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Forest syntaxa spatial distribution hierarchical modelling: preliminary assessment of a Central Apennine (Italy) landscape

Räumliche Verteilung und hierarchisches Modell von Syntaxa der Waldgesellschaften: Erste Einschätzung einer Landschaft im zentralen Apennin (Italien)

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Key words: Plant communities distribution, biodiversity, hierarchical modelling, phytosociological analysis, multivariate analysis.

Schlagworte: Verbreitung von Pflanzengesellschaften, Biodiversität, hierarchische Modelle, pflanzensoziologische Auswertung, multivariate Analyse.

Summary: The aim of this work is to model the role of geomorphological and bioclimatic parameters for γ and β biodiversity distribution and then generate a hierarchical model. For this purpose, field and floristic data are obtained from phytosociological tables; the assessment of bioindication values is also carried out. Then, by means of these data, multivariate statistical analysis was elaborated and the results indicate that the distribution of different syntaxa in a geologically homogeneous environment.

Zusammenfassung: Das Ziel dieser Arbeit ist die Rolle von geomorphologischen und bioklimatischen Parametern für γ und β Biodiversitätsverteilung zu modellieren um daraus ein hierarchisches Modell zu entwickeln. Dazu werden Geländebefunde und floristische Daten von den pflanzensoziologischen Tabellen entnommen. Die Schätzung der Zeigerwerte wurde dabei ebenfalls durchgeführt. Diese Daten wurden einer multivariante Analyse unterzogen dadurch kann die Verteilung verschiedener Syntaxa innerhalb eines geologisch homogenen Gebietes dargestellt werden.

1. Introduction

The forest landscape of Central Italy is enough defined from the phytosociological point of view. Also at the syntaxonomical association level, the characterization of the forest heritage is well clarified and demonstrates that all the most important forest types are nowadays inserted in an organic synsystematical framework.

However, there are some problematic aspects and lacks of information, on the basis of quantitative environmental field data, about the synecology of such forest syntaxa, particularly about the direct link between the different phytosociological type distribution with the main ecological parameters (geology, morphology, aspect, morphology, etc.). Such information, however, necessary to advance in the understanding of the ecological processes involved at the plant community level and at the landscape scale too, through, for example, the geosynphytosociological approach (RIVAS-MARTÍNEZ 2005, BIONDI et al. 2005).

However, floristic differentiation patterns in vegetation are usually too complex to be simplified in either strictly geographical differentiation or in a strictly edaphic or local topoclimatic differentiation (TZONEV et al. 2006). Often these patterns are scale-dependent, showing stronger edaphic effects at finer scales and stronger geographic distinctions on broader scales (CHYTRÝ et al. 2002, KUŽELOVÁ & CHYTRÝ 2004). For many broad-scale data sets, however, edaphic, local topoclimatic and geographical factors can be of comparable importance and interact in complex ways to form vegetation pattern (BERGMEIER & DIMOPOULOS 2001, KNOLLOVÁ & CHYTRÝ 2004).

As a matter of 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 1983). However, the multidimensional complexity of the ecological systems can be broken down into many organizational levels, each containing only a small number of interacting entities, in which mutual relationships and links between the highest and the lowest organizational 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 ecosystem unit (BLASI et al. 2000). This analytical approach can be carried out within a hierarchical landscape context, aimed at interpreting the factors that influence a territory in different spatial-temporal intervals (KING 1977, ALLEN & STARR 1982, BLASI et al. l.c.).

Moreover, how ERCOLE et al. (2005) and CATORCI et al. (1995) emphasize, the assessment of field data (*e.g.*, geology, slope, aspect) would be an useful tool for the ecological interpretation of the plant community distribution.

On this basis, the aim of the present work is to understand the role of geomorphological and bioclimatic parameters for γ and β biodiversity distribution in a submediterranean forest landscape and, then, generate a hierarchical model in order to understand the importance of these ecological features. All the collected data will be used to define predictive models that are useful tools for a more detailed research.

2. Materials and methods

2.1 Study area

The study area is a hilly complex on Eastern facing aspect of Monti Sibillini (Central-West sector of Ascoli Piceno Province, Marches Region, Central Italy) including Aso River drainage basin and a part of Tenna and Tronto Rivers drainage basins (Fig. 1). It is ranging from 250 to 1494 m (Monte Ceresa), and, from a bioclimatic point of view, regards two bioclimatic belts: upper mesotemperate and lower supratemperate (Tab. 1).

