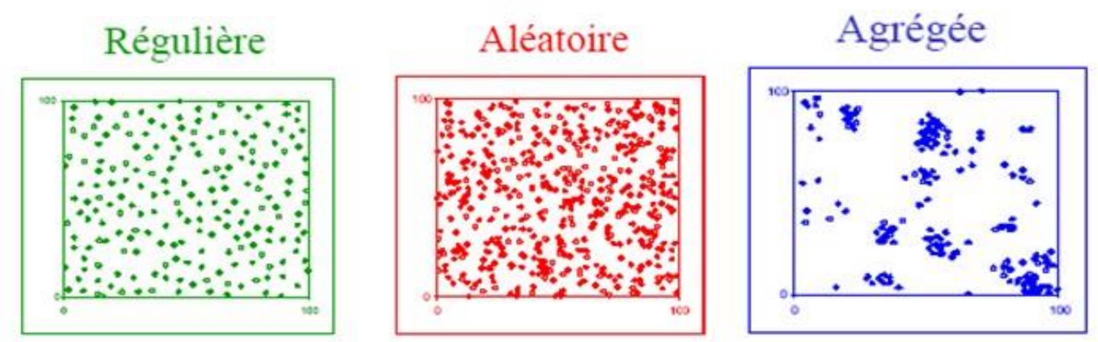


Figure 25. Types of Distribution on a Horizontal Plane

1.1.3.2.2. Distribution on a Vertical Plane

According to their distribution in the vertical plane, we distinguish: aerial animals that live in the air or in trees (monkeys, birds, winged insects…), terrestrial animals that are constantly on the ground (lion, doe, cow…) and underground animals that live in holes (rats, earthworms, …).

For animals, the most characteristic species of an environment are classified into: dominant species that live permanently in the environment and influential species whose action is only manifested part of the year and abundance is expressed as follows:

0: Animal absent

+ : Alone and scattered

++ : Not rare

+++ : Frequent

++++ : Very frequent.

CHAPTER 2: SAMPLING

It is generally impossible to get hold of all the individuals of a population (number of trees in a forest, number of insects in a citrus field…..).Therefore, we do not measure "everything" that can be a biological system, but a fragment of the whole (Sample), taken to judge some properties of this "whole", hence the necessity of sampling. In other words, sampling and the results of the sample can be used to estimate certain characteristics of the population.

Sampling is therefore the procedure by which samples (is a fragment of a whole taken to judge that whole) are taken. The number of samples can be defined in time and space (infrequent surveys (annual for example) but on a large number of plots, a certain number of regular surveys (one per week for example) on few stations). In all cases, the number and distribution of stations to be observed must be set within the framework of a sampling plan.

The choice of the sampling plan consists of choosing how the data will be collected in the field (in certain places chosen at random, in all habitats frequented by the target species, ….) therefore choosing a method to locate the samples.

The sampling plan is therefore conditioned by the choice of the problem and the way it is posed. It must be adapted to test the hypothesis made, at a given spatial and temporal scale, on the structure or dynamics of the studied biological model. The choice of sampling mode depends on what is being sought. It is imperative to take the time to plan one's sampling. Each method has its own technical characteristics of implementation and analysis of results, its advantages and its disadvantages. It is interesting to also point out that when studying a character on several samples of the same size from the same population, it can be observed that the results are not identical from one sample to another; this phenomenon is called sampling fluctuation.

It is therefore important, prior to any study, to clearly define the problem that will condition:

- the definition of a sampling plan that will be carried out according to different variants depending on the technical, scientific, or temporal constraints encountered;
- the measurements to be taken (density, weight, size, etc.), according to the methodological choices adopted, to guarantee the reliability of the statistical interpretation of the data obtained;
- the statistical interpretation of the results. It should be recalled that statistics are non-parametric or parametric.

We summarize that sampling is: the action of sampling, the result of this action, a set of specimens.

Why sample?

- Impossibility (in most cases) to access all the individuals that constitute the studied population.
- Censusing the entire population costs too much and/or takes too much time.
- Ensure better control of operations and more rigorous monitoring.
- Accelerate data collection and processing.
- In the long term, reduce the burden on informants.

II. Quality and Types of Sampling

II.1. Sampling Quality

It is generally impossible to measure one or more characteristics on all the units of a group of interest. This can result from several causes, such as time constraints, money, or a lack of qualified personnel. Or again, it may be impossible to get hold of all the individuals in a population. In fact, it is probably impossible to measure the height of all the trees in a forest of several thousand hectares.

Sampling, when done well, allows measuring characteristics on a limited number of units of the group of interest and arriving at an estimation of the parameters under study that will be not only precise and free of bias, but also representative of all the units of the group. By parameter

we mean a quantifiable characteristic of the population whose value is fixed within a region and a given period of time, but which remains unknown.

Most scientific research programs in ecology primarily aim to carry out data collections under very specific conditions in order to verify the initial hypotheses, after statistical processing of the data and analysis of the results. In this sense, any action to be taken by a researcher to carry out a study falls into four main categories:

- **Definition of the objective:** The first step in designing a sampling is to define the objectives of the study to be carried out, the goals of the data collection.
- **Variables (descriptors):** Variables, also called descriptors, designate any measurable or observable characteristic on each of the elements of the sample or on its environment.
- **Observation scales:** an observation scale refers to the extent (surface area, duration) and resolution (size of the elementary unit) of observations in space and time.
- Choose the sampling plan: Choosing the sampling plan consists of choosing how the data will be collected in the field. It also conditions the mode of data processing and therefore the results.
- **Interpretation of results:** based on comparisons, search for causes, and response to the objective defined at the outset.

II.1.1. Choice of a Method

For the study of biodiversity, inventories (qualitative) are usually distinguished from censuses (quantitative) (Lhonore and Meunier, 2001).

From an ecological point of view, **an inventory is a "set of quantitative and qualitative observations and measurements using standardized protocols, carried out in a limited period of time"** (Hellawell, 1991). It can be added that inventories are carried out according to representative sampling devices.

Finlayson (1996) specifies that this exercise is carried out "without preconceived ideas regarding the content of the results". Lhonore (2001) proposes a similar definition "the most exhaustive census possible of a set of taxonomic data on a precise geographical area and during a limited period of time". An inventory therefore corresponds to a data collection campaign.

Censuses provide not only lists and numbers of species, but also estimates of their numbers (number of individuals or abundance). Their implementation relies on relatively sophisticated methods, which express the abundance of individuals either in densities (so-called absolute methods), or according to other references than the surface area of the studied habitat (so-called relative or index methods). As for frequency methods, they express the frequency of encounters with a species during inventories.

II.1.2. Choice of a Sampling Plan

The sampling plan defines how the elementary samples are distributed over the studied field (and possibly throughout the season or years).

It is designed so that the selected sample represents the entire studied environment as faithfully as possible. This plan is useless when no extrapolation of the collected data is necessary and in particular when the concerned site is small enough to be studied in its entirety.

Most often, and always when using index methods, the sample is divided into a certain number of sampling units. For the best statistical exploitation of the data, these sampling units must be standardized, remaining identical both in space the same year and over time between years.

➢ **Define the number of samples**

The number of samples can be defined in time and space: infrequent surveys (annual for example) but on a large number of plots, a certain number of regular surveys (one per week for example) on few stations. In all cases, the number and distribution of stations to be observed must be set within the framework of a sampling plan.

➢ **Take representativeness into account**

Representativeness constitutes the first quality that a sample must possess. For the results to be generalizable to the statistical population, the sample must be representative of the latter, meaning it must faithfully reflect its composition and complexity and provide a precise and unbiased estimate of the parameters measured on the objects in a given area, at a given time.

➢ **Take into account the size of the sampling units and the site**

The smaller the sampling units, the more numerous they must be, especially for habitats. The number of samples will depend on the size of the site, their nature, heterogeneity, and diversity or of the statistical population.

➢ **Take into account the needs for data analysis and interpretation**

The number of samples must be sufficiently high for a relevant statistical analysis of the results. Classically, the minimum number of samples proposed is 30, for example for factorial analyses. However, non-parametric statistics allow working with a lower number of samples. It is not obvious to demonstrate (statistically) significant changes over time for species that have a low frequency in the surveys. Yet if we want to show variations it is important that these variations appear between the samples. The manager will define a sufficient number of samples to highlight changes over time or in space.

II.2. Types of Sampling

II.2.1. Subjective Sampling

This is the simplest and most intuitive form of sampling. The observer judges the locations representative of the environmental conditions and chooses as samples the areas that seem particularly homogeneous and representative based on his experience.

