

METHODOLOGY FOR SYMPHYTOSOCIOLOGICAL AND GEOSYMPHYTOSOCIOLOGICAL RELEVÉS

Guillaume CHOISNET^{1,2}, *Pauline DELBOSC*^{2,3}, *Frédéric BIORET*², *Charlotte DEMARTINI*², *Farid BENSETTITI*^{2,4}, *Vincent BOULLET*⁵, *Aurélien CHALUMEAU*², *Kevin CIANFAGLIONE*², *Arnault LALANNE*²

¹ Conservatoire botanique national du Massif central, le Bourg, **F-43280 Chavaniac-Lafayette, France**

² Université de Bretagne occidentale, EA 2119 Géoarchitecture, UFR Sciences & Techniques,
6 avenue Le Gorgeu, **F-29200 Brest, France**

³ Conservatoire botanique national de Corse, Office de l'Environnement de la Corse,
14 avenue Jean Nicoli, **F-20250 Corte, France**

⁴ UMS Patrinat, Muséum national d'Histoire Naturelle, 36, rue Geoffroy Saint Hilaire, **F-75005 Paris, France**

⁵ Vourlhac, **F-43230 Frugières-le-Pin, France**

e-mail: guillaume.choisnet@cbnmc.fr; frederic.bioret@univ.fr

Abstract: Based on the main landscape phytosociology works (symphytosociology and geosymphytosociology), elements of methods to carry out sigmarelevés and geosigmarelevés are brought through with the analysis of various concrete cases.

These methodological elements follow an inductive approach for the characterization of sigmassociations and geosigmassociations (series and geoseries of vegetation).

Keywords: Symphytosociology, geosymphytosociology, series and geoseries of vegetation, methods and concepts, sigmassociation, geosigmassociation, sigmarelevé, geosigmarelevé.

Introduction

In the continuation of the notions of complexes (groups) of communities (Du Rietz 1917; Braun-Blanquet 1928 (Gesellschaftskomplex); Pavillard 1935; Braun-Blanquet 1951 (Gesellschaftsmosaik)) the landscape phytosociology (or integrated phytosociology) emerged in the 1970's (Tüxen 1973; Géhu 2004); using methods and concepts of phytosociology transposed to the analysis of the plant landscape.

It studies the community complexes within homogeneous spatial units, which constitute the elements of the landscape [23]. In landscape phytosociology, two levels of analysis are distinguished:

- the serial approach; based on the vegetation series concept, corresponding to the symphytosociology *stricto sensu* whose elementary unit is the sigmetum, sigmassociation or synassociation (association of associations);

- the geoserial approach based on the vegetation geoseries concept, corresponding to the geosymphytosociology whose elementary unit is the geosigmetum, geosigmassociation or geosynassociation (Figure 1).

The distinction between serial and catenal concept is due to Rivas-Martínez (1976) and was formalized by Géhu and Rivas-Martínez [22].

Even if the theoretical developments of landscape phytosociology was clarified [30, 1,

33, 34, 35, 36, 19, 21, 38, 39, 28], the methodological principles of this recent science are not yet fully defined and agreed upon.

An important step forward in defining a methodological framework was initiated in a synthesis work [13] following the work of Theurillat (1992a) which will soon be published (Bioret et al. *in press*).

Concrete unit/ Spatial framework	Category	Nomenclatural unit	Field study
Community / Station	Association	Syntaxon	Phytosociology
Individual of series or tessellar complex / Tessella	Sigmatum, synassociation or vegetation series	Sigmataxon	Symphytosociology
Individual of geosérie or catenal complex / Catena	Geosigmatum, geosynassociation or geoseries of vegetation	Geosigmataxon	Geosymphytosociology

Fig. 1: The different spatial and typological integration levels of phytosociology s.l.

The serial phytosociology (symphytosociologie) studies within similar ecological compartments, tessellas [8], the repetitive combination of communities in order to define the sigmassociation which is analyzed in terms of dynamic succession and allows to define the vegetation series. The sigmetum can be defined as a group of associations dynamically linked and can be characterized by the analysis of a batch of sigmarelevés.

Catenal phytosociology (geosymphytosociology) studies complexes of synassociations (catenal or geoserial complexes) and the geographical and ecological relations that linked many sigmetums within a homogeneous geomorphological unit of territory (catena). The basic taxonomical unit is the geosigmatum (vegetation geoseries or geosynassociation) which can be assimilated to the elementary phytogeographic unit [23] and can be defined as a chain of ecological compartments distributed in a given geomorphological unit. The geosynassociation is characterized by a repetitive combination of sigmassociations or associations highlighted through the analysis of geosynrelevés.

Three main types of approach can be identified for the description of community complexes and the realization of (geo)sigmaterelevés:

- deductive mapping approach;

With the generalized development of Geographic Information Systems (GIS), this approach consists in crossing the maps of the ecological parameters with the maps of the syntaxons, in order to reveal the envelopes of the tessellas and their associated potential vegetations. The maps of the vegetation series established by Blasi (2010), Biondi et al. (2009), and Pinto-Gomes and Paiva Ferreira (2005) are based on this principle. In the same way, the geoserial analysis can be deduced from the vegetation series maps.

- deductive-inductive mapping approach;

The (geo)sigmaterelevés are carried out under GIS according to the previous deductive approach, using ecological mapping layers and syntaxon maps [3]. The relative frequency of plant associations within tessellas and catenas is established by GIS request and transposed into abundance-dominance code. The second step (inductive) consists in a classical sigmataxonomic

analysis of the (geo)sigmarelevés to define the (geo)sigmassociations.

- inductive approach.

In this approach, the methodological basis are the vegetation relevés. Their analysis constitutes the founding stage on which the characterization of the typological units is based. In the bibliography, it lacks concrete elements to support this step, which is always confronted with the problems of scale and homogeneity: "it is the art of the symphytosociologist, like the phytosociologist, to know how to work on the most timely and appropriate scale of homogeneity for the problems to be solved" [17].

According to the principles of an inductive approach proposed by Géhu and Rivas-Martínez (1981) to typify vegetation series and geoseries, through the analysis of concrete cases, this work is a contribution to specify some elements for the factual investigation of the vegetal landscape by the realization of plant community complexes relevés.

1. Sigmarelevé

1.1. Basic principles

Géhu and Rivas-Martínez (1981) define the sigmetum as "the quantified spatial expression of all communities within the same series inside a unique tessela". It represents "the expression of a concrete plant landscape within the same potentiality" [22]. Thus, the sigmarelevé represents a phytocenological and ecological picture of an individual series through a weighted list of associations in an ecologically homogeneous surface presenting the same potential vegetation [25, 2].

1.2. Spatial delimitation

"The sigmarelevé must be carried out in a very homogeneous territory from the dynamic point of view, that is to say within a single "tessela", in other words within a same potentiality leading to a single climax community. It is recommended, especially at the beginning of the analysis, to identify spots gathering the maximum number of substitution steps" [25].

The choice of the surface to be identified is determined by the search for an ecological homogeneity and by the search for individuals presenting an important phytocenotical diversity. The delimitation of the tessella, the stationary compartment, the spatial framework of the individual sigmassociation, represent a fundamental step. This requires an understanding of the ecological parameters that determine the distribution of potential vegetation. Indeed, the spatial framework of the analyzed vegetation complex has to be perceived through its potential vegetation, while the herbaceous vegetations that can express either an ecological diversity, or former uses, could be erased (almost eliminated) by the potential forest (Figure 2).

Initially, it is wise to focus on tessellas housing well-expressed climatic vegetations. The analysis of the ecological variability of the biotope (sensu Géhu 2004), topographical form, geology and pedology, provides important informations for the delimitation of tessellas hosting herbaceous communities.

