Sauteria 16, 2008 13. Österreichische Botanikertreffen 184-190

The importance of a dynamic-catenal phytosociology approach in obtaining a definition of ecological networks: a case study from Central Italy

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Introduction and description of the method

An ecological network can be defined as an interconnected system of ecosystem unities which assume a fundamental role in the maintenance of the vitality of faunistic and floristic metapopulations (BATTISTI 2004). Therefore, ecosystems can be considered the focal point of analysis during the process of defining an ecological network, thus forming the basis for evaluation and conservation strategies concerning species or faunistic and floristic populations.

However, the practical realisation of the described objective presents numerous problems; in particular, the difficulty of cartographically defining the spatial boundaries of the various ecosystem unities involved. In fact, the importance of the environmental components that define the ecological-functional homogeneity of a part of a territory in comparison to its surroundings varies in relation to the scale of analysis and representation (GREIG-SMITH 1993). Nonetheless, the multidimensional complexity of the ecological systems can be broken down into many organisational levels, each containing only a small number of interacting entities, in which mutual relationships and links between the highest and the lowest organisational levels can be explicitly modelled (TAINTON et al. 1996). The problem of spatial definition can thus be overcome by adopting a hierarchical approach according to the ecological definition of the respective ecosystem unity (BLASI et al. 2000). In this regard, the use of methods and concepts of dynamic-catenal phytosociology (OZENDA 1982, GEHU et al. 1991) applied to studies of landscape vegetation can be an ideal tool, given that it is based on a hierarchical definition of plant communities and landscapes. BLASI et al. (2000) and BRANDMAYR et al. (1997) both proposed hierarchical ecosystems approaches, showing important similarities.

With regard to the cartographical representation this method allows the realisation of documents able to represent the environmental unities that distinguish the considered territories, i.e. ecologically homogeneous areas composed of various ecotypes (PEDROTTI 2004). These display structurally characteristic patterns as described by FORMAN & GODRON (1986).

This analytical approach can only be carried out within a hierarchical landscapes context, aimed at interpreting the factors that influence a territory in different spatial-temporal intervals (KING 1977, ALLEN & STARR 1982, O'NEIL & KING 1998, BLASI et al. l.c.). Within this process, each element can be interpreted as part of a superior element or as a structure containing systems of inferior rank (FARINA 2001). This approach introduces the paradigm of systems and nested elements, in which each element's properties influence the higher ranking element and *vice versa* (FARINA l.c.). GIS and compatible databases allow integration of all hierarchical organisational levels in a single digital document, easily enhanced. In a GIS format, in fact, different hierarchical layers of information are simulated in multiple phases of segmentation of the polygons. The objects of the fragmentation must be grouped in such a way that they share the external margins, assuming that a strictly hierarchical system is put in place both spatially and conceptually. This allows simplification of landscape complexity by assigning different ecological attributes to each level (BLASCHKE 2001). It is therefore possible to manage information from different levels through the use of a database structured in such a way that only parameters relevant to each level of investigation are provided. Nonetheless, information and links to higher and lower levels are conserved, as assumed by TAINTON et al. (l.c.).

For all the aforementioned reasons the concept of vegetational landscape used in this study is derived from geosinphytosociology, which is based on the description of the mosaic of vegetational associations typical of a certain territory in a spatial and temporal context. The terms "vegetational associations" and "phytosociology" have been used since the end of the 19th century. Among the pioneers, FLAHAULT introduced the term "association" (1897) and PACZOSKI was the first to use the term "phytosociology" (1891). However, the founder of modern "phytosociology" is BRAUN-BLANQUET (1931, 1964), who founded the School of Phytosociology, also known as the Zurich-Montpellier or Sigmatist School.

The vegetational association is the object of study of phytosociology. It can be defined as a vegetational complex with a characteristic and constant floristic composition and a homogeneous physiognomy that develops in uniform environmental conditions.

The definition of vegetation association has been progressively refined, from a floristic physiognomic to floristic ecological. During The International Botanical Congress in Amsterdam in 1935 a definition was formulated according to which the term "association" refers to individual vegetational units, in particular through the presence of typical species as advocated by the Zurich-Montpellier School.

According to a recent definition the vegetational association can be considered a specific type of vegetational community which comprising environmental characteristics, a specific geographical enclosure, a pool of statistically determined indicator species. The ecology of a confined habitat, a vegetational stage structurally stable within the process of succession (RIVAS-MARTINEZ 2005a).

The introduction of the parameter "time" and the concept of "dynamic succession" in the scientific definition of vegetational association lead to a higher conceptual stage of phytosociology. This approach takes into consideration the "evolutionary" and "spatial" relationships, linking different vegetational communities. In order to understand these aspects it needs to be considered that in temperate regions without anthropogenic disturbances the vegetation producing the most biomass per spatial unit is formed by forestal phytocenoses.

However, since the Neolithic era humans have destroyed a large proportion of primary forests through controlled burning in order to acquire arable land and increase grazing areas for sheep and goats. These events created vegetational associations in equilibrium with the local environmental conditions and with the anthropogenic disturbance (GRIME 2001). These secondary vegetational associations are thus unstable because if they are not "disturbed" by humans they undergo a spontaneous transformation. This leads to a succession of increasingly complex vegetational associations both in structure and floristic composition (TÜXEN 1978 & 1979, OZENDA l.c., GEHU et al. l.c.), resulting in a new forest ecosystem.

