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OBSERVATORY NETWORK FOR LONG TERM ECOLOGICAL MONITORING

ROSELT / OSS

Methodological guide for the study and monitoring of flora and vegetation

RÉSEAU D'OBSERVATOIRES DE SURVEILLANCE ÉCOLOGIQUE À LONG TERME

OBSERVATOIRE DU SAHARA ET DU SAHEL

ROSELT/OSS Collection - Technical Contribution Number 1

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Introduction

Since the 1992 Earth Summit in Rio, problems linked to environmental degradation - such as loss of biological diversity and the quantitative reduction in natural resources -- have taken on considerably greater political, economic, social and cultural dimensions.

The environmental conventions which were drawn up and adopted (particularly on Biological Diversity and Combating Desertification) aim to incite countries to preserve ecosystems within a coordinated legal and legislative framework. However, the problems in question can only solved by taking into account the dynamic realities in the field (people-resources-space). For this reason, the international community deliberately turned to scientists in the hope that a greater understanding of the mechanisms behind land degradation and biodiversity loss would lead to improved environmental and resource management practices and check (or even repair) the effects of serious past misuses.

The objectives of the Convention on Biological Diversity are "the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from commercial and other utilization of genetic resources." The term "biological diversity" (or "biodiversity") is, at least within this context, commonly used to describe the number and variety of living organisms at the biotope level. It concerns the diversity within the same taxon (genetic diversity), at the level of diverse taxa (species diversity), and among ecosystems (ecosystem diversity). The expression "biological diversity" may also refer to the intrinsic value of living organisms in their habitats (biotopes) according to different points of view: such as ecological, genetic, social, economic, educational and cultural.

The Convention to Combat Desertification aims to "combat desertification and mitigate the effects of drought on resources and to increase the population's living standards." Desertification means the degradation of land in arid regions and covers a wide range of processes and phenomena of varying severity. Degradation should not be confused with drought - man plays an important role in degradation processes. Human actions (overgrazing, farming in fragile environments, etc) cause more or less irreversible changes in both soil (fertility, depth) and vegetation (floristic composition, plant cover, etc). Basically, within a given climatic context, human activities directly threaten the biosphere.

In arid zones of Africa, the availability of land (natural pasture, wild and fallow lands, irrigated or rain-fed cultivated plots, etc) plays a fundamental role in determining production systems in a given social context. Land is being put under increasing human pressure (overgrazing, diverse demands on resources, cultivation), generally engendering a regressive dynamic (degradation) in ecosystems. Tropical and Mediterranean pastoral systems (as well as agricultural systems) are complex and numerous factors interact to determine their characteristics.

Ecosystems (also known as biotopes or environmental units) may be described by their own particular characteristics (composition, structure, functioning, etc.) as well as by the different "environmental" factors that define them (climate, geology, etc.). These diverse parameters may be classed as follows:

- ecological parameters:
  - abiotic: climate (variability and risks), substrate, topography.
  - biotic:
    - flora and vegetation (plant physiognomy, plant cover, flora and plant production);
    - fauna, particularly domestic (species, density, feed needs, carrying capacity, production);
- socio-economic parameters :
  - production units (population, occupation and use of space and resources, accessibility of land, etc.);
  - economic factors (commercial possibilities, etc.).
- ecosystem services (noted here for information only).

Given that human activities considerably threaten lands and resources in the short and long term (e.g. the delicate balance Environment-Development), the monitoring of the processes and consequences of human interaction with the environment is crucial. Such monitoring will be even more useful if it can effectively contribute to better management choices that would reduce environmental degradation damage (land and resources) and lead to more suitable management practices.

Science and technology have gradually enabled the implementation of a chain of ecological monitoring operations (and of monitoring-evaluation). The development of the means to observe the planet (geostationary earth observation satellites), and to collect and process data (modelling) now allow a fuller appreciation of the impact of human activities at diverse hierarchal spatial levels (from the plot to the biome to the planet). A certain number of programmes have emerged, along with the clarification of notions such as "Sustainable Development," "Global Climate Change," "Biodiversity," and "Desertification," which have given new dimensions to ecological monitoring.

These programmes focus on:

- evaluating the severity of land and resource degradation phenomena; and
- identifying the most appropriate solutions to check, or at the minimum reduce, the effects of the processes leading to this degradation.

The conceptual and methodological foundations for ecological monitoring have been developed gradually. For example, the Pressure-State-Response (PSR) model, based on the idea that human activities exert pressure on the environment and thereby modify its condition, is frequently used to characterize the appearance and spread of the environmental degradation phenomenon. However, as the degradation of pasture land is progressive and not linear, this model cannot be applied perfectly. Decision makers (from farmers up to politicians) respond to each new situation by modifying their use practices of lands and resources.

Environmental degradation is influenced by numerous factors that act on diverse scales of time and space. The climate and multiple forms of human activity are the most active and influential factors affecting an environment's evolution. The choice of efficient indicators (pertinent and reliable descriptors), ones that take into account both the diverse disciplinary fields and the hierarchy levels of the space involved, can enable a sufficiently precise evaluation of the condition of spaces and resources.

The monitoring of spaces and environments is possible and can become effective once it is based on the following considerations:

- monitoring ecological changes alone is not enough to predict the future development of lands and resources. It also is imper ative to include economic, social, ethnic and other processes;
- an understanding of the reasons behind the changes observed renders it necessary to evaluate and measure explanatory factors and therefore to formulate a hypothesis regarding the nature of these factors;
- to document ecological changes, the same measurements must be repeated, using the same procedures and at rational intervals;
- the extrapolation of ecological research results can only be effective if it follows a rhythm compatible with the fact that new interactions may occur at any time.

Several conclusions must be drawn after taking these points into consideration:

– an interdisciplinary approach is necessary (choice of pertinent indicators in diverse disciplines, scientific and non-scientific);

– existing knowledge must be taken into account (stations with a known scientific history);

– coordinated environmental monitoring programmes must be implemented over the long term (field observatories working, if possible, as a network to compare findings);

– efficient indicators must be monitored to describe an environment's situation and dynamics and should relate to either parameters of structural composition (flora, fauna, microorganisms), functioning, or services provided by the environment.

ROSELT (Réseau d'Observatoires de Surveillance Ecologique à Long Terme, or the Network of Long-Term Ecological Monitoring Observatories), one of the first programmes was launched by the Sahara and Sahel Observatory (Observatoire du Sahara et du Sahel, OSS) to cover the arid and semi-arid regions around the Sahara. It meets the diverse points raised above perfectly. The first network of its kind in Africa, its primary mission is to:

– organize the scientific monitoring of the environment in order to: a) characterize the causes and effects of land degradation, and b) better understand the mechanisms that lead to desertification;

– acquire reliable data on land degradation in arid zones, identify biophysical and socio-economic indicators pertinent to desertification, and establish the state of the environment in the ROSELT/OSS zone;

– provide support to decision making processes in order to improve environmental management and check the spread of degradation phenomena.

This ambitious programme aims first to evaluate ecosystem changes in space (from stations to Observatories) and in time (not simply for a season or whenever it is possible). Steering such a programme to a successful conclusion is difficult because it depends on the availability of interdisciplinary teams and involves the delicate obligation to function as a network covering a large number of countries.

For a given situation in the ROSELT/OSS programme, the ensemble of work (mapping, monitoring measurements, and observations) takes place on an area which is called an Observatory. This is most often a natural region (Table 1) representative of a broader area which has, when possible, an available record of collected scientific data. Ideally, the area is situated close to a natural, protected space such as a national park or Biosphere reserve.

In reality, the participating observatories often correspond imperfectly to the certification criteria adopted by ROSELT/OSS (ROSELT/OSS, 1995) in terms of their broader ecological interest, acquired scientific knowledge, and logistical and operational capacities. Fortunately, in some cases, other criteria (accessibility, interest for numerous research teams, etc) have occasionally prevailed.

In principle, a rigorous application of the approach would have required an initial broad mapping at the circum-Saharan level (otherwise known as the ROSELT/OSS region) based on three component categories: physical (climate), biological (vegetation, fauna), and anthropogenic (land use). This would have allowed a rational allocation (representative, nationally and regionally balanced, etc) of ROSELT/OSS observatories over the broad units of this regional zone. The approach actually followed was more pragmatic. However, having been well thought out, it has been proven effective (Quillevéré, 2004) when the adequacy of the choices made were tested against the theoretical results from a more "standard" approach.

The desire to work as a network make it necessary to use indicators tested and validated in the various observatories as well as to implement common (or at least coherent) procedures for collecting data (from the choice of stations to field measurements) and for processing and interpreting results.

The present methodological guide was developed in reference to the document, "ROSELT Organization, Functioning, and Methods", (ROSELT/OSS, 2001) and to the presentation of the overall conceptual schema for the study of environmental change in the network. The guide aims to provide a harmonized methodological approach to the collection, processing, and analysis of data relative to flora and vegetation (other Guides cover the other components of bio-physical systems).

The essential aim of the guide is to set out the joint approaches to zoning, sampling, and measurement of parameters that were chosen within the ROSELT/OSS framework. It also addresses the principle methods used to analyze results, covering diverse activities from the development and measurement of new indicators to the calculation and interpretation of indexes. In the second part of this document, the contents of the following chapters will be logically laid out:

- zoning and sampling of space (Chapter I);
- evaluation and monitoring of vegetation, surface states, and resources (Chapter II);
- evaluation and monitoring of biodiversity at diverse spatial levels (Chapter III);
- evaluation and monitoring of the ecological diversity of landscapes (Chapter IV).

It would be possible -- and very easy -- to make broad propositions concerning the programme's capacity to provide the most pertinent data that theoretically would be very strong and certainly reassuring to the programme's designers. However, given the way ROSELT/OSS was developed, this frankly would be illusory or even absurd. We consequently face an important dilemma concerning the choice of data to be collected, with the need to satisfy objectives balanced against what is realistically possible. We often must arbitrate between the objectives on the one hand, and the scope of the task and the resources (time, financing, skills) that can be mobilized on the observatories on the other.

It is important to keep in mind that the term 'monitoring', as used in the definition of the ROSELT/OSS programme, in fact refers not only to follow-up - as the French term 'suivi' implies to some. It contains the notion of indicators (at the level of field protocols) and of thresholds (in the interpretation of results). In the interests of clarity, the term "follow up-monitoring" is used in this work.

Another dilemma, one that ROSELT/OSS field staff must often face, is that of time. Characterization operations are but a first step; it is evident that difficulties are born with time, possibly rendering it difficult to continue monitoring operations. Measurements and observations must be made with the same rigor over the medium and long term by observers who are not necessarily the same. The parameters for measuring and observing must correspond to simple, well explained protocols. These parameters must also be relatively few in number to avoid over burdening researchers who are otherwise under much demand. Most research work is conducted over short periods, for reasons related to the favourable relationship between the time consecrated and the possibility of publication in international revues. The very advantage of environmental monitoring -- that it is a long term task -- limits researchers from following another approach. Yet it would possible to associate this monitoring approach with one that provides more immediate results.

Chapter I:
Zoning and sampling a space choice of sites for study and monitoring

Introduction

should be recalled that, at least initially, the delimitation of the ROSELT/OSS observatories was not consistently made with great clarity. However, it always has been possible to modify boundaries when necessary to give them coherence in relation to the programme's objectives.

One obstacle to dialogue between the specialists working in the field is that, between disciplines, and occasionally within the same discipline, references differ with regard to environmental units and levels of spatial perception. As a result, there often are differences in scale at which field work takes place. To improve dialogue with other scientists, natural science experts must define their needs clearly. To this end, ecologists have adopted an ecological spatial perception pyramid with five principle interlinked levels: zone, region, sector, site, and element. Each of these levels corresponds to:

- units identifiable by vegetation;
- variables (or the states of variables) that are preponderantly ecologic;
- levels of integration of ecological systems;
- cartographic scales of expression suited to translating the analytic or overall character of each level.

Within the framework of ROSELT/OSS, it is important not to mistake the overall goal. The primordial objective of follow-up-monitoring by no means involves, even if it does not exclude, long and fastidious academic work. One must be sensible in choosing the appropriate approach, and using the resources available, to gain a solid understanding of the areas under study. It should be possible to establish a Land Cover Map, and the zoning phase that follows, within a reasonable amount of time that is compatible with the scientists' responsibilities. In the framework of ROSELT/OSS observatories, field measurements and observations most often are limited in time and take place on what are sometimes very remote sites. Field work generally is limited to a single annual campaign of measurements and observations. It is important to take this reality into account, and not to excuse scientists from the necessity of scientific rigour, but rather to encourage them to use strategies to distinguish the necessary from the superfluous.

The virtue here is somewhere between too much and too little. Field campaigns would be useless if they allowed only an accumulation of non-interpretable factual data. A supplementary effort, which does not have to be extensive as long as it is well thought out and coordinated, may considerably improve the value of data collected during a campaign. It already is clear that identifying the essential implies considerable consultation and cooperation between scientists (researchers and technicians) working on field data collection.

It certainly would be easy within the ROSELT/OSS programme to arrange work highlighting vegetation-environment correlations (ecological profiles, ecological groups, ordination of units, etc) on all of the observatories. Where this is still lacking, it is not advised that such work be undertaken with the pretence of adhering to ROSELT/OSS concerns.

In ROSELT/OSS programme activities, zoning has a two-fold value. It constitutes: a) an initial frame of reflection for the design of sampling and the location of measurement sites; and b) data defining the initial stage that can be updated though follow-up-monitoring (cf. § B.2). Changes in the space and range of diverse vegetal formations (cultivated or wild) effectively constitute indications that can be expressed in the form of new zones of great interest for follow-up-monitoring.

Table 1 provides the hierarchal spatial levels adopted: the region (Observatory), the landscape (equivalent to a sector), the ecosystem (biotope). The notion of observatory and station do not constitute hierarchal spatial perception levels and therefore are not included.

In Table 1, it likewise is possible to distinguish biological hierarchal levels (at once taxonomic and genetic) at which field measurements are made, e.g. the community and the species.

In nature, the first form of diversity that one notices when in the field is a mosaic of plant formations at diverse stages of development (wild and fallow land, steppes, savannahs, fields, etc). What is less evident is that this mosaic is moving in time (from seasons to years). Thus, for example, plant cover, whether it is natural or cultivated, changes over the course of a year and over a succession of years. It is this double reality of space and time that one must try to capture in maps.

The zoning of space must be done at the level of perception and precision (scale) compatible with the diverse needs of the ROSELT/OSS programme. Such zoning is necessary and in fact constitutes the first step in the process proposed here. The first stage of follow-up-monitoring also must be based on the repetition of zoning over time. Zoning thus has, as already noted, a double purpose: a) to characterize the initial state and b) as a potential tool for follow-up.

It is difficult to imagine that the survey of a map as complete as the Land Cover Map (LCM, see § A which follows) may be made arbitrarily at a fast pace, however, the following is possible:

- either ensure follow-up (and cartographic surveys) of a particularly sensitive portion of the territory of an Observatory, or
- repeat, at a chosen pace, the mapping of a theme (for example, land use) for which the survey may be greatly facilitated through the use of remote sensing satellites. This approach leads to greater intervention only when several alert signals have been detected.

Given their synoptic and diachronic features and their spatial and spectral resolution, remote sensing satellites should be considered a tool of choice for the successful production of such documents. Though variations of spectral signatures and on-site validation, satellite images at low and high resolution effectively facilitate the evaluation of certain parameters such as plant cover, soil surface states, water resources, etc. Having a set of images taken on different dates often is essential; at the minimum images should be taken on two contrasting dates, such as the peak of vegetation and the middle of the dry season.

In Table 1, we have tried to summarise the information and relations concerning the hierarchal levels, observations, measurements, and objectives of the ROSELT/OSS programme.

Table 1: *ROSELT/OSS measurements and observations at different levels of perception and organization of space and living organisms*

Hierarchical levels		Operations, Measurements and Observations 'ROSELT/OSS'	ROSELT/OSS Objectives (Study and follow-up themes)
Ecologic (space)	Taxonomic (living)		
Ecologic region		ZONING Choice and delimitation of the Observatory Land Cover Map Definition of a sampling table	*Representativeness of the selected area* *Interrelations of landscapes*
Landscape		Choice of toposequences and transects Characterization of landscapes	*Interactions Man-Environment Initial characterization/follow-up Relationship, Fragmentation*
Ecosystem and Element or Plot	Community	Choice and characterization of sites and biotopes (minimal area) Floristic inventory Measurements: cover, biomass, etc. Agricultural yields	*Cartography* *Characterization of environments* *Biodiversity Evaluation of resources* *Follow-up of environmental evolution*
	Populatioon and Species	Abundance/Dominance Palatability Life-history traits	*Causality* *Biodiversity*

Zoning

Producing a phytoecological map is long and complex work. It therefore may be interesting to propose passing by way of a map that is more analytic and rapid to execute in the field yet which still satisfies the need to constitute a reliable base for future work.

Such a document, known as a Land Cover Map (LCM), has the following advantages:

- if it is possible to use remote sensing, it can be surveyed rapidly (De Wispelaere & Waksman, 1977, etc.). If one so chooses, this allows one to envision comparative diachronic work on frequency and/or the portions of territory where the mapping is to be renewed,
- it offers the possibility of hierarchal zoning: regions, sub-regions or even environmental units. Such zoning is in particular a fundamental base for the establishment of a monitoring system of the evolution of spaces and resources.

Some definitions

The following were defined by members of the ROSELT/OSS/OSS Coordination team and were adopted for this guide.

<u>*Land Cover*</u> It would be wiser to rely on the term Overall Land Coverand add the description of soil surface states to the notions already contained in the Land Cover Map relating to the description of vegetation.

<u>*Land Use*</u> A Land Use Map corresponds to what is otherwise known as a Use Type Map (agricultural zone, forest zone,).

<u>*Land use allocation*</u>. This term is preferred for scientific work treating Land Use at the plot level (field cultivated with which species, fallow field of what age, etc.).

Relations with Spatial Reference Unit (SRU) in CT number 2 (2005).

To analyze the dynamics of environmental change, the methodology proposed in CT number € 2 consists of formally distinguishing two levels of spatial information expressing two sets of factors. It is only though the subsequent superposition of these two levels that the impact of one on the other and the retroactions that may result can be evaluated.

One must therefore delimit, on the one hand, areas which are homogeneous from the "biophysics" point of view (Landscape Units = LU), and, on the other, areas which are homogeneous from the point of view of human resource use practices (Combined Practice Units = CPUs). The intersection of these two spatial information maps determines the Spatial Reference Units (SRUs).

Put together, the SRUs reconstruct a landscape on which it is possible to identify the respective contributions of these two sets of interacting factors.

The definition of SRUs is an integral part of the 'diagnostic' phases on ROSELT/OSS observatories, which is to say that it must be repeated at regular intervals compatible with the dynamic of change that one wishes to highlight (5 to 10 years).

The multi-use of space and resources is the rule in most arid and semi-arid zones. The characteristics of SRUs are therefore a product of different use practices and they determine the nature and quality of resources available for the use practices considered.

Since the objective is to analyze the state and evolution of SRUs as a function of these different use practices, which are associated with an equal number of different management practices, a module-based analytical approach is preferred before making an assessment constituting the synthesis of interventions and samples. Each use practice is associated with one or more resources and their relationship in time and space are specific.

I. Land Cover Map (LCM)

Note that the usual rules for establishing this document were modified considerably following the decision to add the proposal of assessing the surface states along with vegetation. Despite this modification, it continues to be called a LCM.

Concept and principles

The approach is based on the postulate according to which existing vegetation and surface states constitute synthetic variables expressing the responses of an environment to the pressures exerted on it by human activities (diverse techniques, livestock pressure, etc). The notion of human pressure (degree of artificialization) refines environmental knowledge by adding descriptive elements regarding the terms by which man exploits and uses spaces and resources. In this sense, LCMs already constitute a study and an expression of existing plant resources and their location in space.

This type of poly-criteria document was first proposed to satisfy a need for a quantitative environmental description in map form. It involves representing (and therefore mapping) ground cover elements, namely:

- a cross section of existing vegetation: the dominant types of vegetation, their vertical (height stratum) and horizontal (cover) stratification, and the dominant and co-dominant plant species by stratum, associating this with information relative to the level of human pressure (degree of artificialization) on the environment;

– soil surface states. The initiative of adding this information to the contents of the LCM certainly will prove to be very fruitful as environmental evolutions also are expressed by occasionally important changes (drift, accumulation) in surface soil elements (sand, crust, slaked crust, stones, etc).

Recommendations

The addition of an 'environmental evolution index' to the LCM would not be superfluous for documents established in arid and semi-arid zones, particularly for follow-up-monitoring projects.

The collection and interpretation of field data must be based on a dynamic

vision of environments and systems. One must be attentive to signs (indexes) that may facilitate a clear understanding of the evolution (progress, stability, or regression) of the state of spaces and the resources they hold. All signs, even qualitative and relative, are concerned, for example: the relative germination density (possible evaluation of viable seeds in the soil), demographic evaluation (% of the population that is young/old), soil drift indexes, unearthing of plants, the thickness of wind drifts, etc.

It also is important to insist on the fact that in the most degraded situations, one quickly reaches the stage where vegetation is rare and the flora very homogeneous, no longer allowing one to discern reliable indicators of environmental evolution. It seems that only indicators linked to geomorphology, in their most dynamic form, can be used effectively to evaluate the severity of environmental degradation.

Practical protocols

After deciding an itinerary using a topographic map, or even better an aerial photograph or remote sensing document, one must travel throughout the territory of an Observatory. Each time a new situation is encountered (plant type, land use, etc), a fairly concise assessment of the environment must be made. This work consequently leads to an overview of the entire territory of an Observatory. A brief description of the vegetation (species, height, cover, etc) and soil surface states are drawn from such concise, correctly located assessments (referred to as relevés in French). The information thus surveyed and collected in a set of several dozen descriptions is synthesized. This synthesis leads to the establishment of a preliminary outline of the LCM legend. One also may proceed from there to start coding the local reality, as is presented in the following paragraph. It will be subsequently refined.

A. Codification

Several practical rules for coding observations and field measurements are proposed. Their adoption would facilitate the overall, homogenous reading of maps and other documents established for the same theme on different sites, possibly in diverse countries and biomes.

1. Existing vegetation

a. Dominant plant types

A detailed codification was proposed by Godron et al (1968, 1969) which is described in Annex I a. Overall, the following main types of plants (Table 2) constitute an equal number of strata:

Table 2: Distinction between the main plant types

– Woody:	Tall (height above 2 m.)	Code = TW
	Short (height below 2.)	Code = SW
- Herbaceous:	Perennial	Code = PH
	Annual	Code = AH

This data is essential, for example vegetation referred to as "steppic" in arid zones of North Africa is dominated by the 'short woody' (shrubs) category while south of the Sahara tree and bush savannas are dominated by 'Tall woody' and 'Perennial herbaceous' ones.

Such very general classifications must be able to be adapted to allow correct descriptions of particular situations. Thus in Latin America it often is necessary to add a category, "cactoides", for plants that cannot be compared directly with tall woody plants (Etienne et al., 1983). The same adaptations must be made to describe, for example, the Euphorbia cacti forms of the Moroccan coast. This is not the only special case that may exist with the ROSELT/OSS programme region.

b. Vegetation structure

b.1. Vertical structure (height stratum)

It is evident that the general proposition evoked below must also take into account the size of plants. For example, in sub-Saharan Africa it will be necessary to subdivide the "Tall woody" category as a function of heights that can surpass 2 meters. Examples of such adaptations are reported in Le Floc'h, 1979; Etienne et al., 1983; Ayyad & le Floc'h, 1983. It remains important to try to adhere to a codification that is homogenous (even if not uniform). This is why we propose the following framework (Table 3) in which height codes are combined with those of the dominant plant types described in the preceding paragraph.

Table 3: Codification of the vertical structure (height stratum)

	Class	Code
	2-4 m	TWa
Tall woody plant (HL), height > 2m	4-8 m	TWb
	8-16 m	TWc
	> 16 m	TWd
	0-0.25 m	SWa
Short woody plant (LL), height > 2m	0.25-0.50 m	SWb
	0.50-1m	SWc
	1-2 m	SWd
Perennial herbaceous (H & h)	0-0.25 m	PHa
	0.25-0.50 m	PHb
	0.50-1m	PHc
	>1 m	PHd

b. 2 Horizontal structure (cover)

Herbaceous species, particularly annuals, are likely to show significant inter-annual cover variations (or even inter-seasonal). Due to this, cover data on them should be interpreted with care, taking into particular account weather data of the period.

For these reasons, some authors suggest focusing on perennial plants which are less susceptible to such short-term variations.

For a space as vast as that covered by the ROSELT/OSS programme, regional adaptations are necessary to account for certain particularities such as the abundance of short woody plants in the northern Sahara, the coexistence of tall woody and often annual herbaceous stratum in the Sahel, and the abundance of shrublands in East Africa. Of course, what matters is the coherence vis-à-vis the overall schema chosen within the ROSELT/OSS framework. Cover thresholds are difficult to adopt in each situation having threshold values. The difficulty is related to both: a) the detection capacity of remote sensing equipment and b) the varying significance of degradation thresholds for different vegetation. The thresholds are not necessarily the same.

The classification adopted in the code developed by Godron et al (1968) was not chosen. Given the variety of situations encountered, we effectively opted for a distinctly more analytic vision where the same importance is given to cover whatever the type of plant involved. The classes of cover adopted are provided in Table 4.

Table 4: Codification of the horizontal structure (total cover)

Code	Classes of cover
1	< to 5%,
2	5 to 10 %,
3	10 to 25 %
4	25 to 50 %,
5	50 to 75 %,
6	> 75%

a. Codification of dominant or co-dominant species

The dominant and co-dominant species are those which mark vegetation physiognomies, thereby allowing one to describe these -- if possible -- in a lasting way, which is the reason perennial species are favoured. However, certain formations can only be described usefully by including annual species. For this reason, we strongly advise undertaking cartographic surveys during growth periods.

In actual fact, the most widespread and physically important dominant species often are also the least varied. Consequently, it is important to add 1, 2, or even 3 co-dominant, more diversified species in order to clearly partition (zone) the space. For example, in Tunisia, Rhanterium sauveolons is a physically dominant species on steppes of sandy soil, inferior arid and superior Saharan bioclimatic formations. These steppes can not be usefully differentiated unless a co-dominant species such as Artemisia campestris, or Lygeum spartum, etc., is associated.

The dominant or co-dominant species are coded by two letters that, to facilitate memorization, evoke as much as possible scientific names as they are listed in the Flora, or Catalogue, of reference. In order to help memorization as well as increase the number of possible combinations, we chose the conventional use:

– 2 upper case letters for tall woody plants (phanerophytes). For example, Adansonia digitata (baobab) may be coded as AD.

– 1 upper case letter followed by 1 lower case letter for short woody plants (chamaephytes). Rosmarinus officinalis (rosemary) may be codes as Ro,

– 1 lower case letter followed by 1 upper case letter for herbaceous perennials (hemicryptophytes and geophytes). Imperata cylindrica may be coded as iC.

– 2 lower case letters for herbaceous annuals (therophytes). Neurada procumbens may be coded as np.

Clearly, cultivated areas also may be coded using the same rules.

A codification for height also is proposed in Annex I. It is relatively superfluous for herbaceous plants, whether perennial or annual. In fact, for each geographic space (for example, an observatory), the first round of prospecting allows one to establish a preliminary outline of the list of dominant and co-dominant species. These are then coded in as coherent a manner as possible by following the rules discussed above. Of course, in the same category of plants, there may be several taxa corresponding to the same combination of letters. For this reason, a certain degree of flexibility in the application of the rules is necessary.

2. Level of artificialization

The concept of agricultural pressure on resources in CT number 2 (2005)

In circum-Saharan zones, the dominant modes of resource use with significant impact on the environment have been identified clearly: agriculture uses (cereal crop production), pastoral uses, and domestic energy supply uses.

For each type of use, a space and resource use model is developed. A sole model is used for the spatial representation of practices on rural space (determination of CPUs, or Combined Practice Units). The model adopted is one that concerns human activity which fundamentally structures the landscape: agricultural activity in agro-pastoral Sahel zones, pastoral activity in zones where rain-fed agriculture cannot be practiced.