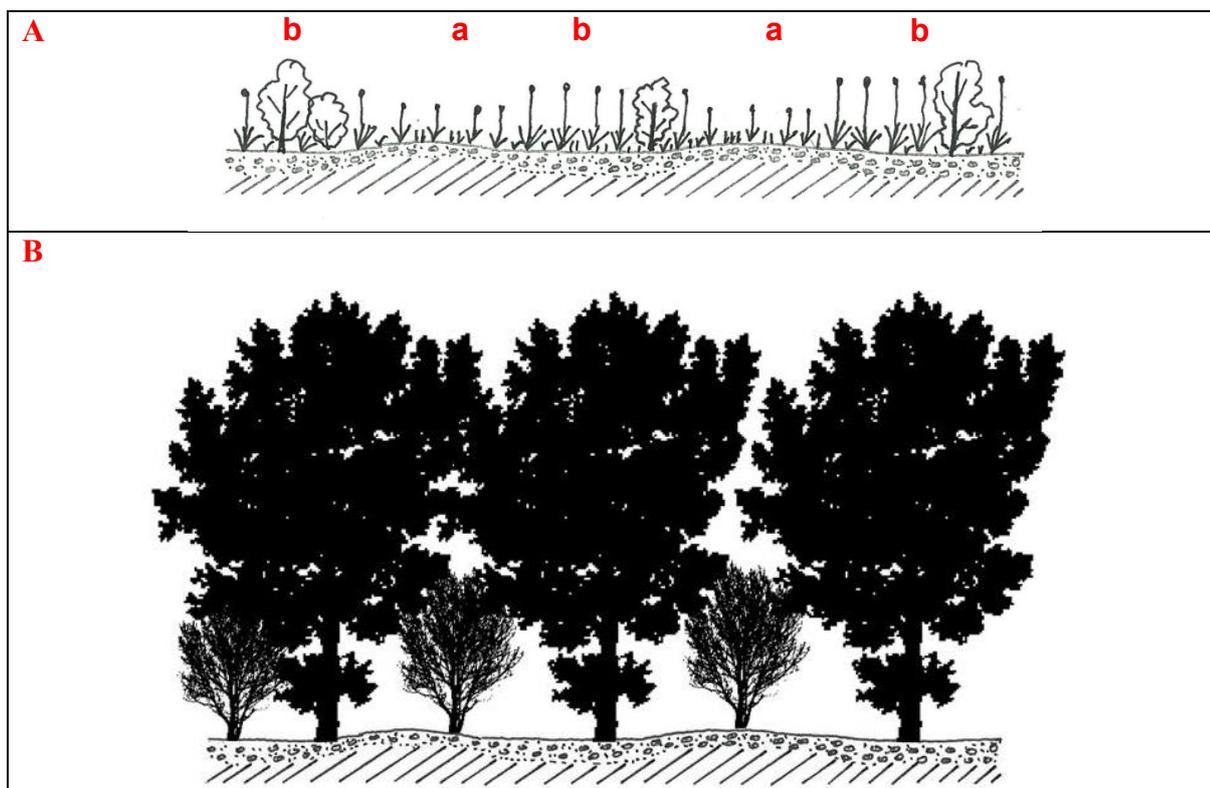


Fig. 2: Jurassic Plateau des Gras, Balazuc (Ardèche); vegetation complexes on marly limestone (Kimméridgien).

A - Minor ecological variations of tessella, of metric to decametric spatial extension, expressed at the level of herbaceous vegetation with:

- [a] herbaceous recolonization community of skeletal soils, *Melica ciliata* and *Brachypodium retusum* community (association to be described as part of *Phlomido lychnitidis-Brachypodium retusi* G.Mateo 1983),

- [b] herbaceous recolonization community of thicker soils, *Dorycnium pentaphyllum* and *Brachypodium retusum* community (association to be described as part of *Phlomido lychnitidis-Brachypodium retusi* G.Mateo 1983).

B - Oak community whose extension masks the minor ecological variations that can sometimes be perceived, through floristic variants of the community (*Quercion ilicis* Braun-Blanq. ex Molin. 1934).

The ecological homogeneity analyzed through the vegetation floor, geology, topography (slope, exposure, concavity / convexity, crest, position on the slope...), soil and water reserves (Figures 3 and 4) usually guarantees a reliable delimitation of the tessella.

It is necessary to multiply the soil sampling points within the surveyed zone: when the area is large, crossings from one tessella to the other may be progressive, so that it is possible to carry out a heterogeneous survey at the ecological level.

Within the same topographical form (ridge, concave slope, convex slope, top of slope, bottom of slope ...) the realization of several pedological soundings of the surface horizon taking into account texture, structure and effervescence, generally allows to confirm the ecological homogeneity of the survey.

According to Béguin, Géhu and Hegg (1979), for a valley, the delimitation of the sigmarelevés follows the ecological divisions: talweg (minor bed), first terrace frequently flooded, second terrace rarely flooded, slopes...



Fig. 3: Small valley of the temporary stream of Granzon, Les Vans (Ardèche); delimitation of the tessellas according to the topography, the thickness of the soils and their water reserve.

1. Minor bed and low alluvial terraces, complex of dynamically blocked series (permasigmetums of *Charetum vulgaris* Corill. 1949 and *Ranunculion aquatilis* H.Passarge 1964, Minorisigmetum of *Rhamno alaterni-Salicetum eleagni* prov.).
2. Intermediate alluvial terraces, Holosigmetum of *Rubia peregrina* and *Fraxinus angustifolia* community (association to be described).
3. High terraces, old alluvium, Holosigmetum of *Geum urbanum* and *Quercus ilex* (association to be described).
4. Bottom of colluvial slope, Holosigmetum of *Pistacia terebenthus* and *Quercus pubescens* community (association to be described).
5. Slope, Holosigmetum of *Viburno tini-Quercetum ilicis* Braun-Blanq. ex Rivas-Mart. 1974.

Theurillat (1991, 1992a) proposes another approach linked to a different definition of sigmassociation. This corresponds with a homogeneous tessella “not only from the point of view of the dynamics and structure of the vegetation, but also from the visual, geomorphological, pedological point of view and its human use” [22].

He specifies (1991): "The symphytosociological surveys were carried out according to a method called "parcelles" developed by Hegg and Schneiter (1978). A parcel is a homogeneous landscape unit ("homogene Landschaftseinheit") defined by: the same geological substratum, a uniform slope, an identical exposure and a uniform vegetation structure (unique or dominant structure, or homogeneous blending of different structures), the same vegetation floor and, incidentally, the same municipality. The parcels are delimited according to these criteria on a 1:5 000 (1:10 000) topographic background using aerial photos and geological maps. Their area ranges from 0.1-1 to 4-12 ha, with an average of 3-4 ha. From case to case, the assessment of the limits has been revised and corrected in the field. Special care has been taken in the search for a uniform geomorphology (slope and exposure), similar to Tüxen".