The basic principle is to survey the study area, and to inventory the main plant units. Within each unit thus defined, a survey will be carried out chosen on criteria of homogeneity and representativeness.

A subjective choice is not random because the surveys will be all the better established if the researcher has proven experience (Gaudin, 1997).

II.2.2. Simple Random Sampling

Simple random sampling, or at random, is a method that consists of randomly and independently taking "n" sampling units from a population of "N" elements.

Each point in the studied space therefore has an equal chance of being sampled.

Remark:

Each selected element can be put back into the population after its draw to possibly be chosen a second time: we then speak of sampling with replacement, also called non-exhaustive sampling. If the selected element is not put back into the population after its draw, we speak of sampling without replacement or exhaustive sampling.

Examples:

- A method guaranteeing security and representativeness consists of drawing up the complete and non-repetitive list of the elements of the population, numbering them, then drawing lots for "n" of them using a system generating random numbers.
- Random draw of a certain number of measurement hours in the year.

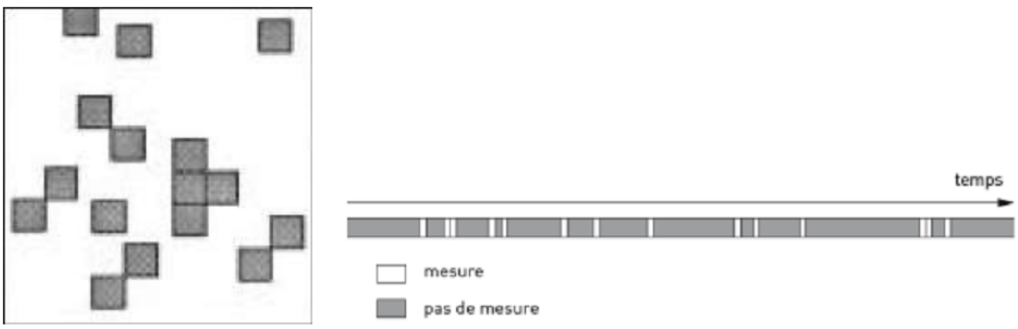


Figure 4. Illustration d'un échantillonnage aléatoire simple dans l'espace (à gauche) et dans le temps (à droite)

Figure 26. Simple Random Sampling

To use the simple random sampling method in an inventory, you must first have the vegetation map of the site to be inventoried.

Advantages and disadvantages:

Simple random sampling has important advantages:

- Unbiased estimation of the population mean, easy calculation of the sampling error. -With random sampling, the plots are selected independently of each other and thus respect the random character of the observations necessary for statistical analyses.

-It has the major disadvantage of time losses consecutive to the dispersion of the samples.

-Also, it is quite rare for vegetation to present a structural homogeneity justifying the use of this type of sampling. In case of non-homogeneous structure of the vegetation, for example the presence of different plant groups within the same vegetation, random sampling causes a loss of precision in the estimation of parameters.

-This error is mainly linked to the fact that plant formations are assumed in this type of sampling to have the same weight in terms of surface area or tree density or other criteria.

II.2.3. Systematic Sampling

A sampling is systematic if individuals are selected at regular intervals (example a daily measurement every six days). It also consists of distributing the samples regularly (e.g. Every "x" meters). It is less time-consuming than random sampling. A grid is usually used (often positioned on the aerial photograph of the studied territory). The sampling points are thus easy to locate at each survey.

Examples:

If species nest in the same place every year, counting becomes easier over time.

Systematic sampling can be carried out when inventories are prioritized in the sectors most likely to harbor the species (potential habitats). Greater attention is then paid to environments that meet their ecological requirements. For example, for bats, we will first look in caves but also mines, buildings, bridges, tunnels, hollow trees.

The positioning of traps for species difficult to observe (invertebrates or even mammals) is often done systematically on a given sector or along gradients. The following figure shows how micromammal traps are located and distributed along a transect in a nature reserve (Glèle Kakai et al., 2016).

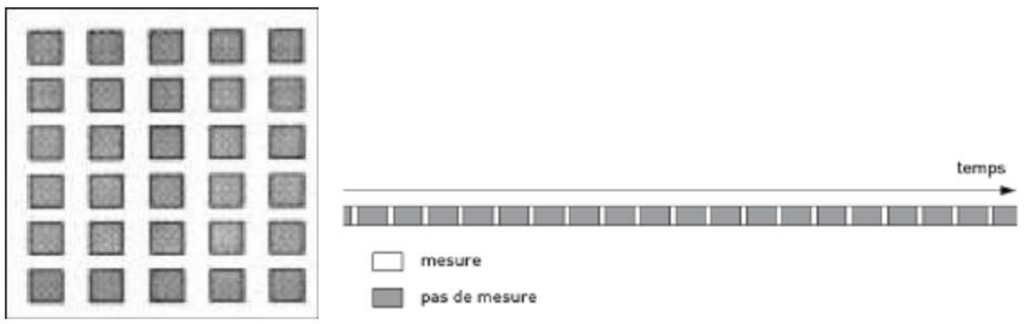


Figure 5. Illustration d'un échantillonnage systématique dans l'espace (à gauche) et dans le temps (à droite)

Figure 27. Systematic sampling

a. Surfaces

Surfaces most often appear in the form of squares and rectangles, more rarely circles. Rectangles or long thin bands would be more representative of the environment than a square (Figure II.5.). The circle, on the contrary, would a priori be the most interesting shape because it presents the weakest edge effect. Yet, very often in ecology.

It is the square that is most often used in the point quadrat method, probably for practical reasons because the thematician can divide the plot into a grid and therefore in matrix format easier to manage in the field to position the detail of the measurements. The dimensions of these surfaces are variable (Greig-Smith, 1952).

Figure 28. Plots in the form of surfaces

There are several methods where the measurement point is a surface:

❖ **Handful Method or De Vries Method:** Characterized by a high sampling intensity with the taking of handfuls along a transect (Figure 29). For each handful, an abundance note is given subjectively to the species that seem to contribute the most to the plant cover. Used for the study of pastures.

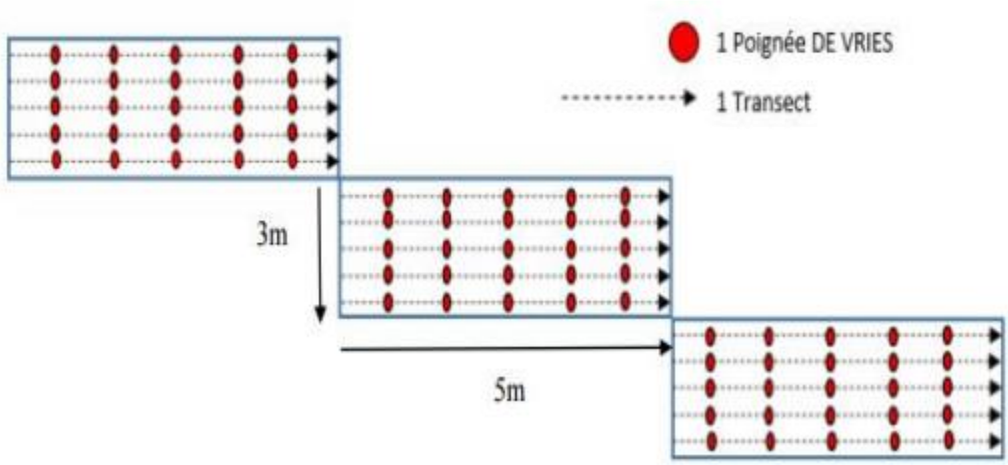


Figure 29. Handful Method

ϖ **Botanal Method:** This is a method of visual estimation of the productivity and composition of grasslands in terms of relative abundances in dry biomass. Tothill et al, rather use frames of 0.2 m2 with a more moderate sampling intensity (12 to 15). For each frame, the notation of abundance is done by a subjective estimation of the abundance of the species.

b. Lines

They are little used. They are materialized by narrow tape measures or decameters stretched. The principle is to calculate the length of the vegetation projected on the lines or tape measures.

ϖ **Linear methods:** the principle is very similar to that of the De Vries method, but here we seek to follow the variations of the vegetation by returning exactly to the same points at more or less long intervals. For this, we use as a sampling unit a ring of 2.5 cm in diameter fixed at the end of a metal rod (Figure 3 a). the sampling points are located along a line materialized by a metal tape stretched between supports by means of clamps (Figure 3 b). The location is obtained using coordinates on the tape at the point of contact with the corners. By operating carefully, it is possible to replace the tape practically in the same position at each reading. The principle therefore is, to measure the length of intercepted vegetation, the differences lie in the mode of discrimination of the strata and the way of calculating the bare ground. For Anderson, only the vegetation in contact with the line counts and the bare ground corresponds to the absence of vegetation for more than 1 (one) cm.