The other function models identified on the territory of an observatory are transferred to SRUs delimited and structured from the "principal" module.

The concept of agricultural resource pressure indicators (CT number 2, 2005) covers several indexes:

- the relative index of agricultural investment on the environment (or the degree of artificialization by agricultural practices) which well coincides with the concepts developed further on. In this document, cited as a reference, the procedure is noted for constructing a relative index of agricultural investment on the environment;
- The absolute index of agricultural investment on the environmental (or the degree of artificialization at the scale of the Observatory);
- other indexes and indicators.

In the same region, different ecological systems are not subjugated to the same level of human pressure. For example, the use of rangeland is known not to require much manpower, contrary to crops, which are more demanding.

Generally, an appreciation of the degree of artificialization is completely subjective yet well-reasoned. To escape from this subjectivity it is possible, for example, to integrate both past human (and animal) pressure and the quantity of on-farm labour needed. This integration may be made by transforming the costs of farm investments into a 'work day'. For example, these may include the cost of insecticides, fertilizers, and other inputs such as irrigation, etc. (Le Floc'h, 1979). One thus obtains a completely evident scale of artificialization that, for example, goes from 0.25 work days per year and per hectare for the traditional management of livestock in southern Tunisia to 365 work days per hectare and per year for crops raised in plastic tunnels. Such an approach also is addressed in CT number 2 under the absolute index of agricultural investment on the environment. (cf. preceding box).

Overall, and without taking into account the considerations noted above, the following classes were selected (Table 5):

Table 5: Codification of the degree of artificialization

Code	Concise Description
ZN	Zone without vegetation: edaphic desert (chott, erg, etc.)
0	Vegetation, possibly rare but considered to be not or only little subjugated to human activities (high halophily steppe, etc.)
1	Spontaneous vegetation little influenced by humans (exclosure areas, etc.)
2	Spontaneous vegetation submitted to regular but reasonable pressure (remote rangelands)
3	Spontaneous vegetation suffering damage from over-exploitation (over-grazed zone with levels possible to describe in detail)
4	Vegetation in place introduced by humans (traditional cereal crops, etc.)
5	Well maintained and farmed crops and plantations
6	Cultivation of crops requiring extensive irrigation, etc.
7	Cultivation of very demanding crops
8	Vegetable farming
9	Greenhouse farming, etc.
10	Non agricultural crops

3. Soil surface states

The development of simulated rain studies have led to the gradual identification of the factors conditioning both rain infiltration and run-off. The preponderant factors are plant cover, roughness of the soil, soil surface characteristics (sand, crust, rocks, etc), and the presence of animals (burrowing, insects, etc).

Under the effect of rain hitting the ground, a superficial reorganization of elements occurs, each new type coinciding with particular hydrodynamic behaviour (Escadafal, 1981, 1989; Casenave & Valentin, 1989). It is evident that, for the same reason as plant cover (protecting the ground from the impact of rainwater), basic elements of the ground surface may be useful in diagnosing the state of environmental degradation, particularly in arid zones.

The typologies put forth in scientific work are fairly complex; this is true, for example, of the determination of crust type in the Sahel (Casenave & Valentin, 1989). While it does not seem possible to retain all of the proposals in such scholarly work, it is nevertheless crucial during LCM surveys to note information relative to the overall cover of different parts of the ground surface using a simple typology. What therefore is proposed is noting the proportions of the soil surface occupied by the following different elements: boulders, rocks, gravel, sands (possibly 'ripple marks'), silt, clay, bare soil, ground litter, etc.

These surface states are observed and recorded on the cartographic document at the same time that existing vegetation is assessed (cf. Chapter II).

A. Constructing the LCM

Zoning is based on the following: the reality in the field, bibliographic data and various other documents such as aerial photos, satellite images, digital topographic maps at different scales 1/20,000, 1/100.00, etc, and other thematic maps.

In fact, it has been shown several times that the LCM (or the map of dominant and co-dominant species formations) constitute an effective zoning of space from a biocenotic, and therefore floristic, perspective. The vegetation, designated by the physionomically dominant and co-dominant species, characterizing different vegetation sub-units is considered to be a sufficiently efficient and relevant indicator of the ecological and phytocoenotical diversity of a space.

Vocabulary for notions of parameter, indicator, index, etc.

(extracts from the ROSELT/OSS Scientific Document number 4)

In the scientific document number 4, 'ROSELT/OSS Ecological Indicators. An initial methodological approach to the surveillance of biodiversity and environmental change', the Roselt/OSS network puts forward several definitions, restated here.

A Parameter is a factor able to have different values that may be a component of appreciation of an element or of a factor. It may be qualitative or quantitative and, for example, describe a permanent environmental characteristic.

An Index usually represents a unique value. It may be considered either as the combination into one of a certain number of variables or as the outcome of the merging of a set of parameters or weighted indicators (OCDE, 1994 in Roselt/OSS, 2004, SD number 4).

An indicator is a parameter, or a value derived from a set of parameters, that provides information about a phenomena or its state. An indicator has a significance extending beyond that directly associated with any given parametric value (OCDE, 1994 in Roselt/OSS 2004, SD number 4). An indicator is conceived for specified objectives and users. It reflects a specified situation and helps in making decisions regarding the situation. An indicator may thus be: a) a standard of quantitative measurement (calculated from field observations into different points and expressed in proportion to the total surface area of a given country or region), b) a qualitative description.

A benchmark is a norm in relation to which the indicators or index may be compared in order to determine trends.

A threshold is the limit value beyond which the nature of the processes, structures, or functions of the system under study significantly change.

Let us recall that the units determined by edaphic or geomorphologic differences strongly linked to sand, gypsum, wadi beds, etc, (Barry et al, no date) are always more easily individualized than the units that differentiate themselves on the basis of climatic criteria.

What now remains to be established is the mapping key, considered to be definitive even if adjustments may always be made up until the time the document is completely finalized. The aim of this key is to both:

- provide useful information on each unit of the thematic map. The establishment of the map key is therefore a crucial operation because it is the pertinence of the elements described (the units) that will determine the possibility of coherent cartographic surveys even if they are conducted by different operators, at least if they have received the same training;

- facilitate communication with the different users, for example through the choice of the language and the standard codification. The extraction of simple themes may be largely helped by this communication.

The key of a vegetation map, even if it does not directly regard the phytoecological units, must carry information from one unit into the ones following or preceding it, in other words, a dynamic schema (sequence of degradation level, etc) that includes the notion of time mentioned previously. For that matter, such a dynamic schema accompanies the key to a certain number of literature documents.

B. Interpretation of the LCM

A hierarchical key must allow a fairly directly consultation of the dynamic schema of the units listed and a rapid understanding of the overall situation in a territory (synoptic vision).

The final document may also:

- be presented in diverse forms according to the parameter one wishes to highlight;
- give rise to several extractions, or more directly readable simplifications, in the form of interpretative maps such as:
    - maps of vegetal formations;
    - maps of vegetation sequences;
    - maps of ligneous resources (in classes);
    - maps of the level of anthropization (degree of artificialization, etc.).
- be moreover associated with other sources of spatialized or non-spatialized data, to give rise to new maps. For example, by associating it with biomass measurements and evaluations of the palatability of species, one may establish a map of grazing potential.

Following, for example, a measurement of the surface areas of units (planimetry), the LCM may also lead to the establishment of assessments, statistics, etc. Such a work phase, by revealing the relative importance of each type of unit, constitutes a major contribution to the development of a sampling table, an issue which will be addressed in further on (B of this chapter).

The evaluation of biodiversity poses particular zoning problems. Rather than favouring a synoptic and overall view of a space, it effectively means that one must take into account the smallest unit that presents an original combination of ecological factors, due to which it is likely to harbour taxa with a limited distribution. This approach will be explained in Chapter III, which is dedicated to monitoring and evaluating biodiversity.

I. Other secondary thematic maps

In this category are gathered the relatively subjective but well thought out documents that may be developed on the basis of the zoning and characterization of space already made for the LCM. Without pretending to be exhaustive, the documents mentioned here are those that already have been established for arid zones of the ROSELT/OSS region and elsewhere. The themes that appear to be the most relevant for the issue addressed by ROSELT/OSS, in particular those likely to facilitate the establishment of an environmental sampling table – discussed later in the chapter - clearly will be favoured here.

A. Map of vegetation sequences

As already mentioned above, the part of the key regarding vegetation should be structured to render evident the transition between units. A dynamic schema that links the units (vegetation sub-units) situated in the same degradation sequence will greatly assist an understanding of the key. Such a dynamic schema will also allow one to establish a map of vegetation sequences as is possible to find in literature (Floret & Le Floc'h, 1973).

B. Map of the actual state of degradation

This theme may be extracted from information relative to the degree of artificialization (Cf. LCM). It is thus easy to reflect on the actual state of degradation using a grill containing only a small number of classes (5 for example). These classes respond to a diagnostic possibility based on the observation of a small number of indicators, allowing a clear interpretation of available data whether or not it is quantified. It also is here, and in the following paragraph, that the recommendations proposed at the end of the first part take on their full meaning.

C. Map of sensitivity to degradation

Such documents may be very useful when choosing sites to observe in an 'early warning' follow-up-monitoring network (cf. § B 2 of this chapter). The proposed approach has been amply developed in arid Tunisia (Floret & Le Floc'h, 1973, 1983 ; Floret et al., 1977, 1978, etc.).

In the absence of experienced natural scientists in the zone concerned, it is necessary to proceed to tests to acquire a sufficiently precise idea of the dynamic of environments and their capacity to heal after regression or even the disappearance of the causes of their degradation (resilience).

There are different types and levels of sensitivity to degradation (Floret & Le Floc'h, 1973). It effectively is easy to imagine that sensitivities may appear differently depending on whether the vegetation has or has not been destroyed. For arid Tunisia, the following have been distinguished:

- the sensitivity of different types of vegetation subjugated either to cultivation or to over-grazing (at several levels of intensity);
- the sensitivity of soils subjugated to human action (cultivation, over-grazing).

In the absence of experimental data, it is possible to address this theme in an analytic manner by retaining the following criteria:

- on the one hand, an area's attractiveness for different human activities. Thus, for example, zones with superficial soil will not be attractive for cultivation, etc;
- on the other, the intrinsic sensitivity of environments to these same human activities. Drifting sand environments are intrinsically very sensitive to cultivation. However, drifting sand environments are in reality not very sensitive as farmers long ago realized it is dangerous to cultivate them (the attractiveness of the environment is weak for cultivation).

D. Landscape Map

The climate, geology, circulation of water, level of human pressure, etc, explain variations in the distribution of soils and types of vegetation that undergo, furthermore, strong interactions. Based on this observation, Forman & Godron (1981) defined a landscape as an 'assembly of ecosystems interacting in a manner that determines the spatial patterns which repeat themselves and which are recognizable.' This definition, which takes into account the relations between different landscape components, was adopted for the needs of the ROSELT/OSS programme. As it is not subject to interpretation, it offers, moreover, the undeniable advantage of making the objective measurement of its delimitation possible. It is recognized that downstream units along a toposequence [field model leading from a high point (summit) to a low point (shoals, depression, river bed)] depend on upstream units due to the circulation and differentiated accumulation of water and soil. People take into account the relatively favourable character of the situation thus created to best locate their activities (water collection on slopes, cultivation of shoals, etc) in a landscape. The landscape thus constitutes a hierarchical level 'intersection' whose importance is even greater as it is recognized by the majority of scientific disciplines involved here. The simplest determination (aerial photographs) of a landscape consists of classing landscapes with watersheds. It is at the level of the watershed that different components effectively interact. It therefore is proposed that the space be cut up, even if this operation remains difficult in plains and other situations with relatively little variations in elevation. Different landscapes (watersheds) of an observatory may be described in turn by the environmental units they contain, the relative importance of these different types of components, and numerous other criteria that will be explained further on (cf. Chapter IV).

E. Map of land use and its evolution

The most practical procedure consists of using the delimitation of different environments (LCM) by considering the vegetal formations and the degrees of artificialization described above.

Based on this information relative to the degree of artificialization, and possibly with the help of indications of the vegetation's vertical structure, it is easy to extract spatial data of land use: tree savannah, grass savannah, steppe, cereal crops, arboriculture, etc.

When available, such documents may be taken into account when planning sampling and follow-up-monitoring of environments.

Remark

It remains possible to cross data collected for the LCM with the values of parameters resulting from station (ex. phytomass) or synthetic (ex. pastoral value of environmental units (cf. Chapter II)) measurements to obtain other secondary maps (map of pastoral value) that will not be discussed here despite their obvious interest because the LCM is not suited to the exercise.

Sampling

Two distinct sampling stages, obviously part of the same methodology, are to be undertaken. They must be thought out carefully. The first and broadest concerns the initial characterization of the environment, the second, follow-up-monitoring.

From the different sampling methods described in Annex I b, the stratified sampling method was chosen for work undertaken within the ROSELT/OSS framework. A random approach is associated with this method to ensure that the work undertaken has robust results.

Two samplings, when possible nested, are required to satisfy the needs of the ROSELT/OSS programme. These two stratified sampling stages must be designed following one coherent approach:

– the first sampling stage is undertaken to ensure a relevant initial characterization of the space under study. This sampling is considerably more extensive and demanding than the second.

– the second sampling stage (for follow-up-monitoring) must be designed keeping in mind the possibility that it may need to be adapted later. To be effective, follow-up-monitoring measurements and observations must be repeated over time (permanent lines and plots) on the same portions of spaces that were selected for being representative and possible to monitor using simplified protocols. It is easy to imagine that as land is put under cultivation - or fields are abandoned - the zoning of a space may be modified considerably. Consequently, the first sampling may become completely obsolete and no longer able to represent the state of the environment.

In the best of circumstances, information relative to a certain number of principle parameters must be available to conduct a well worked out stratified sampling. There are relatively numerous parameters involving the various natural science disciplines that allow an effective description of an environment. They also are relatively difficult to identify and assess. For example, taking into account the geological, hydro-geological, etc characteristics of a territory under study may be considered essential. If this information exists, it will in effect be very useful, however, it seems improbable that their absence in pre-existing literature on an observatory may be filled by work undertaken within the ROSELT/OSS programme.

The study of the climate and its evolution leads to the synthesis, when they exist, of old data series. Failing that, it is imperative to at least obtain recent and current data. There is, in actual effect, a particular advantage in monitoring the climate. Variable rainfall, a characteristic of all arid zones, can explain variations in land use that are sometimes incoherent. Years with favourable rainfall also are the most detrimental for the integrity of environments because they favour the spread of certain misuses. These same data also may be important for the understanding of certain floristic variations (annual absence or abundance, etc.), a point that will be addressed further on.

Other characteristics, such as concise information about the geomorphology, Hydrography, and pedology, often are easy to identify in the field and constitute a significant contribution:

– recourse to the simple notion of topographical position may considerably improve understanding of overall vegetation distribution traits. In fact, close relations exist, at least at the landscape level, between landforms and the distribution mode of principal vegetal formations. This diagnosis of landforms may be realized by consulting topographic maps and aerial photographs followed by a few verifications in the field. It is a question of identifying the principal landform units (mountains and rocky zones, plateaus, hills, filtration zones, summits, slopes, etc.). One must associate hydrographic parameters to geomorphologic ones; these characteristics being equally important for a solid landscape description.

– surface states are given special status among pedologic characteristics because these parameters are known to be good indicators of the state of the environment.

It is out of the question to provide here a complete description of all methods set out in the relevant literature. Rather, the aim is to present the practical features of the sampling method adopted to constitute the methodological foundation of ROSELT/OSS. Other methods and procedures are presented in Annex 1 b.

The sampling of vegetation, as well as of surface states, draws on general statistical theory to take a sample from a target population. The sample should be as representative as possible of the whole and, after its characteristics are measured and observed, be able to define the properties of the entire population.

The prerequisite of any study of vegetation is to clearly define the issues that will govern:

– the definition of a sampling frame, which may be implemented in varying forms depending on technical, scientific, and time constraints;

– the measurements to be made (density, weight, height, etc), according to the methodological choices adopted in order to guarantee the reliability of the statistical interpretation of results obtained;

– the statistical interpretation of results. One must remember that statistics are either non-parametric or parametric. The former, which are generally less powerful and sometimes more tedious to calculate, are rarely used. However, they have the advantage of being more robust in terms of the hypotheses put forward and are particularly interesting when there are numerous samples and the distribution diverges from the norm. Parametric statistics often assume the presence of a normal distribution, which is not always the case.

I. Definition and description of stratified sampling

Applied to the study of vegetation, stratified sampling consists of dividing the space to be sampled into successive units (or stratum) that are homogeneous in terms of the parameters considered, a priori, to be the active factors determining plant distribution. A stratum that is homogenous in relation to the initial criterion (factor) is then subdivided by taking into account a second criterion, and so on. For this operation, the criteria (factors) adopted must be able to be divided into a sufficient number of classes (for example, 5 to 7). In a sampling table, one often finds cases referred to as 'lethal'; they correspond to a combination of factors that could not possibly exist in the field (ex: a steep slope associated with marshes, etc).

Natural vegetation generally has a heterogeneous, haphazard distribution and relatively extensive statistical knowledge is required for its interpretation.

Within the ROSELT/OSS programme, sampling must be both stratified and random if the information drawn concerning the entire sampled population (or space) is to be valid (Godron, 1976).

One must also try to well plan the number and distribution of survey readings. The two principal pitfalls to be avoided are:

a) taking useless readings (over representing certain stratum), and

b) paying excessive attention to the most frequent environments and ignoring less extensive but ecologically very significant ones.

A procedure to measure the quality of sampling described by Daget et al. (1997) is described in detail in Annex I c. For a sampling to be 'optimal' (better put, 'optimal in the sense of Neyman' or 'N-optimal'), it has been proven that the number of survey readings must be the same for all stratum of the sampling table present in the field. These readings must be sufficiently numerous (around 100 in total) for the ensuing statistical calculations to be valid. The choice of sites and location of readings must be planned in order to be both relevant and economical. Consequently, if one of the classes (ex. tree savannah) of a selected criterion (ex. vegetal formation) occupies the majority of the space (whence a risk of over-sampling and a poor sampling quality), it remains possible and important to subdivide (for example by the density of woody plants, etc.).

Clearly, sampling is not always necessary if the population (number of stratum to be studied) is relatively small: the population of a rare species with a limited distribution, or a small planted parcel, may be studied in their entirety.

II. ROSELT/OSS sampling stages

A. Initial characterization of environments and the state of resources stage

When stratified sampling is applied, the choice of criteria defining the progressive stratum should take into consideration the major ecologic gradients (climatic, geomorphologic, anthropogenic pressure, etc). A priori, such a schema allows one to follow macro variations that may exist in a given space, for example, at the level of an Observatory.

Concretely, one may have a sampling table whose first discrimination criterion is geomorphologic units (or the topographic position) that is subdivided by the dominant types of plant formations (second criterion), then subdivided again by the level of anthropization (third criterion). The units thus established constitute as many stratum (entities considered to be homogeneous vis-à-vis one, or even better, several descriptors chosen as discriminatory descriptors). It is clear that thematic cartographic documents (climate, soil, geomorphology, vegetation, etc) can provide powerful assistance during this stage. From this point of view, the Land Cover Map (LCM) may be an essential prerequisite for establishing an optimal sampling table. The number of stratum adopted determines the volume of work to be done. The themes described for secondary maps (actual state of degradation and sensitivity to degradation) may of course, according to local needs, constitute stratum for the sampling table.

A schematic example of a sampling table, taking into account rainfall, lithology, and topography, is presented in Table 6 below.

Table 6: Example of the construction of a sampling table

	Lithology and topographic situations												
Rain mm/year	calcrete			sand			loam			alluvia			
	1	2	3	1	2	3	1	2	3	1	2	3	4
< 50 mm	x	x	-	-	x	x	-	-	-	-	-	x	x
50-100	x	x	-	-	x	x	-	-	-	-	-	x	x
100-200	x	x	-	-	x	x	-	-	x	-	-	-	x
200-300	x	x	-	-	x	x	-	-	x	-	-	-	x
300-400	x	-	-	-	x	x	-	x	x	-	-	-	x
> 400	-	-	-	-	x	x	-	x	x	-	-	-	x

Situations actually observable on field x - Lethal situations (non observable) -
Topographs: 1: summit; 2: mid-slope, glacis; 3: lower slope, plain; 4: depression

Relevant sampling based on the clear interpretation of a LCM thus allows one to establish reliable statistics for major environmental types, overall levels of anthropization, the potential sensitivity to degradation, etc.

B. Follow-up-monitoring stage

The approach clearly is the same as that described for the preceding stage. Nonetheless, its markedly different objective imposes relatively significant modifications in protocol.

In fact, long (and medium) term follow-up is an operation that, although crucial, is too rarely undertaken. This situation should be improved while ensuring the permanence and pertinence of follow-up by accepting streamlined procedures when choosing:

- phenomenon to be monitored, retaining only those considered essential;
- appropriate sites (and placements) that allow prolonged follow-up;
- a 'minimum kit' of relevant indicators for the follow-up proposed.

A major problem arises when choosing sites. The evolution of practices on a given territory effectively requires one to reflect on the placement of follow-up-monitoring sites over the space of the Observatory. One must follow changes while at the same time maintaining measurement and observation sites in formations that remain little changed.

We propose that follow-up begins with a 'watch' intelligence system [with possible recourse to satellite remote sensing, followed by Geographic Information Systems (GIS)], at the level of changes in land use practices. The field operator will have to calculate, taking into account the initial state of land use (overall statistics obtained by reading the LCM), the threshold level of land use changes which will signal the start of more extensive station measurements and observations thereby rendered significant.

Once past the chosen threshold, modifications in land use will lead to modifications in the sampling table. The aim of these readjustments is to distribute new measurement sites to clearly identify the emerging phenomena.

These instructions clearly cannot be absolute rules; what is important is the field operator's capacity to react. The first sampling effectively may turn out as imperfect or unforeseen events (fire, floods, etc) may alter, or even destroy, the quality of follow-up put into place.

The diverse operations (ex. establishing a sampling table), measurements, and observations proposed for different hierarchical spatial levels on a ROSELT/OSS observatory will be explained in detail in the chapters that follow. It remains possible to present a synoptic view as found in Table 1 where we also noted the targeted objectives. It seems that the consideration of measurements made at one level can only be really integrated and interpreted at the hierarchical level that is above it.

Landscape and ecosystem levels (or biotopes or environmental units) are the most affected. This means that data collected during measurements made at the level of different ecosystems certainly will profit from also being interpreted at the scale of the landscape which encompass them.

The large majority of protocols apply to the ecosystem level (biotope) with the choice of stations (plots, lines, etc).

The analysis of plant diversity may be made at different hierarchical levels of space. It requires taking into account environments that are sometimes small and even negligible in terms of resources but which, when subjugated to particular ecological conditions (microclimates, edaphics, inaccessibility, etc), present striking floristic differences. The characterization and follow-up-monitoring stages therefore merit special attention which will be explained in greater detail in Chapter III.

III. Choice of measurement and observation sites

A site is a surface where the ecological conditions are considered to be homogeneous and where vegetation is uniform. In the vocabulary adopted here, a site effectively corresponds to a cartographic unit.

On a site, a station is the precise spot where the measurements and observations that will characterize a unit of a thematic map key are taken. If possible, the sites (units) chosen should be fairly spread out so that one may, for example through a blind draw, place on them a number of measurement stations equalling the number of repetitions.

It is important to think through the choice of the sites and stations of these two stages (characterization and follow-up-monitoring) with field operators. While this precaution unfortunately cannot prevent disagreements, it certainly will limit them.

A. Initial characterization of environments and state of resources stage

Concept

Note that the objective is not to undertake photo-ecologic research aiming to study the relations between flora-vegetation and environmental factors but to characterize the initial state of the environment and resources. The careful consideration and integration of all information available in cartographic (LCM, landscape, topography, etc) or other forms (data on climate, unit dynamics and relationships, etc) must produce an optimal plan for the selection of sites. The ensemble of measurement sites selected is never fixed; it must provide the mechanism with efficiency while leaving room for chance (random approach). By replicating on each site a certain number of measurements (on randomly chosen sites) such a precaution aims to ensure the statistical validity of results.

An important problem must be noted here. It was hoped that the ROSELT/OSS observatories be situated when possible in the immediate proximity of protected zones (National parks, Biosphere reserves, etc). Comparisons between perturbed and not or little perturbed areas would then be possible. But one must question how much credit should be given to such comparisons. In effect, degraded biotopes constitute an extreme in a deterioration sequence but the same is true for protected situations which are, after all, artefacts in nature. If a zone is protected (without any anthropogenic activity) for a long time, one must question the exact significance of a comparison with data collected under very different circumstances. Given such extreme contrasts, the location of sites must be made with great care using a very precise definition of conditions (status of exploitation or protection, etc.).

Protocol

To maintain a solidly representative sample (equal number of survey readings per stratum of the established sampling table), several avenues may be followed, each with its own advantages:

- identify and select sampling sites along a natural gradient of eco-geographic variability (or an environmental gradient relative to climate or anthropization);
- identify the toposequences best suited to understanding interrelations between units and choose sites from them;
- identify and place stations on the units by keeping in mind the gradient dynamic (ex: stations at the beginning, in the middle, and at the end of a unit series of the same dynamic trajectory).

If one adopts the 'transect' approach, one must be able to identify several similar transects (repetitive succession of units in space) in order to finish with a sufficient number of repetitions per unit type selected to be measured and observed. Clearly, the transect method can only be meaningful if the chosen transect responds to the criteria of representativeness. The number of repetitions needed depends on the variability of the station measurements; there must be a minimum of 5 stations to obtain statistical reliability.

When possible, one should choose sites keeping in mind the option of remote sensing. Following the precautions and recommendations mentioned previously, one must identify a set of 'homogeneous' sites, inventory them, and choose from them a minimum number of test stations for each type of environmental unit one wishes to study. These must allow the characterization of natural environments from the ecologic point of view, will serve as training plots for the 'remote sensor', and possibly will be selected for follow-up.

B. Follow-up-monitoring stage

Concept

Follow-up must be a simplified procedure based on an agreed upon reduction in both the number of measurement stations and parameters assessed. Consequently, the choice of transects, gradients, and sites must be relevant for the operation to effectively fulfil its mission, which is to follow and monitor using an 'early warning' approach that requires sensitive indicators.

A principal problem of follow-up-monitoring is linked to the fact that the evolution of practices and modes of exploiting space and resources can bring significant modifications to these spaces and resources. The sampling table adopted for the initial characterization of the environment is thus rendered obsolete. For example, fallow land may be put back under new cultivation while old fields are abandoned, with a re-equilibrium then becoming necessary. In consequence, new measurement and observation sites must be chosen outside of the previous mechanism.

Follow-up-monitoring must also make the most of powerful opportunities such as exceptional years. It is in particular during such years that the profoundest developments take place and it therefore is important not to miss their characterization. Clearly, these exceptional circumstances are not predictable in time, space, or intensity. Follow-up-monitoring under these conditions must be conducted with the greatest amount of reactivity and flexibility in response to conditions that often are richer in information (potentials, vulnerability, resistance, etc) than ordinary years. For example, during a recent series of dry years, the death of olive trees that had resisted rainfall variations for at least 400 years was observed in arid Tunisia. During this same climatic series, the death of almond trees in certain ecologic situations also was observed. A chronicle of ecologic observations of the consequences of exceptional years remains to be undertaken.

Protocol

Follow-up-monitoring of changes and of dynamics (of vegetation, resources, flora, surface states, etc) can be made using at least two procedures:

a) putting into place permanent measurement and observation lines and plots. The study and follow-up of flora and vegetation must be made (choice of spaces, detection of phenomena to be monitored, etc) in accord with the operators in charge of field work. The ideal would be to choose stations, transects, and sites from among those already studied during the preceding stage of initial characterization. However, there are two obstacles:

- the difficulty of maintaining necessary field markers (stakes, etc) intact. Actors in the field (livestock owners, farmers) have the unfortunate habit, probably in fear of their land being 'frozen' (or some other motive), of systematically destroying markers. Of course, the possibility remains of marking using very sophisticated, but largely unavailable, equipment such as infra metric GPS.