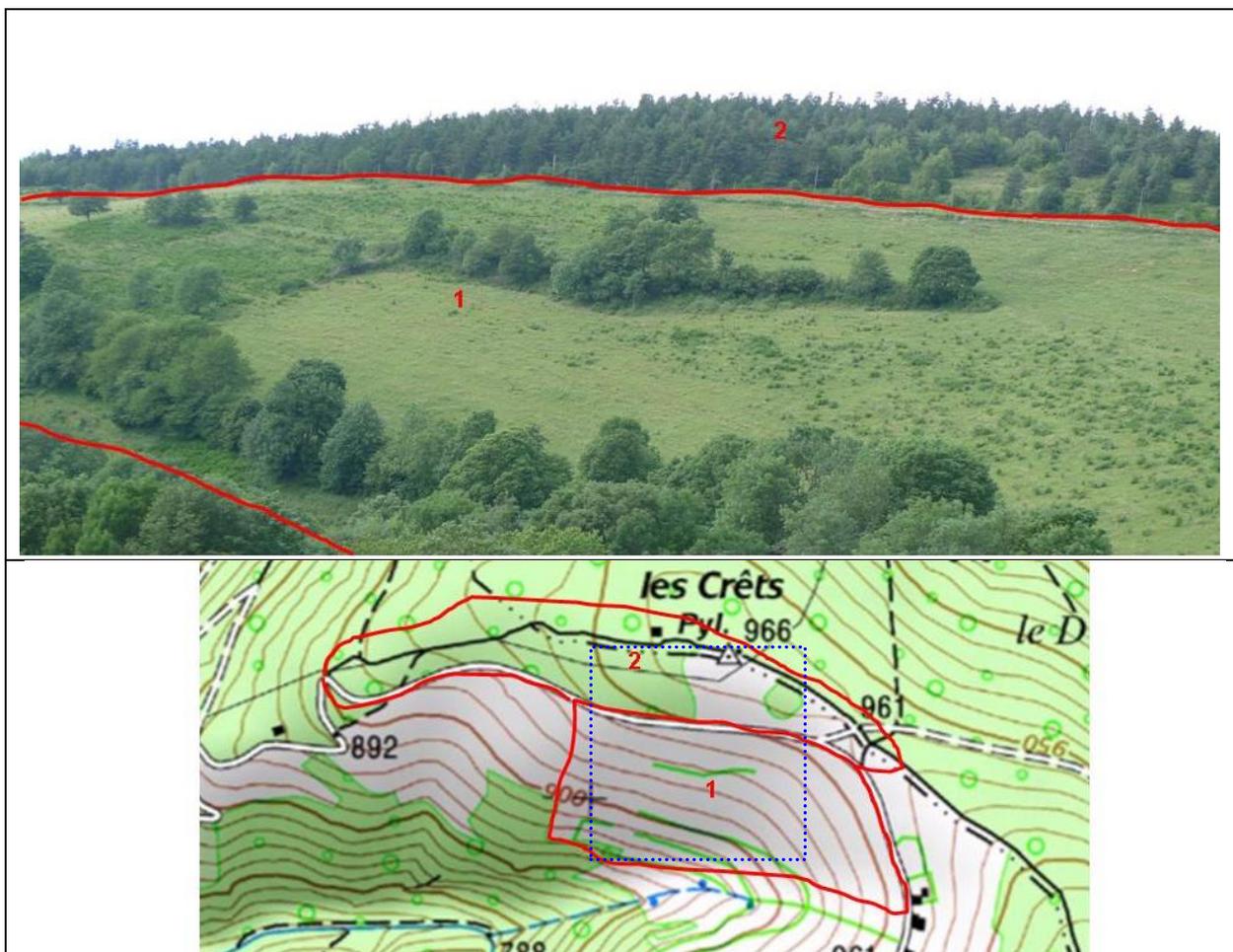


Fig. 4: Demarcation of two synrelevés. Northern hillside of Massif du Pilat, Loire département. In blue, area of the photo.

1. Concave slope housing an individual of the collinean acidophilous Series of *Holcus mollis* and *Fagus sylvatica* community – series' head to be described.

2. Top of slope with an individual of the high collinean acidiphilous Series of *Teucrio scorodoniae-Fagetum sylvaticae* Renaux, Le Hénaff & Choisnet 2015 *vaccinietosum myrtilli*.

The limit of these two tessellas corresponds to a rupture of the slope. The bottom of the slope constitutes another tessella, spatial framework of the neutroclinophilous Series of *Polygonato multiflori-Fagetum sylvaticae* Cam.Roux in Thébaud, Cam.Roux, C.-E.Bernard & Delcoigne 2014.

1.3. *Expanse and minimum area / Surface area and minimum area*

The surface of the sigmarelevé is dependent on the tessella's size. It can range from a few square meters for permaserries, spread on several hundred (or even thousand) of hectares. Usually a few hectares to several tens of hectares, as in the cases here analyzed.

According to Géhu and Rivas-Martínez (1981), the minimum area of the sigmarelevé can be estimated at 10 times the surface area of the minimum area of its potential community.

Delbosc (2016) states that "unlike the phytosociological plot and the area-taxons curve establishing in phytosociology [26], the area-syntaxons curve incorporates too many aleatory/random fluctuations to be based on a mathematical theoretical relationship. Indeed, in Europe, for a tessella, the greatest number of plant communities results from anthropogenic influence [20]. The notion of minimal area in symphytosociology can't therefore be used insofar

as many ecological and anthropic parameters intervene in the structural modelling of an individual of vegetation series. This is in line with that of Biondi (2011), who states that the number of associations constituting a vegetation series is considerably dependent on natural conditions and on the effects of landscape exploitation."

1.4. Collected data

Realized at a period offering a good compromise between the optimal phenological periods of the various vegetations present, the *sigmarelevé* consists of a weighted listing of plant communities and the collection of ecological information.

1.4.1. Spatial and temporal data

These are classical spatio-temporal data specifying the identity of the survey: inventor, date, administrative locality, GPS coordinates.

The *relevé* area data specify the measured area (ha) and the general shape of the survey (linear, spatio-linear, spatial, cross-linked).

1.4.2. Ecological data

The synthesis of this major information allows the causal study of vegetation complexes. When climatic communities are unknown, it also provides approximation of the potential vegetation. This deductive approach is often the only possible recourse for the interpretation of truncated complexes where the anthropic constraints do not allow the expression of all the dynamic stages.

This data concerns:

- the ecological description of the studied tessella: altitude, medium slope, overall exposure (eventually confinement), bedrock, pedology (soil type and depth), specific perturbations (biotic factors);
- physiographic position due to the topographic shape (geomorphology) and localisation of the tessella inside the landscape in relation in vegetation series that it is in contact with; a scheme like « transect » could present the observed gradients [24].

1.4.3. Phytocoenological data

Syntaxonomical identification. The exhaustive list of syntaxons is realised by looking for the most precise syntaxonomical rank determination. This identification can be completed by a floristic description of the coenologically unsaturated communities (Figure 5; [12]).

Fgt	Fragmentary community: floristic composition truncated by the insufficient surface of the station not allowing the optimal expression of it.
Bas	Basal community: juvenile or disturbed with a truncated cortège containing only characteristic and differential species of the upper syntaxonomic units, as well as companion species.
Der	Derivative community: floristic composition truncated by the dominance of a given species (especially alien invasive species).

Fig. 5: Floristic nature of communities according to Catteau et al. 2016.

General physiognomy and vegetation structure. It is useful to give an overview of the physiognomy of the community complex corresponding to dominant communities (ex.: *Ericaceae* heathland punctuated by shrubs with beech groves; sessile oak woodland with clearcut shrubby vegetations...).

For each community, average vegetative height and total vegetal recovery can be noted. Data relative to stratification provides comprehensive elements about phytodynamics. The most common stratification used in phytosociology is shown below (Figure 6).

Tree layer [strate arborée ou arborescente, Baumschicht]: height greater than 7 m; denoted T [or A]
Shrub layer [strate arbustive, Strauchschicht]: 7 to 1 m; denoted S [or a]
Herb layer [strate herbacée, Krautschicht]: less than 1 m; denoted H
Moss layer or ground layer [strate muscinale (ou cryptogamique), Kryptogamenschicht]; denoted M [or m]

Fig. 6: Usual stratification of vegetation.

Dominance-abundance and dominance. These coefficients are usually attributed to plant population within a community. Dominance-abundance is a semi-quantitative scale mixing two notions [9]. Dominance assess the percentage of spatial cover related to the surface of the relevé by vertical projection of the aerial limit of all the individuals of each taxon.

Counting communities corresponding to individuals of concretely observed syntaxa is often problematic. For example, within a given tessella, should one community presenting a fragmented spatial expression be considered as unique or as a bunch of individuals? Considering only the community spatial cover (Figure 7), it seems that it is possible to represent relatively realistically the image of the studied complex of communities. The dominance coefficient appears to be appropriated.

Coefficient	Spatial cover (%)		Average spatial cover (%)
+	< 1	< 1/100	0,1
1	1 – 5	1/100 – 1/20	2,5
2	5 – 25	1/20 – 1/4	15,0
3	25 – 50	1/4 – 1/2	37,5
4	50 – 75	1/2 – 3/4	62,5
5	> 75	> 3/4	87,5

Fig. 7: Braun-Blanquet et Pavillard (1922) dominance scale completed by '+’.

Géhu and Rivas-Martínez propose a surface scale (Figure 8), that can provide complementary information but could make it confusing during the relevés synthesis because it is based on the same coefficients as the dominance scale.

The remote sensing observation (for example on the opposite slope, but also by using aerial photographs), can help for quantifying, in the way that it helps to be located at the appropriate observation scale. That is to say the landscape’s scale. Nevertheless, field surveys of the studied area remain indispensable.

Coefficient	Bounds of value
i	1 m ²
r	10 m ²
+	100 m ²
1	1 000 m ²
2a	10 000 m ² (1 ha)
2b	50 000 m ² (5 ha)
3a	100 000 m ² (10 ha)
3b	500 000 m ² (50 ha)
4	100 ha (1 km ²)
5	1 000 ha (10 km ²)

Fig. 8: Surface scale (Géhu and Rivas-Martínez 1981).

Spatial form. Several categories have been proposed in order to describe surface form of the community within the studied area: ‘spatial’, ‘linear’ and ‘punctual’.

The proposed scale makes the synthesis of several propositions [42, 1, 18, 25] (Figure 9).

O	S	« spatial » form
/	L	« linear » form
Ø ou 0	sL	« spatio-linear » form
	M	« mosaic » or « pluri-punctual » form
,	dL	« disjoint linear » form
.	P	« punctual » form

Fig. 9: Spatial form or spatial distribution scale for communities.