Canfield, uses "intercepts" lines and differentiates between herbaceous plants which he measures at ground level and chamaephytes (small woody plants) whose crown he considers. Parker and Savage use more or less narrow bands depending on the herbaceous (0.5 cm) or woody (10 cm) nature of the vegetation. These lengths are difficult to use for statistical calculations and order relationships unlike points (Figure).

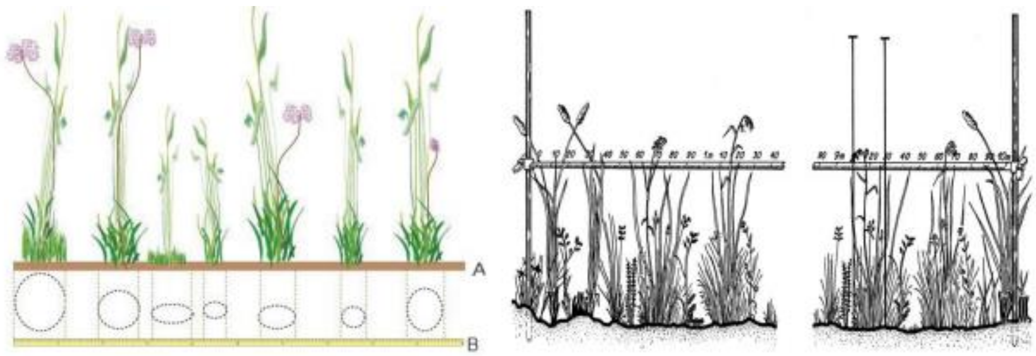


Figure 30. Measurement of linear cover (A. Portion of line showing the position of the tape relative to the vegetation; B. Horizontal projection view of the line).

c. Points

Theoretical studies have shown that sampling on surface plots presents statistical biases. It would thus be more judicious to multiply the number of plots, so as to reduce the sampling surface, until canceling it and arriving at a point surface. Using a needle, the observer indicates all the species that come into contact with it, until they touch the ground. The needles are lowered vertically into the plant mass. Wilson developed a slightly different method, where the needle is inserted obliquely into the vegetation but the interest of this approach is controversial.

- **Point quadrats:** The objective is to quantify the various elements of the structure of a flora, a vegetation, or even an environment. The method consisted of assembling ten aligned needles. Point plots were first sampled in the form of a rigid frame with 10 needles that are moved from place to place. To do this, it would be necessary to act on the mesh of the line or the distance between the needles. It involves counting vegetation points along a graduated line according to a regular mesh. It allows transposing all measurements made on a surface onto one dimension and determining quantitative parameters such as cover, frequency, density, and the contribution of species to the plant cover. This method has proven effective for monitoring vegetation cover.

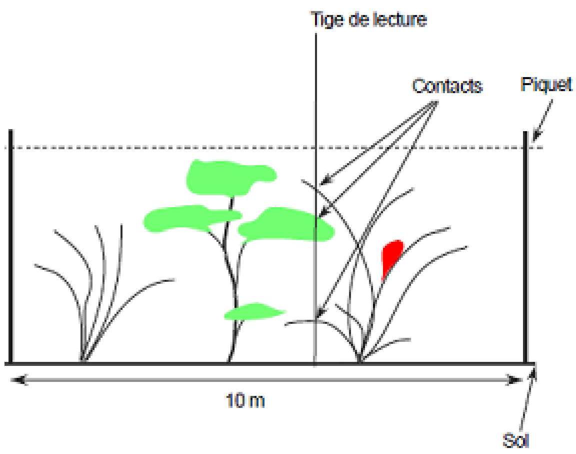


Figure 31. The point-quadrats system

- **Aligned points:** In this device, the line is provided with a regular mesh. A needle is slid vertically along the line, without a frame (unlike point quadrats) and contacts are counted. For discontinuous woody strata, the method used is that of the 'Cooper gauge'. The gauge has the general shape of a T whose two parts are precisely 10 and 70.7 cm long for the 'arm' and the 'leg'. The end of the 'leg' opposite the 'arm' has either a sighting eyepiece (perforated metal plate), or a staff (Figure II.10). At a point in the study station, the observer brings the gauge to his eye and notes the number and nature of the species whose height exceeds the length of the 'arm'. He turns around to scan the entire surroundings and repeats the operation at different places in the station. This operation is repeated 10 times minimum per station.

Figure 32. Cooper's Gauge

- **Wheel:** a variant of the aligned points method, is the use of a rimless wheel, equipped with spokes that are rolled in the vegetation. These authors show that if the spacing is sufficiently large, this allows approaching a random distribution. To make measurements with this equipment, three operators are needed, the first, at the handles of the machine, ensures its progression and stops it when one of its points touches the ground. The other two operators each devote themselves to a wheel and note if the point in contact touches bare ground, or a species, which must then be determined; he also notes the species that are vertically above the contact. For some observers, a contact is also noted if the wheel touches an aerial plant organ before contact with the ground, for others not (Figure 33).

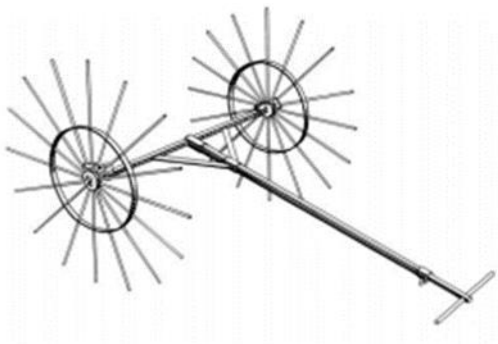


Figure 33. The spiked wheel

Advantage and disadvantages

The main advantage of this type of sampling is that it is:

-easier to carry out in the field, due to the fact that the sample is evenly distributed over the entire area.

As disadvantages:

- the calculation of the sampling error can be biased if not careful.
- Similarly, the mean can also be biased, particularly in cases where there is autocorrelation between sampling points (here plots) that are geographically/spatially very close.

This is a sampling often recommended in large-scale forest inventories such as national forest inventories.

II.2.4. Stratified Sampling

It is particularly used when the studied area is divided into differentiated zones (strata). The strata can correspond to administrative divisions, zones with different topography, ...etc.

It consists of subdividing a heterogeneous population into more homogeneous sub-populations or strata. Stratification is necessary when results are sought at the level of each of the sub-populations. The samples are then distributed within the strata (possibly by proceeding with random sampling for example) with a number proportional to the area of each.

Example:

- All acquired knowledge on vegetation and the environment can be used to divide the area to be studied into more homogeneous sub-zones which will be sampled separately.

*A pre-sampling is possible, notably using mapping (aerial photographs, geological, pedological, topographic maps,…).

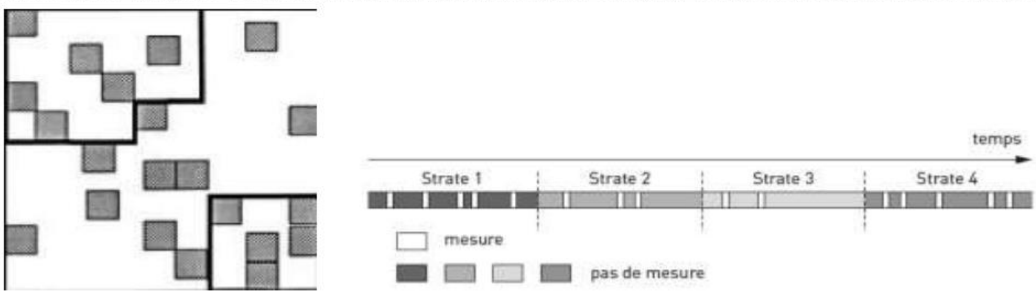


Figure 6. Illustration d'un échantillonnage stratifié dans l'espace (à gauche) et dans le temps (à droite)

Figure 34. Stratified Sampling

Advantages and disadvantages

The main advantages of stratified random sampling are related to the possibility of estimating, for each stratum, the means and variances, and this separately; different sampling devices can be used in the different strata. With stratified random sampling, the plots are selected independently of each other and thus give the random character of the sampling necessary for statistical analyses.