- to maintain an equilibrium between sampling stratum, modifications in land use may force one to abandon follow-up on certain stations and choose new stations not studied previously. The important point is to continue to adhere to the approach put into place during the preceding stage. This would consist, for example, of replacing destroyed or abandoned measurement stations with new stations chosen on the same transects and gradients in order to maintain a minimum of comparability.

b) depending on the importance of transformations, envision the possibility of abandoning permanent station procedures. In this case, it remains possible to choose new stations for each new measurement period. The basic precaution is to choose stations on sites as similar as possible to the previous ones. In fact, this is most often the case and as such respect for the necessity of making a maximum of replications is imperative to maintain the statistical validity of results.

Chapter II:
Evaluation and monitoring of vegetation, surface states and resources

Introduction

The diverse pressures exerted on an environment lead to more or less striking changes in vegetation, influencing plant abundance and physiognomic characteristics (height, crown dimensions, etc.). Modifications in the spatial organization of vegetation, otherwise known as the structure, also may result. Consequently, the challenge in the study of vegetation is to be able to describe both the flora (floristic composition) and the most salient features of its structure (ex: frequency of taxa, cover, etc.).

The initial characterization of environments and the evaluation of natural resources (grazing potential, etc) require the application of a rigourous methodology that allows one to obtain an up-to-date picture of the state of biotopes and to follow the dynamics of the environment and vegetation. This is achieved by highlighting potential changes and evaluating degradation processes in environments that have been weakened by extensive human activity.

Another objective of the measurements and analyses made on natural resources and the environment is to identify the biophysical indicators that best capture the start of a degradation process.

The availability of a natural resource only has meaning in relation to a potential use or uses. The "resources/availability-uses/consumption" set evolves continuously over time. The result at any given moment determines the balance one seeks to evaluate.

The two main operations - already noted in Chapter 1 -- which must be integrated together from the start are:

- Phase 1: Initial characterization of spaces, the resources they hold, and their status in relation to anthropogenic pressures, aridity, and recurrent droughts. In this phase, relevés essentially are made in a synchronic manner.

- Phase 2: Follow-up-monitoring of changes at the biotope level through diachronic studies such as the follow-up of shifts in the values of certain parameters (multi-temporal or multi-station measurements). More or less long-term follow-up-monitoring studies (diachronic and/or synchrony-diachronic approach) aim to detect trends -- in spaces and resources - that evolve under the effects of the climate and anthropogenic pressure. The descriptive parameters proposed in this chapter do not all share the same sensitivity (or reactivity) to variations in the factors evoked; consequently, they do not present the same advantages for follow-up-monitoring. Given this fact, one must take care not to impose irrelevant follow-up on field teams.

While certain indicators may be relatively easy to monitor, they can be difficult to evaluate in a context of great environmental heterogeneity. Furthermore, some indicators are obtained through multiple observations which, despite the care that may be taken, are often spotted with errors (cf. the use of excessively large needles for cover measurements). The precision of certain indicators is also hard to estimate, for example the height of individuals, etc. In contrast, the density of individuals parameter should be considered one of the most reliable indicators of degradation states, enabling one to obtain reliable references on vegetation that are of the same type and in good shape for example.

Among the numerous methods developed by ecologists, pastoralists, animal production scientists, etc one may broadly distinguish two types of approaches: a) qualitative (non destructive) and b) quantitative (at least partially destructive). They are compared in Figure 1 below.

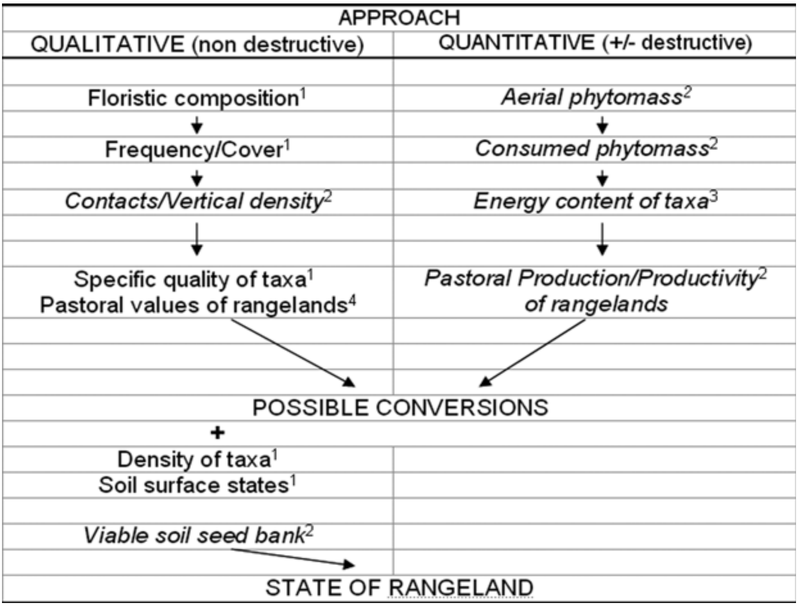


Figure 1: Diagram of proposed approaches

[1]. *data directly or easily measurable in the field*

[2]. *data directly measurable in the field but demanding in terms of time and resources.*

[3]. *data obtained through laboratory analysis*

[4]. *calculated data*

In this methodological document, it is necessary to describe these two types of approaches separately. However, for greater efficiency in the field, one usually must assume a compromise will be made between the two and plan the implementation of an intermediary approach. This compromise should be considered realistic. For the two approaches to be efficient, the same rigourous sampling principles must be respected.

Parameters other than those noted in the diagram may be observed and measured in:

- the field, for example, measurements of reflectance, etc;
- laboratories:
    - the calculation of indexes and combinations of indexes may be developed to make comparisons between stations: biodiversity index, equitability index; etc.
    - it is also possible to acquire new data, for example the energy content of a pastoral species obtained through chemical analysis (Bechtel & Nedjraoui, 1980 ; Alibes & Tisserand, 1990).

Henceforth, the choice of measurements and observations required for follow-up will be based on indicators whose importance in highlighting the state of a biotope (stability, degradation or reconstitution), an environment, or a landscape, etc, largely has been proven (Jauffret, 2001, etc). Frequent references may be found in various ROSELT/OSS documents. Their importance would encourage the retention of such parameters from the start of field operations and this on the sole basis of experience that allows one to assume, a priori with reason, which parameters will be good indicators. This is the gamble at the core of the choice of parameters whose measurement (or observation) will be explained later in the chapter. The parameters to be integrated into the minimum kit of indicators most are often chosen from the non-destructive approach. They also are distinguished by the potential capacity of being followed up on the same stations on the same sites.

It seems essential to monitor in short periods of time a limited number of parameters (minimum kit) that are sensitive, reliable, and relevant (indicators).

These indicators pertain to LCM cartography, a certain number of biological parameters, and of course socio-economic evaluation parameters. The a posteriori examination of the most efficient correlations, ones that, for example, reduce the need for destructive evaluation methods of phytomass, highlights the advantages of parameters such as density, average diameter, and height. The measurements of these allometric parameters, which are easy to make, should be required and included in the minimum kit. This minimum kit will only be useful if the measurements and parameters proposed (necessary and sufficient) permit an appropriate field diagnosis. Any that do not allow such autonomy invalidate the notion of a minimum kit. The concepts of a minimum indicator kit and of the timing between two measurement campaigns take on their full meaning here. The collection of thematic data using incoherent protocols - the pace too rapid, an assessment of parameters that are not significant or of mediocre sensitivity or reliability - in the end leads to an impasse. No useful interpretation effectively can be made and an accumulation of data is not necessarily a sign of effectiveness. Follow-up-monitoring is a perilous operation and in perpetual danger if it is too time consuming. The need to save time must promote well-thought out operational choices for field measurements.

The use of a minimum kit never excludes the possibility of returning to more complete and complex data collection if certain parametric thresholds (to be determined) are passed. Such measurements can in effect prove to be very useful for the confirmation of data.

Parameters in the qualitative approach mainly relate to composition-structure while those in a quantitative approach to the functioning and services of ecosystems.

In reality, the type of work required in the ROSELT/OSS programme requires several measurement, observation, and survey methods. We present a panorama of these methods in Table 7. In addition to being presented in the text, the methods are described in the annexes.

We will apply this diagram in the following presentation of the relevé (data collection process) for different parameters.

Let us recall a number of important ROSELT/OSS rules for the implementation of measurement and observation mechanisms:

- place measurement stations on well-identified units (biotopes) considered to be homogeneous (cf. Preliminary characterization of environments).
- schedule field measurements with a compromise between precision and work time in mind. Some indicators may be too long and difficult to measure

and it would be best to favour observations or measurements that are easier to replicate and whose significance (statistical robustness) consequently will be less risky.

– where and when possible, rely on little or non-destructive methods.

– choose measurement dates that take into account the nature of the parameters one wishes to measure (or observe). The rhythm of the vegetation that one hopes to qualify or quantify is itself fixed by climatic events, particularly rainfall, which therefore determines favourable periods. Peak vegetation (April-May in North Africa, September-October in the Sahel) is one of these favourable periods. The calendar of human activities (extension of surfaces put under cultivation, harvest, etc) that may profoundly modify vegetation is also determined by climatic events.

Table 7: Parameters and methods of measurement and observation

PARAMETER TYPE	METHOD OF MEASUREMENT OR OBSERVATION
Qualitative characterization	**Non-destructive methods**
Homogeneity	
Homogeneity of vegetation	Establishment of the species-area curve
Composition and structure	
. Composition	
Floristic composition	Research and 'Point Quadrat' method
Index of specific quality	Field surveys
. Horizontal structure	
Cover	'Point Quadrat' method
Surface states	Id
Density of individuals per taxa	Count on a basic surface
Diameter of individuals	Individual measurement
. Vertical structure	
Density of contacts	'Point Quadrat' method
Height	Individual measurement/'Point Quadrat' method
Calculated parameters	
Pastoral Value	Calculation (quality index x specific frequency)
Phytovolume	" (height x diameter)

Quantitative characterization	**Destructive or partially destructive methods**
Phytomass	Cuttings & weighings or other field evaluations
Production	Cuttings & weighings
Productivity	Cuttings & weighings

A single annual measurement campaign does not allow one to address concepts of seasonal variation, rhythm, succession, etc. A floristic list established during one vegetation peak does not acknowledge that a species absent at that time could be, in another period, the essential pastoral resource and the basis for animal alimentation. Important seasonal variations in the evolution of vegetation were highlighted by numerous works in arid and semi-arid zones. Consequently, the ideal would be to take certain measurements once a season.

The problem of choosing measurement dates in the field becomes critical when using satellite remote sensing. One must find the best fit, if possible simultaneous, between the date of the satellite's passage (providing images and data for the creation of a map) and the date of data collection in the field. Large gaps between dates can easily affect the precision of follow-up on field validation stations. This leads us to recall the importance of multi-temporal images. At least two satellite images are needed, on contrasting dates, of peak vegetation and the middle of the dry season.

In concrete field situations, we cannot insist enough on the flexible spirit needed to make timely choices of the units where measurements will be made in order to reserve the possibility of extrapolating data without too much risk. Knowledge of the dynamics and relations between different units may constitute a valuable aide when choosing the units to be measured in a way that renders the extrapolated results comprehensible. On a dynamic known series of 5 successive stages it may be wise, for example, to take measurements on stages 1, 3, and 5 with the others possibly being extrapolated.

Note that methods for the study and follow-up-monitoring of plant biodiversity will be presented in Chapter III.

Qualitative characterization of environments

This characterization calls upon two essential field data sources, one of measurements, the other observations (index of specific quality of taxa). These two sources can be complementary (floristic composition).

The measurements and/or observations of these qualitative criteria are a priori non-destructive. If a few precautions are observed, they also have the advantage of being able to be repeated regularly on the same locations, opening numerous possibilities for later comparisons. These parameters essentially relate to the concept of homogeneity and to the characterization of the composition and structure of vegetation, namely:

- floristic composition;
- plant species and vegetation cover (horizontal structure);

- taxa density (horizontal structure);
- contacts (vertical structure).

Certain interesting, synthetic parameters are produced through calculations made a posteriori, which for example is the case of:

- phytovolume (height x diameter), etc.
- pastoral value (contacts x index of specific quality).

I. Measurement and observation methods

A. Homogeneity (minimal area)

This concept is crucial in the ROSELT/OSS programme. The primary aim of the measurements and observations proposed is to characterize the units considered to be homogeneous.

The distribution of plant and soil elements is usually very irregular in arid and semi-arid zones, rendering the notion of homogeneity difficult to address. Among these difficulties is the determination of the number of measurements to take for each site on the basis of the calculation of the confidence interval applied to acquired data. In arid zones, one often must accept a quite relative reliability for the averages obtained. This is the case, for example, with standing phytomass measurement values. These are among the data showing the greatest spatial heterogeneity and for which the number of measurement plots rapidly attains a size incompatible with what is in reality possible at the level of an observatory.

Principle

The concept of area-species relations allows one to control in particular the representativeness of a vegetation. It is based on the probability that a species will be present on a portion of the space studied. Consequently, the surface considered to be representative constitutes a model adapted to the type of vegetation, studied to the extent that it takes into account the frequency of each species present.

The representative minimal area of the vegetation present is one of the major characteristics of each type of environmental unit. Data from relevant literature clearly illustrate both the similarities (types of formation) and the differences (level of human and climatic pressure) that one can observe in nature. The method is based on research by Calléja et al., 1962 ; Godron, 1970, 1971 ; etc.

Practical protocol

On a unit considered a priori to be homogeneous and sufficiently spread out, a certain number of placements (stations) where the relevés will be made (cf.

Annex 1 b) are randomly chosen. In a practical (if not very rigorous!) manner, randomness is achieved by blindly throwing a long handled tool whose point of fall will establish the start of readings. This approach is not totally inappropriate for small unit areas (rare in arid zones) which are likely to be completely covered by these throws. The mechanism is implemented gradually, the relevé consists of establishing the floristic list on larger and larger plots [the surface area doubled at each stage (1, 2, 4, 8, 16, 32 m2, etc.)]. Among the mechanisms proposed in the literature, we selected that which corresponds to the diagram in Figure 2.

The sum of species found at each stage allows one to establish the species-area curve. If the environment is homogeneous, the number of species being added to the list progressively falls to zero (cf. Figure 3a). In arithmetic coordinates on this graph, the point of inflexion of the curve of new taxa acquisition should determine the minimal area (the surface measured in m2) for this relevé. In practice, we admit that it is often necessary to take measurements on surface areas that are double the minimal area thus established.

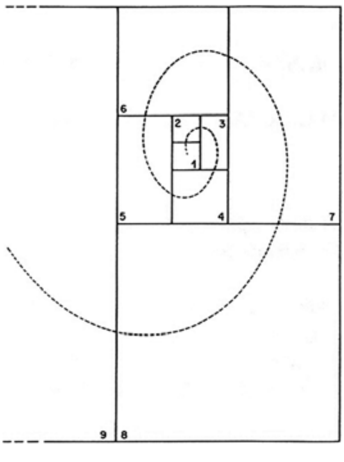


Figure 2. Mechanism for increasing surface areas in m2 (doubling at each stage) to determine the minimal area

The species-area curve may be presented in different types of coordinates: arithmetic, semi-logarithmic, or logarithmic (Figure 3 a,b,c). The latter two types generally procure good linear adjustments and allow an equation of the species-area curve as shown in the diagrams taken from Daget & Poissonet, 1969.

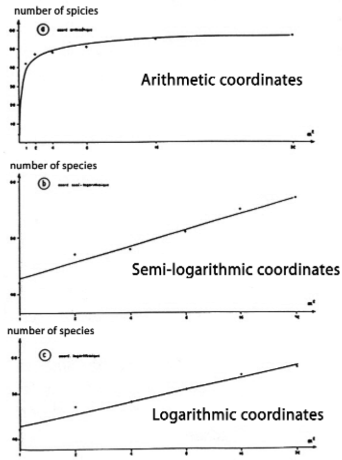


Figure 3. Different mathematical expressions of species-area curve data (Daget & Poissonet, 1969)

The interpretation of such curves leads one to qualify the unit studied and this minimal, representative area must be considered as the minimal surface required for the majority of field measures. It is on the basis of the minimal area that measurements of both plant density (qualitative approach) and phytomass (quantitative approach) will be made.

<u>*Some results*</u> Tunisia and Algeria: chamaephyte steppe minimal area = 32 m2 (Floret et al., 1978; Djebaili, 1978). Niger: Fallow field of Sida cordifolia, in exclosure = 16 m2 (Ouattara et al., 2000). " " " , grazed = 60 m2.

As has been noted elsewhere, the degradation of rangelands through over-grazing leads to the reduction in height, diameter (and therefore phytovolume and phytomass) of individuals, at least for the taxa most appreciated by cattle. Their growing scarcity and even disappearance (biodiversity regression) follow.

B. Composition and structure (Point quadrat method)

1. Floristic composition, horizontal vegetation structure, and surface states

Principle

The objective is to quantify the different elements in the structure of flora, vegetation, or an environment. To achieve this, we rely on the point quadrat method, with possible recourse to several complementary methods in special situations.

The point quadrat method was developed by Levy & Madden (1933). A model field record form, to be adapted to the needs of each situation, is given in Annex II a. Using this method, it is possible to determine during the same field operation and on the same environmental unit:

- floristic composition (cf. preceding section),
- structure (horizontal and vertical),
- surface states.

The principle of the method is to make observations (presence) or measurements (contact count) on vegetation at regular intervals along a line. The method is based on the fact that it is possible, when the number of observations or measurements is fairly high, to compare frequency with cover.

To achieve precise measurements, we opted for the point quadrat method over the method known as 'line intercept' (Canfield, 1941). During comparative studies, the point quadrat method was shown to be the most valid. Nonetheless the 'line intercept' method, whose protocol is described in the annexes (Annex II a), may be selected when circumstances require more rapid field campaigns.

Certain very homogeneous environments may be difficult to study. An example is concentric aureoles around salty depressions. The notion of a unit in this kind of situation is fairly difficult to discern. Complex zones and occasionally rapid transitions do not allow a delimitation of units that are sufficiently large or spread out to be able to rigorously apply the environmental study methods noted. In such a situation, an adaptation of mechanisms using a procedure such as the one proposed by Corre (1970) may enable one to demonstrate correlations even when modifications in the environment (and flora) are relatively continuous. The transect method is employed with recourse to other ingenious adaptations. Transects are put into place that follow the ecological variation axes that one wishes to highlight. The application of 'optimal' limits (Godron & Bacou, 1975) then allows one to separate with the greatest rigour possible two or more parts of a heterogeneous biocenose. The identification of 'cuts' in an ecological continuum then allows one to apply to the left and right of the intervals thus determined the procedures for reading point quadrat lines with sufficient confidence as far as the homogeneity of the environments one wishes to characterize. Such a mechanism may also be applied to the study of a dunal profile from the depression up to the peak then across the spit. The same type of procedure could be applied to spaces that are much more spread out.

Protocol

The simplest protocol, adopted and described here, is that adapted by Daget & Poissonet (1971). The proposed procedure is the following:

- a graduated line (often a double measuring tape) is stretched across the vegetation. A needle, as fine as possible (simulating a sighting line) is dropped at regular, identified intervals over the vegetation to the ground along the graduated line.
- two people (1 reader, 1 recorder) are required to make the relevé. At each observation point, the reader follows the needle sighting line into the vegetation and announces the observation point and the list of elements found there. This involves either plant species, of which at least one organ should touch the needle, or elements on or of the ground (litter, bare soil, rough elements, basal vegetation, etc) touched by the point of the needle as it arrives on the ground. The second observer records the information on a pre-established record form. Note that the measurements are more precise on days when there is no wind.

The length of the line as well as the space between two observation points along the line may vary with the type of vegetation. The distance between two observation points along a line is chosen to be less than the average diameter of plants and at the distance separating two individuals of this vegetation. The intervals most often used range between 5 and 20 cm with a marked preference for 10 cm. Statistical calculations based on numerous line measurements have demonstrated that the 10 cm grid is the most suitable for assessing steppic species (Nedjraoui, 1981) and probably for the survey of all open vegetation in arid and semi-arid regions.

The most frequent slip, one that leads to occasionally very important over-estimations of species frequency, is linked to the use of overly large needles and to a failure to acknowledge that readings should be made by considering the needle as a simple sighting line. As far back as 1952, Goodall signalled the problem with the diameter of the needle and noted that readings must be made as if along a sighting line (without actual width).

There is a direct relationship between the number of points read and the precision of the measurement. The length of the line is thus determined to obtain a minimum of 100 observation points where vegetation will be recorded. The number of points read therefore increases with the increasing scarcity of plant cover.

2. Vertical vegetation structure

Principle and practical protocol

The precision applied to measurements along a line of point quadrats describing horizontal structure may also be applied to the reading along a needle dropped into the vegetation describing the vertical structure of this vegetation. It involves an extension of the protocol already described. Nevertheless, one must keep in mind that this extension is quite expensive in terms of time and effort.

Protocol

Along the needle dropped vertically into the vegetation, one counts and notes the number of contacts between the needle and the vegetation (vegetation vertical density) at each observation point. The information (contact count) is collected for each separately identified plant species by distinguishing the plant stratum where they are present. This protocol is long to implement, particularly in the case of vegetation with numerous stratum (height classes).

II. Characterization of composition and structure

In reality indicators other than those concerned with composition and structure may be added which would improve and complement the characterization of environmental units, particularly function and service indicators. These two points are not actually addressed in this guide, at least not formally so. In fact, productivity may be interpreted as being a function indicator in the same way as phytomass (cf. Quantitative characterization in this chapter) is an indicator of services. The complete characterization of the functioning of environmental units is a complicated operation outside the required objectives of ROSELT/OSS. In contrast, the notion of services is to be seriously considered and represents an interesting potential future issue for ROSELT/OSS.

We will limit ourselves here to the characterization of composition and structure while keeping in mind the close relationship between composition, structure, functioning, and services. In effect, a modification of the structure of vegetation may modify its functioning as well as the quality of services provided, etc.

A. Composition and specific qualities of different taxa

1. Floristic composition

Please note again that the floristic list established, as here, at the level of vegetation relevés does not replace the need to conduct work related to plant biodiversity addressed in Chapter III.

Principle

The list of taxa found along the observation line using the 'point quadrat' method provides a succinct but very insufficient description of floristic composition. Numerous species that are either present but infrequent on the site or are small in terms of height or coverage may not be noted during the quadrat point line reading. Therefore, one cannot be satisfied with this result.

Practical protocol

The establishment of the floristic composition of a given unit (a floristic list that may be considered complete) requires, in addition to the relevé of the list of species on the point quadrat line, complementary canvassing along the sides (notion of extension) of the observation line on a surface that is at least equal to the minimal area. This requires a certain botanic competence among staff responsible for such assessments.

Interpretation

The floristic composition (abstraction without considering abundance) may be the focus of interpretations separate from those of the data obtained on other parameters studied simultaneously:

The Jaccard coefficient of floristic similarity

This coefficient enables comparisons between stations. The most well-known is the Jaccard coefficient of floristic similarity (1902, 1928; in Roux & Roux, 1967). On the basis of the following mathematical formula, the coefficient Pj expresses the proportion of species in common (c) in relation to the species (a and b) particular to each survey reading compared two by two.

$$P_J = \frac{c}{a+b-c} \times 100$$

Where a = number of species on list a (relevé A),
b = number of species on list b (relevé B),
c = number of species in common.

elevés made on the same site will have higher coefficient values in the same way that geographically distant sites presenting the same ecological conditions sometimes do.

Hamming distance
Daget et al. (2003) propose, for floristic comparisons between two relevés, the calculation of the Hamming distance using the following formula:

$$H = 1 - J$$

where J is the Jaccard order coefficient explained above.

Daget et al. (op. cit.) adopted the following thresholds:

- very weak floristic difference : $H < 20$,
- weak " " : $20 < H < 40$,
- average " " : $40 < H < 60$,
- strong " " : $60 < H < 80$,
- very strong " " : $80 < H$

Other indexes enable one to weigh species as a function of their respective contribution (abundance) to the vegetation on a given site.

It is always possible to improve interpretations by associating other parameters relative to taxa (species, sub-species) with floristic composition. Some research already has addressed the relationship that exists between biodiversity and pastoral management (Le Floc'h, 2001). It is advisable to gradually collect information on the maximum number of biological (biological type, phenology, life traits) and bio-geographical (naturalized, sub-spontaneous, endemic, etc) features of the taxa on an observatory, and on their possible need to be protected. This type of question will be treated more fully in Chapter III.

2. Specific quality index (Is) and other biological trait categories

Principle
The pastoral value of a plant species draws from several parameters: its energy content and palatability as well as its speed of growth, possible toxicity, etc. Livestock owners and shepherds have subjective knowledge on the subject that, while often poorly formulated, can be concrete and possibly wise to collect.

Evaluations of the specific quality index of pastoral species are fairly numerous (Algeria : Aïdoud et al., 1982 ; Egypt : Ayyad & Le Floc'h, 1983 ; Mauritania : Mosnier, 1961 ; Tunisia : Le Houérou & Ionesco, 1973 ; El Hamrouni & Sarson, 1974, etc.).

It has been noted that when the index of a taxon is well-determined it is also found to be strongly correlated to its energy content. The most digestible taxa with high energy contents are sought out by animals, these therefore have a high Is (Nedjraoui, 1981).

Practical protocol
In practice, the procedure adopted is to class perennial and annual taxa according to the average appreciations estimated by a certain number of livestock owners and shepherds interrogated on the subject during field surveys. One may finish with classes ranging from 0 (toxic, not consumed) to 10 (very good species, greatly sought out by cattle), or 0 to 5. The relative grade accorded a taxon constitutes its specific quality index (Is) as it is used in the formula to calculate the pastoral value of a unit presented previously.

Interpretation
An initial approximation of the quality of rangelands may also be obtained through the simple examination of the Is index values of the species on the rangeland. A very degraded pasture, and therefore one with little value, will be characterized by a relative abundance of taxa with weak Is index values.

The determination of Is index values may be made at a national level in a country (Le Houérou & Ionesco, 1973 for Tunisia) or at a regional level (Ayyad & Le Floc'h, 1983 for the N.W coastal region of Egypt) as needed. For the same taxon the appreciation of this index may vary according to the ecological context and animal pressure. A taxon refused on a site that is little grazed and where the pastoral offer is therefore high may be better appreciated elsewhere where the pastoral offer is more limited.

We also note that, as has already been shown, particularly by Waechter (1981), a taxon's relative level of acceptability depends on the physiologic state of the animal, the phenology of the taxon, the way the flock is driven, etc. Gnawed by hunger, animals are capable of modifying their consumption instincts. Taxa (Thymelaea hirsuta and Asphodelus microcarpus) that are ignored completely on the steppes of Tunisia are, in contrast, consumed well in north-west Egypt. The Is of these taxa is weak in Tunisia and high in Egypt. There is thus room for reflection when it comes to interpreting this parameter.

The results obtained produce different illustrations that can take into account different categories and communities of taxa, for example:

- palatable taxa a) perennial: graminaceae/vegetables/other
  palatable taxa b) annual: " "
- non-palatable perennial taxa

B. Horizontal structure: frequency, cover, and density of taxa and vegetation

1. Frequency/cover

The procedure is the same as the one already presented in this chapter.

Practical protocol complementary to the point quadrat method

The point quadrat method has been proven difficult if not impossible to use for tall woody plants (trees). For this reason, numerous substitute protocols (e.g. radiometry, etc) have been proposed, amongst which we adopted:

- emlen mirror periscope (1967). Described by Hamidou (1987), it allows one to follow the same observation method as in point quadrat. The principle is that this instrument allows one to take sight readings on tall woody plants immediately above the line points where readings were taken for herbaceous and small shrubs;
- Crown projections. This method, fairly rapid but relatively imprecise, consists of measuring along a line -- and if possible when the sun is at or close to its zenith -- the shadow of the crown or to determine the projection of this crown on the ground;
- enumeration for the analysis of woody grazing plants. The diameter of each sprig of woody plants is measured, to the centimetre, at each observation point and species by species. The evolution over time of these diameters also reflects the evolving state of all stands. In young stands, strong variations in the amount of regrowth is only translated as a weak modification in woody plant cover; in this case, the exact count of the individuals present on the reference plots constitutes a solution. On these plots, the average diameter of stems is measured using a flexible tape with graduations spaced at 3.14 cm (the value of ?) to convert circumference into diameter. One 3.14 cm measure of circumference is equal to 1 cm of diameter. The tape is wrapped tightly around the stem, permitting the direct reading of the average diameter. The alternative is to use a normal measuring tape and divide the value obtained by 3.14.