1.5. Associated vegetations and punctual abiotic elements

According to the authors, associated communities of small surface area can be either included or excluded from the sigmarelevé. For Béguin, Géhu and Hegg (1979), the "sigmarelevés will include not only the climax communities and their different substitution steps, but also the communities linked to a deep artificialisation (roadside, *Polygonion avicularis* ...) or, if possible, so-called conditioned ones (for example, forest bryo-lichenic vegetation) or extra-climatic specialized ones (communities of isolated rock blocks, for example)".

Géhu and Rivas-Martínez (1981), stress that when taking into account dependent communities (particularly bryo-lichenic ones), «about rupicolous communities, we will retain only those which are located underneath the tree layer».

Taking into account these considerations, it is proposed that geoserial and serial complexes, or communities taking place within a low surface tessela (or catena) associated or conditioned (about a dozen square meters), could be included to the sigmarelevé. It can be vegetated rocky blocks, artificialised communities (roadsides, embankments...), bryo-lichenic communities, pounds, watersprings, ditches... These series and geoseries could be independantly described as they are widespread and can be the subject of a (geo)sigmaterelevé.

Landscape abiotic natural or anthropogenous elements can also be integrated in the sigmarelevé and quantified: stonewalls, rocks, bare soil, open water, buildings... (Figure 10).

1.6. Example



Fig. 10: Demarcation of a sigmarelevé on a shrubby slope, arranged in terraces.

The non-vegetable elements of anthropic origin of the landscape are integrated into the survey (stonewalls, stone piles).

N° rel.: 20140721-2 G. CHOISNET / CBNMC 21/07/2014 Banne (07); SE Mas de Granzon N°GPS 220 à 224	Surface area: 0,5 ha; $R_T = 90\%$ Slope (°): min. 5; max. 30 Exposure: SSE à S Altitude (m): inf. 165; sup. 180 Marly limestone (Berriasien)
Mesomediterranean complex of recolonization on marly limestone	
Slop in terraces; shrub/garrigue	
Low chamaephytic community with <i>Aphyllanthes monspeliensis</i> <i>Argyrolobio zanonii-Aphyllanthes monspeliensis</i> Vanden Berghen ex Gaultier 1989 <i>Dorycnium pentaphyllum</i> var. / <i>Aphyllanthes monspeliensis</i> faciès	3 S
Low phanerophytic community with <i>Genista scorpius</i> Bas <i>Genista scorpius</i> community	1 M
High chamaephytic community with <i>Stachelina dubia</i> Fgt <i>Stachelina dubia</i> and <i>Lavandula latifolia</i> community	+ P
Recolonization hemicytophytic community with <i>Brachypodium retusum</i> <i>Dorycnium pentaphyllum</i> and <i>Brachypodium retusum</i> community	1 S
Shrub with <i>Prunus mahaleb</i> and <i>Quercus pubescens</i> <i>Prunus mahaleb</i> and <i>Pistacia terebinthus</i> community	3 S/M
Pubescent Oak grove Fgt cf. <i>Pistacia terebinthus</i> and <i>Quercus pubescens</i> community	+ P
Shrub with <i>Juniperus oxycedrus</i>	2 M
Stonewall	2 L
Stone piles	1 P

2. Geosigmarelevé

2.1. General principles

The recognition and characterisation of geosigmassociations (geosynassociation, geosigmatums) are complex due to a recurrent problem of scale. Low surface catenal complexes (saxicol communities, wet meadow, peatbogs...), generally take place within spatially extended sigmetum individuals. On the opposite hand, following the spatial integration approach of géosymphytosociology, geoseries are defined as widespread elements corresponding to wide landscape geomorphological units. Geoseries is also used in mapping as a substitute to the knowledge of the series concerning anthropogeneous landscapes whose potentialities have been erased by human activities, such as wide alluvial plain geoseries, or cultivated plateaux geoseries.

Numerous definitions are proposed with a common point: the spatial frame defined by «*homogeneous geomorphological units of variable length*» [23]. Most generally, the geosigmassociation is considered as a level corresponding to "*high geomorphological units*" that can be interpreted as an elementary phytogeographical unit » [22, 23].

In order to illustrate the complexity of the scale, we can cite Rivas-Martínez (2005) who distinguishes topographic geoseries (on wide surfaces) composed of smaller geoseries with ecological determinism (fractogeosigmatums). The topographic geoseries or geomorphological geosigmatum illustrates the pattern «*crest – slope – piémont – valley*». It concerns all the edaphohygrophilous, climatophilous and edaphoxerophilous contiguous series, which correspond to the topographic catena occurring in a biogeographical area. The geosigmatum can also represent a portion of the geoseries called fractogeosigmatum.

Theurillat (1992b) proposes to distinguish four catenal levels according to the type and size of the catenas:

- hypogeosigmassociation (spatial framework: hypocatena): limited spatial extension; specialized vegetations (dozens to hundreds of meters);
- geosigmassociation s.str. (catena): linked to a geomorphological element of "mesorelief" (hundreds of meters to kilometer); mapped to 1:25 000;
- hypergeosigmassociation (hypercatena, catena of catenas): part of geologically homogeneous mountain flanks that can cover several floors of vegetation (kilometric); mapped to 1:50 000;
- mégageosigmassociation (megacatena, catena of hypercatenas); geologically homogeneous valley flank; alluvial plain (10 to 100 kilometers); cartography at 1:100 000.

The choice of the surface of the relevé and of the limits of the geosigmarelevé depend directly on the designated spatial scale.

It is proposed here to pay attention only to low surface geoserial complexes (hypogeosigmassociation and geosigmassociation of Theurillat) because the approaches linked to superior integration levels corresponding to "wide geomorphological units" are yet to be defined. In addition, as mentioned by Blasi, Capotorti and Frondini (2005), an inductive approach is difficult to set up at the landscape level. It is not easy to assess the size and limits of the relevé area and to provide phytocoenosis cover values [3]. At these spatial scales, deductive methods appear more relevant.

Theoretically, the geosigmarelevé represents a weighted list of sigmetums, reflecting the sequence of individual series mostly distributed along a topographic gradient. However, as proposed by Géhu and Rivas-Martínez (1981), «it can be the list of present plant communities [...] if the synassociations are not sufficiently known». Particularly this is the case of agricultural territories (eutrophilous meadow complexes, cultural complexes) for which series heads are not always known.

2.2. Spatial delimitation

Let us recall that we will focus here on proposing methodological elements for the survey of individuals of geoseries of limited spatial extension (hypogeosigmassociation and geosigmassociation).

These small catenal complexes are generally inserted into sigmetum individuals of larger size. They often correspond to environments with high ecological constraints and are represented by assemblies of series blocked at herbaceous or shrub stages. They include complexes of saxicolous communities, moist grassland complexes, peat bogs, small valley bottom complexes, river beds, coastal environments...

At the level of the proposed spatial integration, the delimitation of the survey is first sought by respecting the criteria of homogeneity in terms of vegetation floor, geology and of the type of complex or ecological habitat (pond, rock slab, peat bog ...).

The demarcation of the geosigmarelevé must then meet the criteria of topographic homogeneity (crest, slope, talweg, depression ...) following the large ecological compartmentalization according to a water gradient. Three main types of compartments can be chosen:

- complex of xerical compartments;
- complex of mesophilous compartments;
- complex of wet compartments, integrating mesohydrophilous to hydrophilous vegetation complexes and aquatic-amphibious complexes.

Thus, geoseries can be classified according to three main types:

- climatophilous with predominant climate determinism corresponding to the mesophilic compartment;
- edaphoxerophilous with predominant edaphic determinism due to water deficiency;
- edaphohydrophilous with predominant edaphic determinism by abundance or excess of water.

A special case is that of specialized complexes corresponding to truncated series (permaseres and minoriseres) such as those encountered in coastal or high mountain environments. According to Lazare (2009), it is proposed, for these environments marked by very restrictive ecological factors, to bring together the contiguous permaseres in a geopermaseres and the contiguous minoriseres in a geominoreses; geosigmassociations are thus constructed on the basis of a unifying ecological factor (see 2.4.3).

2.3. Information to gather

The weighted list of the individuals of the series and of the communities constituting them is drawn up exhaustively, seeking the identification with the most precise syntaxonomic rank.

As for the sigmarelevé, the same information is collected: spatial and temporal data, ecology, syntaxonomic and (or) sigmataxonomic identification, vegetation structure, associated vegetation and abiotic elements, dominance, and spatial form.