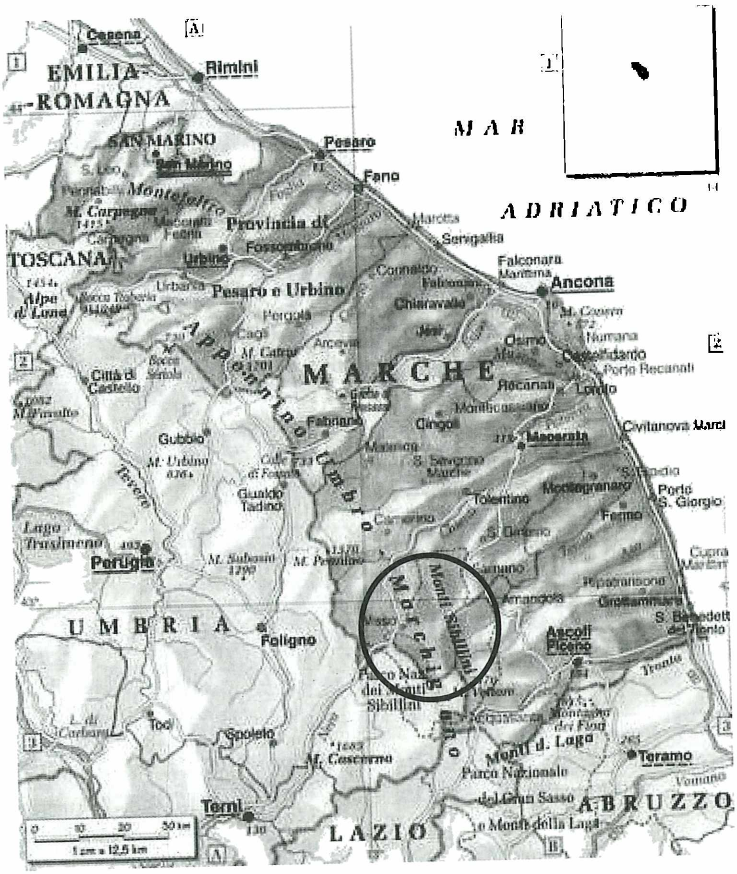

Fig. 1: Study area.
(http://www.portalestoria.net/IMAGES%2043/Marche%5B1%5D.jpg)

Tab. 1: Bioclimatic belts of the study area.

BIOCLIMATIC BELTS	Altitudinal range (m a.s.l.)	Annual average T (°C)	Annual average rainfall (mm)	Summer average rainfall (mm)	N° months with average T<10 °C	N° months with minimum T<0 °C	Drought stress (N° months)	Cold stress (N° months)	Length of growing period (N° days with minimum T>6°C)
Upper Mesotemperate	400-900	11-13	850-1100	165-180	5-6	0-1	0	3-4	190-220
Lower Supratemperate	900-1400	9-11	1100-1300	195-210	6-7	1-2	0	4-5	160-190

From a geological point of view, this area is characterized by sandstone deposits (REGIONE MARCHE 1991).

The forest landscape is characterized by 15 syntaxa (CATORCI et al. 2008), whose main features are summarized in Table 2.

Tab. 2: Ecological factors of studied syntaxa.

		Geological substratum	Aspect	Altitudinal range (m)	Slope (°)	Dominant species	Costant species
RsQp ea	*Roso sempervirentis-Quercetum pubescentis ericetosum arboreae*	Siliceous	S-SW	(<) 200-350	10-40	*Quercus pubescens s.l.*, *Fraxinus ornus* subsp. *ornus*, *Carpinus orientalis* subsp. *orientalis*, *Erica arborea*, *Viburnum tinus* subsp. *tinus*, *Arbutus unedo*	*Quercus pubescens s.l.*, *Fraxinus ornus* subsp. *ornus*, *Carpinus orientalis* subsp. *orientalis*, *Erica arborea*, *Viburnum tinus* subsp. *tinus*, *Cyclamen repandum* subsp. *repandum*, *Ostrya carpinifolia*, *Sorbus domestica*
EaQp ea	*Erico arboreae-Quercetum pubescentis ericetosum arboreae*	Arenaceous	SE-WSW	350/400-850/900	25-40	*Quercus pubescens s.l.*, *Fraxinus ornus* subsp. *ornus*, *Acer monspessulanum* subsp. *monspessulanum*, *Erica arborea*, *Juniperus oxycedrus* subsp. *oxycedrus*, *Emerus majus*, *Cytisus hirsutus* subsp. *polytrichus*	*Quercus pubescens s.l.*, *Fraxinus ornus* subsp. *ornus*, *Ostrya carpinifolia*, *Erica arborea*, *Juniperus oxycedrus* subsp. *oxycedrus*, *Brachypodium rupestre*
EaQp qc	*Erico arboreae-Quercetum pubescentis quercetosum cerridis*	Arenaceous	SW-SE	800-900/950	20-35	*Quercus pubescens s.l.*, *Quercus cerris*, *Castanea sativa*, *Cytisus scoparius* subsp. *scoparius*	*Quercus pubescens s.l.*, *Quercus cerris*, *Fraxinus ornus* subsp. *ornus*, *Cytisus scoparius* subsp. *scoparius*, *Juniperus oxycedrus* subsp. *oxycedrus*, *Brachypodium rupestre*
EaQp Cs	*Erico arboreae-Quercetum pubescentis* var. a *Cornus sanguinea*	Arenaceous	W-SW	600-800	10-20	*Quercus pubescens s.l.*, *Prunus spinosa* subsp. *spinosa*, *Euonymus europaeus*	*Quercus pubescens s.l.*, *Fraxinus ornus* subsp. *ornus*, *Juniperus oxycedrus* subsp. *oxycedrus*, *Brachypodium rupestre*, *Cornus sanguinea*, *Hedera helix*