Moreover, the method assumes prior knowledge of the distribution of certain strata in the population and a sample must be taken from each stratum if an estimate relative to it is desired. This is the most used and recommended sampling method for the study of vast plant formations

III.2.5. Exhaustive Sampling

Exhaustive analysis could be similar to an adaptation of systematic sampling. Instead of sampling a small part of the elements whose first point will have been drawn at random and inferring to the whole, the entire set is sampled.

The operating procedure consists of placing plots along a line and studying the structural properties of the vegetation. But it must be specified that the pursued goal is not the same. As the study focuses on structure, the lines do not necessarily have to be very long and the plots sufficiently important for us to consider that we somewhat approach the population.

***** Grids or bands of contiguous plots****

This is the original technique of Greig-Smith (1952). Surfaces arranged in n lines of p contiguous squares and multiples of 2 then grouped by 2, 4, 8 ... and on which appropriate statistical tests will be carried out.

***** Succession relations along a line or a band****

This involves noting the order of succession of individuals of the species along the line of the band. This method allows calculating linear densities or per unit area (when it is a band) and using statistical tests.

The individuals of each encountered species are recorded on a form where each line represents a species. The presence of an individual is indicated by a cross on the line corresponding to a species and we move one column to the right for each new individual encountered. When the vegetation is quite dense, we can operate on a band of 2.5 cm, materialized by a plumb line. When the vegetation is too sparse, such a narrow band contains very few individuals. Also it is preferable to adapt the width of the band to the density of the vegetation.

***** Line of contiguous segments****

The presence of species is noted along contiguous segments, with possible grouping of segments to obtain frequencies. This method can be applied to all types of vegetation. The device of contiguous segments is used when we want to study the heterogeneity of a small territory: on each segment, the present species and the elements of the soil surface (litter, stones, gravel, bare ground) can be surveyed. The species can also be surveyed taking into account the stratification of the vegetation.

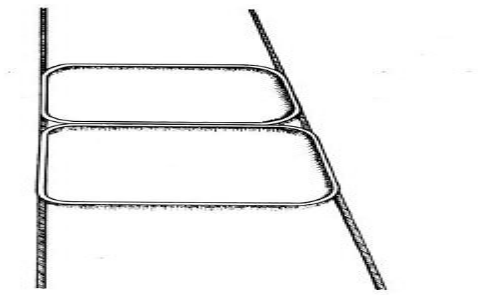


Figure 35. Study device of aligned contiguous squares

- **Sampling according to a transect**

The transect is a band of contiguous rectangular plots arranged according to a gradient of variation of an ecological factor. The transect is a very precious device when we want to sample the vegetation-environment relationships according to such or such gradient of maximum ecological variability. For example, if this gradient is commanded by altitude, it is beneficial to place the transect along the steepest slope, in salty lands; transects will be placed starting from the center of the salty zones and ending at their periphery. If we want to test the effect of pluviothermic continentality in a region, transects will be established perpendicular to the isolines that characterize this continentality.

All units present on the transects must be studied or only some of them (stratified random sampling). The transect has the merit of allowing a fairly exhaustive and immediately demonstrative study on the order relationships between species, plant communities, and types of environments.

- **Advantages and disadvantages**

Having a practice similar to systematic sampling, exhaustive analysis could suffer from the same constraints as it, namely the non-independence (or linkage) of the measurements and the absence of random distribution of the samples. But a large number of plots would allow a relative emancipation from these constraints.

II.2.6. Mixed Sampling

This is the most used sampling in the field.

Fieldwork therefore often consists of combining several simple samplings into a more complex sampling rightly called mixed sampling.

Often studies begin with a stratified sampling consisting of a delimitation of homogeneous zones (stratification) of the study area.

Resulting for example in a land use map. Then within the retained strata, they choose surveys subjectively (subj. samp.) or at random (rand. samp.).

Once the points are chosen, they can implant a line (sys. samp.) to extract the specific frequencies.

CHAPTER 3: HIERARCHIZATION AND CLASSIFICATION OF COMMUNITIES

III. Hierarchization and Classification of Communities

III.1. Qualitative Methods

The study of vegetation and its relationships with the environment developed from the beginning of the 20th century through phytosociology. It studies plant communities and their relationships with the environment in a descriptive way, from both a phytoecological and phytogeographical perspective (Guinochet,1973).

Its objective is not only the floristic diagnosis and classification of plant communities but also the study of their dynamics, their relationships with environmental variables, their evolution, and their genesis. The methodological foundation of phytosociology is the vegetation survey (Colasse et al., 2014).

III.1.1. Signatist Method and Phytosociological Nomenclature

III.1.1.1. Presentation of the Braun-Blanquet Method

a. The Relevé Technique

To describe the plant cover of a region, it is essential to know its flora and to have recognized, in the field, socio-ecological groups made up of plants having approximately the same requirements regarding the characteristics of the environment where they grow. The notes taken must constitute documentation as precise and as objective as possible. An effective method is one based on the vegetation survey technique, introduced in ecology during the second half of the 19th century and developed by J. Braun-Blanquet (1951) and his collaborators and the "Zuricho-Montpellieraine" school.

- **Choice of the studied plot: homogeneity and dimension**

The first thing to do before carrying out the surveys is to clearly visualize the different homogeneous vegetation units (which by extension are called individuals of associations) of the site. This delimitation is based on floristic homogeneity (specific composition) and physiognomic homogeneity (structure), these two aspects reflecting ecological homogeneity (Godron, 1970).

First, you must start by spotting the uniformity of colors and textures in the vegetation, the repetition of a pattern on the ground, and the coherence of the vertical stratification.

This first step only requires a "visual competence" for now, therefore an ability to distinguish and separate the units that are physiognomically homogeneous in terms of their general structure (plant formations) (Delassus, 2015).

Then, within each of these formations, it will be necessary to ensure that the floristic composition is homogeneous and repetitive and that there is no ecological break. Each unit that is floristically and ecologically homogeneous within the formations potentially constitutes an individual of association.

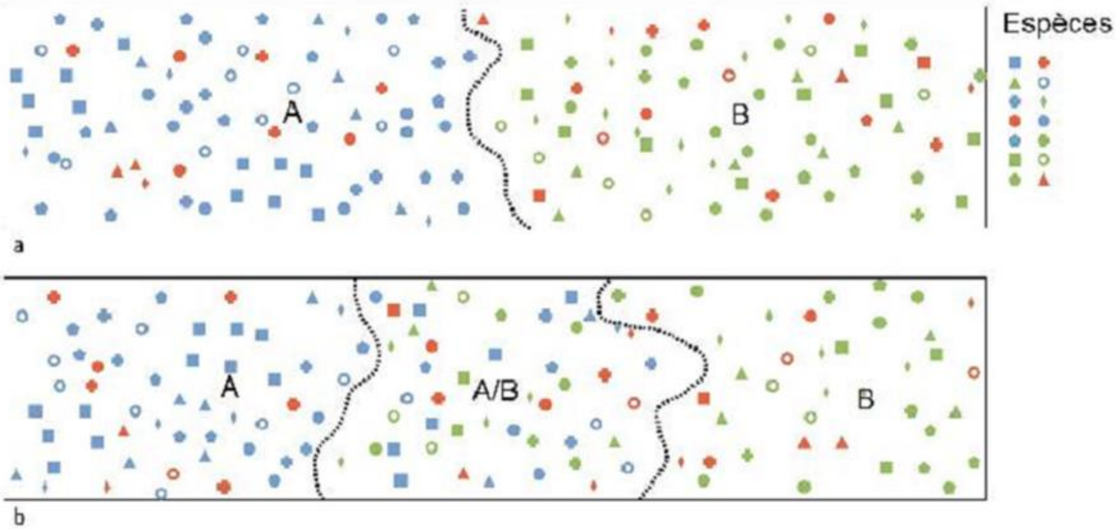


Figure 36. a. the individuals of association A and B have a clear limit; b. the individuals of association A and B have a fuzzy limit (Delassus, 2016).

- **Minimum Area**

Floristic homogeneity can be tested by the minimum area test. To do this, it is sufficient to list the species present on a sample surface delimited in an apparently homogeneous place; we successively take into account and add, to the first list, all the species that appear each time the surface is doubled. The curve of increase in the number of species as a function of the surface first presents a steep slope which ends up inflecting and reaching a plateau; this shape indicates that from a certain dimension of the sample, -called **minimum area-**, the increase in surface area is practically no longer accompanied by a gain in species.