Here again, remote observation (for instance: from the opposite side, and aerial imagery) can help to carry out the survey and quantify it.

Associated communities linked to a different nature catena with a small surface area (of the order of about ten square meters) are included in the geosigmatorelevé. They can be vegetalized rock blocks, associated bryo-lichenic communities, ponds, springs...

Similarly, abiotic natural or anthropogenic landscape elements can also be integrated into the geosigmatorelevé and quantified: stonewalls, rock slabs, bare soil, open water, buildings ... (Figure 11).

2.4. Examples

2.4.1 Catenal complexes of saxicol communities



Fig. 11: Geosigmatorelevé example of an edaphoxerophilous complex of vegetation, Massif du Pilat (Loire département).

This individual geoseries includes a complete series individual (Series of the *Cytisus oromediterraneus* and *Pinus sylvestris* community) and two individuals of permaseries.

N° rel.: 20150311-1 C. HOSTEIN / CBNMC 11/03/2015 Bourg-Argental (42); Argental, west side of the Argensol valley N°GPS: 8 to 15	Surface area: 0,2 ha; R _T = 60 % Slope (°): 35 Exposure: S Altitude (m): inf. 710; sup. 740 Granite		
Medium collinean saxicol complexe on granite; traces of fire			
Convex slope; heathland and shrub			
Non-vegetal rock slab		2	S
Permaseries of the <i>Umbilicus rupestris</i> and <i>Asplenium septentrionale</i> chasmophytic community <i>Umbilicus rupestris</i> and <i>Asplenium foreziense</i> community		+	P
Permaseries of the <i>Micropyrum tenellum</i> community			
Therophytic community with <i>Micropyrum tenellum</i> <i>Narduretum lachenalii</i> Korneck 1975		+	P
<i>Sedum hirsutum</i> basal community	Bas	1	S
Series of the <i>Cytisus oromediterraneus</i> and <i>Pinus sylvestris</i> community			
Therophytic community with <i>Ranunculus paludosus</i> [5 m ²] <i>Rumici acetosellae-Airetum caryophyllae</i> Billy 2000 var. à <i>Ranunculus paludosus</i>		+	P
Therophytic community with <i>Filago minima</i> <i>Rumici acetosellae-Airetum caryophyllae</i> Billy 2000		+	P/M
Primary low phanerophytic community with <i>Cytisus oromediterraneus</i> and <i>Calluna vulgaris</i> <i>Plantagini holostei-Cytisetum oromediterranei</i> M.-T.Arnaud, Gamisans & M.Gruber 1983 <i>typicum</i>		3	S
Recolonization hemicytrophitic community with <i>Agrostis capillaris</i> <i>Peucedanum oreoselinum</i> and <i>Agrostis capillaris</i>		2	S/M
Shrub with <i>Quercus x calvescens</i> and <i>Sorbus aria</i> Fgt		2	P
Saxicol Pinewood with <i>Calluna vulgaris</i> <i>Cytisus oromediterraneus</i> and <i>Pinus sylvestris</i> community		1	P

2.4.2. Catenal complexes of mesohygrophilous to hygrophilous meadow communities

The geoserial complex relevé is spatially limited. Edapho-hygrophilous sigmassociations of this territory are unknown: due to anthropic and spatial reasons, their potential vegetations can not expressed.

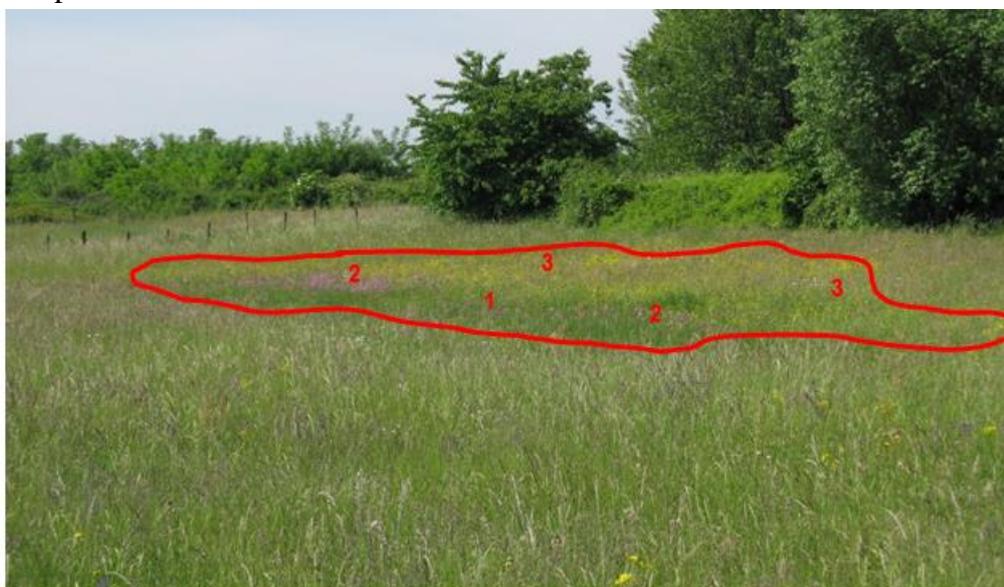


Fig. 12: Geosigarelevé limits of a geoserial complex of wet meadows; Rhodanian Piedmont, Loire department.

N° rel.: 20140511-1 G.. CHOISNET / CBNMC 11/03/2014 Chavanay (42); La Loge	Surface area: 150 m ² ; spatial; R _T = 100 % Slope (°): 0 - 2 Exposure: / Altitude (m): 375 Granite
Lower collinean hygrophilous meadow complex on granite; mowing and grazing of regrowth	
Depression of granite plateau	
Linked with <i>Salvio pratensis-Trifolietum molinierii</i> Billy 2000	
1 <i>Ranunculo repentis-Juncetum acutiflori</i> Billy 2000	2 sL
2 <i>Oenanthe peucedanifolia</i> and <i>Juncus acutiflorus</i> community (association to described of <i>Bromion racemosi</i>)	2 sL
3 <i>Scorzonero humilis-Serapietum lingua</i> Billy 2000	4 S

2.4.3. Coastal catenal complexes

Following Spanish and Italian symphytosociological works [34, 35, 29, 6, 16] propose a survey and mapping methodology of French Channel-Atlantic coastal geopermaseries and geocurtaseries. This methodology has been transposed in the Corsican territory, through explorations in the Cap Corse [15].

On the seashore (Figure 13), vegetations are organized in belts parallel to the sea, and generally spread over reduced surfaces. In this case, the geosymphytosociological approach seems well adapted. Thus, neighbouring permseries in which tessellas are in catenal arrangement are gathered within a geopermaseries. Similary neighbouring curtseries are gathered within a geocurtaseries.

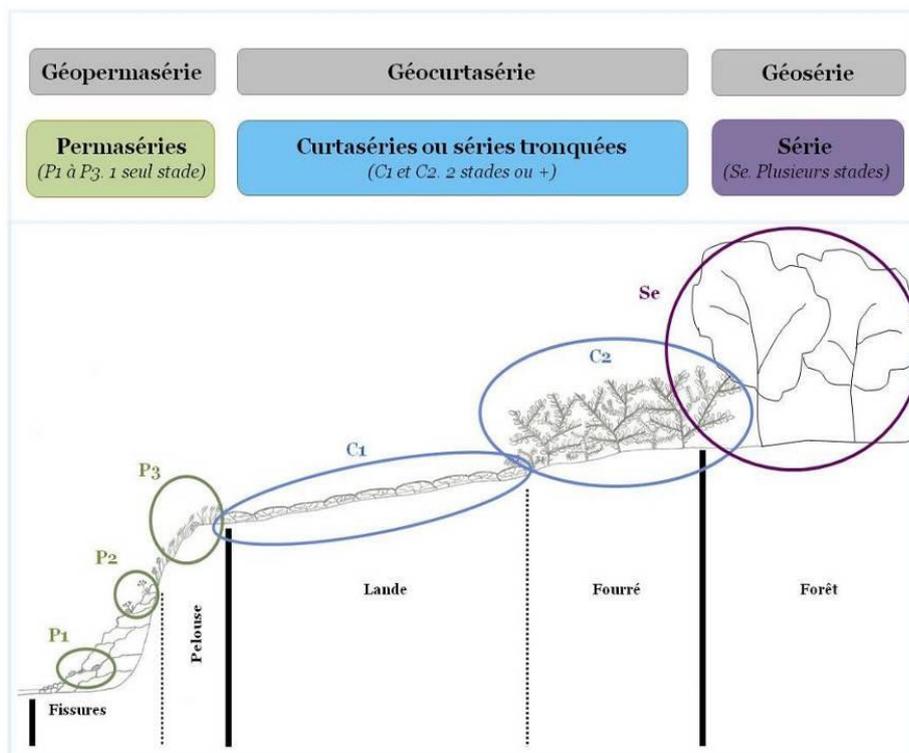


Fig. 13: Organization levels of the vegetal landscape of Atlantic coastal cliffs [16].