Calculation and interpretation

Given the role of woody plants in certain plant communities, this is a necessary operation. Cora & Daget (1996) propose a protocol to compare results concerning woody plant counts. The standard statistical parameters (maximal and minimal diameters, average and median diameter, standard deviation, basal area) may be assessed or calculated.

For each taxon noted along a point quadrat observation line, it is possible to proceed to different processing and interpretations. Clearly, the results of these measures may be interpreted separately (parameter by parameter) or together, which is most often preferred in the ROSELT/OSS framework.

a. Overall plant cover
The record form (cf. Annex I a) provides direct access to information concerning the number of points where at least one taxon was found and, through the difference with the total number of points 'read', the number of points without vegetation. The overall frequency (often given as the global vegetation cover R) expresses this data as a percentage of the total number of points read.

This evaluation of global frequency can only be equated with the overall vegetation cover if it satisfies the conditions of probability evoked in the following section, Specific frequency. 'Bare soil' (absence of vegetation at this point) is the opposite of 100% overall cover. Woody plant strata are very persistent and their cover only becomes a reliable and sensitive indicator of degradation over periods of 5 to 10 years. Herbaceous strata are much more reactive (even excessively) to rainfall changes and environmental degradation.

The evaluation of taxon cover, as well as that of vegetation, leads to an appreciation of the state of vegetation, its evolution (reconstitution, stability, or degradation).

b. Absolute specific frequency (SF)
The specific frequency (SFi) is the number of observation points where a given taxon i is noted during a count along the observation lines. A chart (Figure 4) allows one to know the confidence interval of the SF observed. For example, for a taxon with a frequency f (x axis) = 10%, a set of 200 measurement points will give 95% probability p (y axis) of having a result between 6 and 15%. This means that the greater the number of relevés, the smaller the confidence interval (bracket of 'good' values). There is thus an advantage in increasing the number of observations. Following the same reasoning, field measurement results are more reliable for the most frequent taxa.

f: observed frequency (in %) for a sample size n
p: proportion (in %) of the population sampled

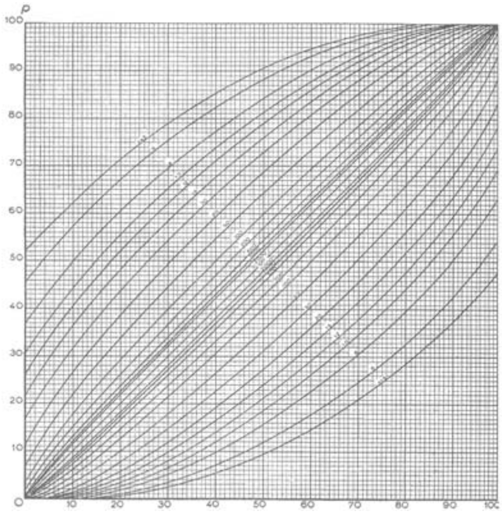


Figure 4: Chart giving the confidence interval as a function of frequency

c. Centesimal specific frequency (CSF) and specific cover

The CSF is the ratio between the number of points where the taxon is present and the number of points in the relevé, all in percentage points. In other words, the centesimal specific frequency (CSFi) of taxon i is equal to the ratio, expressed as a percentage, of the number of times (ni) where the taxon i is found along the line to the total number of points sampled:

$$CSF_i\,\% = \frac{n_i\,x100}{N}$$

The specific frequency expresses the probability of the presence of a taxon on a unit sampled. The precision of the measurement will depend on the number of units sampled. The CSF leans towards a limit which, when there are an infinite number of points, equals the probability of the presence of a taxon on the unit. If the relevé points are considered as having no dimension, the probability of presence is synonymous with the cover of the taxon. In fact, 100 observation reading points of vegetation is considered necessary to class frequency with cover.

The cover of a taxon is defined as being the percentage of the surface of the station covered by the vertical projection from the ground of aerial organs of the taxon.

Most often, and especially once vegetation attains a certain cover threshold, the total cover does not coincide with the sum of the covers of the taxa present. In effect, several taxa can be present (and thus noted) at the same observation reading point.

It remains possible to establish relations with other parameters. Jacquard et al drew the graph in Figure 5.

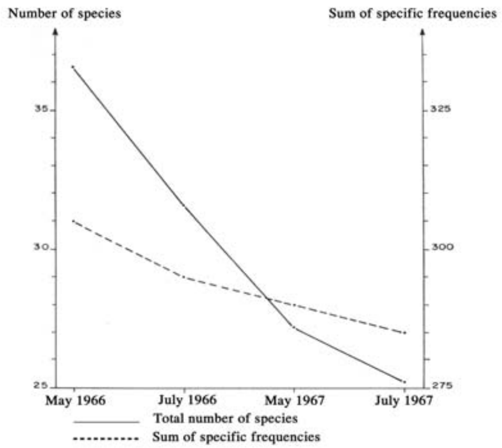


Figure 5: Variations of the total number of taxa and the sum of specific frequencies in time (In Jacquard et al, 1968)

- Specific contribution

The specific contribution (SCi) of a species i defines its participation in plant cover. It is equal to the quotient of the taxon's centesimal specific frequency (CSFi) divided by the sum of the specific frequencies of all the taxa found during the relevé (Daget & Poissonet, 1971).

$$SC_i\% = \frac{CSF_i x100}{\sum CSF_i} = \frac{n_i}{\sum n_i} x100$$

On all open formations with little cover in arid zones, relatively sparse plants (clumps, etc) can be spread out and it is interesting, in order to have a more precise idea of the state of plant cover, to weigh the specific contributions by the overall vegetation cover (R). The corrected value SCi' expresses the real contribution of the species i to plant cover (Aidoud, 1983).

$$SC_i'\ \% = SC_i x \frac{R}{100}$$

In special and extreme cases, where only a single species is found at each point along an observation line, one may say that the centesimal specific frequency is equivalent to the specific contribution (Hirche et al, 1999).

$$SC'_i = CSF_i$$

Remark

One must keep in mind that the higher the frequency of a taxon, the more the data is reliable. Even on permanent lines, it is never certain that the absence in a given year of a taxon of very low frequency may be interpreted as an index of degradation. Chance may lead one to 'miss' such taxa. It is only for the taxa present above a certain frequency that interpretation is relatively reliable.

Daget & Poissonet (1970) used a graphic method of illustrating the frequency distribution of taxa. This method allowed them to highlight (in herbaceous vegetation of Cantal - France) the appearance of bi-modal curves (increasing frequency of certain taxa and increasing scarcity of others) in taxa distribution in environments undergoing extensive change.

2. Density of individuals

Let us note again that this is one of the most reliable, sensitive, and significant indicators and it should be included in the minimum kit as soon as possible.

Principle

The concept of taxon density, expressed as the number of individuals of each taxon per surface unit (m^2), is crucial to the characterization of units. Over-grazing may be easily detected when the density of good pastoral species (cf. § 1b 'Specific quality index) begins to decrease. The end phase of over-grazing is marked by the disappearance (or extreme scarcity) of taxa that can be consumed by animals and the spread of non-consumable taxa.

Practical protocol

Density corresponds to the number of individuals of each species present on each surface unit. For perennial plants, this measure (count) is taken on surfaces corresponding to the minimal area discussed earlier. For annual plants, whose density generally is higher, the count is made on 1 m^2 plots.

The application of this protocol assumes a relatively regular plant distribution. In spontaneous steppic formations, the heterogeneity of plant distribution sometimes makes it difficult to be satisfied with the density observed on a surface such as a minimal area. In such situations with extensive heterogeneity, one can always increase, sometimes considerably, the number of plots to be counted.

For perennial grassy species (Cynodon dactylon, Stipa tenacissima, Panicum turgidum, Stipagrostis pungens, etc.), and for species that essentially reproduce through vegetative multiplication, the determination of individuals is not evident and one may fall back on counting clumps even if one is not sure that each represents a unique species.

Interpretation

The interpretation of results may be achieved by comparing the density of the same taxa in the same types of vegetation or, more rigorously, by comparisons over time (follow-up) on the same site.

3. Diameters of individuals

Concept

Such rapid measurements may be made along transects. They are easily associated with the concept of density (but also of height) if one takes the measurements of these parameters on the same individuals. They will provide an interesting indication of the state of the development or of the degradation of a given stand.

In reality, plants grow according to a characteristic design that can be classed according to known geometric volumes (frustrum, cylinder, double inverted and stacked cones, etc). The measurement of diameter consequently may allow later calculations of phytovolumes (basal diameter, crown diameter, etc).

Practical protocol

Generally the procedure to determine the average diameter of an individual's crown consists of measuring the largest diameter followed by the diameter that is perpendicular to it.

The measurements of diameter on trees may be made either on the trunk (at the base or at a man's height, 1.30 m) or on the crown. The projection on the ground (shadow when the sun it at its zenith) of the crown enables the measurement of the crown.

It is also possible, particularly for perennial grassy tufts, to refer to the basal diameter.

Interpretation

The diameter(s) are frequently associated with height in the calculation of phytovolume (cf. 'Calculated parameters').

4. Surface states

The collection of data about these states is described here for coherence, these data being collected jointly with those of structure in the procedure described previously.

Escadafal (1989) defined soil surface as being the volume of transition between the atmosphere and pedological cover. It refers to the interface between the atmosphere and the soil, an interface that is, in arid zones, very thin. Consequently, soil surface appears very often to ecologists as being the external character of a 'vegetation substrate', in other words, belonging strictly to the ground (Godron et al, 1968).

The presence of special structures (thin slaked surface crust, etc) on soil surfaces is characteristic of arid regions. This soil surface presents other elements such as pebble and gravel paving, sandy plates, algae, or salt efflorescence. Among these elements, one must not omit the possibility that the needle dropped into vegetation may touch the basal part of a plant. The concept of basal cover has occasionally been mentioned elsewhere but it will no longer be a topic in this document.

Concept

Soil surface includes the superficial part of pedological cover in direct contact with the atmosphere and other living beings. The surface therefore becomes a means of diagnosing environmental conditions.

The different components noted above influence infiltration, plant development, and soil sensitivity to hydric erosion and sinking as was shown, for example, in Tunisia (Escadafal, 1989 ; Floret & Pontanier, 1982). Studies show that soil surface roughness (ploughed land, etc) favours water infiltration.

The descriptive method proposed by Escadafal (1989), one based on observation at the macroscopic level, was adopted.

To close, we note that from the start of research on the use of remote sensing in arid zones, the consideration of soil surface characteristics appeared indispensable in the interpretation of satellite images (Long et al, 1978).

Practical protocol

At each point along the chosen line, the needle is dropped vertically at the observation reading points to just touch the ground. Different soil surface elements must be noted, amongst which are: bare soil, sand, glazed or flaked crust, pebbles, gravel, blocks, source rock, litter, basal part of vegetation, etc.

A mistaken practice is to limit the observation of soil surface states to the points without vegetation (notion of bare soil mentioned above). This is a grave error that erases any interest in the interpretation of the data.

Interpretation

As for plant taxa, the frequency of diverse states can possibly be classed with cover (in %). Fragmentary and qualitative as it may be, the resulting description provides an overall sense of the organization of different constituents and their relative disposition.

The interpretation may be done from the angle of different constituents' cover.

The proportions of these diverse states linked to data collected on vegetation and flora provide information on an environment's health. In arid North Africa, the degradation of plant cover generally leads to the reduction -- by deflation -- of sand deposits which ultimately hampers the development of annual herbaceous species.

A comparison of data on surface states obtained at points without vegetation with data obtained at points with vegetation would certainly be full of information regarding the actual role of vegetation and thus on the cover thresholds favouring phenomena like deflation, for example.

One of the most informative interpretations concerns the search for thresholds in the relation between overall vegetation cover and certain surface states such as the presence of sand deposits. Such a threshold marks the rugosity of vegetation that favours capturing sand blown in the wind in addition to diasporas (seeds) and explains the relatively greater abundance of an annual plant stratum.

C. Vertical structure

1. Density of contacts (Specific contact contribution)

Concept

Alone, the reading of the presence of taxa along a needle dropped into vegetation (cf. point quadrat, § 2 of this chapter) furnishes no details on their design. When vegetation is relatively dense, it remains possible to take these differences into account by the number of contacts of the needle dropped into the vegetation. It is evident that a relationship exists between this number of contacts and the weight of the standing living matter (cf. phytomass).

Practical protocol

This protocol already was described (§ 2 b of this chapter). Some species may therefore have several contacts with the needle during a relevé, this is particularly true in the case of perennial graminaceae.

In general, the number of contacts is measured for vegetation made up of dominant, perennial species. When vegetation is confined in the lower stratum, counts become tricky to undertake and results are difficult to interpret.

Interpretation

The specific contact contribution (SCCi) of a species i, is the ratio (in %) of the total number of contacts with the needle of this species (Ci) to the cumulative sum of contacts for all points 'read' (N).

$$SCC_i = \frac{C_i x 100}{N}$$

In formations under strong anthropogenic pressure, the 'contact density' provides distinctly more precise data concerning the actual phytovolume than that produced only by exterior parameters of diameter and height (cf. following §).

By comparing different situations, the number of contacts conveys the state of individuals of a taxon and permits an evaluation of the relative intensity of degradation. It is well evident that certain extremely over-grazed individuals sometimes sprout very long new branches even though the vegetation has little density.

2. Height of individuals

Practical protocol

The usual measurement of this parameter remains the average height of individuals. However, in certain situations the notion 'vegetation roof' was used, noting at each measurement point along the point quadrat line the maximum height of the vegetation. This 'vegetation roof' may then be graphically illustrated.

Note that height is to be associated with form. Thus degradation caused by grazing sometimes leads to modifications in forms ('en diabolo' carriage, etc) without the total height (being too high for grazing) being affected.

The procedure used to measure this parameter in order to assess phytovolume can rely on the measurement of particular parameters such as trunk height, total height, height at the maximum diameter, diameter of the crown, basal diameter, height under the canopy, etc, to adapt to the particular situation of the chosen geometric form.

Interpretation

After one has chosen a form (straight cylinder, straight or tilted cone, sphere, etc), turning to the notion of phytovolume allows one to determine the volume occupied by a sample using measurements such as diameter, circumference, height, etc.

Diameters, heights, phytovolumes, and other structural parameters allow, in association with, for example, measurements of phytomass, the establishment of calculated correlation equations authorizing the easing of field work (cf. § Quantitative approach, measurements according to a mixed or indirect approach).

D. Calculated Parameters

1. Pastoral value (PV)

Concept

The concept of pastoral value, conveying the quality of grazing lands, was introduced by de Vries et al (1942) and developed by Daget & Poissonet. It is based on the fact that it is possible to express the quality of a pastoral vegetation type by crossing, for each perennial or annual taxon (or category of species) present, the value of its cover (cf. point quadrat line method) with the quality index (Is) of this taxon (or category of taxon).

Protocol

The general calculation formula for a station (or for a species) is the following:

$$PV = 0.1 \sum_n SPC_i \times Is_i$$

where n = the number of taxa on the station
SPC : specific contribution (in %) calculated as already presented
Isi : specific quality index of taxa (cf. § afferent 1b) whose maximum value is 100.

Initially defined and developed for temperate zones of Northern Europe (de Vries and de Boer, 1959; Daget and Poissonet, 1972), the formula leads to over-estimations of pastoral value when applied to arid zones where plant cover is weak. This may be corrected by using one of the following formulae:

a) the first (Aidoud,1989) is:

$$PV_i = 0.1\ R.\ \Sigma_n\ SC_i \times Is_i$$

The pastoral value is weighted by the overall cover (R) of the vegetation (in %).

b) the second (Hirche et al., 1999) is calculated like this:

$$PV_i = 0,1\ \Sigma_n\ SFi{*}Isi$$

with SF_i: Specific frequency expressed in % of species i.

This formula takes into direct account the weakness of plant cover.

The pastoral value has only a relative, and therefore comparative, significance in a given context (local or regional). To apply it on a larger scale (country, etc), it must be calibrated using a chart establishing the relationship with pastoral production, which measured by weight is an absolute attribute.

A concrete example of a vegetation assessment and the different parameters noted above are given in the table that follows.

Concrete example of the interpretation of measurements.

The Menzel Habib Observatory (situated approximately 50 km north-east of Gabès, Tunisia) is a representative example of the arid zones of North Africa where natural equilibriums have been disrupted since the 1960s by strong anthropogenic pressure (essentially farming but also over-grazing and wood collection) notably following land privatization. The example presented (Table 8) concerns a station of the steppic type most widespread on sand: the Rhanterium suaveolens steppe in a good state (Floret et al., 1987 modified). This type of steppe is today in danger due to its attractiveness for farming. The results from a point quadrat measurement (240 observation points) are interpreted from the overall cover (RT) to the pastoral value (PV) of the station.

Table 8: Breakdown and interpretation of brute data collected (field record form) by the 'point quadrat' method

Date 11 Nov. 1974 Location : Zougrata Plain Author : Saïd Sassi

Length of observation line = 12 m, with an observation point every 5 cm, for a total of 240 points read (a)

Number of points where vegetation is present 162 (b)

Cover calculated from the vegetation RT = b/a x 100 = 67.5 %

Percentage of the surface without vegetation 'bare soil' = 32.5 %

SPECIES	Number of points where the species is present SF	Centesimal specific frequency (CSF) en %	Total number of contacts	Specific contact contribution (SCC) in %	Specific presence contribution SPC in %	Quality index Is	SPC x Is
Rhanterium suaveolens	120	50	208	67.9	55.1	2	110.2
Plantago albicans	41	17	41	13.3	18.7	5	93.5
Medicago truncatula	22	9	22	7.2	10.1	5	50.5
Picris coronopifolia	17	7	17	5.5	1.7	4	30.8
Hammada schmittiana	7	3	7	2.3	3.3	1	3.3
Launaea resedifolia	6	2	6	2	2.1	5	11.0
Lobularia libyca	2	1	2	0.6	1.1	1	1.1
Cutandia dichotoma	1	+	1	0.3	0.4	4	1.6
Daucus syrtica	1	+	1	0.3	0.4	3	1.2
Hippocrepis bicontorta	1	+	1	0.3	0.4	4	1.6
Centaurea dimorpha	1	+	1	0.3	0.4	0	0
Total		90.6	307	99.8	99.8		304.8

Calculation of pastoral value (PV) = 0.2 ? (SPC x Is) x R = 0.2 x 304.8 x 67.5 = 41.1

Interpretation

– the overall vegetation cover (vegetation was present at 162 of the 240 points read) reached 67.5%.

– Rhanterium suaveolens (a short woody plant species belonging to the Asteraceae family), appreciated by cattle, was 'contacted' 120 times on the 240 points along the line where the vegetation was surveyed, and has a specific frequency (SF) of 120 and a centesimal frequency (CF) of 50%. Its specific contribution [the ratio between its CF and the sum of all the species' CF (90.66%)], is equal to 55.1%. Its specific contact contribution [ration between the total number of contacts (208) and the sum of contacts of all the species present (307)], is equal to 67.7%.

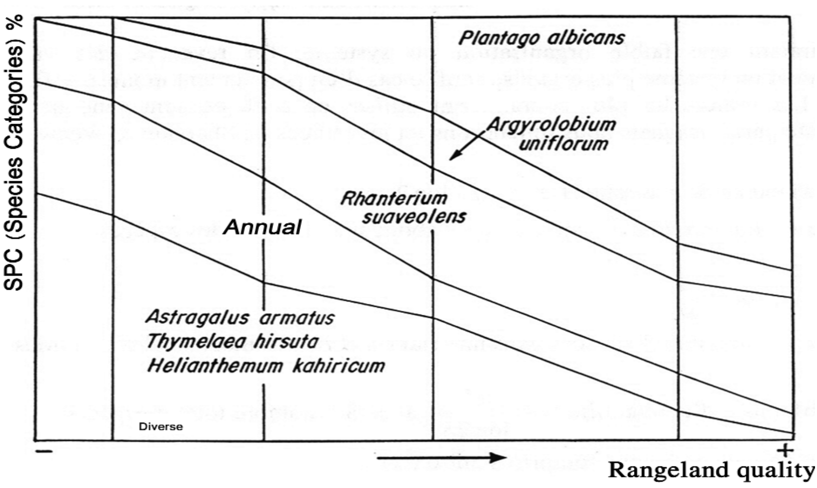
– the relative pastoral value (PV) of this unit, calculated from the sum of the specific presence contribution (SPC) of all species x their specific quality index Is, and taking into account the total vegetation cover RT, is:

$$PV = 41.1$$

with $\sum SPCi \times Is = 304.8$ and $RT = 67.5\ \%$

Two examples of illustrations of the results are given in Figures 6 and 7.

Figure 6: Graph of the synthetic expression (by category)
Floret et al. 1987



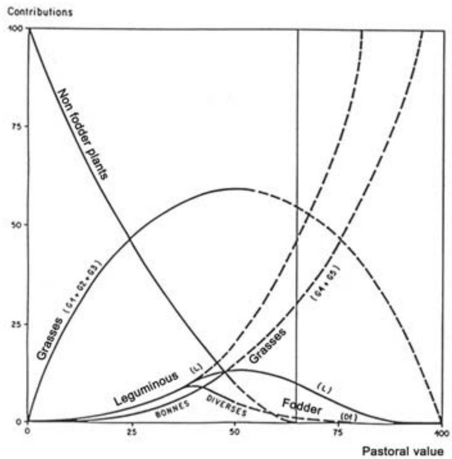


Figure 7: Example of a synthetic diagram by D.M. de Vries representing grasslands sampled in Margeride, France (in Daget & Poissonet, 1971)

2. Phytovolume

The necessary measurements (diameters and heights) will be more or less numerous according to the schematic, geometric form adopted.

Interpretation may concern form as much as the phytovolume itself. It appears that diverse human practices, in particular those linked to the pastoral practices, can modify vegetation. Thus on a certain number of shrubs in arid zones, grazing can lead to a carriage said to be 'en diabolo', particularly for thorny plants.

Quantitatice characterization of environments

The placement of monitoring plots, whether they are to be permanent or not, often involves determining a plot shape that is easy to access and which will not get stamped down through repeated observations over time. Very elongated, small (0.5 to 1 m) rectangular shapes are preferred as observations can be made from outside without the observed plot being disturbed.

3. Phytomass

A. Definition and concepts

Above-ground phytomass is the quantity (weight) of plant material, living or not, present above the surface of the ground per unit of surface at a given moment. In a population in a satisfactory state of development the above-ground phytomass constitutes the major part of the total phytomass.

Standing above-ground phytomass is the quantity of standing vegetation present, per surface unit, at a given moment. It is generally expressed in kilograms of dry material per hectare (Kg/DM/ha).

Standing 'green' phytomass distinguishes standing phytomass from dead material which is part of the standing necromass.

Necromass includes the ensemble of dead material, whether or not attached to above ground parts, present per unit of surface at a given moment. The necromass that has fallen to the ground is called litter.

Total phytomass is the underground phytomass (weight of living and dead roots per surface unit) at a given moment and for a known surface added to the above-ground phytomass.

Consumable phytomass is the quantity of standing plant material that can be consumed by domestic animals. For different reasons, all parts of a standing phytomass are not consumable: difficult access on thorny plants, overly fibrous branches, parts that are out of reach, etc. The phenomenon is especially important in trees because it is evident that the majority of small ruminants only consume leaves situated between ground level and a height of 1.5 meters. This notion must be well thought out if one wishes to quantify it, as with the methods explained below.

To measure primary production (cf. § B), one needs to know the phenology of the phytomass' constitution.

We must insist again on the fleeting nature of such data when one is aware of the speed of vegetation development, especially in the Sahel. There is a fairly grave dilemma in so far as the cost in time and resources does not seem to be greatly compensated by extremely valuable data collected. Nevertheless, the theme will be pursued below.

B. Measurement protocols

1. Destructive method

Protocol

The conditions of the measurements on which data interpretation will depend must be clearly defined. Among the conditions to highlight are: presence or absence of pasture land (and level of pastoral pressure), position vis-à-vis the phenologic cycle of dominant species, climatic situation (and especially rainfall) of the year of vegetation underway, etc.

The minimal area constitutes an appropriate base for measurements of weight for perennial vegetation.

Vegetation cut to the ground on a given surface (minimal area) is:

– sorted in order to separate living material from dead. The sorting may also be perfected by separating species or, going even further, separating leafy branches of wood, etc.

– weighed on site to know the fresh weight. A sample of known green weight is then taken and dried in an oven at 75 to 80° C for over 48 to 72 hours (until a constant weight). The ratio (%) between the green weight and the dry weight of the sample brought to the laboratory becomes the coefficient which, when applied to fresh weights in the field, will convert data into dry weights. It is advisable to sort the physionomically dominant species and weigh them separately in the field.

The quotient green weight/dry weight varies with the seasons and the state of the vegetation; each time, one must calculate anew the coefficient to be applied for conversions into dry weight.

For annual vegetation, the measurements are made on 1 m^2 plots with a large number of repetitions given the very random character of plant distribution in this stratum. The second step in the procedure (sample, weight, drying) is the same for the two categories of plants.

A major problem in the application of this protocol is the determination of the number of cuts to make to attain a sufficient representation. This number (generally from 10 to 20) is dependent on the relatively great homogeneity of plant distribution. In principle, the number is determined by calculating the cumulated average to obtain a confidence interval of 5%:

$$p = 2\,\sigma / m\,\sqrt{n}$$

where p = degree of precision; = standard deviation; m = mean; n = number of plots sampled.

It remains possible, for the same reason as we mentioned for the area-species curve, to opt to establish an area-phytomass curve. The measurement principle consists of taking a series of biomass cuts on surface squares increasing at a power of 2 (4, 8, 16, 32 m^2). The initial squares are chosen at random.

Interpretation

Phytomass (dry weight) is considered in the context of a hectare (kilograms of dry material per hectare = Kg/DM/ha) which allows access to comparative values.

Each series will include n measurements on a given area in a given biotope. The averages and the variation coefficients are calculated.

It is also possible to calculate and represent fluctuations in the variation coefficient (ratio of the standard deviation to the mean) in relation to increasing surface units of an area-phytomass curve. Variance analysis allows us to define the most representative minimal sampling surface which will correspond to the monotone inflection point of the curve. This method, which is very long to implement, is rarely used. For the choice of minimal areas, one may turn to the findings of authors who have worked in similar regions.

Daget (1996) notes that because pasture vegetation is by nature heterogeneous, the analysis of phytomass data using traditional methods based on the Gaussian distribution of measurements hypothesis is not appropriate. To assess phytomass, the same author suggests turning to the median of measurements and non-parametric tests (described, for example, by Sprent, 1992) for comparisons. He adds that the confidence interval of the median is calculated by classing n values measured according to an increasing order and that the median is the ranked value: (n+1)/2.

The phytomass measured at a given moment does not represent the total green material produced during a vegetation cycle, in other words, the primary net production. At least among over-wintering species, this phytomass only represents the part of produced material that still remains, other parts produced during the same vegetation cycle having already been consumed, died (necromass), or no longer in production. As has been abundantly illustrated in the work of Fournier (1991) on some West African savannahs, for example, the various main taxa -- to consider just them -- of a plant formation have vegetal cycles staggered over time. Consequently, it may be interesting to follow the annual kinetics of phytomass but this largely surpasses the scope of the ROSELT/OSS programme.

The phytomass at peak vegetation of the dominant species in a formation already constitutes a critical contribution to knowledge of the formation's functioning. But one must take care to indicate precisely the moment in the species' cycle the measurement is made, and if possible the phenological stage reached by the co-dominant species.

2. Mixed or indirect methods said to be 'little' or 'non destructive'

The quantitative methods presented above are destructive and can be singularly limiting if one aims to maintain follow-up, even in the medium term. We therefore give special attention to the methods grouped here under 'Mixed or indirect methods'.