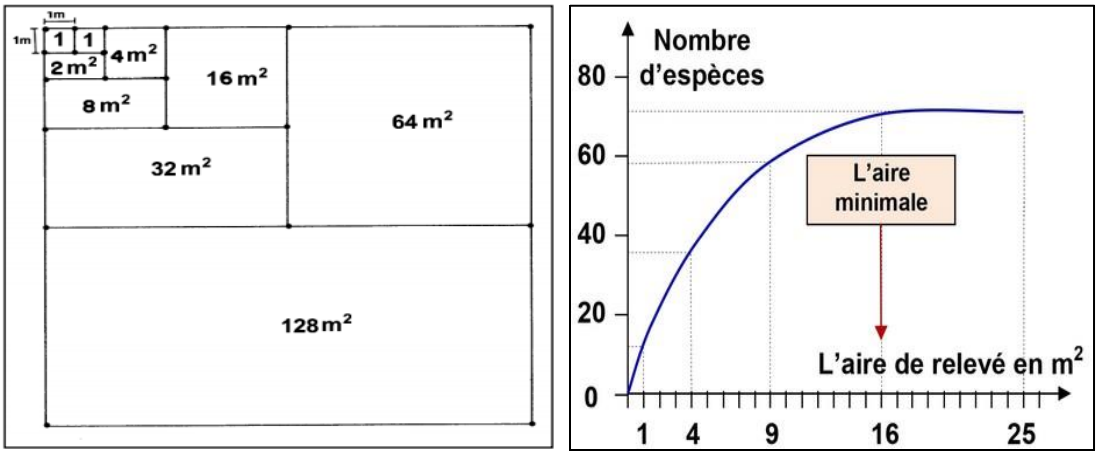


Figure 37. Minimum area

For a given vegetation, the size of the individuals of association is obviously very variable depending on the ecological conditions; that of the minimum area is approximately constant. On the other hand, the minimum area is extremely variable depending on the type of vegetation (from a few dm² for spring communities, to a few ares for forest communities and even a few km² for desert formations, see Table 2.

Table 2: Minimum areas of temperate vegetation

Type of vegetation	Minimum Area
Forests	200-500 m²
Dry lawns	50-100 m²
Chamaephyte heaths	10-25 m²
Meadows	10-25 m²
Amended grasslands	5-10 m²
Bryophyte Communities	1-4 m²
Lichen Communities	0.1-1 m²

b. Phytosociological Relevé

Often even before starting the floristic part of the work, the greatest possible number of information relating to the station occupied by the vegetation is collected: topographic situation, altitude, slope, exposure of the latter. Similarly, the date of the survey (important for the visibility or determination of the species) and the most precise location possible of the place (municipality, place name and GPS location or on a topographic map) are indicated. The soil profile, mainly by indicating the pH of the different horizons, can be described (at least the surface pH) (Buckland, 1993).

Anthropogenic treatments and the history of the site are often primordial to know, whether in forest or for areas already restored or managed in open environments.

After these preliminaries, we move on to the floristic inventory of the plot by census of all present species.

The analysis is done in an orderly manner, stratum by stratum, starting with the one furthest from the ground. Some of the observed plants may possibly not be determined immediately, they receive a provisional name and are herbariumized. Cryptogams (Bryophytes, Lichens, Ferns) as much as possible, are not neglected, as they often have very restricted ecological niches and therefore provide precise information on abiotic conditions (Gerard M., 2012).

*The coefficients**

Each species in the survey is generally accompanied by two coefficients: abundance-dominance and sociability.

The name of each of the species is affected by a coefficient that indicates, with sufficient precision, its relative abundance and its degree of cover. The scale usually used to quantify this **abundance-dominance coefficient is as follows.**

Braun-Blanquet Scale:
+: Low abundance and dominance (A single plant or only two)
1: Low or medium abundance and low dominance (less than 5%)
2: High abundance and dominance between 5% and 25%
3: Whatever the abundance, the dominance is between 25% and 50%.
4: Whatever the abundance, the dominance is between 50% and 75%.
5: Dominance greater than 75%.

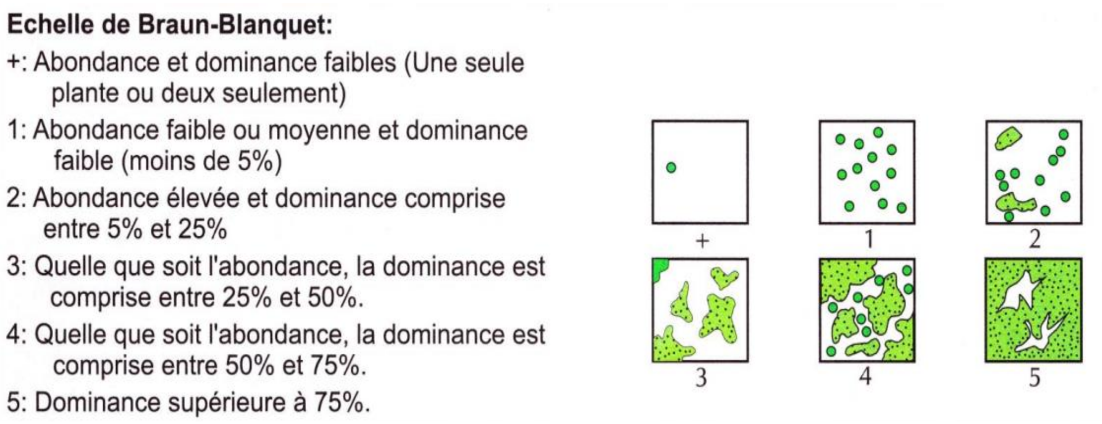


Figure 38. Braun-Blanquet's abundance-dominance coefficients (1950) according to Bouzillé, 2007.

Individuals of the same species can appear as isolated plants or, on the contrary, in more or less dense colonies. This character, of sociability, is evaluated using the following scale:

- 5: species in almost pure stand
- 4: species in large colonies or troops
- 3: species in patches or cushions
- 2: species in clumps
- 1: isolated individuals

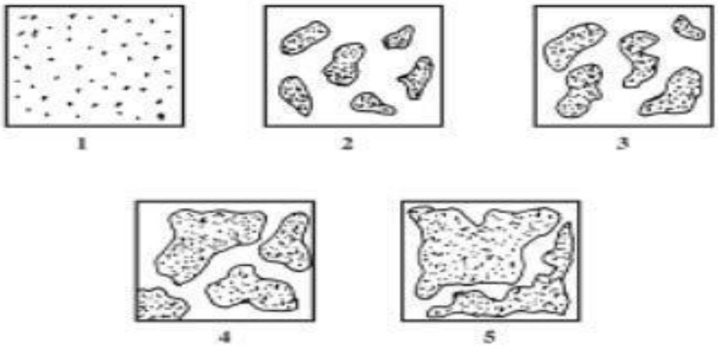


Figure 39. Braun-Blanquet's Sociability Scale

c. The Synthesis

The table method (Ellenberg, 1956) aims to modify the order of the surveys and the species to group them in the most logical way possible.

We can distinguish five phases:

ϖ **The raw table:**

This is a double-entry table. The columns correspond to the surveys taken in any order and the rows to the species listed in the order they appear in the first survey.

We add to it the species of the second survey that are not in the first and so on until all surveys and all species have been entered. In the box at the intersection of a row and a column, we indicate the abundance-dominance and sociability of the species in the survey. If the species is not represented in the survey, the box at the intersection of a row and a column, we indicate the abundance-dominance and sociability of the species in the survey. If the species is not represented in the survey, the box remains empty. In the raw table, surveys and species are placed without order.

Table 3: example of a raw table (Bouzidi et al, 2009)

	Indices d'abondance-dominance *												F
Espèces	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	(%)
Strate arborescente													
Ficus carica L.	-	-	-	-	-	+	-	-	-	-	-	-	8,3
Olea europea Var. *oleaster* Dc.	+	+	+	+	-	-	-	-	-	-	-	+	41,3
Pinus halepensis Mill.	+	+	-	+	-	-	-	-	-	-	-	-	25,0
Pistacia terebinthus L.	1.1	-	-	-	-	-	-	-	-	-	-	-	8,3
Quercus ilex L.	-	-	-	-	-	-	-	-	-	1.1	-	-	8,3
Quercus ozendae L.	1.1	-	-	-	-	-	-	-	-	-	-	-	8,3
Quercus rotundifolia Lamk.	1.1	+	-	-	-	-	-	-	-	-	-	-	16,6
Tamarix gallica L.	-	-	-	-	-	+	-	-	-	-	-	-	8,3

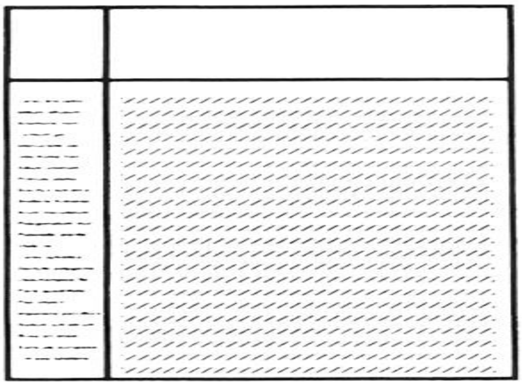


Figure 40. Raw table

-: absent species. +: a few isolated individuals (species present).