For the coastal zone, catenas should be included to coastal geomorphological systems:

- sand beaches;
- shingle beaches;
- dune systems;
- rocky coasts;
- saltmarshes;
- dune slacks;
- estuaries.

The identified geomorphological unit could be therefore divided into one or several entities, in order to define geopermaseries and geocurtaseries individuals, and possible adjacent series (Figure 14).

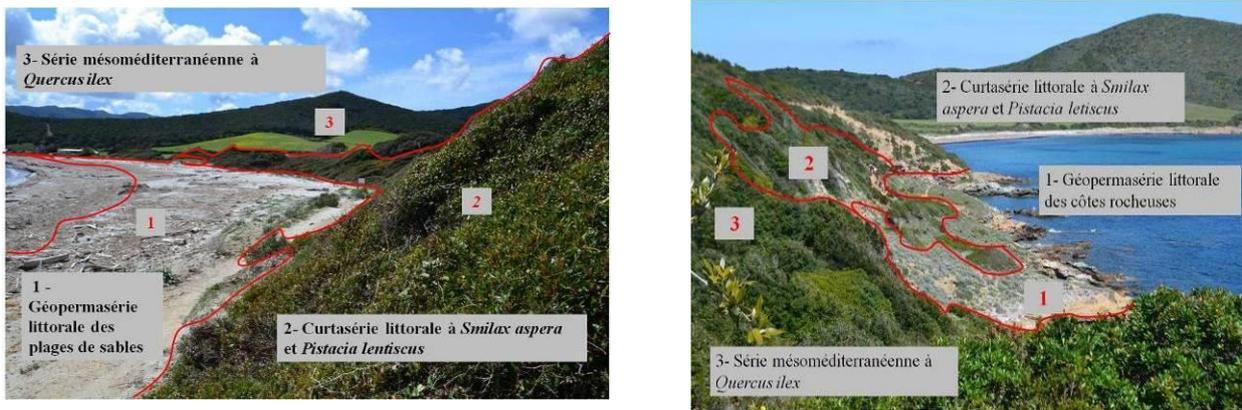


Fig. 14: Demarcation examples of geoseries individuals on the sandy and rocky coast of Macinaggio, Cap Corse (Delbosc 2016).

Each time a geomorphological change of the coastline is observed, a new geopermasynrelevé or geocurtasynrelevé is realised.

Structural analysis of a catena appears sometimes very complex, due to the interlocking of dynamic stages and the number of syntaxa.

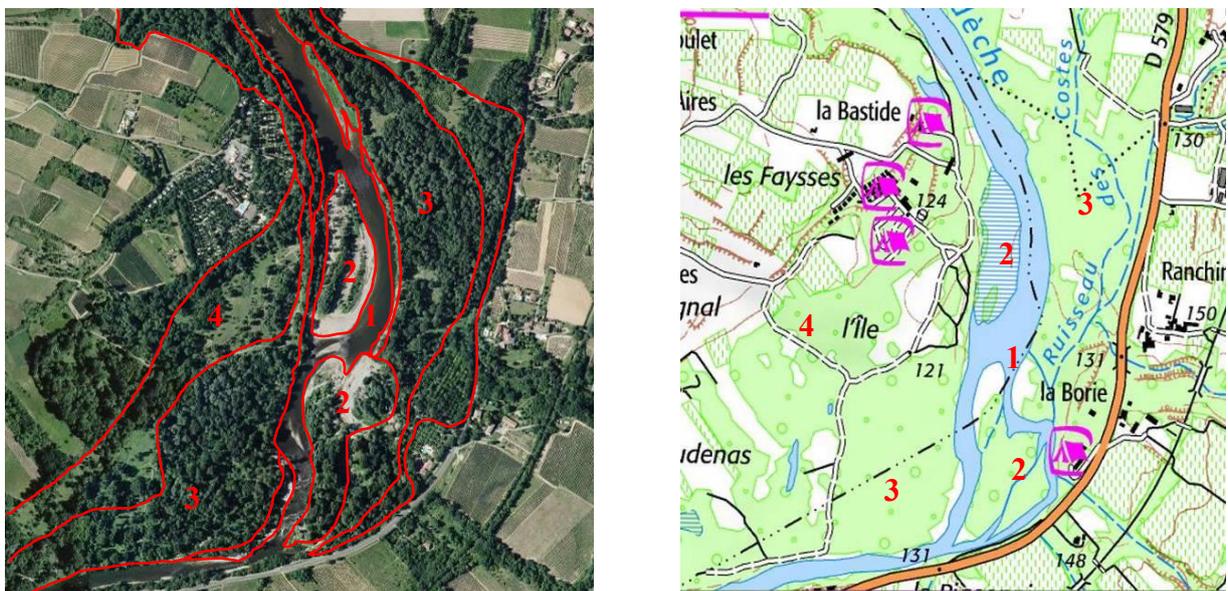


Fig.15: Large ecological compartments of the river complexes on the middle course of the Ardèche: 1 - minor bed, 2 - low terraces, 3 - middle terraces, 4 - high terraces.

2.4.4. Rivular catenal complexes

These complex environments represent a juxtaposition of different ecological systems, mainly conditioned by the fluvial dynamics of alluvium and erosion, and by the influence of the alluvial water table (Figure 15). We can observe:

- the minor bed and its hydraulic annexes,
- the low terraces and their wet depressions annually flooded,
- the average terraces subjected to decennial variability of floods,
- the high terraces very rarely flooded.

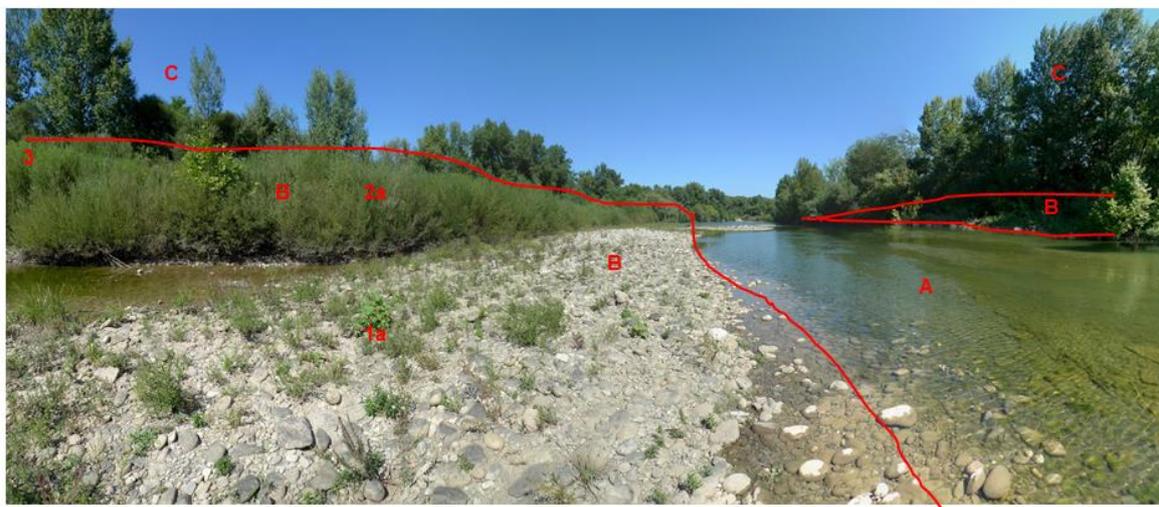
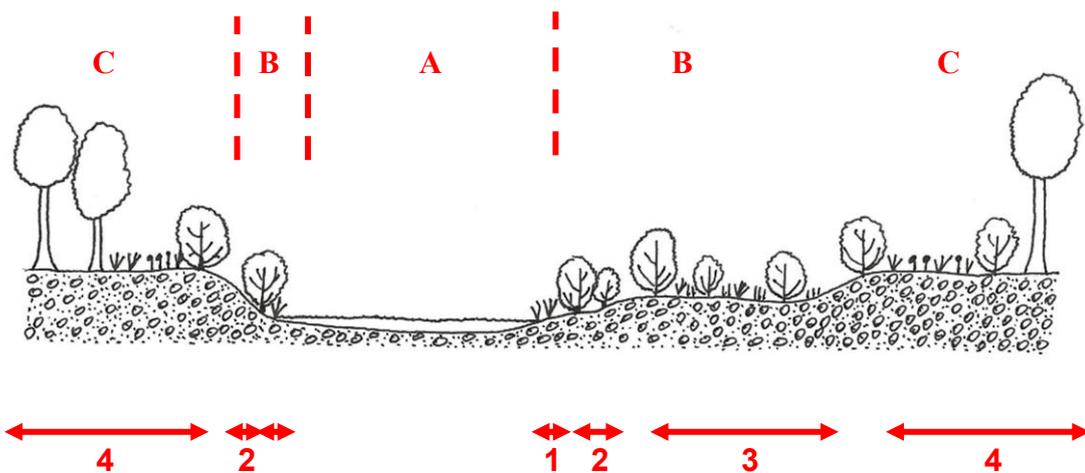


Fig. 16: Spatial organization of the sigmassociations of a straight stretch of the Ardeche silico-limestone valley and delimitation of the geosigmarelevés.