These methods are not equally as easy to apply, nor does each hold equal interest. Among the numerous methods described in literature, preference is given to the following methods. However, the choice may also result (or benefit) from the scientific and technical skills available at the level of observatories.

a. Observer training method

Protocol

This method was used greatly (Floret & Pontanier, 1982, etc) for the study of steppic vegetation in arid Tunisia. The method involves the execution of field measurements inspired by those of Pechanec & Pickford (1937).

For each type of unit where phytomass is to be determined, approximately 30 basic plots (each the size of a minimal area) are chosen at random. On each first plot in a set of three a visual estimation is made of the green weight of each clump. This is then cut to the ground and weighed. The data obtained (the estimated then measured weight) are all recorded. For the two following plots in the set of three, the weight of each clump is only estimated and this estimation is recorded. The same procedure is repeated for each type of environment for the 9 other three-plot sets and the data also are recorded. The observers, who should always be the same when possible, progressively improve their visual evaluation. In any case, the results are corrected by the average error calculated on the individuals that were both estimated and weighed (1 plot out of 3).

Interpretation

The results may then be expressed in dry weights after a sample has been sent to the drying oven and the correlation between green and dry weight has been calculated.

The method offers the advantage of being both economical in terms of time - which provides the possibility of increasing the number of samples - and much less destructive.

b. Establishment of regression equations method

Concept

As we already noted in the discussion of measurements of vegetation structure (diameter, height, and phytovolume), an 'allometric' method (Gounot, 1969; Heim, 1977; Aidoud, 1983) allows, based on knowledge of the relations that exist between phytomass and certain parameters that are easily quantifiable (cover, density, phytovolume), a relatively reliable evaluation of phytomass. The relations are expressed by regression equations and correlation coefficients between the different variables used.

Protocol
The first step is to measure a set of parameters (height, diameter, etc) of a large number of individuals of different dimensions. After these same individuals are cut, weighed green, dried, and weighed dry, correlative results are expressed in the same manner as for direct measurements.

Interpretation
Weak relationships were found between the measured values of parameters and the standing phytomass for short woody bushes and perennial graminaceous clumps. Numerous researchers (Floret, 1971; Joffre, 1978; Gaddès, 1978 cited by Floret & Pontanier, 1982; but also Daget & Poissonet, 1971; CRBT, 1978; Aidoud, 1983; Nedjraoui, 1990; Boughani, 1995, etc.) have found correlations between a certain number of qualitative and quantitative parameters that then allow an estimation of phytomass in an only slightly destructive context. Once past the fairly complicated beginning, the method is fairly rapid because it then suffices to measure the qualitative allometric parameters already used to establish the charts and calculate the equations. Reading the charts allows the evaluation of phytomass by knowing the values of the qualitative parameters.

Depending on the taxa, formulae have been found by researchers that give good correlations between: a) the average diameter of the crown and the green weight (Joffre, 1978 for short woody plants), b) the average diameter, the height, and the green weight (Joffre, 1978; Aidoud, 1983; for short woody plants), c) the average basal diameter and the green weight (Gaddès, 1978 for perennial graminaceous clumps).
This method is developed further with an example in Figure 12 (Annex II b).

c. Radiometric method

Concept and protocol
This non-destructive method (Grouzis & Methy, 1983; Boutton & Fleszen, 1983) used to estimate phytomass, measures the reflectance of vegetation cover in red (0.600 to 700nm) and near-infrared (0.750 to 1.00nm) bands. Relations exist between these calculated indexes and standing herbaceous phytomass, or more exactly, photosynthetic activity, has been shown time and again. A lack of chlorophyll activity when vegetation becomes senescent (or at rest) renders the method unusable.

The procedure consists of measuring the reflectance, then of calculating the vegetation indexes (NDVI, TSAVI, etc). It is necessary to take phytomass measurements (destructive measurements) on the ground on representative reference sites (spread out and homogeneous units). These phytomass data are then correlated to index values measured at the same sites. One may then establish the regression curve and transform in all points of an image the index values (NDVI, TSAVI, etc) in phytomass. The procedure is effective if one is satisfied with results expressed in phytomass classes.

For example, an experiment was run in Niger for a programme covering a 1.5 million hectares area with a four-year series of measurements of herbaceous phytomass at the peak of vegetation. This experiment was based on a selection of 36 SPOT sites of 60 m x 60 m and a protocol of 36 on-ground measurements per site. During the most favourable years (good rainfall and good adjustment to vegetation peaks), the precision ($R^2 = 0.74$) was considered good. However, there is a consensus that the method remains too expensive to be used outside of an experimental context.

It is possible to simplify the procedure by practicing radiometric measurements with the aide of a portable instrument. Here, too, the method is considered reliable for graminaceae-based biocenoses as long as the ratio of green material/total biomass surpasses 30%. In contrast, the method is relatively imprecise for dry vegetation. It is necessary to calibrate the instrument for each type of vegetation and at each phenological stage.

The method loses its reliability if the stratification of the population (structure) is complicated or irregular. It is also difficult to apply when there is little plant cover, which generally is the case in arid zones where reflectance from vegetation is weak compared to that of bare soil. One therefore 'sees' more soil than vegetation which is only perceptible beyond a cover threshold of between 17-20%.

The enormous advantage of this technology clearly is its capacity to permit the spatialization of data collected. The constraint on the use of this spatialization in multi-temporal studies is dependent on the possibility of rigorously superposing satellite images taken on different dates.

Lahraoui (1987) applied this method to the study of alfa and white Artemisia steppes in Morocco.

Interpretation
The surface sampled by the portable radiometer corresponds to a circle with a radius of 0.63m (the radiometer held three meters above the vegetation) which generally allows one to integrate the bands comprising vegetation and bare soil. Methods currently are under development to combine the radiometry of soil and of vegetation (methods of unmixing or spectral deconvolution).

d. Average tree method

Protocol
For trees and large bushes, the method known as 'average tree' (Ovington, 1956 ; Whittaker & Woodwell, 1971 ; Duvigneaud, 1974) may be used. It is an approach practiced essentially by forestry specialists and causes little destruction.

First, an inventory is taken of trees on 1 ha plots (100 x 100m; or a circle with a radius of 56.4m). The individuals on each plot are grouped in classes (up to 10) in function of their height and possibly the diameter of their crowns, etc. The weighing of the phytomass is then made on an average tree (average characteristics). Generally, the weighing is made by distinguishing the leaves, trunk, and some diameters of branches. This forestry technique known as 'average tree' is only actually applicable - according to those who have used it - to the study of even-aged formations (plantations where individuals are all the same age, etc). It was used thus by Zaafouri (1993) for measurements on tree and fodder shrub plantations in arid Tunisia.

In certain situations (tree savanna, etc) it remains possible to combine such a method, applied to the measurement of trees, with the destructive method (cf. beginning of §) applied to the measurement of low lying vegetation.

Interpretation
The phytomass of a population (or of the trees of a population) is obtained by multiplying the 'average tree' results by the number of trees in the population.

Reminder

To obtain a good correlation, certain conditions must be respected:

- Phytomass measurements (and those of other parameters) must be made simultaneously (season and even weather period) and when vegetation has reached optimal development (vegetation peak).
- Variations in pastoral pressure, which must be estimated carefully, have a markedly greater effect on phytomass than on dimension parameters (height, diameter, etc), at least at first.

The most useful information may be obtained by taking timely measurements and observations during exceptional climatic periods (drought, flood) on both cultivated systems and natural formations, and possibly for animals. In situations where a fixed pace has been adopted, the arrival of exceptional events can justify the start of new calculations for this period. The main obstacle remains the reactivity of field operators who, being involved in other tasks, cannot always free themselves at the required moment.

Note that the fleeting character and high cost of such data does not encourage us to include them on the list of required measurements in the ROSELT/OSS framework.

III. Production and Productivity

Definition and concepts

Primary production is the photosynthesis capacity, in other words, the quantity of assimilates produced by chlorophyllous vegetation on a given surface at a given time. It is expressed in mass per unit of space. One distinguishes:

net primary production, which expresses an increase of standing phytomass, taking into account the litter produced and degraded vegetal matter, and

gross primary production, a notion difficult to measure that includes net production plus losses from respiration.

Net primary production is the quantity of produced material attributed to the dimension of one or several factors of production. It is a ratio of production per unit of time and surface. It therefore involves the speed of production.

Notions of primary production and primary productivity will only be explored in the context of research that does not fall within the priority objectives of ROSELT/OSS. However, each observatory represents an ideal site for scientific research aiming to understand the functioning of biocenoses. In addition, these primary production and productivity parameters are essential for the determination of the existing potential of graze land. An understanding of them would allow the proposal of rational management methods of these spaces to developers.

Just as there are regression equations between phytomass and parameters characterizing vegetation, there are relationships between productivity and other parameters. Figure 8 illustrates the relationship that exists between pastoral value (PV), calculated from the sum of specific contributions presence (SCP) of all the species x their specific quality index Is, and taking into account the total vegetation cover, RT, and pastoral productivity for 5 main types of steppes in the South Oranais of Algeria. The establishment of such curves permits one to credit this non-destructive approach after it has been validated during a measurement campaign (weighing). However, it remains anon-priority measurement in the context of ROSELT/OSS.

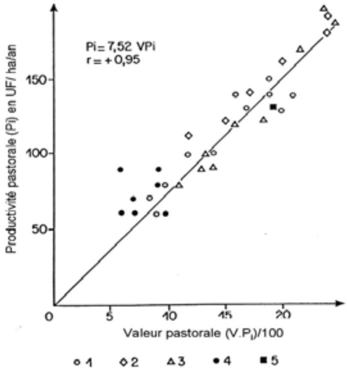


Figure 8. Relationship between pastoral value and pastoral productivity on several units of steppic pastoral vegetation in the South Oranais, Algeria (in Aïdoud et al., 1982).

1. Stipa tenacissima Steppe
2. Lygeum spartum Steppe
3. Seriphidium herba-alba Steppe
4. Hammada scoparia Steppe
5. Artemisia campestris Steppe

A significant omission in this approach, which aims to evaluate and follow-up-monitor resources and spaces, is the measurement of strictly agricultural resources. We shall only address the box below to this subject.

<u>*Agricultural features of resources*</u>

Table 1 described the ROSELT/OSS approach to measurements and observations that include mention of agricultural plots and yields. It is not our intention in this guide to address the problems posed by their measurement. This does not mean that these resources should be overlooked. Food demand and economic and social competition

(labour needs) are powerful engines motoring the evolution of social practices and therefore use practices of spaces and the resources they contain.

The scenario is further complicated by the fact that resources sometimes are mixed. Fallow fields may alternate as agricultural then pastoral spaces.

These measurements require specifically adapted protocols that seem to be well-known in the agricultural world. Consequently, ROSELT/OSS observatories are strongly encouraged to collaborate with agronomists who are skilled in such measurements.

Chapter III:
Evaluation and monitoring of biodiversity at different levels

Introduction

For over two decades, ever since the Rio Summit in 1992, the once vague and ambiguous notion of biodiversity has been the focus of an on-going virtual plebiscite, particularly among politicians.

Among the issues scientists have had to settle are the definition of biodiversity (concepts), measurement and interpretation procedures (methods and tools), and the objects (elements) concerned. In actual fact, the term 'biodiversity' covers a variety of concepts; it therefore is important to define it clearly and describe the procedures with which it will be evaluated under different circumstances.

As diversity remains a fairly vague concept, we rely on the definition given by Daget & Gaston (2001): "Diversity measures the overall heterogeneity of a countable set whose elements may be regrouped into categories, consequently a set that is divisible." Biodiversity is the diversity related to biological entities (animals, plants, etc). Working from there, biodiversity measures the heterogeneity of an ensemble (survey area, landscape, etc) which contains countable entities (taxa) that may be regrouped into categories (biological types, functional groups, etc).

General concepts

One may still add that biodiversity should describe the totality of the variety of living organisms. Therefore, biodiversity must encompass the different levels of organization of living things and in this way embrace the genetic diversity of populations (of the same animal or plant species), infra-specific diversity, compositional diversity (at the level of taxa or genes), functional diversity, diversity of ecological systems (such as environmental types) and landscapes. Each of these organizational levels (population, species, ecological system, landscape) are themselves difficult to define because the biological entities involved range from genes, or more generally the taxa recognized at the level of flora (species, sub-species, variety), up to biotopes and landscapes.

In addition, one must remember that the analysis of floristic biodiversity, for example, focuses -- most often in a restricted fashion - on higher plants, namely biological taxa close to each other. This appears to be due to the difficulty in determining non-vascular plants and to the fact that these plants frequently constitute the principal resources. Yet under certain circumstances it may be more interesting to consider, for example, from a strictly biological perspective, moss and lichen. At the same time, one also must remember not to mix elements that have no relation (ex: plants and birds) in one's analysis.

Biological diversity, or biodiversity, constitutes a key stake in development from ecological, sociological, economic, and even ethical perspectives. It seems increasingly clear that misuses of spaces and resources provoke the increased scarcity and even disappearance of the most used (high palatability, plant material prolonging grazing periods, etc) and probably the most efficient (productivity and strength) plant material.

It is also evident that in the short-term, the implementation of techniques to restore and rehabilitate ecosystems will confront a scarcity of plant material (grains or cuttings) that are both suitable and efficient. Part of the genetic capital that was developed through the necessary and successive adaptations of organisms to variations and changes in environmental conditions is today in danger. It is the entire capacity of biocenoses to adapt, through the organisms they contain, that may be reduced to nothing, leading to increased fragility and incapacity to auto-regenerate (loss of resilience).

It is clearly in preserved biocenoses that genetic and specific diversity is the greatest. In the context of arid and semi-arid regions, where environmental degradation is increasingly rapid, it is proving difficult to conciliate the three components of development: Improvement-Restoration-Conservation.

With the above remarks in mind, the ROSELT/OSS programme needs to focus sustained efforts on the understanding of biodiversity. ROSELT/OSS sites, most often located near -- and occasionally within -- protected zones (Parks, Biosphere Reserves, etc), constitute a favourable setting in which to take biodiversity and its characterization into account. However, this point of view needs to be nuanced in so far that adaptations to human actions are no longer effective in environments protected for lengthy periods. Man is not only a consumer in relation to space and the resources he exploits but also a breeder, which reveals the difficulty of managing and maintaining biodiversity in service of the human community.

Biodiversity research on taxa is plentiful and sophisticated. However, less work has been done at the level of landscapes. For this reason, we go from the specific (taxa) to the general (landscape), all the while insisting that such work on biodiversity at the observatory level first must be based on relevant zoning.

Data collection protocols

As a first step, one must establish a synthesis of the floristic knowledge characterizing the territory under consideration (Observatory).

This information can, if the data is precise and reliable, allow one to monitor the evolution of plant diversity over time. With this in mind, priority activities will aim to:

- make the most of existing knowledge;
- preserve and constitute biological reference collections;
- archive old inventories.

Biological collections are made up of previously established herbariums representing reference knowledge regarding the flora that are characteristic of the ecological region sl of which the Observatory is part. Efforts must be made to recuperate as much old data (species lists, maps) on biodiversity as possible while verifying their validity. These two sources of data provide a basis on which to evaluate changes (loss or addition of taxa) over time, from time t_{-n} years to the current time t0. This base will be updated periodically (periodic inventory), completely or not, every t_{+4} years, t_{+8} years….

The brute data is the floristic composition, as complete as possible, of the Observatory. Preparations for the study of a site's flora must be made with absolute rigour if their value is not to be reduced to zero.

The first phase of activities concerns the delimitation of environmental units with the constraint of finding the most original sites in terms of the combination of the ecological factors that define them. It is this originality that also may determine the originality of the flora residing in them.

I. Delimitation and qualification of landscapes and biotopes

In so far as they exist, data contained in thematic cartographic documents (ecosystems, biotopes, and landscapes) can be synthesized to the scale of 1/10,000 to 1/25,000, for example. The general availability of such documents covering the entire ROSELT/OSS area will allow one to establish a list of the main biotopes of the region and define their relative value for conservation.

In biodiversity studies, the subdivision of space responds to the same criteria evoked in Chapter I. However, the distinction and delimitation of biotopes must be undertaken in a shrewd manner.

Aerial photographs (particularly colour photographs) are an indisputably important zoning tool for biodiversity related studies. Their stereoscopy, which accentuates variations in relief that are otherwise barely visible, allows one to refine the zoning. What is sought here is somewhat in contrast to what is sought when zoning a LCM (cf. Chapter I) where a more global view of the land is preferred. In the present situation, what is important is to highlight the more original features of the space even if they cover a limited area, e.g. opposed slopes, strong variations in slopes, marked changes in substrates, etc. All of these multiple landscape attributes effectively may add to the biodiversity of the taxa present in the space.

Cartography is not always an adequate tool for identifying diversity at a specific level. An abrupt or uneven slope may hide important taxa that greatly add to the biodiversity of the ensemble. In such cases, other means of marking, such as GPS positioning, may be unavoidable.

Management practices of a space also may introduce important changes at the level of biotopes (and of biocenoses). They permit a subdivision of space otherwise homogeneous in terms of biophysical parameters (climate, soil, geomorphology, etc). This is the case, for example, with exclosures that create different development states in the same vegetation.

II. Choice of sites and stations

A. Characterization of the initial situation stage

The main idea is to establish the most complete list possible of the 'plant taxa' richness of different biocenoses. While it remains interesting, the concept of a minimal area is no longer operational. It is still possible to place a station on a part of the biotope that is as homogeneous as possible and to execute the first part of the survey on a surface that coincides with a minimal area before continuing on to surrounding areas and ultimately the farthest corners of the space. This relentless effort to let nothing escape attention is often facilitated by the more-or-less developed 'nose' of researchers who also must be good botanists.

B. Follow-up-monitoring stage

As for the measurements and observations presented in Chapter II, there are certain issues involved in biodiversity follow-up. The approach adopted must follow a serious consideration of the objectives of the follow-up-monitoring:

- monitoring a particular population of a given taxon: requires periodic surveys (possibly cartographic) on the same, well-identified site. The distribution of species confined to the level of a specific biotope (biotope-specific species) may be used as an indicator of such biotopes. The monitoring of their distribution may be used to predict changes affecting this biotope.

– general monitoring: proceed to the choice of sites located on gradients of human activity or another factor provoking possible environmental changes.

– study of the value of the biodiversity¸ the sites in environments situated, for example, on the same toposequence or on a gradient of particular ecological factors (rainfall, etc).

III. Floristic census: Establishment of floristic lists

The base data are those contained in the complete floristic surveys with notes on observations or measurements that permit one to judge the absolute or at least relative abundance of taxa (cf. § d.1 which follows). Interpretations are often based on the number of taxa (species and possibly sub-species of a variety).

Data collection at the station level in a given environment type follows the procedure for the establishment of floristic lists evoked in the § 'Floristic composition' of Chapter II. Practically, it involves establishing a list of taxa present on the minimal area to which is added the list of taxa found in the extended areas nearby. The research should respond to several requirements:

– attention paid to 'refuge' biotopes (rare and limited ecological situations) which constitute a particular case of biodiversity and whose monitoring seems indispensable to the study of biodiversity even if they have been neglected, due to their weak scope, in resource studies (Chapter II);

– research based on very attentive observations;

– surveys possibly repeated over the year, in order to ensure that the observation of a species (ephemeralphyte, geophyte, etc) with a very short cycle is not omitted;

– surveys possibly repeated during exceptional years (very high rainfall) in order not to miss observing species which, due to their ecological requirements, may be observed only rarely;

– surveys possibly repeated every four years on sites considered to be the most fragile;

– surveys made following exceptional climatic events with the objective of increasing knowledge on the ecological requirements of species.

Reminder

Serious constraints are faced in the field, but serious research must be conducted with the help of experienced flora specialists. The above adjustments are useful but their absence does not constitute a major obstacle to interpreting solid data collected.

IV. Quantification of taxa

If the operation was easy to undertake, the simple count of individuals per surface unit (density) would be a sufficient quantification for the needs of calculating indexes to qualify biodiversity (ex: alpha diversity). In practice, the following concepts are most often used.

The absence of this type of quantified information concerning the balance between taxa renders an assessment of biodiversity of vegetation impossible.

A. Evaluation of abundance-dominance

Braun-Blanquet and Pavillard (1922) defined these concepts as follows:

- abundance is an estimation of the number of individuals of each species entering the constitution of a plant population on a given territory,
- dominance concerns the cover of individuals of each species.

Quantification usually relies on the evaluation of abundance (qualitative notion) and of dominance (quantitative notion) as defined by Braun-Blanquet (1928, 1952). The presence probability of a taxon in an environmental unit is evaluated by its effective participation in the cover.

This coefficient of dominant abundance, used in phytosociology, allows one to appreciate the importance of a species in an environmental unit.

The coefficients used allow one to place the taxa inventoried into one of 6 classes:

+. rare individuals, very weak cover < 1%

1. fairly abundant individuals whose cover is weak, less than 5% of the surface studied
2. abundant individuals covering 5 to 25% of the surface studied
3. abundant individuals covering 25 to 50% of the surface studied
4. abundant individuals covering 50 to 75% of the surface studied
5. abundant individuals covering more than 75% of the surface studied

The qualitative information collected according to the Braun-Blanquet method can be translated into cover using the formula established by Daget (1998). The conversion as calculated by this author is the following: the values 0 (or +), 1, 2, 3, 4, 5 statistically and respectively correspond to cover values of 0, 1, 3, 10, 30, and 90%.

B. Cover measurements (specific contribution)

This type of measurement (cf. Daget & Poissonet, 1971, 1991) was presented in Chapter II. Remember that the reading of point quadrat lines generally allows the survey of only a fraction of the individuals present on a biocenosis. This data must then be complemented or substituted by the concept of abundance-dominance (cf. preceding §).

INTERPRETATIONS

I. Station richness and its various expressions

This is based on a consideration of the list of taxa present only, and even occasionally on their number alone without noting their identity. When journalists refer to biodiversity, it most often predicates on this sole notion.

A. Concept

Floristic richness accounts for part of the diversity among flora by the number of taxa inventoried on a unit of the environment under study. This index, useful (Connor & Simberloff, 1978) and simple to use, was greatly employed in discussions of biodiversity (Hill, 1973). It is the most commonly-used measurement of the taxonomic richness (diversity) of a community. However, one must keep in mind that one is faced once again with relative values and that this concept is only given full meaning when surveys made on similar stations and along ecological gradients are compared.

Spatial heterogeneity, whether natural (geology, exposition, soils, etc) or provoked by man (constitution of landscape mosaics, diversification of vegetation stratification - as much horizontal as vertical) most often leads to an increase in biodiversity. Likewise, for a given environment, human activity maintained at a moderate level is reputed to increase biodiversity. However, biodiversity (at the station level) generally regresses when human pressure ('artificialization') goes beyond a certain level.

One must insist here on the fact that the quality of results is directly dependent on the botanical knowledge of the people taking the surveys.

Too frequently, only erroneous or incomplete data are available, which invalidates any interpretation one may try to make.

At this level, a very rare taxon acquires as much importance as a taxon that is markedly more frequent and/or, for example, very productive from a pastoral perspective.

It is essential to take into account accumulated scientific interpretations and knowledge concerning the taxa found in the field. It is also important to consider the perception of the user populations of these taxa. Each identified taxa could then be characterized by:

– its ecology (autecology): preferences and ecological requirements, biotopes,

– its quantitative data: specific frequency, cover, phytomass, density, spatial distribution (cf. chorological maps),

– the uses made of it: food for people, fodder, fuel, pharmaceutical, stabilization of soil, cultural and social value, and other services,

– its protective status: international or national red list, rules for protection and conservation…

As already suggested, the consideration of floristic richness alone does not allow any definitive judgment of the production or the potential of the vegetation that it harbours. It does not involve taking into account considerations relative to production, such as plant cover.

Already at this level comparisons should be made of what can be compared, and field surveys should be conducted during relatively brief campaigns. Ideally, interpretation should be limited to comparing data series collected 'simultaneously'. During a single year's survey campaigns, a lag of just three weeks can make comparisons between data impossible due to, for example, the start or end of the biological cycles of certain species. Likewise, in short periods of time, dramatic climatic events (heavy rain, heat waves, frost, etc) can significantly change a situation and the interpretation of data collected 'before' and 'after'.

All that remains is to encourage initiatives to concretely implement protocols aiming to study the evolution of biodiversity on one station over time. Such an initiative would of course justify surveys that are spaced over time.

B. Different expressions of station richness

1. Number of species

This is not actually biodiversity because it does not take into account the identity of the taxa present. This old-fashioned notion has fallen out of use.

2. Relative station richness by biotope

Daget & Poissonet (1991, 1997) and Daget (2002) proposed the following reference scale for this station floristic richness. It allows one to establish comparisons between stations on the same unit or which belong to different environmental units:

- rare flora = less than 5 taxa on an environmental unit
- very few flora = 6 to 10 taxa "
- few flora = 11 to 20 taxa "
- average flora = 21 to 30 taxa "
- fairly rich flora = 31 to 40 taxa "
- rich flora = 41 to 50 taxa "
- very rich flora = more than 51 to 75 taxa "
- extremely rich flora = more than 75 taxa "

As Daget suggests (op. cit.), this allows a calculation of average richness (for a type of biotope, for different biotopes on an observatory, etc) and its security interval. This average richness is not, however, a very good expression of biodiversity, principally when the numbers surveyed are low, increasing the influence of extremes. It is better to turn to median richness (the middle value in a distribution above and below which lie an equal number of values). The same author adds that there is an advantage in characterizing this type of data by calculating the minimum, the maximum, the 1st and the 3rd quartile, as well as the first and ninth decile. He proposes a graphic image representation of the distribution of these values.

Daget & Poissonet (1997) also point to the advantages of studying the variability of biodiversity between different surveys on the same environmental unit. At a certain level, this translates the potential of an environment and it is commonly said that, all things being equal, an environment is as fertile as its floristic diversity is high. For example, biodiversity increases with the thickness of sandy plates. Such an assertion clearly is not always substantiated when one changes environments. The following example relating to pasture land in Burkina Faso will illustrate the ideas of these authors.

In nature, it seems that all excessive exacerbation of certain ecological parameters (saltiness, humidity, drought, cold, etc) is manifested by a consequent regression in biodiversity. Along the same lines, Sanon et al (1994) demonstrated, through a reciprocal averaging, biodiversity regression in pasture land on the Menegou territory in Burkina Faso along four main lines: a decrease in the thickness and an increase in the mobility of sand deposits, as well as an increase in the proportion of stones and duricrust, in the overall humidity of the station, and of human pressure (most often by an increase in the animal load).

The data obtained for the same region (or some other geographic entity) allows the calculation of an average and its confidence interval. For a Mongol steppe, Daget (2002) calculated an average floristic richness of 29.3 taxa with a standard deviation of 8.09. It is still often preferable to calculate the median (the middle value in a set of numbers above and below which lie an equal number of values).

3. Floristic similarity by biotope

The Jaccard coefficient of floristic similarity and the Hamming Distance (described in § 'Floristic composition', Chapter II) allow one, using a very simple and expressive calculation, to compare established floristic lists (Daget et al, 2003):

- at the same sites on different dates,
- at the same dates on different sites, etc.

4. Life-traits and other characteristics of taxa

It remains possible to compare surveys by classing taxa according to:

- their rarity within the local or international context (IUCN, etc);
- the bio-geographic status (proportion of ubiquist, menaced, etc, taxa),
- their specific quality index (Is) (cf. Chapter II),
- their difference of stratification,
- their biological spectrum, etc.

This recourse to the notion of life forms often proves to be interesting. There is a close relationship between a station's biological spectrum (proportion of each biological type category in a given unit) and the ecological conditions on the station.

Many other comparisons between stations are possible that are all very instructive but whose actual value depends on the proposed objectives. Some of these analyses will be elaborated further on.

In this floristic richness approach, all taxa carry the same weight, all being considered as having an average abundance. Of course, this is not true in reality as observers of dominance, abundance and cover have found (cf. preceding §).

5. Notion of spectrum by botanic family

This concept is close to that of pastoral or fodder spectrum developed by Poilecot & Daget (2002). The expression of floristic richness takes place by botanic family. Such a spectrum on flora may also be transformed in spectrum on vegetation by associating with the taxa information relative to their specific contribution (cf. Chapter II)

6. Conservation value

Field observers in charge of research on biodiversity must be alerted to the possibility of finding taxa with great bio-geographical value. Rare taxa, or those part of very discrete populations, should be identified with great care both in terms of precision (GPS, photography, sketching) and discretion. Quality research is imperative and it must be admitted that other vegetation assessment work (measurements of structure etc) generally produces limited floristic inventories.