When the species is sufficiently represented, the **left** digit indicates **abundance**, on a scale up to 5: 1 for a cover rate less than 5% (species present), 2 for a rate of 5 to 25% (scarce species), 3 for a rate of 25 to 50% (abundant species)… The **right** digit indicates the **sociability** of the species, on a scale up to 5: 1 for isolated individuals, 2 for individuals in groups, 3 for individuals in troops, 4 for individuals in small colonies, 5 for individuals in stands. Frequency is the ratio between the number of surveys (n) where the species (X) exists to the total number of surveys (N). It is most often expressed as a %

$$\mathbf{F(x)=(n/N)\times 100}\boldsymbol{F(x)=(n/N)\times 100}$$

Example: if in 25 surveys we find species x 5 times; F= 5/25 ×100 which is 20%

Frequencies are ranked into 5 classes:

- **Class I**: frequency between 0 and 20% (species is very rare).
- **Class II**: frequency between 21 and 40% (species is rare or accidental).

- **Class III**: frequency between 41 and 60 % (species is relatively frequent).
- **Class IV**: frequency between 61 and 80 % (species is abundant). -
- **Class V**: frequency between 81 and 100 % (species is very abundant or constant).

✓ **The presence table:**

This is a transformation of the raw table: the species are ordered according to their decreasing degree of presence. Very rare species or species with a very high degree of presence (present in all or almost all surveys) are of little interest.

The essential operation of the method consists of searching if there are groups of species that are generally found together in a part of the surveys and are generally simultaneously absent from the others. These species are qualified by the name of differential species.

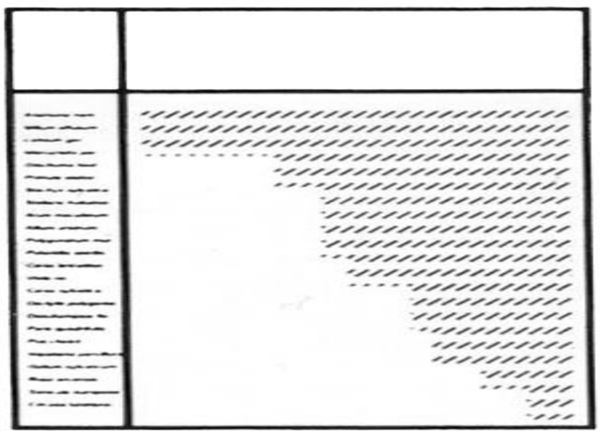


Figure 41. Presence table

✓ **The partial table:**

Once the differentials are highlighted, the partial table is written by keeping only the differential species and grouping the species that belong to the same group of differentials. At the bottom of this table, the total, for each survey, of the differential species of the different groups it contains is made.

∅) **The ordered partial table:**

The surveys are written in such a way as to place those that contain the most differentials of one or the other group at the two ends, the surveys having few differential species or a mixture of differentials from several groups being located in the middle part.

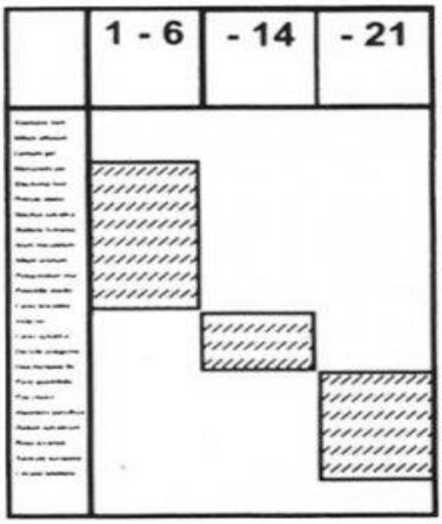


Figure 42. Ordered partial table

∅) **The differential table:**

The differential groups of the distinguished groupings are entered at the top, then the other species or companion species in order of decreasing presence. On this table, we may be led to delete aberrant surveys. In particular, surveys comprising few differential species and many rare species are eliminated, which are interpreted as surveys belonging to groupings other than those appearing in the table. Surveys comprising differentials of two (or several) groups that generally exclude each other are also eliminated. These are aberrant cases corresponding to mixtures or transitions between groupings.

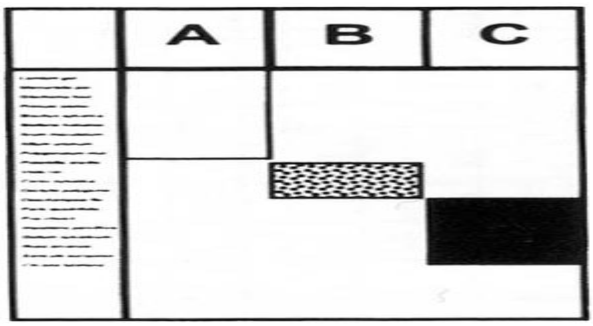


Figure 43. Differential table

d. Identification of Plant Associations

A plant association is described based on:

- **The characteristic species**

Species strictly linked to a single grouping or that grow there with optimal vitality are called characteristic species of this grouping (exclusive or preferential). They are represented, with variable abundance coefficients, in more than 80% of the surveys.

- **The differential species**

These are plants present in several groupings but absent in others.

- **The indifferent species**

Some plants appear in the most varied plant groupings. They show no fidelity to a specific plant grouping and can be qualified as indifferent species.

- **The accidental species**

A foreign or accidental species is a plant whose presence within the grouping is fortuitous. Its vitality is often reduced and it will probably be quickly eliminated without leaving offspring.

e. Hierarchization

We distinguish:

a) the association which is the original combination of species some of which are particularly linked to it, the others being qualified as companions. The companions are either characteristics of other associations, or species participating with substantially the same frequency in several associations.

b) the alliance set of associations which includes common characteristic species and companions.

c) The order which groups alliances and which includes characteristic species of order.

d) The class which groups floristically related orders and includes characteristic species of class.

III.1.1.2. Phytosociological Nomenclature

The denomination of a plant association is formed from the name of one or two species (characteristic or dominant) (Flahault et Schröter., 1910).

When there is a single species, the suffix **etum** is added to the root of the genus name. **Ex: Quercetum illicis**

When there are two species, the suffix added to the root of the genus name of the first is **eto and this word is joined by a hyphen to the next. Ex: *Ericeto-lavanduletum stoechidis.***

The names of alliances, orders, and classes are formed in the same way as those of associations, but by replacing the suffix etum with **ion, étalia, etea respectively. Ex: Quercion illicis, Quercetalia illicis, Quercetea illicis.**

III.1.2. Statistical Floristic Methods

Currently, the use of spreadsheets allowing to modify rows and columns at will leads to a significant gain in time. More advanced techniques allow complete analysis of the results. Several software now allow numerous analyses.

Two complementary methods have developed.

Classification or grouping aims to organize the surveys into classes or groups. The members of each class have in common a number of characteristics that set them apart from the members of other classes.

Ordination arranges the surveys or species in a space defined by a small number of dimensions, in which similar entities are close and dissimilar ones are distant (Gauch, 1982). Ordination, in the broad sense, sets itself three objectives:

(1) synthesize the data from a survey table,

(2) relate communities to environmental gradients and

(3) understand the structure of communities.

In the strict sense, ordination seeks to relate vegetation to one or more environmental gradients or axes.

A. Data Formatting

To be analyzed, the data must be presented in the form of a table crossing the species observed in all the stations; the cells of the table contain the values of dominance or cover. Only cover data are used. This contingency table (frequency table) is a multivariate table and is easy to build with common spreadsheet software (Excel,…) but becomes quite tedious as soon as the number of surveys increases.

The multidimensional representation of these data can take two graphical forms: either we consider that the space is defined by "station" axes where the species are placed according to their abundance coefficient; or we consider that the space is defined by "species" axes where the stations are placed according to the abundances of the species present there. We can thus quickly highlight the relationships of ecological proximity between species or the species with the highest dominances for each station (Fiers et al., 2003).