A: Minor bed, characterized by the presence of aquatic grass beds

B: Low terrace, Geoseries of the *Saponaria officinalis* and *Salix purpurea* community, edaphophilous unit comprising:

1: Series of *Pericario mitis-Xanthietum italici* prov. (*Chenopodium rubri*, **1a**) and/or Permaseries du *Mentha longifoliae-Phalaridetum arundinaceae* prov. (*Convolvulus sepium*)

2: Hygrophilous Minoriseries of *Saponaria officinalis-Salicetum purpureae* var. à *Lythrum salicaria* (*Salicion triandrae*, **2a**) or Series of *Salicion albae*

3: Temporhygrophilous Curtaseries of *Saponaria officinalis-Salicetum purpureae* var. type

C: Middle terrace

4: Minoriseries of *Rhamno alaterni-Salicetum eleagni* prov., Series of *Rubus-Populion nigrae* or Series of *Populion albae*

On the typological scale chosen the boundaries of the geosynrelevés follows this large ecological compartmentalization. Their spatial demarcation must also take into account the determining ecological factors (strength of the river current and alluvial deposit or removal, topographic level, and nature of the substratum), which are generally expressed, particularly in the low terraces, through continuous gradients. Figures 16 and 17 illustrate the choices made. The geosynrelevés present very variable surfaces related to the size of catenas (100 m² to several tens of hectares).

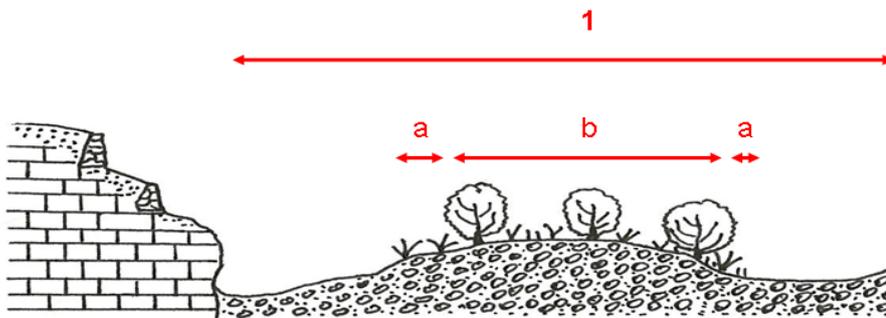


Fig. 17: Spatial organization of the sigmassociations of low terraces of an intermittent mediterranean river (valley of Ibie, Ardèche).

1: Temporhygrophilous geoserries individual of *Rhamno alaterni-Salicetum eleagni* prov.

a: Minoriseries of *Rhamno alaterni-Salicetum eleagni* var. à *Glaucium flavum* with, *Ptychotido saxifragae-Glaucietum flavi* prov.

Rhamno alaterni-Salicetum eleagni var. with *Glaucium flavum* prov.

b: Minoriseries of *Rhamno alaterni-Salicetum eleagni* var. à *Satureja montana* prov. with, *Epilobio dodonaei-Saturejetum montanae* prov.

Centaurea asper and *Bromus erectus* community

Conclusion

Integrated phytosociology is a recent science in which principles are not yet entirely defined. Nevertheless, a certain consensus does exist about the sigmetum concept, allowing to propose a methodological framework for the realization of sigmarelevés which represent the

methodological basis of the symphytosociology.

The geosigmetum notion is subjected to various interpretations due to its link with the considered spatial scale. However, geoserial units of small aereas constitute concrete and repetitive objects, easily identifiable in the field because they most often match habitats which are spatially well delimited.

The *in-situ* identification of tessellas and small catenas, and the description of the community complexes in which they gather, represent an important work base for further integrative steps leading to integrated chorology [22].

REFERENCES

1. Béguin, C., Géhu, J.-M., Hegg, O., 1979, La symphytosociologie: une approche nouvelle des paysages végétaux [Symphytosociology: a new approach of vegetal landscapes], *Documents Phytosociologiques*, **IV**: 49–69.
2. Biondi, E., 2011, Phytosociology today: Methodological and conceptual evolution, *Plant Biosystems*, **145** (1): 19–29.
3. Biondi, E., Casavecchia, S., Pesaresi, S., 2011, Phytosociological synrelevés and plant landscape mapping: From theory to practice, *Plant Biosystems* **145** (2): 261-273.
4. Biondi, E., Zivkovic, L., Esposito, L., Pesaresi, S., 2009, Vegetation, plant landscape and habitat analyses of a fluvial ecosystem in central Italy, *Acta Botanica Gallica* **156** (4): 571-587.
5. Bioret, F., Boullet, V., Choisnet, G., Roux, C., Thébaud, G., Panaïotis, C., Chalumeau, A., Delbosc, P., Demartini, C., Gauberville C., Cianfaglione, K., Bensettiti, F., Lalanne, A., 2019, *Landscape phytosociology concepts and definitions applied to serial and catenal vegetation mapping* (in press).
6. Blasi, C., 2010, *La vegetazione d'Italia, con carta delle serie di vegetazione in scale 1:500 000 [The vegetation of Italy, with map of the vegetation series in scale 1:500 000]*, Roma, Palombi editori.
7. Blasi, C., Capotorti, G., Frondini, R., 2005, Defining and mapping typological models at the landscape scale, *Plant Biosystems*, **139** (2): 155-163.
8. Bolòs (de), O., 1963, Botánica y geografía [Botany and geography], *Memorias de la Real Academia de Ciencias y Artes de Barcelona*, **34**: 443-480.
9. Braun-Blanquet, J., 1928, *Pflanzensoziologie. Grundzüge der Vegetationskunde [Phytosociology: principles of vegetation study]*, Biologische Studienbücher 7, Berlin, Springer.
10. Braun-Blanquet, J., 1951, *Pflanzensoziologie. Grundzüge der Vegetationskunde [Phytosociology: principles of vegetation study]*, 2nd. ed. Vienna, Springer.
11. Braun-Blanquet, J., Pavillard, J., 1922, *Vocabulaire de Sociologie végétale [Vocabulary of Plant Sociology]*, Montpellier, Romégou et Dehan.
12. Catteau, E., Argagnon, O., Causse, G., Choisnet, G., Collaud, R., Corriol, G., Delassus, L., Fernez, T., Giord, L., Guitton, H., Hendoux, F., Lafon, P., Millet, J., Panaïotis, C., Sanz, T., Simler, N., 2016, Évaluation patrimoniale des végétations et des séries de végétations: état des réflexions et proposition méthodologique nationale du réseau des CBN [Assessment of communities and vegetation series: state of reflection and national methodological proposal of the CBN network], *Botanique*, **1**: 55-68.
13. Chalumeau, A., Bioret, F., 2013, *Méthodologie de cartographie phytosociologique en Europe: approches symphytosociologique et géosymphytosociologique. Synthèse bibliographique. [Methodology of phytosociological mapping in Europe: symphytosociological and geosymphytosociological approaches. Bibliographical synthesis]*, Rapport Institut de Géoarchitecture, Université de Bretagne Occidentale, Ministère de l'Écologie, du Développement Durable et de l'Énergie, Brest.
14. Du Rietz, G.E., 1917, Några synpunkter på den synekologiska vegetations beskrivningens terminologi och metodik [Comments on characterization, terminology and methodology of the vegetation synecology], *Svensk Botanisk Tidskrift*, **11**: 51-71.
15. Delbosc, P., 2016, *Phytosociologie dynamico-caténale des végétations de la Corse: méthodologies typologique et cartographique [Dynamical and catenal phytosociology of the Corse vegetation: typological and cartographic methodologies]*, Thèse de doctorat, Université de Bretagne occidentale.