These spatial-temporal relationships linking different vegetational communities are the study topic of sinphytosociology or serial phytosociology (RIVAS-MARTINEZ 1976). These vegetational associations linked through temporal and evolutionary (dynamic) relationships create a "vegetational series"

In other words, the vegetational series, also known as *sigmetum*, is defined by all the vegetational communities linked by dynamic relationships found within a part of an ecologically homogeneous territory.

These areas are therefore territorial sectors which can be considered and evaluated as a whole (environmental unit), from an environmental, agronomic and management perspective.

Therefore the vegetational series assumes a central role for geobotanists in territorial planning with important consequences for management (ORSOMANDO et al. 2000, BIONDI 1996, BACCHETTA et al. 2007).

A further step in environmental analysis was taken with the introduction of the concept of geoseries or geosigmetum, a basic unit of dynamic-catenal Phytosociology or Environmental Phytosociology.

A geosigmetum is an edaphoxerophilous, climatophilous and edaphohygrophilous vegetational series in spatial relation to each other within certain bioclimatic conditions which alternate according to edaphic and topographical conditions (RIVAS-MARTINEZ 2005b). In conclusion, the possibility of including the different aspects of the vegetational landscape in GIS technology is the main theme in this study of ecological networks, using the dynamic-catenal phytosociology approach.

Materials and Methods

Study Area

The experiment was carried out in the Marches region of Central Italy, in the province of Macerata which comprises the valleys of the rivers Fiastra, Entogge and Salino, all tributaries of the river Chienti, one of the main rivers in the region. The three studied rivers flow from west-south-west to east-north-east.

The study area extends from a maximum altitude of 1450 m.a.s.l. of the eastern slope of Pizzo di Meta (Sibillini Mountains) to a minimum of 150 m.a.s.l. at Abbadia di Fiastra (Urbisaglia). The area encompasses several lithotypes of the umbro-marchigiana stratographic succession: calcareous, marnous-calcareous, arenaceous, pelitic-arenaceous, pelitic-clay and pelitic-sand, ancient, recent and current alluvial deposits. These are present in an altitude interval which extends from the bioclimatic belt of the inferior mesotemperate (100-450 m.a.s.l.), superior mesotemperate (400-450 m.a.s.l.) and inferior supratemperate (900-1000 and 1350-1450 m.a.s.l.) of the microclimatic temperate region (RIVAS-MARTINEZ 2004).

The potential vegetation is represented by woods of Carpinion orientalis for the bioclimatic mesotemperate belt, subdivided into Lauro nobilis-Quercenion pubescentis in the inferior mesotemperate and Laburno anagyroidis-Ostryenion carpinifoliae in the superior mesotemperate. However, the woods of Geranio versicoloris-Fagion sylvaticae characterise the climax vegetation of the inferior supratemperate bioclimatic belt.

Phytosociological research, vegetation cartography and relationships database

The study of the vegetation was carried out according to the method of the Zurich-Montpellier School (BRAUN-BLANQUET 1931) as well as the most recent phytosociological and geosinphytosociological research (GEHU & RIVAS-MARTINEZ 1981, THEURILLAT 1992, BIONDI l.c., BIONDI et al. 2004).

The individual syntaxa were cartographically presented using photo-interpretation and georeferencing of the phytosociologically homogeneous polygons. This allowed the realisation of the "map of the current actual vegetation" (PEDROTTI l.c.), representing the distribution of the observed vegetational communities (syntaxa).

A hierarchical system was formulated based on geological and bioclimatic information (BLASI et al. 2000).

Only after having considered phytosociological and catenal phytosociological information (RIVAS-MARTINEZ 1976) and after having verified in situ the models found it was possible to define the sinphytosociology, geosinphytosociology and spatial distribution of the vegetational series found in the study area.

A geosinphytosociological map of the river valleys Fiastra, Entogge and Salino (1:25.000), was subsequently created. It represents a mosaic of the different stages of each vegetational series.

All cartographic-vegetational information obtained was then digitalised in a GIS database using the software ArcGis 9.0 in order to allow territorial planning and in-field application.

Vegetational maps are therefore a collection of the vegetational resources and biodiversity of an area at a phytocenotic level (PEDROTTI l.c.), thus playing a fundamental role in planning, evaluation and support of the territory. This is due to the possibility of graphically representing the polygons with the same characteristics in terms of physiognomy, floristical composition, dynamic and ecology (syntaxon, sigmetum, geosigmetum, etc.). For this reason, any type of datum, no matter how minimal, can be linked to the whole polygon as long as it is somehow correlated to the characteristics of the vegetational communities.

In conclusion, the information contained in the geosinphytosociological map has been used as a basis for the analysis of the vegetational environment, in particular to realise a series of cartographic documents. This made it necessary to continuously implement the following databases: "Map of Landscape Units"; "Carta della naturalità" on a phytosociological basis; "Map of Landscape Structure"; "Map of Geobotany"; "Map of Ecosystems"; "Map of forested ecosystems" and some of its components, such as a structural map, map of slopes, map of relationships between forests and other ecosystems, map of vegetative periods and periods of snow-covered soils and a map of edible phytomass for deer.

These maps do not yet contain applicable frameworks, but contribute fundamentally to the understanding of the studied territory, essential elements and correct natural and urban planning.

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