B. Measuring Similarity Between Stations and Between Species

The graphical visualization of the positions of stations or species in their reciprocal space immediately suggested the possibility of measuring the distance that separates them from each other. This distance is indeed the best multivariate measure of the differences that exist either between species or between stations.

A distance measure is therefore an inverse estimate of similarity. Numerous distance measures or similarity indices exist in the literature (Legendre & Legendre, 1984). The indices generally used belong to two main groups: distance measures (D) and similarity indices (S = 1 – D). Symmetric similarity indices consider double-zeros as resemblances (Gauch et al.,1982).

The choice of an appropriate index is fundamental because any subsequent analysis will be done on the resulting matrix. The Steinhaus similarity index (S17) is an asymmetric quantitative index intended for species abundance data. Its equivalent in terms of distances is the Bray & Curtis index (D14 = 1-S17).

C. Analysis Methods

- **Ordination Methods**

The objective of ordination methods is to order objects relative to each other so as to distance the most different objects while trying to limit the number of necessary variables. Several ordination methods are widely used in botany, but **Correspondence Factor Analysis (CFA) and Canonical Correspondence Analysis (CCA) are currently the most widespread (Bouxin, 2004). The axes reflect the major variations of ecological factors (humidity for example). This method therefore allows directly grasping the factors of variations, in order of importance as well as the reaction of species to these various factors and the way in which the environment structures itself from them. Socio-ecological groups are thus easily detected (Dervin, 1990).

Numerous ordination techniques have been developed: factor analysis (FA), Bray and Curtis technique (Polar ordination), principal component analysis (PCA), principal coordinate analysis (PCoA), correspondence analysis (CA) and its variant.

Principal component analysis disperses surveys little but species much better and remains useful with abundance data or continuous variables (mesological for example). Correspondence analyses (CA and DCA) are very sensitive to rare species (some authors do not hesitate to delete these rare species).

The processing of other data than species and surveys, such as ecological data, is possible: canonical correspondence analysis (environmental data processed in addition to the vegetation table) or multiple factor analysis (several tables together). The analysis then allows grouping the surveys (individuals) according to their floristic composition and the species (main variables) according to their sociology within the surveys. Ecological data intervene in a second step as "supplementary variables" (Hirche, 2015).

- **Grouping Methods**

The principle of a grouping method is to bring together objects that have a sufficient degree of similarity to be grouped in the same set. In the context of vegetation analysis, surveys are grouped to highlight particular ecological conditions that preside over the recognition of plant associations.

There is a wide range of grouping methods. They are generally first classified according to their hierarchical or non-hierarchical character.

The designation hierarchical refers to methods that definitively impose the position of an object within a classification pathway. All objects must necessarily be found in the final structure. They allow the construction of a dendrogram that shows the sequence in which the divisions or fusions of groups are made. These are the most used and easiest to understand methods.

Non-hierarchical methods establish a classification that is independent from one level to another. Some also allow an overlap of objects in two or more groups to well reveal their intermediate character. the criterion allowing to decide the fusion of two classes is based on the increase of the intra-class dispersion.

For each class, the two classes that cause the smallest increase in intra-class moment are merged. This is an aggregative hierarchical method. Several aggregation criteria exist based on distance measures (complete link, average link, single link) (Fellegi, 2003).

- **Indicator Species**

a. Twinspan Method

The basic principle is to perform a hierarchical classification of the surveys based on the first axis of a correspondence factor analysis. This axis serves as a basis for separating the surveys into two groups. The program then evaluates the indicative character of the species based on the concept of "pseudo-species". Since the affinity of a species with a group is measured in terms of presence/absence, TWINSPAN uses pseudospecies to evaluate these presence/absences for different levels of relative abundance. A relatively complex procedure is implemented to best identify the abundance levels that are preferential to one of the two survey groups. The procedure then restarts for each of the two initial groups. Each of the two survey groups is itself subjected to a CFA and split into two subgroups. At each division, the program identifies the indicator species. This method seems to be used less and less due to its complexity (Ducerf, 2008).

b. The IndVal Method

It was proposed by Dufrène & Legendre (1997). It proposes the same approach: a classification of the surveys is used to identify the species that are indicative of them. The principle is based on the definition of the indicative character of a species: a species is considered indicative if it is typical of a group of surveys (it is absent from the other groups) and if it is present in all the surveys of this group (Dufrène et Legendre, 1997). It combines a measure of the specificity of a species with that of its fidelity:

- The measure of specificity:
  Aij = N individuals ij / N individuals i

  with N individuals ij: the average number of individuals of species i (average abundance) present in group j and N individuals i: the sum of the averages of the numbers of individuals of species i (average abundance) in all groups.

- The measure of fidelity:
  Bij = N surveys ij / N surveys i

  with N surveys ij: the number of surveys in group j in which species i is present and N surveys j: the total number of surveys in group j.

The indicator value (IndValij in %): **IndVal ij = A ij x B ij x 100**

The indicator value of the species for a level of classification of surveys into different groups is the highest IndVal value observed for one of the groups. Specificity is maximum (100%) when the species occupies only one group and fidelity is maximum (100%) when the species is present in all surveys of a group. The indicator value of the species is maximum (100 %) when specificity and fidelity are maximum (Falissard, 1998).

These indicator species will give an ecological meaning to the previously constituted groups and will allow identifying the levels at which it is useless to continue the classification.

III.1.3. Concept of Ecological Group

These are groups of species having the same environmental requirements.

An ecological group is therefore formed by a certain number of indicator species. Gounot (1969) considers that a species is indicative of a factor if its presence varies in the surveys significantly with the classes of the factor.

The definition of Flahault and Schröter in 1910 is the most retained "an association is a plant grouping of determined floristic composition, presenting a uniform physiognomy and growing in equally uniform station conditions".

Thus, ecological groups of species are determined for acidic soil (acidophiles) or neutral soil (neutrophile), shade (sciaphiles) or light (heliophiles), average hydric conditions (mesophiles) or deficient (xerophiles).

III.1.4. Phytoecological Approaches

Phytoecological methods are based on the notion of ecological group

the characterization of an indicator species requires an in-depth knowledge of environmental factors, and in particular

- **edaphic factors:** soil texture, pH, chemical composition
- **climatic factors:** precipitation, temperatures, and bioclimatic stage ……etc.
- **ecological factors:** are difficult to define very precisely thus rainfall also depends on microclimatic factors.

Phytosociology deals with the recognition, classification, ecological study, evolution, and distribution of forest plant groupings. This definition reveals the static aspect (recognition and classification of plant groupings) and dynamic aspect (evolution of one grouping towards another) of phytosociology.

This method of vegetation study was developed according to the conception of Josias Braun-Blanquet. This method is favored by phytosociologists of the temperate regions of Europe and is the most widely used. Plant communities are characterized by their floristic composition.

The information here is provided by the realization of complete lists on a determined surface (= survey). The composition of the surveys allows highlighting that certain species tend to live in common, being regularly found together on the various lists.

The notion of association is deduced from the comparison of a large number of surveys, it is therefore defined by the frequent, but not obligatory, presence of certain so-called characteristic species. On the other hand, many species have a wide ecological amplitude allowing them to adapt to station conditions, these are accidental species. According to the intensity with which a species is linked to an association, we distinguish:

*Exclusive characteristic species of an association: they belong only to this association.

*Preferential characteristic species of an association: they exist in several associations but prefer one of them.

*Indifferent or companion species: they can exist indifferently in several associations.

*Accidental or foreign species: they are found accidentally in an association.

III.1.5. Different Zoocenoses Depending on Plant Formations

The term zoocenosis designates the animal component of a biocenosis, i.e., the set of animal populations it contains. The stratification of animal communities, as well as that of entire zoocenoses, is generally very marked, particularly in forest ecosystems.

Very obvious in the case of the vertical structure of bird communities, this stratification exists for many groups constituting the zoocenosis, particularly in mammals. It is associated with the exploitation of the respective trophic niches of the various species that these communities comprise.

In a forest, large trees, especially senescent or declining woods, frequently present cavities on the trunk and branches. These alterations form different living environments that shelter a very great diversity of species, most of which participate in the good functioning and balance of the forest ecosystem:

- Woodpecker holes, fissures: the numerous cavity-nesting birds, i.e., 41% of the 68 strictly forest bird species, and the bats that frequent them are, among others, important predators of defoliating insects,
- Lightning-struck trees, dead branches in the canopy, debarked wood, rot, foot cavities filled with water:

They host a multitude of insects, fungi that are at the beginning of the wood decomposition cycle.