At the observatory level (the approach is also possible for country observatories, etc), the consideration of taxa lists allows one to identify a statistic on the number of times a given taxon is found on the number of different biotopes where it is present. From this may be deduced the notion of relative local rarity or abundance.

During a second stage, biographical research should identify the same type of information at the regional level. However, it is important to critically assess flora indicators that concern relative abundance or the supposed level of rarity of diverse taxa. The work of botanists sometimes is filled by consulting herbariums.

The threats (regression, extinction) to plant taxa are in the majority linked to human activity. According to their demographic traits and certain other characteristics, plant species from the same location subjugated to the same pressures do not all present the same threat level. Adding in the varied rarity of these taxa (at the local, regional, and international level), the result is great differences in terms of their value for conservation.

Parallel to the regression of some taxa, one must consider possible introductions (voluntary or not), possibly leading to a status of a sub-spontaneous or naturalized taxa. The history of plant introductions is as interesting as it is full of information.

Numerous publications (Debussche & Thompson, 1999; Molina et al, 1999, etc) address different features of the identification of threatened taxa and the establishment of protected species lists. Without going all the way up to this level, a preliminary diagnosis may be envisioned on each ROSELT/OSS observatory.

The potential of an environment may be manifested in a relatively high level of anthropization and it is generally admitted that this pressure has negative effects. Predictive models (already discussed) that were developed to understand composition variations in time and space try to demonstrate the role of these perturbations on the conservation of biodiversity (Pickett, 1976; Connell, 1978, etc). Connell (1978) regrouped these models into just two, one known as the 'equilibrium' model, the second, the 'non equilibrium'. The coexistence of plant species under successive and varied frequencies of perturbation is better explained by 'non equilibrium' models. According to this type of model, perturbations (biotic and abiotic) favour the coexistence of taxa by reducing the phenomenon known as competitive exclusion. It is generally acknowledged that compositional diversity is maximal when perturbations are of average intensity and frequency. This is Connell's hypothesis of intermediary perturbation (1978). A high level of frequency would limit diversity, only pioneering taxa being able to install and maintain themselves. If the frequency of perturbation is low, processes of succession would be in full play and the most competitive species would tend to make diversity regress. However, an intermediary level of perturbation generates the elimination of competition and therefore would favour diversity. In sum, when there are disturbances, diversity first increases, reaches a maximum if the pressure remains moderate, then regresses if the pressure is sustained or accentuated.

'Richness' in a broad sense is, at the first level of analysis, expressed by biotope but it is also possible to express it by landscape, observatory, region, etc. However, the expression of biodiversity at spatial levels above that on which it was measured is misleading. Strong specific diversity at the biotope level does not necessarily signify great diversity at the regional level if the 'ubiquitous' taxa present are most often the same on the different biotopes constituting the region. In contrast, a region with numerous, very different biotopes, each holding a small number of different taxa, may present high biodiversity.

II. Specific diversity

A. Principle

In the study of station richness (for an identified biotope), the level of knowledge of the flora does not take into account the varying abundance of the taxa on the unit. However, one must keep in mind that the study of vegetation focuses, at least in part, on the comparative importance of taxa in the constitution of vegetal cover. This thus suggests their objective quantification (cf. the protocols explained above). It therefore is at this level that weights intervene: the recording of abundance-dominance or the measurement of taxa cover.

Four types of biodiversity traditionally are identified (Whittaker, 1972, 1977; Blondel, 1995; Barbault, 1997; in Daget, 2004):

- internal biodiversities (characterization):

  . in a hierarchical unit of space, whether it be an observation reading, a station, a biotope, or even a landscape: biodiversity α This always involves a unit of space considered in its entirety.

  . in a group of observations of a square degree, of a landscape, etc: biodiversity γ. It involves dealing with the biodiversity of two (or more) stations from a same set, these stations being considered separately.

- external biodiversities (comparison):

  . comparison of relevés, stations, landscape elements: biodiversity ß. The comparison may also, for example, concern two readings taken on the same station but on different dates.

  . comparison of relevés' groups, stations, landscape: biodiversity δ. This may for example consist of comparing the biodiversity of two landscapes.

Maximal diversity also corresponds to maximal incertitude, namely the case where all contributions from all taxa would be the same. For the different biodiversity indexes, a rare species and a very frequent species would not be considered as diversifying.

B. Types of diversity

1. Alpha diversity (diversity-α) or intra biotope

Definition and concept

Diversity- α is 'the diversity of species in a community' (Huston, 1994) or the intra biotope diversity. It may be evaluated thanks to indexes based on parameters (measured abundance-dominance or specific contribution) related to taxa considered separately.

Remember that diversity is maximal in populations where all of the species have the same number of individuals (Barbault, 1995). In contrast, a population in which one species holds the dominant majority will have a low diversity index.

Data processing

We selected the following indicator from those proposed in literature:

– the widely used Shannon & Weaver index (Shannon & Weaver, 1949): its value is calculated based on quantitative or semi-quantitative vegetation data. A high index value (between 0 and 1) corresponds to high diversity.

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where S = the total number of species
pi(nj/N) = relative frequency of the species
nj = relative frequency of the species j in the sampling unit
N = sum of relative specific frequencies

Interpretation

The interpretation is complemented by the calculation of evenness (E) that, for the Shannon & Weaver index, corresponds to the following formula:

$$E = \frac{H'}{\log_2 S}$$

Evenness is high when all species are well-represented. Its evaluation is useful in detecting changes in the structure of a community and sometimes has proven its effectiveness in detecting human induced change.

The dominant indexes (Magurran, 1988) as well as the Hill index (1973), though not described here, also may be used.

2. Beta diversity (diversity-ß) or inter biotope

Definition and concept

Diversity-ß is defined as being 'the importance of the replacement of species or of biotic changes along environmental gradients' (Whittaker, 1972).

It measures the diversity between different biotopes along a gradient (or transect) of change concerning different sites or biocenoses. Beta diversity may be measured by using different similitude indexes. It complements alpha diversity studies and provides a picture of diversity at the regional scale.

The availability of old floristic lists that have been established along gradients can be very valuable by allowing one to establish a reference situation to which other data can be compared.

Data processing

Different indexes allow one to evaluate this diversity.

– the Jaccard index (1902, in Roux & Roux, 1967) already has been discussed several times in this document (cf. § 'Floristic composition', Chapter II). The formula is repeated here:

$$P_J = \frac{c}{a+b-c} \times 100$$

where a = number of species on the list a (reading A),
b = number of species on the list b (reading B),
c = number of species common to both readings.

This frequently used index allows one to quantify the similarity between habitats. This similarity increases with the value of the index.

– Sorensen index (1948) calculated according to the formula:

$$P_S = \frac{2c}{a+b} \times 100$$

where the symbols have the same meaning as in the Jaccard formula, the species in common having, however, a more important weight.

Other indexes and other methods exist to evaluate plant diversity of a biocenosis although they are not presented here. For example, the Whittaker (1960), Cody (1975), and Wilson & Shmida (1984) indexes, and the rank-frequency diagram method (Frontier & Pichod Viale, 1993) etc.

3. Gamma diversity (diversity-$_\gamma$), Landscape biodiversity

Diversity-$_\gamma$ (or biodiversity at the level of the region or the scale of an observatory) may be measured using the Shannon index (Shannon & Weaver, 1949) which takes into account the number and relative importance of elements (i) in the space studied. The formula already was presented in §1.

This index is considered to be the most important in the determination of biodiversity. It integrates all of the other measurements and is affected by the ecological heterogeneity in and between different biotopes. In general, the most heterogeneous environments favour greater gamma diversity which may, in turn, promote an increase in the heterogeneity of ecological landscapes.

Diversity at the level of biotopes

In the long run, one may hope that biotope types may be described and priority lists established following the European model (e.g.: CORINE programme). This European programme developed a classification of habitats according to their importance in nature conservation. There are six descriptive levels. The habitats are defined using phytoecological references. In each type of habitat the physical parameters and the types of ecosystems and landscapes are taken into account. The habitats are mapped and geo-referenced for each country, constituting the base of the 'Natura 2000' network (Cherpeau, 1996).

In order to reinforce the ROSELT/OSS network, it would be possible to map the biotopes from the sub-national and national scales to the continental scale, on the basis of a reference that is more phytoecological (including land use) than phytosociological.

Diversity at the level of cultivated spaces

Cultivated environments -- particularly fallow land -- harbour flora that often is very rich at the station level. It remains interesting for ecologists to invest themselves in this sector.

Diversity at the level of fauna

Although this diversity is addressed too infrequently, it is also important to consider. For example, it is evident that the presence or absence of large herbivores can profoundly modify plant biodiversity.

The hierarchical spatial level that a landscape constitutes can also be monitored and evaluated according to a certain number of other parameters other than those related to biodiversity. It is important to remember that any approach addressing specific biodiversity must first pass by the delimitation of landscapes and then biotopes.

Chapter IV:
Evaluation and monitoring of the ecological and structural diversity of landscapes

Introduction

It can be important to monitor spatial diversity at the level of the assembled sets of ecological units (biotopes and biocenoses) that are landscapes. They can thus be described a) in a somewhat formal manner and b) according to their evolution and that of their diversity. It is, moreover, this evolution, under anthropogenic pressure, that leads to a certain floristic trivialization of biocenoses.

Concepts

We retain the image that human activities are a constant source of change in spatial heterogeneity at different levels of space and biotope, landscape and region. The landscape is fabricated by man and consequently is constantly evolving. It is also defined by the fact that man leaves a footprint (uses) on a bio-geophysical 'matrix'.

In accordance with the definition of landscapes adopted (cf. § Zoning of Chapter II), one can easily class landscapes with watersheds. It is then possible (particularly with the aid of aerial photographs) to delimit different 'landscapes' on an observatory.

The diversity of a landscape is linked to the diversity of the biotopes -- or units of land use -- that compose it. This diversity is considered as being essentially due to the diversity of ecological situations as well as the structure (expanse, length of perimeters of units of the same type, number of units of each type, etc). Bizarre as it may appear, these parameters may constitute good descriptors of environmental organization. Thus, for example, the length of biotopes perimeters provides interesting information about the possibility of exchange between these units. Corridors (continuous natural linear spaces between two environmental units) are among the important elements playing a significant role in the functioning of biotopes by favouring, for example, the dissemination of animal and plant species. In this way, corridors may be used as indicators, in so far as impacts and changes in land use, of biodiversity.

Other authors (Godron et al, 1972, 1999) follow an approach that is based more on remote visual perception ('the landscape is what one sees'). Due to the difficulties inherent in the need to obtain measurements (surface area, other parameters up to functioning) that can be repeated over time, this method was not adopted here. We prefer the definition of Forman & Godron (1981).

I. Ecological diversity (diversity of biotopes)

It would be interesting to apply to landscapes the schema for taxa discussed in Chapter III. In this schema, one must define the type of biotope, which here would be equivalent to a species, as an element. Other types of environmental units may be adopted (types of plant formation, phytosociologic units, etc) if the terminology used refers to elements that are constant, identifiable, and as homogeneous as possible.

A. Protocol

In the field, with the aid of remote sensing equipment, biotopes (or other types of environmental units if they meet the criteria defined above) are delimited and mapped. A certain number of descriptors allow the definition of a typology and the development of a key for the map. It is the key of this map that provides information on the biotopes identified on a mapped territory and their possible dynamics. This list of different biotopes may then serve as a point of diachronic comparison (disappearance, addition) and thus help in the monitoring of the evolution of the surface areas occupied by each of them (extension, regression).

Biotopes may be monitored by recurrent cartography and their distribution evaluated. Changes in size and in distribution of these biotopes can also serve as indicators in the overall evaluation of changes in land use, notably those linked to the impact of human activities (cf. Landscape Unit Maps).

It is also proposed to class biotopes, distinguishing, for example:

. biotopes that are small but have a large distribution (numerous small units of the same biotope),

. 'endemic' biotopes of an 'ecological region',

. biotopes on the periphery of the principal allocation area,

. biotopes in decline or in the process of disappearing.

Each ROSELT/OSS observatory should be able to establish a list of the most unique biotopes (red list at the observatory level) by identifying those flagged on the national lists that are present on the Observatory. By establishing complete floristic lists, one may situate the observatories in relation to biodiversity existing on other scales; in so doing, one will be better able to judge the actual richness of the site by comparing it to sub-national, national, sub-regional, regional, and global contexts. Of course, the state of national knowledge, and in consequence regional and international, is linked to the level of local knowledge and this level, with a few exceptions, is still weak in the ROSELT/OSS region. The scientists in charge of this activity face a huge undertaking.

B. Data processing

As in the case of taxa (cf. Chapter III), it is possible to present findings on a landscape where different biotopes (or environmental units, or types of land use) are present in a mosaic in terms of:

– richness, namely, the number of different biotopes identified,

– gamma diversity (diversity-?) which may, for example, be measured by using the Shannon index (Shannon & Weaver, 1949) which takes into account the number and relative importance of elements (i), in this case the biotopes, in the space under study. The calculation of the value of the index is complemented by the simultaneous calculation of evenness.

– This index is considered to be the most important in the determination of ecological biodiversity. It conveys ecological heterogeneity (numerous parameters of contrasted values), in this case, that of the biotopes of a landscape. In general, the more an environment is heterogeneous, the more it favours gamma diversity; this can, in turn, favour the increase of heterogeneity of ecological landscapes. Thus overall diversity grows with ecological diversity. Inversely, a reduction in ecological heterogeneity reduces the options of specific diversity (Naveh, 1994).

While the Shannon equation can take into account the number and relative importance of elements (units of space), it does not consider the arrangement of these elements whose measurement parameters are inherently different. Parameters related to structure must be processed and interpreted in a manner different than that described in the paragraph that follows.

Other methods and indexes, such as those cited by Farina (1993), may still be used.

C. Interpretation

Among the possible expressions of results, one must retain:

– the rate of threatened (regression, extinction) biotopes (habitats) in comparison to those known on red lists and on inventories. These also testify to biotope biodiversity losses on the territory of the observatory;

– diachronic comparison (disappearance, addition) of lists of different biotopes but also a monitoring of the evolution of the surfaces that they occupy (extension, regression).

II. Structural diversity

A. Concept

A landscape may, for example, be constituted of the following elements: 50% savannah, 25% dry forest, 10% land lying fallow, 10% cultivated fields, 5% riverine forest. Such an observation does not imply that any of these elements (savannah, dry forest, etc) exist as a single spot. It is far more probably that the fields are numerous in number but small in size, and that the forests and savannahs also are divided up. Consequently, at this stage, the units of each element (clear forest, etc) become an interesting parameter to consider. Likewise, in the landscape it may be important to describe what lies next to the clear forest.

B. Protocol

In the present case, it would be wise to keep in mind that the different environmental units present, as well as the type of unit (element of the preceding paragraph), may occupy very variable expanses of space. Baudry & Baudry-Burel (1982) concluded from this that patches were excluded from being selected as individuals and proposed the following solution:

– take samples per transect by adopting equidistant points classed in the same category as individuals;

– arbitrarily apply a grid (known in French as a 'carroyage') to a biotope map. Each square is then considered as an individual whose identity is that of the biotope which occupies the greatest proportion of the square. The values of different parameters (excluding here the parameters strictly linked to taxonomic composition discussed above) concerning the biotopes of a given landscape or of different landscapes on the same observatory may also be calculated in a laboratory as long as good maps are available. Numerous parameters are noted in literature. For a given landscape, Baudry & Baudry-Burel adopted the following:

. number of land use units;

. surface occupied by each unit (or number of squares in the grid evoked above occupied in majority by this type of unit);

. perimeter of each unit (length of contact with adjoining units);

. dispersion of units (number of basic patches).

Farina (1993) presented numerous mathematical indexes calculated from parameters qualifying the ecotones and unit mosaic.

Aronson & Le Floc'h (1996) proposed 16 different vital attributes at the landscape level. To be evaluated in the field, some of these attributes require the availability of improbable skills. The more accessible attributes are:

. type, number, and importance of geomorphological units,
. number of biotopes,
. types, numbers, and importance of environmental units,
. diversity, length, and intensity of past human pressure,
. number and proportion of land use types,
. level of anthropogenic transformation of the landscape,
. extent of perturbations in the landscape,
. number and importance of biological invasions,
. nature and intensity of diverse sources of degradation.

It is possible to add other parameters to this list. What is essential is to choose the most relevant parameters after thoroughly considering the questions one wishes to ask. In this regard, we would add:

– rate (%) of biotopes disappeared v. appeared: an indicator of changes in environmental conditions;

– the total length of infrastructure in a region (roads, fences, hedges, canals, etc). This parameter may be adopted as an indicator of the fragmentation of the landscape;

– length of natural and semi-natural linear elements (corridors) in the fragmented landscape;

– number/size of protected areas at local level (cf. exclosures, range reserves…). Modifications in protected areas here serve as indicators of biodiversity conservation implementation strategies.

Note that Forman & Godron (1981) described four types of corridors:

. linear corridors: narrow bands bordering habitats (paths, hedges, roadsides),

. strip corridors whose width is sufficient to facilitate the prompt movement of characteristic species from inside the spot,

. 'water course' type corridors, able to function like the first two, but which also control bed erosion of a water course, silting, and the level of nutrients in the stream,

. networks constituted by interaction between corridors subdividing the matrix into numerous spots.

C. Data processing

Baudry & Baudry-Burel (1982) used two types of measurements:

1. Pooling of descriptors (measure of diversity at the level of biotopes)

The processed parameters then become: the total surface area of the territory studied (S), the total surface area of the type of biotope considered (S'), the total number of patches (environmental units) of this biotope (N), the total perimeter of the patches of this biotope (P).

According to the same authors, the induced diversity D per surface unit is:

. proportional to the importance of the P/S borders, and to the average number of patches N/S,

. inversely proportional to the average dimension of patches:

$$1/(S'/N \times 1/S) = 1/S'/NS = NS/S'$$

. all the more large as the term 1/(S'/S) x 100-50 is large, or, in other words, that the unit studied occupies a surface area close to the average.

2. Measurement of the complexity of biotopes using information theory

The authors propose using this protocol for a sampling along a transect looking at equidistant points. The calculations relating to this application are too complicated to be presented here. However, one should remember that the environment will be considered as being all the more complex because the units will be distributed randomly.

Chapter V: Metadata

In order to facilitate the sharing and diffusion of the data collected and processed by each observatory, a metadata service for the ROSELT/OSS programme is responsible for cataloguing and circulating data. It relies on the description of each type of data by using the metadata. This chapter defines the specific metadata elements (metadata profile) to describe the ecological data sets such as they were defined by the ROSELT/OSS network. Its implementation will rely on the international standard ISO 19115, including the data elements below. They will be the focus of a specific metadata profile.

I. Metadata for the description of data sets on an inventory of habitats, flora, and diversity

Heading: information on the spatial and temporal spread of a data set

- Observation date
  - o Type of date
  - o Date
- Observation season
- ROSELT/OSS observatory involved
- Geographic coordinates

Heading: information on the quality of the data set

- Sampling protocol
  - o Description of the sampling method
- Collection protocol
  - o Description of the collection method
  - o Operator
    - (Family name, first name, etc)

Heading: supplementary information on the data set

- Type of inventory
- Flora used
- Inventory of biotopes
  - o List of biotopes
  - o Description of biotopes

- List of species' characteristics
- Calculated indexes
- Rank-frequency diagram
- Biotope map
- Evaluation of the rarity of the biotope
- List of biotopes in danger
- Interactions species/biotopes
  - Inventory of species
    - List of species
    - Description of species
    - Description of the species' biotopes
    - Description of populations
    - List of calculated indexes
    - Map of species
    - Evaluation of the rarity of species
    - List of species in danger
    - Interactions species/biotopes

II. Metadata for the description of data sets on an inventory of vegetation

Heading: information on the spatial and temporal spread of the data set

- Observation date
  - Type of date
  - Date
- Observation season
- ROSELT/OSS observatory involved
- Geographic coordinates of the sampling zone

Heading: information on the quality of the data set

Collection protocol

- Identification of the protocol
- Description of the sampling method
- Operator
  - (Family name, first name)

Sampling protocol

- Identification of the protocol
- Description of sampling protocol
- Operator
    - (Family name, first name)

Heading: supplementary information on the data set

- Type of survey
- Climatic conditions
- Measured parameters
    - Name of parameter measured
    - Description of parameter measured
    - Parameter unit
- Description of kilometric transect
    - identification of the transect
    - location of the departure point
    - Latitude coordinates PD
    - Longitude coordinates PD
    - location of arrival point
    - Latitude coordinates PA
    - Longitude coordinates PA
    - length
    - orientation
- Station description
    - identification of the station
    - floristic homogeneity
    - surface area
    - Latitude coordinates
    - Longitude coordinates
    - Slope
    - Geomorphic description
    - Soil type
    - Cover estimation

Black: heading or element in the ISO norms

Blue: heading or element specific to the ROSELT/OSS programme

Chapter VI
Recapitulation of the parameters to be surveyed

We must remember that the timing of activities, a major constraint for follow-up-monitoring programmes, must be suited to one's specific objectives. Parameters that are monitored as indicators are essentially biologic and largely vulnerable to climatic variations. Climatic variations themselves set in motion the activities of actors in the field, whether they are farmers or livestock owners. The timing of the ROSELT/OSS programme should, if such things can be foreseen, take into account climatic variability and its effects. The reactive response to this situation is to adopt an extremely flexible attitude in terms of choosing measurement and observation years. It clearly is necessary to set a schedule, but it is just as necessary to be able to react to events that are exceptional for their size or duration (drought, floods, invasion of locusts, etc).

Two essential follow-up modes may be distinguished:

– 'experimental' follow-up serving to determine the variability of selected parameters. These are tests aiming to understand the sensitivity of parameters or potential indicators. This type of follow-up therefore is experimental and observations may be made, for example, annually over a period of 5 years (in order to know different rainfall situations). Such experiments also allow one to evaluate the relevance of some possible extrapolations and can seriously simplify the follow-up mechanism described below.

– operational follow-up to obtain current values on a certain number of parameters contributing to the updating of 'decision support tools'. In this case, one must regularly monitor several simple parameters. When the diagnostic and interpretation tools in place indicate that the situation in the field has been significantly modified, one then sets into motion more complete survey campaigns., Basing our approach on the 'Pressure-State-Response' model, we believe that updating (for example, every two years) all or part of the Land Use Maps (or the SRU map) would allow a sufficiently close monitoring of significant modifications of land use. It is not always relevant to decree a fixed schedule, no matter how convenient and reassuring that might be.

The set of considerations noted above are regrouped and summarized in Table 9.

Parameters	Scale	Method	Unit	Schedule	Implementatio
Mapping					
1. LCM survey	Observatory, portions sensitive or exposed	Remote sensing & field validation	map	Minimum every 2 years or following exceptional events	**Required**
Qualitative measurements					
2. Floristic composition	Main units of the sampling table	'Point quadrat'linear survey	Species list	Minimum every 2 years for special sites	**Required**
3. Cover			%/taxa	id.	id.
4. Surface states			%/state	id.	id. id.
5. Density		Count & measurement 'Minimal area'	Number individuals/m²	4 years or following an exceptional event id.	Recommended id.
6. Average diameter			Meter	id.	id.
7. Height				id.	id.
8. Complete floristic list & contribution	Rich, vulnerable, biotopes	Canvassing	Species list abundance	4 years or following an exceptional event	Exceptional.
Laboratory calculations					
9. List of biotopes	Idem 1	Examination of map/1	List	Idem 1	Recommended
10. Gamma diversity of biotopes/landscapes	id.	Calculation of indexes/1	Index value	id.	Recommended
11. Plant cover	Idem 2	Calculation	%	Idem 2	**Required**
12. Pastoral value	id.	Cover calculation x *Is*	Value/100	id.	**Required**
13. Specific richness	Idem 8	Count of/8	List	id.	**Required**
14. Alpha diversity	Id.	Index calculation /8	Index values	Idem 8	Recommended
15. Beta diversity	id.	id.	id	id.	Recommended
16. Total production	Idem 2	Cuts & weighing	KgMS/ha	4 years	Recommended

Table 9: Recapitulation of parameters to survey

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Annexes

Annex I a.

Establishment of the land cover map

I- Design and Definitions

The Land Cover Map (LCM) brings together descriptors concerning the structure of vegetation, dominant flora, and land use. As has been proposed in this document, information concerning soil surface states (cf Chapter II, Zoning § 1) also may be included.

Vegetation is described by its horizontal and vertical (stratum) structure by distinguishing the cover classes of its components: Herbaceous (H), Short Woody (SW), Tall Woody (TW). We will return to the definition of these components and of descriptive classes below.

Flora (dominant and co-dominant taxa) is noted for each unit mapped, and, if possible, for each of the structural components (H, SW, TW).

Land use: The notion of degree of artificialization (Chapter I) has evolved into the concept of Units of Combined Practices (UCP). For the ROSELT/OSS programme, the latter was constructed based on an evaluation and a spatial modelling of the set of space and resource use practices of populations. This allowed a better understanding of the multiple uses of a space, for example, than the concept of the degree of artificialization as it was developed elsewhere (Godron et al, 1968).

Soil surface *states*: It would appear appropriate, when concerned with the horizontal structure of vegetation, to also focus attention on the elements directly covering the surface of the soil.

> ***Remark***
>
> Elements relating to the diagnosis of environmental evolution (restoration, stability, degradation) may also need to be added, e.g.: indexes on the unearthing of plants, the deflation or accumulation of sand drifts, active hydrological erosion, etc.
>
> In effect, maps derived from the LCM (sensitivity to, or actual state of, desertification, etc) unfortunately cannot pretend to well represent the phenomena invoked by their titles, due to the fact that the phenomena in question are not described in them.

Due to its focus on analytically describing the principal components of vegetation, the LCM is perfectly suited to mapping procedures based on aerial remote sensing, particularly satellites. It also lends itself to the ROSELT/OSS objectives of short- (2 years for the most sensitive spaces), medium- (4-5 years), and long-term (> 10-20 years) follow-up - monitoring of change. Such maps constitute reference documents for the siting and establishment (stratified sampling) of follow-up-monitoring stations (measurement and observation of change). Moreover, through station measurements, they allow extrapolations to the whole of the observatory territory.

Finally, coupled with other thematic maps, the LCM may serve as a base document for the establishment of a Landscape Unit map.

II. Implementation

The LCM belongs to a kit of documents that must be established at time T0, in other words, the initial documents that embody the effective start of work on an observatory territory. This is the first step in the implementation process of long-term surveillance mechanisms.

We suggest dating documents, photos or other past works, with reference to this T_0. For example, for a T0 of 2002:

– documents dating from 1975 would be coded t-27,
– documents dating from 1950 would be coded t-52,
– documents dating from 2005 would be coded t+3, etc.

a. Mapping aids

1. Aerial photographs

The ideal is to have the most up to date aerial coverage as possible. National geographic institute missions offer the advantage of guaranteeing:

– a relative geometric and radiometric homogeneity of photographs,
– the possibility of stereoscopy,
– good quality photographs (good resolution of ground objects) at relevant scales for mapping (from 1/25,000 to 1/75,000).

One of the constant inconveniences of aerial photographs is parallax errors that affect the borders of each image and which make it difficult to join mapping units during the concatenation of images. However, there are methods aimed at reducing this inconvenience. Digital scanning makes it possible to geometrically correct images and thereby obtain an 'orthonormed' image of the entire Observatory territory. If one also has a topographic base that is itself digitalized, this may be used as a reference map where the observed or measured values for parameters monitored on the Observatory territory will be geo-referenced.

In the long-term, it would be desirable that, when possible, each observatory possess all past and current aerial photographs concerning their territory. This would be a source of what may be unique information for retracing the evolution of land use.

2. Satellite images

The use of satellite images has become a necessary and widely used practice that largely suffices when aerial photographs are unavailable. However, one must be careful that the maps made from satellite images meet the quality norms that are indispensable in the evaluation of change. The most important advantage of this means of remote sensing is its repetitiveness, which allows one to tighten follow-up when the need arises.