16. Demartini, C., Bioret, F., Lazare, J.-J., Typologie et cartographie des géopermaséries et des géocurtaséries des végétations littorales des côtes Manche-Atlantique françaises [Typology and mapping of geopermaseries and geocurtaseries of coastal vegetation on the French Channel-Atlantic coast]. *Documents Phytosociologiques*, série 3 (in press).
17. Géhu, J.-M., 1977, Le concept de sigmassociation et son application à l'étude du paysage végétal des falaises atlantiques françaises [The concept of sigmassociation and its application to the study of the vegetal landscape of the French Atlantic cliffs], *Vegetatio*, **34** (2): 117-125.
18. Géhu, J.-M., 1979, Pour une approche nouvelle des paysages végétaux: la symphytosociologie [A new approach of vegetal landscapes: symphytosociology], *Bulletin de la Société Botanique de France*, **126** (2): 213-223.
19. Géhu, J.-M., 1986, Des complexes de groupements végétaux à la phytosociologie paysagère contemporaine [From plant community complexes to contemporary landscape phytosociology], *Informatore botanico italiano*, **18** (1-2-3): 53-83.
20. Géhu, J.-M., 1988, L'analyse symphytosociologique et géosymphytosociologique de l'espace. Théorie et méthodologie [The symphytosociological and geosymphytosociological analysis of space. Theory and method], *Colloques Phytosociologiques*, **XVII**: 11-46.
21. Géhu, J.-M., 1991, La phytodynamique: approche phytosociologique [Phytodynamics: phytosociological approach], *Colloques Phytosociologiques*, **XX**: 15-28.
22. Géhu, J.-M., 2004, La symphytosociologie trente ans plus tard (1973-2003): concepts, systématisation, applications [Symphytosociology thirty years later (1973-2003): concepts, systematization, applications], *Bulletin de la Société Botanique du Centre-Ouest, Nouvelle Série*, **35**: 63- 80.
23. Géhu, J.-M., 2006, *Dictionnaire de sociologie et synécologie végétales [Dictionary of vegetal sociology and synecology]*, Édition J. Cramer, Berlin – Stuttgart.
24. Géhu, J.-M., Biondi, E., 1994, Végétation du littoral de la Corse, essai de synthèse phytosociologique [Vegetation of the coast of Corsica, phytosociological synthesis test], *Braun-Blanquetia*, **13**: 1-149.
25. Géhu, J.-M., Rivas-Martínez, S., 1981, Notions fondamentales de phytosociologie [Basic notions of phytosociology], *Berichte der Internationalen Symposien der Internationalen Vereinigung für Vegetationskunde 1980*: 5-33. Rinteln: Édition J. Cramer.
26. Guinochet, M., 1973, *Phytosociologie [Phytosociology]*, Paris, Masson.
27. Hegg, O., Schneiter, R., 1978, Vegetationskarte des Bachalp ob Grindelwald [Vegetation map of Bachalp of Grindelwald], *Mitteilungen der Naturforschenden Gesellschaft in Bern*, NF, **35**: 55-67.
28. Lazare, J.-J., 2009, Phytosociologie dynamico-caténale et gestion de la biodiversité [Dynamical and catenal phytosociology, and biodiversity management], *Acta Botanica Gallica*, **156** (1): 46-61.
29. Loidi, J., Burrin, I., Campos, J.-A., Gracia-Mijangos, I., Herrera, M., 2011, *La vegetación de la Comunidad Autónoma del País Vasco. Leyenda del mapa de series de vegetación a escala 1:50 000 [The vegetation of the Autonomous Community of the Basque Country, legend of the vegetation series map at scale 1:50 000]*, Ed. Universidad del País Vasco (edición electrónica).
30. Mériaux, J.-L., Géhu, J.-M., 1977, *De l'analyse symphytosociologique des complexes de végétation à celle des végétations complexes. Exemple des groupements aquatiques et subaquatiques [From symphytosociological analysis of vegetation complexes to complex vegetations. Example of aquatic and subaquatic communities]*. In *Assoziationskomplexe (Sigmeten)*, Rinteln, J. Cramer, edited by R. Tüxen: 97-116.
31. Pavillard, J., 1935, *Éléments de sociologie végétale (phytosociologie) [Elements of plant sociology (phytosociology)]*, *Actualités scientifiques et industrielles 251. Exposés de biologie écologique*, **II**: 1-12.
32. Pinto-Gomes, C.-J., Paiva Ferreira, R.J.P., 2005, *Flora e Vegetação do Barrocal Algarvio (Tavira-Portimão) [Flora and Vegetation of the Barrocal Algarve (Tavira-Portimão)]*, Comissão de Coordenação e desenvolvimento Regional do Algarve.
33. Rivas-Martínez, S., 1976, Sinfitosociología, una nueva metodología para el estudio del paisaje vegetal [Symphytosociology, a new methodology for the study of the vegetal landscape], *Anales del Instituto Botánico Cavanilles*, **33**: 179-188.
34. Rivas-Martínez, S., 1987^a, Introducción: nociones sobre fitosociología, biogeografía y bioclimatología [Introduction: notions about phytosociology, biogeography and bioclimatology]. In: *La vegetación de España*: 19-45. Madrid: Serv. Publ. Universidad de Alcalá de Henares.

35. Rivas-Martínez, S. 1987b, Memoria del mapa de series de vegetación de España [The map of vegetation series of Spain], *Ministerio de Agricultura, Pesca y Alimentación, Edicions I.C.O.N.A., Série Técnica*.
36. Rivas-Martínez, S., 2005, Notions on dynamic-catenal phytosociology as a basis of landscape science, *Plant Biosystems*, **139** (2): 135–144.
37. Theurillat, J.-P., 1991, Toposéquence paysagère dans la région d'Aletsch (Valais, Suisse) : Méthodologie et possibilités d'applications pratiques [Landscape toposequence in the Aletsch region (Valais, Switzerland): methodology and means of practical applications], *Colloques Phytosociologiques*, **XVII**: 221-231.
38. Theurillat, J.P., 1992a, *Études symphytocœnologiques dans la région d'Aletsch (Valais, Suisse) [Symphytocœnological studies in the Aletsch region (Valais, Switzerland)]*, Thèse de doctorat ès Sciences, Université de Berne.
39. Theurillat, J.P., 1992b, L'analyse du paysage végétal en symphytocœnologie : ses niveaux et leurs domaines spatiaux [The plant landscape analysis in symphytocœnology: its levels and their spatial areas], *Bulletin d'Écologie*, **23** (1-2): 83-92.
40. Tüxen, R., 1973, Vorschlag zur Aufnahme von Gesellschaftskomplexen in potentiell natürlichen Vegetationsgebieten [Proposal for recording community complexes in potential natural vegetation areas], *Acta Botanica Academia Hungarica*, **19**: 379-384.
41. Tüxen, R., 1978, Versuch zur Sigma-syntaxonomie mitteleuropäischer Flusstalgesellschaften [Proposal for the sigma-syntaxonomy of Central European river communities], *Berichte der Internationalen Symposien der Internationalen Vereinigung für Vegetationskunde 1977*: 243-286. Rinteln, Edition J. Cramer.
42. Tüxen, R., 1979, Sigmeten und Geosigmeten, ihre Ordnung und ihre Bedeutung für Wissenschaft, Naturschutz und Planung [Sigmetum and geosigmetum, their organisation and their significance for science, nature conservancy and planification], *Biogeographica*, **16**: 79-92.

METODOLOGIA RELEVTELOR SIMFITOSOCIOLOGICE ȘI GEOSIMFITOSOCIOLOGICE

(Rezumat)

Pe baza principalelor lucrări de fitosociologie peisageră (simfitosociologie și geosimfitosociologie), sunt prezentate elemente din metodele de realizare a sigmarelevelelor și geosigmarelevelelor, prin analiza diferitelor cazuri concrete.

Aceste elemente metodologice urmăresc o abordare inductivă pentru caracterizarea sigmasociațiilor și geosigmasociațiilor (serii și geoserii de vegetație).