The percentage of trees bearing these micro-habitats and their number increase with the size of the trees. Some insects with a life cycle spread over several years (larval stage) only develop on large dead trees of at least 150 cm in circumference that take a long time to decompose (more than 10 years).

The presence of epiphytic plants (mosses, lichens, ferns) and ivy on the trunks of living or declining trees also creates particular environments favorable to certain birds and many very small animals.

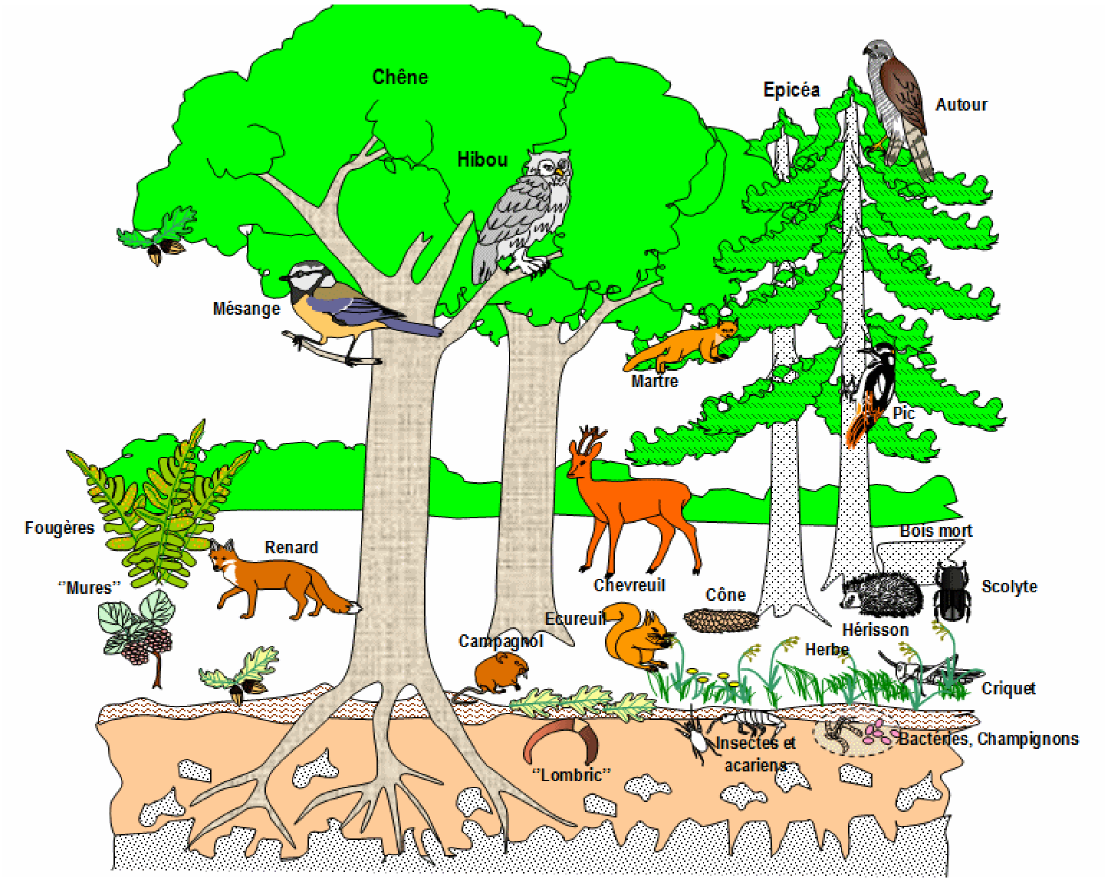


Figure 44. Distribution of different animal species in a forest

III.2. Quantitative Methods

These methods are based on the measurement of biomass (dry plant matter per unit area), for example to estimate the pastoral value of a meadow. Heavy to set up, they are therefore rarely used, but can for example serve as a monitoring method for the evolution of a reconstituted meadow, or the effect of management measures.

III.2.1. Linear Analysis (The "Loop method")

The "Loop method" is a simple means of analyzing pastoral vegetation requiring very little material means: two "surveyor's pins", a graduated ruler. Commercially available or specially made from a graduated slat, a ring of 2 cm in diameter brazed to a rod perpendicular to its plane and a hammer (Levy et al., 1933).

By means of the two pins, the ruler is fixed parallel to the ground. The ring, held by hand, is lowered vertically and the species of which at least one organ is visible through the ring are noted; the plant organs must be gently removed to the side to examine the species that may be located below, then the ring is lowered, and this progressively until the soil surface. The observations are renewed at regular intervals along the ruler.

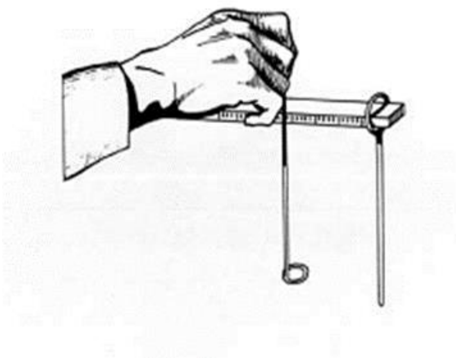


Figure 45. The loop method (Daget et al, 2010)

III.2.2. Point Quadrat

It consists of a frame equipped with 10 needles spaced 5 cm (2 inches) apart and 2 pointed feet for installation. The needles are successively lowered into the vegetation and the species they touch at least once are noted as they go.

Several series of points are necessary to characterize a station; the authors recommend 75 series to characterize the dominant species and between 40 to 50 for all the species of the plant cover. Currently, it has appeared, as will be emphasized later, that 100 vegetation points are sufficient.

It seems, from reading their texts, that the authors made their observations by noting the species successively in contact with the tip of the needle in its vertical movement; however, many have read that it was appropriate to first lower the needle into the vegetation to the ground and then look at the species in contact with the surface of the needle.

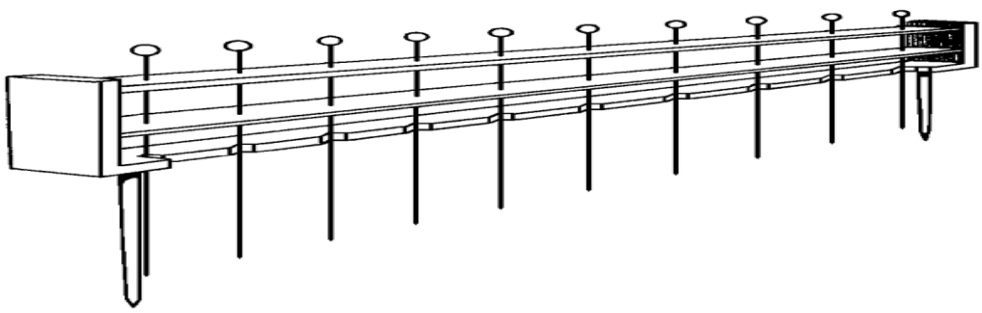


Figure 46. Levy's point quadrats system (from a photo by Levy and Madden, 1933).

III.2.3. Aligned Point Quadrats Method (Transects)

The aligned point quadrats or point-contacts method allows an easy and rapid study of the herbaceous cover: it is also inexpensive and requires little bulky equipment. It consists of characterizing the importance of each of the species by measuring its cover by observing frequencies vertically above points (generally 100) arranged regularly along a line, which can be for example a decameter stretched above the vegetation. To obtain 100 points over a length of 10 m, a needle (or bayonet) is introduced vertically into the cover every 10 cm, taking into account only one contact per species, at the level of the leaves or stems.

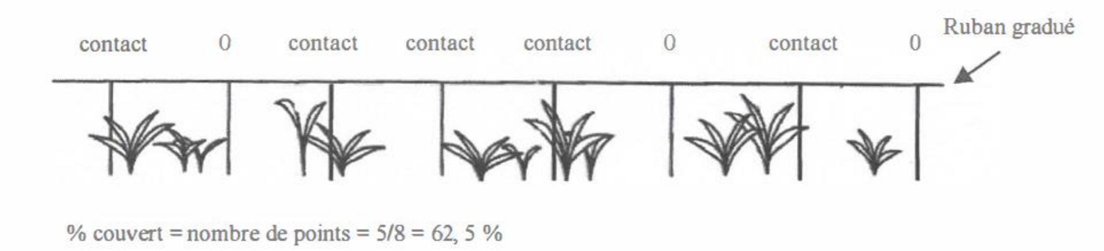


Figure 47. Estimation of herbaceous cover according to the aligned point quadrats method (Poilecot, 2002).

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