Satellite images (these are not photographs) have different 'advantages' when it comes to:

– the spectral resolution represents the number of wavelengths of a spectrum that the sensor can detect in visible and invisible forms (infrared, thermic infrared, etc) of light. For example, to consider SPOT 3 in multi-spectral mode alone, each pixel (representative surface on the ground of approximately 20m sided squares) is characterized by 3 reflectance measurements in the 3 wave-lengths detected. Each of these 3 'channels' may be the object of separate numeric files. The 3 channels may be combined to obtain a colour composition which closely resembles a classic 'aerial photograph' when printed out on paper. However, it is only an approximate image of what actually exists on the ground. The sensor cannot distinguish between objects or elements smaller than the minimum size of a 'pixel'. The 'form' distinguished will by necessity have the shape of one or several pixel (square or rectangle). The convention in colour compositions is to choose colours complementary to those visible on the ground; e.g., very active vegetation appears in red, rubified soils in green, etc).

The low spatial resolution NOAAH/AVHRR satellite has a high spectral resolution while the SPOT 3 has high spatial resolution but low spectral resolution. Only three channels (infrared, red, and green) are detected.

– the spatial resolution represent the size of the smallest object detected on the ground by the sensors. The size of these objects ('pixels'), square or rectangular, depends of the sensor:

. from 5km sided squares for METEOSAT

. 1km for NOAAH/AVHRR

. 80m for LANDSAT MSS

. 30m for LANDSAT TM

. 20m for multi-spectral SPOT 1-3 (10m in panchromatic mode).

The resolutions to the meter that now are available allow one to detect scattered covers (less than 20% of cover) characteristic of perennial vegetation in arid and semi arid zones.

The combination (multiplication, division, subtraction, or addition) of the channels chosen allows the calculation of indexes constituting the neo-channels which express the characteristics that one wishes to highlight. Vegetation and brilliancy indexes, etc, are generally calculated. They reflect the reality on the ground.

This means of remote sensing offers the possibility to repeat scenes, for example, theoretically every 3 days for SPOT3. This permits follow-up of plant phenology and, therefore, the possibility of discriminating between species whose biological cycles are not simultaneous. Inter-annual comparisons made on dates relevant to vegetation cycles allows one to monitor the evolution of vegetation from year to year over a vast region (180 km path for a LANDSAT scene, 60 km for a SPOT scene).

The mapping of vegetation and the detection of possible inter-annual changes remains difficult operations, particularly in arid zones. Vegetation cover is at times too weak (<20%) to 'mark' the pixel, and in such a situation, soil surface states are detected as simple image classes.

The classification procedure for an image corresponds to the same basic principle:

– one selects on the screen homogeneous zones (called learning zones) comprising a quantity as large as possible of pixels with approximately the same colour and texture, namely, the same combination of digital counts;

– one statistically calculates the average and the standard deviation of the class thus determined;

– one then proceeds, with the aide of appropriate software, to the classification of all of the pixels in the image in relation to their statistical distance from the predetermined classes. In function of its digital characteristics, each pixel is thus appointed to a class produced by these learning zones. It is therefore possible to determine a priori the number of classes that one wishes to make appear on the resulting satellite image map.

The classifications may be:

– supervised in the case where the author of the classification decides the classes of 'ground objects' that he wishes to retain in the final classification. These 'ground objects' may be cartographic units recognized in the field, for example on selected transects. The purpose of the classification of an image is, when possible, to highlight these units.

– unsupervised, and therefore the process is inversed. The author of the classification, using the statistical base produced by the software, determines the number of classes (objects) that he wishes to obtain and makes a virtual classification, at times without reference to the objects classed. It is then possible to verify in the field the relevance of the classification as well as the nature of the objects classed (validation phase).

The trend prevailing in the ROSELT/OSS programme is to favour the approach that goes from the field to the image rather then the reverse. However, in reality the satellite image maps produced are often the result of an iterative approach alternating between classification and the field.

Two important problems are linked to the use of satellite image classifications:

– some confusion in the restitution. The classified pixels generally only meet a single, synthetic cartographic criterion that coincides most often to a landscape approach. In the key, different and possibly self-exclusive themes concerning vegetation (dense, less dense), geomorphology (dunes, plateau), land use (fields, fallow), etc are juxtaposed. Effort must be made so that each classed pixel is the object of an identified poly-criteria legend (for all of the criteria) in order to arrive at the LCM (essentially plant formations).

– the product obtained, a satellite image map, is in fact an ensemble of classed pixels without limits on homogeneous units (grain, texture, tone). It is therefore necessary to carry out a contouring of homogeneous 'patches' of pixels which then become the mapping units and produce a classic map providing information on spatial units rather than only pixels. This contouring may be done manually or automatically using software, with the latter offering the possibility of 'learning windows' on the computer.

No matter which is the case, one must verify that the final map is made part of an international geo-referencing system, superimposed, for example, on a simplified topographic base, which would allow one to find one's position in the field with the map in hand.

b. Some preliminary reflections

The cartographic scale generally proposed for the creation of a LCM is 1/50,000. In the sub Saharan area of ROSELT/OSS, one is faced with several constraints:

- the desire to have a map (plant formations, etc) sufficiently precise to take into account changes over a period of 4 to 5 years,
- weak to very weak plant cover (often < 20%),
- a strong and already old homogenization of plant structures resulting from a long history of land use (cultivation, cutting of woody plants, grazing). The major consequence is that spatial variations in vegetation structure, particularly near areas under heavy anthropogenic pressure, are expressed by fine structural nuances (variation in cover of dominant species, differences in the size of individuals, disappearance or apparition of some species) that are very difficult to highlight.

In most cases, as they are unable to capture these nuances, the makers of maps at 1/50,000 include in one vast cartographic unit an ensemble that has more in common with a physiognomic unit in mosaic than a land use unit as defined above. Recourse to satellite images, whose actual minimal resolution detects with difficulty variations in weak plant cover classes, accentuates this trend.

Even more, the contraction of vegetation in dry zones along notably water course axes is rarely taken into account at work scales. However, the contraction of such formations represents a fundamental response of arid ecosystems to the increasing scarcity of resources. In these zones, plant and animal species find in the concentration of resources the best development conditions and biological productivity is always greater.

The original designers of the LCM had the habit of saying that the minimum size of a cartographic unit was limited only by the possibility of writing its contents onto the final map, or about the cm^2. With the gradual digitalization of maps, this constraint is less important (digital files associated to spatial representation). However, the size of a descriptive unit allowing one to acknowledge spatial and temporal variations in plant formations must still respect this order of size.

When the association pattern of different plant features is too subtle, these same authors recommend, in order for each to be individualized, to represent the unit in the form of a mosaic of features identified in the key.

Given the risk that units will be fragmented, it remains important that the main unit distribution phenomena (main lineaments, etc) should be visible at a distance of 2 or 3 meters when observing the satellite image map.

c. Propositions and recommendations

It seems clear that at the level of the ROSELT/OSS programme it will be necessary to adapt the cartographic scales to the nature of the phenomena that one aims to highlight. For environmental surveillance, all zones of a territory do not need to be mapped on the same scale. An irrigated perimeter, a valley, the outskirts of a village, may be mapped on a large or very large scale (1/10,000e). Temporary Saharan rangeland may be represented on a small scale (1/100,000 e).

The scale 1/50,000e is convenient for the representation of the entire territory of an observatory, with the possibility of zooming in to a greater scale on particular zones. When all is said and done, one must adapt the scale of the cartographic information and its representation at different levels of landscape organization from 1/1,000 e (for example the fine organization of irrigated perimeters) to 1/10,000 e (spatial structures around wells and villages), 1/20,000e to 1/50,000e (scales generally adapted to the traditional village territory or 'terroir'), and finally to 1/100,000e or 1/200,000e (the entire observatory, with extensive formations of nomadic or transhumance rangelands).

d. Cartographic measurements and their notation

Ideally, the contouring and identification of a cartographic unit is made in the field. From the start of mapping operations, one must be able to comb the length of the observatory, including the most inaccessible zones whose satellite surveillance may be limited, for the sake of ROSELT/OSS.

Again ideally, this exhaustive canvassing must be undertaken during a year (and season) when rainfall encourages the maximum development of vegetation and flora (these also are the conditions and the occasion to make an inventory of the specific richness of each observatory…).

Lastly, all of the landscape units of a territory must be mapped with the same care, including agricultural zones. Within ROSELT/OSS, the evaluation of change passes through the comprehension of the modes of functioning of these zones that seem to 'escape' from the natural space of ecosystems, although perhaps only in the short run…before being returned to successional ecosystem processes.

This ideal approach is not always possible on the entire observatory territory. It is therefore indispensable to proceed to a preliminary zoning at an appropriate scale (1/100,000e to 1/200,000e) for the entire territory in order to identify large, ecologically and socio-economically homogeneous zones. This zoning also may rely on existing cartographic documents (geology, topography, etc), aerial photographs, and colour compositions produced by satellite scenes. This first zoning document, already poly-criterial (several layers of information in a GIS), corresponds to a first environmental stratification. It has a double purpose: for sampling ecologic sectors that will be the focus of the LCM on an appropriate scale, then later for the extrapolation from these sectorial LCMs to the entire territory (small ecologic region, ecologic region).

The field mapping relevé, for which a form is provided in this annex (Figure 9), serves to identify the mapping units distinguished. These units are filled in after sighting, field identification (defined limits), and contour report on the map (tracing of aerial photograph or colour composition, topographic base at a relevant scale).

FIELD RELEVES	
Author:..	Altitude (GPS):..
Reading number....................................	Projection (GPS):....................................
Date:...	Topographic map:.................................
Place:...	Aerial photo:..
Longitude (GPS):...................................	Satellite image: Path...........Row...........
Longitude (GPS):....................................	Satellite image: Path...........Row...........
Latitude (GPS):..	Number isophenic unit:.......................
Climatic events:......................................	Climate:..
Rainfall(mm):...	Bioclimate:...
m(°C):..	Thermic variant:.....................................
Q2:...	
Exposure:..	Geomorphology:..................................
Slope:..	Lithology/Geology:...............................
Topography:...	Hydrography:...
Micro relief:..	
Plant formations:....................................	Average distance between bushes:.....
Horizontal structure:..............................	Rate of regeneration:............................
Vertical structure:....................................	1st dom. species (W, H):........................
Average diameter of bushes:.................	2nd dom. species (W, H):......................
Condition of bushes:...............................	3rd dom. species (W, H):.........................
Overall veg cover:..................................	Rough element cover (gravel):................
Litter cover:...	" " (stones):..
Bare soil cover :.......................................	" " (rocks):..
Sand cover:..	
Slaked surface cover:.............................	Mother rock cover:................................
Saline efflorescence cover	
Degree of degradation:.........................	Use:..
Means of access:....................................	
Hydric erosion:..	Water table:...
Wind erosion:...	
Diagram of the station	**Horizontal structure**

Figure 9: Field description form

The limit between two units is defined by the change in the state of one or several of the fundamental LCM descriptors noted above: horizontal and vertical vegetation structure, dominant species, land use. It is sometimes necessary to go over the sector several times to decide on limits, which in any event remain subject to the appreciation of the map. One must remain aware that there is very little chance that two authors working independently of each other on the same sector in the field will define the limits exactly alike. However, careful work should mean that only a few adjustments in coordination are necessary without altering the bases of the mapping.

Once canvassed, the unit then may be described.

a) Composition and structure of vegetation

Clearly, noting this information requires the identity of taxa to be known. However, it is possible that the stage of development of certain taxa at the start of their biological cycle (plantlet stage) does not permit reliable identification. In this case, it is recommended that a sample be collected and meticulously labelled [provisional name (or number); reading number, etc.], and identified in another season [or through reference to a herbarium] so that it is not omitted from the field form. It may be useful during the collection of the sample to already note the biological type.

Very simple definitions must be respected. In effect, height limits are very important in the definition of vegetation structure, height being one of the most discriminating life traits in the comparative evaluation of change. One therefore may distinguish:

- Tall woody (TW) strictly are all woody individuals over 2 meters tall, regardless of their biologic type (trees, bushes, etc).
- Short woody (SW) strictly are all woody individuals less than 2 meters tall regardless of their biologic type (trees, bushes, etc).
- Herbaceous (H), for which one may distinguish perennial from annual.

The evaluation of the height of woody plants must be undertaken in the field and not, a posteriori, in the laboratory by consulting flora. In effect:

– the height of plants expresses environmental conditions, the age of the formation (secondary succession), production constraints (aridity, low fertility, etc). A formation of Acacia tortilis subsp. raddiana, of which all individuals are less then 2 meters tall, is a short woody Acacia dominant formation (LB) and not a forest of acacia. Its cartographic notation in this form communicates the ecologic conditions of the site.

– when resources are evaluated (defined in ROSELT/OSS as a function of the uses identified by the populations), availability will be evaluated based on the maps made of vegetation: the more precise the description of the structure, the more precise the evaluation of availability will be, notably through the calculation of the overall visible 'phytovolume' (for which height plays an obvious role - cf infra, LCM use).

– the evaluation of change also will look at the growth of plant formations at the level of the entire observatory; height variations must therefore be able to appear.

Given the different forms of growth in Africa, the Northern Sahara (bi-modal Mediterranean climate), and the southern Sahara (mono-modal, sub-tropical climate), height limits are often adapted to the eco-geographic region: multicaule species (the Combretacea Guiera senegalensis or Combretum micranthum, for example) are considered biologically to be bushes, even if they may reach 4 to 5 meters in height. Inversely, the biologic types like Boscia angustifolia or B.senegalensis, considered to be trees (a trunk), are often found in edapho-climatic conditions under which they barely reach a height of 2 meters.

It is therefore indispensable to note what is, and not what should or could be. In any event, it is advisable, working from this basic differentiation (2m), to proceed to subdivisions into classes that conform rigorously to those proposed in Table 3 (Chapter I):

– the following subdivisions for TW: TWa 2-4 m; TWb 4-8 m; TWc 8-16 ;, TWd > 16 m.

– for the SW, one may distinguish between the following stratum: SWa : 0-0.25 m; SWb : 0.25-0.50 m; SWc : 0.50-1 m; SWd : 1-2 m.

The cartographic measurements of herbaceous stratum absolutely must distinguish between perennial herbaceous (Hp) and annual herbaceous (Ha). The vegetation structure and production (seasonal, quality) of these two broad types of plants are very different in arid and hyper arid zones. Consider, for example, a cover of 20% of Aristida pungens and of Zornia glochidiata. For the first taxon, a rapid calculation reveals a density of about 2,000 clumps/ha of perennial, leathery grass (or 500 to 2,000 m^3 of standing plant material, of which about one quarter always may be consumed, or between 125 and 500 m^3). In the other case (Zornia glochidiata), the diffused cover of this small, leguminous, well-appreciated plant represents about 300 m^3 of standing green material exclusively in vegetation season, and it is nearly entirely consumed (150 to 250 m^3).

One may also note the horizontal structure of herbaceous vegetation according to whether it is organized 'in clumps', distributed in concentrated patches, or totally diffused. It finally may be useful to note the height by distinguishing the stratum: Ha 0-0.25 m; Hb 0.25-50 m; Hc 0.50-1 m; Hd > 1 m.

The cover classes adopted are those already provided in Chapter I:

- 1 cover < to 5%,
- 2 " from 5 to 10 %,
- 3 " from 10 to 25 %
- 4 " from 25 to 50 %,
- 5 " from 50 to 75 %,
- 6 " > 75%.

The cartographic formula concerning vegetation structure, for example, will therefore take the following form: TWc1, TWa2, SWd3, SWa2, PHc3, AHa5. Once translated, this would read as:

. less than 5% of Tall Woody above 8 m
. from 5 to 10 % of Tall Woody from 2 to 4 m
. from 10 to 25 % of Short Woody from 1 to 2 m
. from 5 to 10 % of Short Woody from 0 to 0,25 m
. from 10 to 25 % Perennial Herbaceous over 1 m
. from 50 to 75% Annual Herbaceous less than 0.25 m.

Such a formula allows the calculation of apparent phytovolume or 'aerial load' by the simple multiplication of the median value of cover classes by the median value of height classes for each stratum. For the preceding example, this gives:

(2.5 * 8) + (7.5 * 3) + (17.5 * 1.5) + (7.5 * 0.125) + (17.5 * 1) + (62.5 * 0.125) = 20 + 22.5 + 26.25 + 0.935 + 17.5 + 7.813 = 95 m3 of which 25.3 m3 is herbaceous.

This calculation, if the relation apparent phytovolume and standing phytomass is known [sampling of a certain number of representative mapping units and application of quantitative measurements of vegetation (cf. Chapter II)], permits an evaluation of phytomass. The entire map can therefore provide information on the quantity (phytomass) of plant resources that one can differentiate into basic constituents (woody, herbaceous, consumable, etc). Clearly, these are rough assessments.

The map also lends itself to the first, simple phytoecological analyses and it is easy to obtain a preliminary classification of plant formations, from the most simple to the most complex. Better interpretations may be obtained if one takes into account different environmental types (geomorphology, soil, relief, etc).

Rich as it is, one must beware of substituting the data produced by the interpretation of such a map with data obtained during a complete phytoecological relevé campaign. Such relevés, while recommended for all observatories, remain difficult to realize and it is improbable that they will be available everywhere.

b. Soil surface states

This already was explained in Chapter I.

Basic soil surface states are useful in the diagnosis of the state of environmental degradation, particularly in arid zones. Each combination of surface states determines a type of hydrodynamic behaviour (Escadafal, 1981, 1989; Casenave & Valentin, 1989).

Due to a lack of skills (hydraulic soil expert), it appears difficult to adopt very complex classifications such as those proposed by the authors mentioned above. This stage of field work involves noting cover data relative to simple parameters concerning soil surface states. We therefore propose to note the proportions of soil surface occupied by the following different elements: boulders, rocks, gravel, sand, loam, clay, naked soil, ground litter, etc.

Annex I b

Review of different sampling methods

In the field, ecologists and other natural scientists rapidly find that they must restrict their observations of nature to relatively small spaces. Therefore, the first obstacle they must overcome is the significance of their observations as a representation of the entire space under study.

In phytoecology, there were two opposing camps:

- on the one side, partisans of an approach that focused a primary emphasis on transitions between units (ecotones).
- on the other, partisans of an approach aiming to characterize homogeneous ensembles (units), thereby excluding ecotones and transitional zones.

Over time, the two points of view have grown closer and for reasons related to clarification and result interpretation, the second approach has prevailed. Without denying continuum in nature, it allows the subdivision of ecological factors into classes (e.g. rainfall brackets, pH classes, topographical position classes, etc). The adoption of the rule to take relevés on units considered to be homogenous according to the criteria selected for their characterization was key for data processing and such concepts as floristic richness (cf Chapter II) and specific biodiversity (cf Chapter III) etc.

The stratified sampling method adopted by the ROSELT/OSS programme certainly is not the only procedure available in literature. It would be interesting to situate it within the context of the ensemble of methods available classed into two main types: non-probabilistic methods vs probabilistic methods.

A. 'Non probabilistic' method

We will not insist upon these procedures insofar as the results are not very reliable. It involves putting one's trust in the a priori choice of stations to be in the sample without prior knowledge of the field. The method is, in contrast, rapid and simple to implement. It remains clear that in this case a certain number of statistical tests cannot be meaningfully applied. However, principal components analysis or factor analysis may be applied with validity (Godron, 1976).

The results obtained are therefore necessarily subjective; Godron (1976) expresses it in this way, 'if the relevés were chosen in two very different types of vegetation, the statistical tests will confirm this difference, but they will be unable to prove that two distinct vegetation units exist rather than a continuum of progressive transitions'.

The same author recognizes, however, that when ecologists are trained and consciously let themselves be guided by their 'nose' to place field observation (or measurement) sites, they are implicitly making a stratified type of sampling (cf. Chapter I).

B. Probabilistic methods

Relevés and field measurements (floristic or ecological relevés, biomass measurements, etc) are time consuming and sometimes not easy to undertake (difficulty in accessing certain sites). One therefore must optimize work by planning samples, which leads, when possible, to only taking relevés that actually are useful or necessary.

1. Purely random sampling

The procedure may be a random draw (random numbers table) of relevé points on a precise topographical map. In the field, one must then eliminate a certain number of points corresponding to objects excluded from study (side of a road, houses, etc).

The main disadvantage to this procedure is the over-sampling of the most spread out environments and the risk of under-sampling units that are small but very important to the understanding of the ecological functioning of the zone.

However, we accord this method the merit of speed and acknowledge its value in first level investigations of unknown regions for which there are no existing maps concerning the main ecological factors (soils, geology, climate, etc).

2. Systematic sampling

Instead, it is possible to proceed to a solid systematic sampling by turning to a systematic network of regularly distributed points (representing relevé or measurement stations).

The procedure is considered to still be probabilistic if at least one of the coordinates of the first point is drawn at random. In effect, if this condition is met all of the points studied have, a priori, the same chance of being selected. If the space to be studied presents recurrent irregularities, one must ensure that the sampling grid does not have the same dimension as the range of the periodic succession of environments (to avoid the risk of always sampling the same unit).

For example, when applying the procedure to dunal massifs presenting regular rows of dunes and inter-dune hollows, one must take care that the use of the systematic sampling grid does not lead to the over-sampling of dune rows and an under-sampling of hollows. In such a situation, it would be preferable to use a purely random sampling procedure (cf. § 2.1 of this annex).

One may argue that in fact samples are not taken at random as the researcher generally chooses the gradient line to observe. A way of getting around this problem is to grid the zone by attributing to it x,y coordinates and choosing from them two points representing the ends of the line with the aid of a random number table. However, this solution is only partially satisfactory because the points of the line will be distributed according to a regular grid and therefore there is a strong presumption of dependence between the points. In addition, the use of the table may make the line pass into a zone that holds no ecological interest. The operator therefore will have the tendency to repeat the operation until a satisfactory line is achieved, which is contrary to orthodox statistics because choices are made. Another approach consists of turning to information theory (Godron, 1966) which is more robust in terms of statistical requirements.

Systematic sampling is one of the best adapted to the purposes of the ROSELT/OSS network which aims to follow, among other things, the evolution of vegetation. It suffices to establish a relatively simple measurement protocol, in this case two stakes and a measuring tape or line to take the measurements. This has been practiced for a long time in the form of vegetation transects conveying ecological gradients with the help of order theory. In the case of recurring plant motifs, the grid must be adapted to the distribution of vegetation so that it does not mask useful information.

3. Subjective sampling

Subjective sampling is probably the most used in phytosociology as it is the simplest to implement. The technician usually has only a minimum of field information at his disposal. Once at the study site, he then canvasses the different communities present, chooses the most representative and homogenous ones, and takes his readings from them. The choice is made on the basis of the technician's experience and it is possible that two different technicians will have divergent results. This type of sampling, which relies greatly on the knowledge and experience of the technician, is therefore subjective. However, in practice trained technicians obtain roughly the same results because subjective sampling is not random but obeys a recognized work method. Furthermore, once the readings have been taken, it is possible to proceed to use verification concerning, for example, homogeneity (species-area curve).

This sampling is thus often practiced in the absence of field data in order to obtain a preliminary picture. However, it is not alone enough and must be complemented by a rigorous stratification.

More and more studies are now undertaken as quantitative evaluations of vegetation based on empirical phytosociological coefficients using a method proposed by Long (1954). However, Gounot (1969) emphasizes that it would be insufficient -- and perhaps even dangerous -- to replace empirical coefficients with measurements, in this way simulating a quantitative approach. He adds that, "this would be time totally wasted as the underlying model to such an operation (the existence of uniform vegetation at the scale of the sample used, with some variations considered 'accidental') has no chance of being practically realized."

4. Random sampling

This is the main type of sampling used in experimental biological studies. One should remember that the use of these tests presumes the preliminary existence of a working hypothesis according to a sampling plan. One of the base principles is that the distribution of the samples must be undertaken in a random fashion. Today, the field selection of randomly distributed sampling points can be done fairly simply by using geographical information system software programmes and with the help of GPS. It suffices to have material mapping the area (topographical maps, aerial photos, thematic maps). These are scanned and then geo-referenced using a software programme. The map can then be read as geographical, cartographic or more simply non-terrestrial coordinates which are easier to read because they are expressed directly in metric units. A statistical random numbers table can then be used and the different points are plotted as Cartesian coordinates (x,y). The position of the points can then be identified by the GPS. This method thus requires a rigorous approach whose main difficulty resides in the fact that surfaces do not always have a rectangular form. Like other constraints, the spotting requires the use of GPS which is not always easily available to teams in southern Mediterranean areas. Furthermore, points thus identified may be difficult to access if the zone covers rough terrain.

To avoid long journeys, Gounot (1969) reports that one can consider choosing at random principal points that will serve as bases. A certain number of samples will be randomly placed in a fairly small area around each base in such a way that the exact identification may be easily made by sighting and by step distance measures with a 30 meter tape or with an optic mechanism (cluster sampling).

Another method, one less rigourous yet still acceptable and more rapid, consists of randomly choosing angles and distances (or the number of steps) and to take the points thus identified as the sampling points. To avoid wasting time, one must first verify (on a map or photo) that the path does not surpass the limits of the community.

The method of throwing rocks or hammers that randomly land on a point can only be used when the surface area is relatively small so that whoever is throwing can cover the entire area. In arid zones, where plant communities are spread over hundreds or thousands of hectares, this method is simply obsolete and provides only an illusion of random choice.

Another important constraint is due to the nature of the plant communities present:

- if the surface areas occupied by the units are too unequal, random sampling will overestimate the most spread out community by multiplying the number of measurement points on them.
- if the differences are too pronounced, one even may find oneself with zones that are not sampled but which nonetheless play an important ecological role. This is notably the case with wadis -- their surface areas naturally being limited, they risk not being sampled at all.

The solution would be to increase the number of points until a sufficient number of samples from these communities is obtained, but one then finds oneself in opposition to the thrift principle, which is fundamental to all sampling.

Ultimately, this type of sampling does not seem very suited to the ROSELT/OSS network, which needs continuous measures on identical parcels in order to eliminate spatial variability. It also does not allow the examination of major ecological gradients such as, for example, the study of anthropogenic pressure along a degraded gradient.

5. Exhaustive analysis

In exhaustive analysis, the use of the word, 'sampling', may pose a problem. In effect, it no longer refers to the analysis of a part of a population in order to infer the properties of the sample to the whole. Rather, it is to test the whole in order to study the homogeneity, the structure, and even the minimal sampling areas in order to validate them, which is to say, to verify if they conform to the theoretical model proposed. Exhaustive analysis follows from the work of Greig-Smith (1952). It was taken up by Slimani in 1988 in the Algerian steppes. Numerous techniques may be used for this objective:

a. Grills or bands of adjoining squares: This involves putting several lines containing n adjoining squares or rectangles to the number of 2^n to allow the regrouping of the squares and to facilitate statistical interpretation.

The structure of the vegetation may be studied closely and measurements such as cover density are facilitated. The plots may be randomly chosen if they are sufficiently numerous, which generally is not the case as the regrouping actually aims to extract the maximum of information from a minimal sampling effort. In the case of regrouping, the samples are no longer chosen at random. To remove the independence constraint, information theory seems to give promising results for the interpretation of results as it is based on non-parametric statistics that are more robust for application conditions.

b. Lines of adjoining segments: Godron (1966) uses a method inspired by aligned points. He places adjoining segments and notes the presence of species, allowing one to arrive at frequencies.

c. The ordination of individuals along a line or a band: This method allows one to discern ordered relations and notably to calculate linear densities or densities by surface units.

6. Stratified sampling

Avoid over sampling the most frequent environments to the detriment of other less representative but possibly more informative (Daget et al., 1977).

One must acknowledge that scientists with extensive field experience are instinctively able to make a sampling that, despite a strong subjective element, is by nature probabilistic ('stratified' type of sampling).

This is the most powerful sampling method as it uses numerous sources of information. It aims to divide a heterogeneous zone into sub regions that are as homogeneous as possible and which are then sampled. The base documents are thematic maps and aerial photos. In the first case, thematic layers are superimposed and the intersection of different units produces a synthetic layer where ecologically homogeneous units are individualized. The second method is based essentially on aerial photos or satellite images. The interpretation of the photos allows one to define isophenous zones assumed to be homogeneous.

a. The use of cartographic documents: Once the factors deemed effective are decided, one proceeds to the collection of available maps. Topographic maps not only provide toponymic information but also identify the hydrographic network and allow one to extract slopes, exposures, and hypsometric values. Thematic maps are generally pedagogical, bio-climatic, geomorphic, or geological and the choice is made naturally as a function of one's work objectives. Obviously, this presumes, if one uses a calques system, that their scales are identical. However, if the projections of the maps are different, the problem is more difficult to resolve because it requires more resources. The current use of information tools allows one to resolve projection problems more easily. The automatic superposition functions of GPS software also allow the superposition of different layers and to automatically extract the overlay representing homogeneous zones. This work presumes, as a preliminary measure, the existence of studies finalized by thematic maps that were elaborated at the same period, which in reality rarely is the case.

b. The use of aerial photos or satellite images: Due to the lack of recent thematic maps, satellite images or aerial photos constitute an important source for the stratification of the study area. Aerial photos, generally panchromatic (most often between 1/60,000 and 1/20,000; the choice of the scale obviously depends on one's objectives), have the advantage of a large spatial finesse, while satellite images offer a better spectral resolution and, in particular, repetitive and synoptic views that greatly facilitate work.

Zones with similar appearances, defined by textural, structural, and environmental criteria, are defined as isophenous zones. In principle, the latter translate homogeneous vegetation ranges. Laboratory work is complemented by field research in order to verify the proposed legend keys. Verification also will be made of the quality of extrapolation work on the reference homologous zones in which the phytoecological readings were made.

7. Mixed sampling

Practical experience shows that in many studies, the technician often starts by taking a subjective sample when there is a lack of information, and a stratified sample when information sources are available. If the selected zone is considered homogenous, he may then use a random number table to choose where to locate his relevé. He then may be led to make quantitative measurements such as the evaluation of the phytomass or the estimation of ground cover. In this case, the use of lines is part of systematic sampling. The operator thus may use several types of sampling methods in order to mobilize all of the information sources. This is mixed sampling. This type of sampling is very effective because it is complete; it is the one most often used in evaluation studies of natural resources and in monitoring vegetation dynamics.

Annex I c

Measurement of sampling quality

Let us review several precautions already noted in Chapter I.

A heterogeneous and random distribution, as well as fairly advanced statistical knowledge, is needed to interpret natural vegetation.

For the purposes of ROSELT/OSS, we chose a sampling method that is both stratified and probabilistic; the only one that allows information to be drawn regarding the entire population (or spaces) sampled (Godron, 1976).

This approach involves rationalizing or planning the number and repartition of relevés by avoiding:

- taking useless relevés (over representation);
- ignoring environments that are less extensive but very significant from an ecological point of view.

The samplings therefore are more or less well-established and their quality is variable, which is something that may be evaluated. We look here at a procedure described by Daget et al (1997) to measure the quality of a sampling.

For each sampling to be optimal (or, better put, 'optimal in the Neyman sense', or N-optimal), it has been proven that the number of relevés must be the same for all sampling table strata present in the field. A sufficient number of relevés (a total of about 100) is also necessary if the statistical calculations made are to be valid. If, for a criteria adopted (e.g. plant formation), a class of the criteria (e.g. tree savannah) occupies the majority of the space (with a risk of over-sampling this class and a poor sampling quality), it remains possible and important to subdivide the class (for example by the density of woody plants, etc).

The population profile of a descriptor is given by the absolute frequencies series of relevés in diverse classes of this descriptor. Clearly, if the descriptor has only one class, none of the relevés made can contribute information to this. The theoretical formula of the population profile is provided in the table below (Daget et al, 1997).

	Descriptor L having several classes						Set of relevés
	Class 1	Class 2	...	Class K	...	Class NK	
Number of relevés	R(1)	R(2)	...	R(K)	...	R(NK)	$NR=\sum_{1}^{NK} R(K)$

In fact, the quantity of information brought by a population profile is measured by its entropy calculated from relative frequencies of relevés on different classes:

$$H(L) = -\sum_{1}^{NR} \frac{R(K)}{NR} \log_2 \frac{R(K)}{NR}$$

It was shown that H(L) passes by a maximum when all the relative frequencies R(k) are equal (Daget et al, 1997).

$$R(k) = \frac{NR}{NK}$$

We should add that the choice of sites and placements of relevés must also be planned in order to be both relevant and economic.

Annex II a

Common methods to measure vegetation cover

Numerous methods have been developed to measure field parameters. Several of these methods are presented here purely for information purposes. In the ROSELT/OSS framework, the method known as 'point quadrat' was adopted.

A. The linear method

The principle is to follow variations of vegetation by sampling points at different periods and by using a relatively loose sampling grid. The sampling points are situated along the length of a metallic tape stretched between supports by clips on which slides a ring that is 2.5 cm in diameter (Parker, 1951-1954; Long, 1958) that is fixed to the end of a metallic rod. The mark offs are obtained with the help of three corner pegs on which one traces a reference line at the level of the passage of the tape.

If the metallic tape is first graduated, it is easy to place the ring every time at the same position as in the first sample. Otherwise, the sides of the tape at the point of contact with the corner pegs are noted to enable one to return the tape to the same spots. Readings are taken on 100 reading points (a variable number) that are equidistant (in general, every 10 or 20 cm) by identifying all of the species within the ring, rooted or not. It is nevertheless preferable, if only for statistical reasons, that the reading points be to the order of 2 (2^n).

According to Gounot (1969), the method is suitable for the study of the evolution of pasture in semi-arid zones or in other types of open vegetation (halophilic groups). However, it is, in practice, fairly complicated to put into operation because it uses a relatively clumsy system. Furthermore, other than graminaceae vegetation, the ring has difficulty grasping thickets of bushes. This method also does not seem appropriate for the arid zones of North Africa.

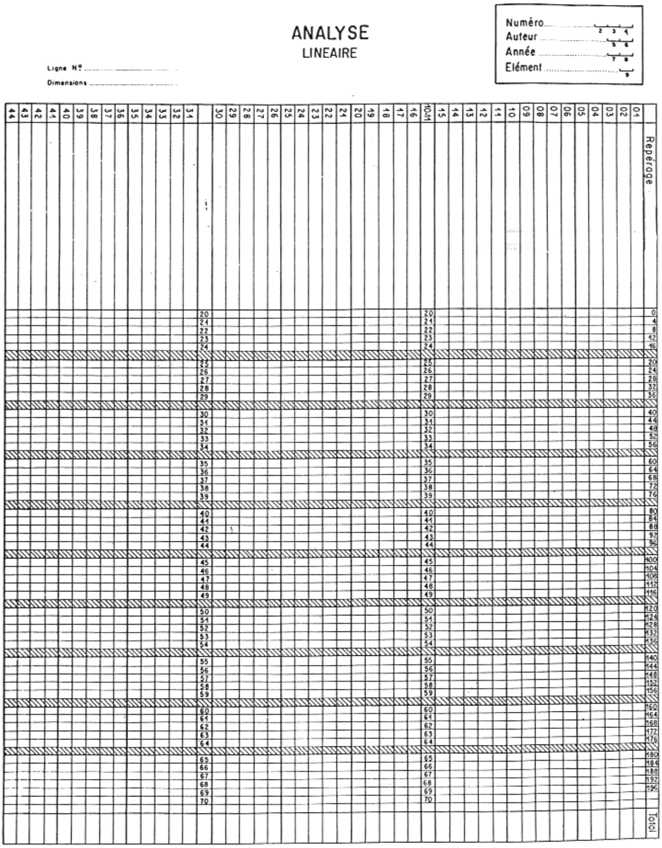
B. Point Quadrat

As initially defined, the point quadrat method consists of assembling ten aligned pins. This arrangement clashes with important statistical limits. In effect, Goodall (1952) demonstrated that in reality the distribution of vegetation is contagious and reading points are not independent and therefore do not follow binomial distribution law. Random point sampling would be the most efficient but this would no longer be systematic sampling.

It is theoretically possible to vary the grid and the number of points until the distribution is binomial. The use of a spoke on a rimless wheel that one rolls through the vegetation (Graetz and Gentle, 1990; Melzi, 1986) demonstrates that the variance leans towards what is obtained with random points.

In the ROSELT/OSS framework, an original variation of the procedure is proposed, specifically, the use of aligned points. It is the method used most often (Gounot, 1969; Long et al., 1970; Daget & Poissonet, 1969, 1971, 1974; Jonasson, 1983; Daget & Godron, 1995).

Figure 10 represents a relevé form for linear analysis using the point quadrat method.


ANALYSE
LINEAIRE

Numéro
Auteur
Année
Elément

Ligne N°
Dimensions

Repérage
Total

Figure 10: Relevé form using the point quadrat method

This involves counting the points of vegetation along a graduated line (or tape) according to a regular grid. All of the measurements made on a surface may then be transposed onto a dimension and quantitative parameters determined, such as: cover, frequency, density, and the contribution of species to the plant cover. This technique does not require a heavy frame, it is simple to apply and it is perfectly adapted to low lying, open formations of arid and semi arid regions. It has been tested, validated and used by numerous authors to evaluate the state of vegetation and soil elements in steppic and pre-Saharan ecosystems all over North Africa as well as in the Sahel. This method has proven itself effective in the realization of follow-up of plant cover by maintaining permanently placed lines on observation stations (Aidoud, 1989).

However, the method presents the disadvantage of over-counting the number of contact points.

The method was described in Chapter II (§ Composition and structure). The lines generally are 20m long and the grid is most often between 10 and 20 cm. However, in the absolute the grid and the number of points must be adapted to achieve random distribution. It therefore is recommended to verify, through appropriate, non-parametric statistical tests (e.g. test of conformity to binomial law), the homogeneity of the vegetation and study, even if briefly, the vegetation structure. Studies of the vegetation structure requires a specific statistical approach that is often complex. Within ROSELT/OSS, where we are primarily concerned with the evaluation and follow-up of the actual state of degradation of dry zones south and north of the Sahara, a preliminary study can identify the ideal number of reading points, which would determine how many lines of 20m should be 'read'. No matter what the case, the more the vegetation is scattered, the greater the number of reading points (and therefore lines) there should be.

According to one's needs, at each reading point along the graduated line or lines, one will note either the presence of taxa, or the number of contacts, by stratum, with the needles descended vertically into the vegetation (cf. details of the practical procedure and interpretation in Chapter I, § Composition and structure).

Well adapted to plant formations of the savannah, the aligned point method has proven less effective in formations dominated by chamaephytes (short woody plants) found, for example, on the steppes of North Africa. Other types of lines are used to study this type of vegetation.

For discontinuous, woody plant stratum (for example, Acacia), the 'Cooper gauge' method described in Daget & Godron (1995) is used. The gauge usually has a T-shaped form whose two pieces are precisely 10 and 70.7 cm long for the 'arm' and 'leg'. On the end of the 'leg' farthest from the 'arm', either an eyepiece (a pierced metal plaque) or a foresight is fixed (Figure 11).

Figure 11: Cooper gauge

At a study point, the observer brings the gauge to his eye and notes the number and nature of the species whose height surpasses the length of the 'arm'. He pivots in a circle to sweep the entire surroundings and restarts the operation at different points of the study station. A minimum of 10 observations is necessary.

C. Segment reading

This method consists of stretching a line above vegetation and measuring where it is intercepted by different species at the level of their crowns (Gounot, 1969). For each species, the results are expressed in the form of relative frequencies through the relationship between the intercepted length by species and the total length of the line.

D. The interception line method

This method consists of stretching a string in a line and noting the contacts the string makes with the different elements present in the environment. The square of the length of each object gives the cover area of the object (Le Houerou, 1987). The length of the line depends on the abundance and uniformity of the vegetation. It varies from 15 m for a cover of 5 to 15% to 30 m for a cover of 5% (Floret, 1988), but these recommendations are more a suggestion than a rule. The number of lines depends on the uniformity of vegetation (about thirty lines is appropriate for most types of vegetation).

For mathematical reasons, tufts of grasses are measured at ground level. In effect, if they were measured at a higher level, the value of their cover would increase considerably more than their actual cover.

In the case of other herbaceous species, one generally measures the diameter of the stem if it is alone, and the diameter of the basal leaves for plants in rosette. For woody plants and small bushes, the measurement is taken at the crown (Floret, 1988).

Annex II b

Commonly used methods to measure phytomass

A. Definitions

Definitions of the terms above-ground phytomass, standing above-ground, standing 'green' phytomass, standing necromass, necromass, total phytomass, and consumable phytomass already were provided in Chapter II § Quantitative characterization, a. Phytomass.

Above ground dry phytomass, which is our main interest, may be expressed in different ways and in different units. Pastoral science is interested in the phytomass present in grazed plant formations, or pastoral phytomass. This pastoral phytomass may be total, or contrary to consumable, if one takes into account in particular the accessibility of this resource to animals. The expression of one or the other of these notions of pastoral phytomass will be:

- in green weight (fresh material)
- in dry weight (dry material). It also would be possible to express it in calories or in the carbon content of dry material according to the needs of the study. However, for pastoral scientists, the most common expression remains the weight of dry material.

B. Fundamental problems

Numerous pitfalls must be addressed, including: the surface unit, the numbers, the form and the distribution of samples.

1. The form of the plot requires a choice between circles, squares and rectangles.

The circle presents the fewest border errors. However, it presents a fairly serious inconvenience in that even a slight error in the measurement of the radius will modify greatly the surface taken into consideration.

For relatively large surfaces and in situations where one must make several observations and measurements on the same plot, the rectangle is considered a good option. It is in effect possible to choose a width that avoids the risk of trampling.

For small surfaces, the square remains the most frequently used form.

2. For the size of the plot, ROSELT/OSS has opted for one that conforms to the minimal area of the formation under study (cf. Chapter II Homogeniety). As an example, in southern Tunisia, the standard plot dimension was 32 m^2 in the

form of an 8 x 4 rectangle. For annual species, it is frequently recommended to choose a 1 m^2 square. For formations dominated by trees (steppes and tree savannahs), the minimal area will be clearly much more spread out. Complex formations with two or more stratum require measurements that can be made on different surface areas adapted to the types of plants present.

It is recognized that an increase in the size of samples, if it does not modify the mean, only reduces the standard deviation and consequently increases the quality of the results.

3. The number of plots to measure is closely linked to the plot size chosen. In fact, this involves trying to arrive at the optimal combination of sample size and number in order to obtain the greatest precision possible at the lowest cost in terms of manpower.

It is recognized that the increase, up to a certain level, of the number of samples improves the precision of the mean and the standard deviation. However, what is gained in precision by supplementary measurements diminishes as the number of samples increases. In other words, gains in precision are increasingly costly. For the Sahel, Levang & Grouzis (1980) arrive at the conclusion that for the measurement of herbaceous phytomass, one should adopt an optimal combination of 30 sample plots of 1 m^2 each. Milner & Hugues (1968) reported a formula expected to rigorously determine the number (N) of samples to take in order to achieve the desired level of precision.

$$N = \frac{tS}{DX}$$

with:

S = standard error obtained in sampling, by cutting, a limited number (10) of plots, t obtained from statistical tables

D = the degree of precision desired (in decimals, for example 10% = 0.1)

X = arithmetic mean of measurements made on the reduced number of samples.

Greig-Smith (1964) proposed a graphic method (in Milner & Hugues, 1968) to visualize, as work progresses, the increase in the precision of results. The establishment of such a graph allows one to choose the limit after which there is no longer any point of adding more work.

4. The distribution of samples also must be chosen. It is clear that the samples must be distributed over the entire formation studied in order to take into account its heterogeneity. The heterogeneity of sites has been shown to be very important to consider. It is key, when a heterogeneity gradient is detected, to

take care to situate samples in the direction (or the axis) of this gradient. In environmental situations considered to be homogeneous or heterogeneous but without an established gradient, the distribution of samples must be undertaken randomly. Several methods have been adopted such as randomly throwing an object or determining a direction at random and counting a given number of steps. An assessment of these practices was provided in Annex I b.

The precise identification of sample sites is only necessary if measurements must be retaken at the same location.

C. Measurement of total pastoral phytomass

.1. Cutting method

Protocol
The choices noted in the preceding paragraphs having been made, the sampling plot has materialized (stakes and cord). The perennial vegetation is cut to the ground on the entire plot. If this is done manually, the cut can be at the origin of serious mistakes, the height of the cut varying greatly with the operator. One also must take into account the fact that although offering more regularity, mechanical cutting equipment cannot cut to the ground. Ellenberger (1977) reported the following height cutting norms of different tools:

- sheep mower	1-3 cm
- powered mower	3-4 cm
- tractor cutter bar	7 cm

The plants cut to the ground (complete harvest) are sorted taxon by taxon or by species category (graminaceae, leguminous) according to the precision desired for the study. For annual species, the cut is undertaken on a surface area generally reduced to 4 or 1 m². At the end of the cutting, the selected categories of plants are weighed green separately.

While this procedure poses no difficulties for herbaceous (perennial and annual) nor for short woody plants, it is not directly applicable for tall woody plants. However, as the importance of woody plants expresses (even in arid and semi arid zones) in a relatively faithful way the condition of a population, it is critical to also measure their phytomass. Methods were noted regarding this subject in Chapter II § Quantitative characterization, a. Phytomass, for example, that of the 'average tree'.

At the time of the weighing, one takes a sample for each category of plants and puts it in a sealed plastic bag to be brought to the laboratory for weighing and analysis. The dry weight is obtained after the samples have been put in an oven at 70°C for 12 hours. The ratio between the green weight of the fresh sample and its weight after being in the drying oven provides the quotient used to convert the data of green weight obtained in the field to dry weight. This expression of results, independent of the water content of the fresh plant material, facilitates inter-seasonal and inter-annual comparisons.

Results and their precision

In the majority of cases of weight studies applied to pasture formations, the authors calculate the arithmetic mean, the standard deviation, and possibly the precision index (P) of the mean. This index is not very common although key. It is calculated according to the following formula:

$$P = \frac{s\ t}{x\sqrt{n}}$$

where s is the standard deviation, t the Student coefficient, and x the arithmetic mean.

According to Daget (1996), pastoral vegetation being, especially in arid zones, very heterogeneous, classic methods of result analysis are not suitable. All of the authors note the wide variability of results and the difficulty of taking a sufficient number of measurements to arrive at an acceptable precision. In actual fact, the natural heterogeneity of this type of vegetation invalidates the hypothesis of Gaussian distribution of measurements and renders it difficult to refer to the calculation of a mean. Daget (1996) advises one to then no longer calculate the arithmetic mean but rather the median. The values of n measurements being classed in increasing order, the median occupies the rank:

$$\frac{(n+1)}{2}$$

Daget (op cit) also contests the means proposed by mathematicians to calculate the confidence interval in this situation and proposes the following solution. The rank of the boundary marker of the confidence interval of the median is given by:

$$\frac{(n+1)}{2} \pm z = \frac{n}{2}$$

where z is the value of the normal variable at the chosen threshold (at threshold 0.95, z = 1.96 and at 0.99, z = 2.6).

For a set of 30 above ground dry phytomass measurements, the boundary markers of the confidence interval are given by the formula:

$$\frac{31}{2} \pm \frac{30}{2} = 15,5 \pm 5,5$$

In a set of measurements organized in increasing order, the boundary markers therefore will be the tenth and the twenty-first value.

.2. Other methods

These other methods are addressed and broadly described although they are based on indexes, estimations, and other sets of statistical relations between rigourous results obtained by the cutting method described in the preceding paragraph and by evaluations obtained through other means. These means, which frequently were developed to be less time consuming and less destructive, often still need to be refined.

a. Approximate method by estimations (observer training method)

This in fact involves the method derived from that of Pechanec & Pickford (1937) presented in Chapter II.

The principle is that a good observer, one who is well-trained and regularly monitored, can arrive at estimating the weight of a standing plant with reduced error. The observer first tests his skills on a single space. The weight of clumps is estimated then this same clump is cut to the ground and weighed green on site. Progressively, the observer refines his judgment to the point of being able to work with a degree of certainty on slices of green weight of plus or minus 10 gr. Once well-trained for one species, the observer gradually complicates the exercise by extending the method to diverse spaces of the same plant formation.

Once the training is complete, the work procedure consists of proceeding, on plots delimited according to the rules described in the complete cutting method, first to an evaluation of the weight of a clump followed by its cutting and weighing. This procedure is applied to all of the clumps of the same species and then extended to all of the species on the plot. It is possible, for example, to proceed from the estimation and then the weighing of one plot to the estimation alone of two following plots and in this way to sets of three plots. It is recommended that each day begin with this double 'estimation-weighing' exercise. The act of systematically noting the estimated results and then looking at the weight results allows the calculation of a regression equation between the two results obtained for the sampling plot (1 plot out of 3). This calculation allows the application of a calculated correction of results from plots that were only estimated, thereby increasing precision. Traditional statistical calculations are applicable to this data.

Floret 1988) reports an example of these calculations for data obtained on 20 plots 16 m^2 (of which 7 were both estimated and weighed) with a mean of the 7 measured of 2851 $gr.m^2$ and a mean of those estimated of 2540 $gr.m^2$.

The regression equation between estimations and measurements for the 7 plots takes the form: $y_{(estimé)} = a + b\,(x - \bar{x})$

where a = the mean of estimations on the 7 lots that also were measured; b = constant

x = mean of 20 plots estimated

x = mean of the measurements on the 7 plots.

b. Method based on the specific contribution and standing phytomass ratio.

We already noted the ratio (almost linear in certain cases) between the Specific Presence Contribution (SPC) and the Specific Contact Contribution (SCC) for dense herbaceous (Poissonet & Poissonet, 1969). These authors also established a strictly linear relationship between SCC and standing above-ground phytomass (weight expressed in dry material). The ratio must be established species by species. It appears that the SPC may be adopted as an appropriate expression of phytomass.

The logical procedure (two-step sampling) proposed by Anderson & Kotmann (1982) comprises two steps with, successively on the same spaces and the same individuals, the determination of cover (SF, SPC, SCC) then phytomass.

The results are fairly unequal depending in particular on the biological type of taxa.

The procedure may eventually be applied at the level of the entire plant formation. One considers a) the above-ground standing phytomass and b) the cover or bio-volume. The procedure followed may consist of measuring the cover along 10 lines of 100 points each and nearby measuring the phytomass by the complete cutting method on 6 bands of 10 m^2 (25 x 0.4 cm). One then calculates the linear regression equation passing by the origin of type:

$$y = bx$$

where y is the biomass and x the cover.

This procedure apparently improves the precision of results.

The quality of the cover-phytomass ratio is much less good for short woody plant formations that are very common in arid zones. This has been shown by a methodological study made (Joffre, 1978) in south Tunisia on 5 short woody species. In point of fact, the correlation is good for small individuals (Figure 12) but deteriorates for individuals weighing more than 350 grams.

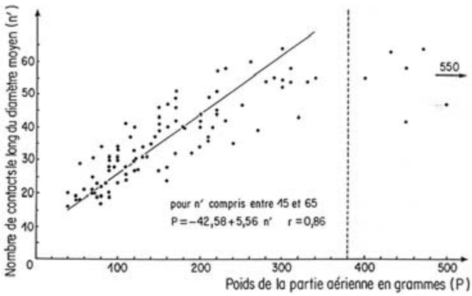


Figure 12: Correlation between above-ground phytomass of Seriphidium herba-alba and the number of contacts (SPC) observed on the mean diameter (Joffre, 1978)

For large bushes, the method of reading point quadrats is difficult to implement. This is why in pluri-stratum formations (low herbaceous stratum and taller woody stratum) it is important to dissociate measurements for each stratum. As already has been mentioned, for the measurements of large clumps, it is possible to refer to forestry techniques.

Glossary

Biocenosis: cf. Biotope

Biodiversity: Daget & Gaston (2001) provide the following definition: "diversity measures the global heterogeneity of a countable ensemble whose components may be grouped in categories, therefore, an ensemble that can be partitioned. (cf. Chapters III & IV)

Biological diversity: cf. Biodiversity

Biomass: The mass of living material per surface unit. It is subdivided into vegetal biomass or phytomass and into animal biomass or zoomass. (Chapter II)

Biotope (or a habitat): a limited but variable surface unit (ecosystem or agrosystem) that can be described by specific prevailing physical and chemical conditions (abiotic descriptors) and is occupied by a biocenose (biotic descriptors).

Contact: a notion linked to the vertical structure of vegetation. The number of contacts is evaluated by the point-quadrat method. (Chapter II)

Density: The number of individuals per surface unit or per unit of volume. (Chapter II)

Diameter: Measurement of the average width of a plant (Chapter II)

Ecological diversity: Generally the number of different ecological units in a given space. It is often accessible through the number of insets of the legend of the most precise map on the subject (Chapter IV).

Ecosystem: a whole constituted by a physico-chemical environment (biotope) and the living beings inhabiting it (biocenose).

Energy content: From a nutritional point of view, the energy content of a species is its nutritive value, a value which depends on both the digestibility of the organic material and its chemical composition (nitrate and other mineral). (Chapter II)

Floristic composition: A list of species surveyed in a place on a surface at a given date (Chapter II).

Follow-up: the measurement of the potential evolution of a component, most often applies a certain number of parameters known as 'indicators'. (Chapters I to IV)

Frequency: The ration between the number of points where a species is present and the total number of points studied. (Chapter II)

Height: The average height of individuals measured in cm. (Chapter IV)

Land Cover Map (LCM): A thematic cartographic document including the description and localization of principal vegetal formations, dominant and co-dominant species, soil surface states, and the level of pressure put on it by people. The LCM accounts for the actual state of vegetation and the influence of human action on the environment. (Chapter I, Zoning)

Landscape: A set of ecosystems interacting in a way that determines spatial patterns which repeat themselves and are recognizable (Forman & Godron, 1981). (Chapter IV)

Minimum area: The smallest surface area necessary to identify most species of homogeneous groups. The method to identify a minimal area is given in Chapter II.

Monitoring: The methodology is based on the fact that for each measured parameter (indicator) it is possible to detect a threshold value beyond which one considers change significant. It is then possible, for example, to activate an early warning system. (Chapters I to IV)

Necromass: The quantity of dead organic material (e.g. vegetation) per surface unit at a given moment. (Chapter II)

Palatability: The palatability of a plant is determined by the intensity by which animals consume it. It may vary as a function of the seasons and be dependent on the chemical composition of the species, the leaf/stem/seed relationship, its nutritional value, and repulsive elements (tannins), etc. (cf. Chapter II).

Pastoral value: The index characteristic of the value of pasture land that takes into account the abundance of species measured by their specific contribution and of their quality measured by a specific index (Djebaili et al, 1992). It is most often determined though surveys of livestock owners. (Chapter II)

Phytovolume: The volume of vegetation measured by the height and the diameter of the plant. (Chapter II)

Radiometry: The recording of different spectral responses of surface soil components. These spectral signatures establish the distinction between soil and vegetation.

Region: An extended geographic territory with its own specific characteristics in terms of the flora, fauna, and natural conditions (soil, climate, etc.). (Chapter I)

Sampling: A set of operations to select individuals from a population to constitute a representative sample. (Chapter II)

Sensitive zone: An ecologically fragile space where development activity can not be undertaken without taking into account its specificity. (Chapter I)

Species-area curve: A graph in which the ordinate represents the evolution of the number of taxa and the abscissa the surface of a homogeneous group whose number of taxa one wishes to count. It enables one to establish the minimal area (cf. minimal area).

Species cover: The proportion of the soil surface covered by the vertical projection of the aerial organs of a species. It is evaluated based on the frequency. (cf. Frequency)

Specific contribution (SC): The ratio of the frequency of a species to the sum of specific frequencies of all of the species counted along a line by the vegetation analysis method called points contact. (Chapter II)

Station: A basic ecological unit defined by homogeneous ecological conditions and where a well-defined plant group develops. (Chapter I)

Structural diversity: Associated with ecological diversity, it notes the average size of a unit type and indicates the largest to smallest fragmentation of a space. (Chapter IV)

Surface state: The composition and organization of a soil surface at a given moment. It takes into account erosion layers, saline efflorescence, stoniness, and other superficial formations, as well as the covering of the soil by algae, moss, etc (Chapter II).

Zoning: Designates the subdivision of a geographic area into homogeneous sectors by taking into account certain criteria that attributes specific functions to each defined zone. (Chapter I).

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