HmOc hm	*Hieracio murori-Ostryetum carpini-foliae hieracietosum murori*	Arenaceous	E-NW	450-500	30-45	*Ostrya carpinifolia*, *Fraxinus ornus* subsp. *ornus*, *Quercus pubescens s.l.*, *Acer opalus* subsp. *obtusatum*, *Carpinus orientalis* subsp. *orientalis*, *Laburnum anagyroides* subsp. *anagyroides*, *Acer campestre*	*Ostrya carpinifolia*, *Fraxinus ornus* subsp. *ornus*, *Quercus pubescens s.l.*, *Acer opalus* subsp. *obtusatum*, *Carpinus orientalis* subsp. *orientalis*, *Hedera helix*
HmOc aa	*Hieracio murori-Ostryetum carpini-foliae asparagetosum acutifolii*	Arenaceous	W-NE	400-600/650	25-45	*Ostrya carpinifolia*, *Quercus pubescens s.l.*, *Asparagus acutifolius*, *Rubia peregrina* subsp. *peregrina*, *Erica arborea*, *Buglossoides purpureo-caerulea*	*Ostrya carpinifolia*, *Quercus pubescens s.l.*, *Rubia peregrina* subsp. *peregrina*, *Acer opalus* subsp. *obtusatum*, *Carpinus orientalis* subsp. *orientalis*, *Hedera helix*, *Fraxinus ornus* subsp. *ornus*
HmOc cb	*Hieracio murori-Ostryetum carpini-foliae carpinetosum betuli*	Arenaceous	N	400-700/750	<30	*Ostrya carpinifolia*, *Carpinus betulus*, *Pulmonaria apennina*	*Ostrya carpinifolia*, *Carpinus betulus*, *Quercus cerris*, *Acer opalus* subsp. *obtusatum*, *Carpinus orientalis* subsp. *orientalis*, *Hedera helix*, *Fraxinus ornus* subsp. *ornus*, *Acer campestre*
HmOc fs	*Hieracio murori-Ostryetum carpini-foliae fagetosum sylvaticae*	Arenaceous	N	650/700-900/1000	25-35	*Ostrya carpinifolia*, *Fagus sylvatica* subsp. *sylvatica*, *Neottia nidus-avis*, *Ranunculus neapolitanus*, *Campanula trachelium* subsp. *trachelium*, *Lactuca muralis*	*Ostrya carpinifolia*, *Fagus sylvatica* subsp. *sylvatica*, *Acer opalus* subsp. *obtusatum*, *Hedera helix*, *Fraxinus ornus* subsp. *ornus*
AoQc fs	*Aceri obtusati-Quercetum cerridis fagetosum sylvaticae* var. a *Castanea sativa*	Calcareous	E-WNW	750/800-950/1000	15-30	*Quercus cerris*, *Ostrya carpinifolia*, *Castanea sativa*, *Fagus sylvatica* subsp. *sylvatica*, *Acer opalus* subsp. *obtusatum*, *Crategus monogyna*, *C. laevigata*, *Carpinus betulus*, *Rosa arvensis*, *Laburnum anagyroides* subsp. *anagyroides*	*Quercus cerris*, *Ostrya carpinifolia*, *Fagus sylvatica* subsp. *sylvatica*, *Castanea sativa*, *Acer opalus* subsp. *obtusatum*, *Fraxinus ornus* subsp. *ornus*, *Rosa arvensis*, *Festuca heterophylla*
ChCs ts	*Cyclamino hederifolii-Castaneetum sativae teucrietosum siculi*	Arenaceous	N	650-750/800	10-30	*Castanea sativa*, *Ostrya carpinifolia*, *Fagus sylvatica* subsp. *sylvatica*, *Fraxinus ornus* subsp. *ornus*, *Prunus avium* subsp. *avium*, *Acer opalus* subsp. *obtusatum*, *Rubus hirtus*	*Castanea sativa*, *Pteridium aquilinum*, *Hieracium murorum*, *Ptilostemon strictus*, *Acer opalus* subsp. *obtusatum*, *Sanicula europea*, *Ostrya carpinifolia*, *Festuca heterophylla*, *Fraxinus ornus* subsp. *ornus*, *Rubus hirtus*
ChCs fs	*Cyclamino hederifolii-Castaneetum sativae fagetosum sylvaticae*	Arenaceous	E-WNW	700-1000	15-35	*Castanea sativa*, *Fagus sylvatica* subsp. *sylvatica*, *Cornus mas*, *Carpinus betulus*, *Corylus avellana*	*Castanea sativa*, *Fagus sylvatica* subsp. *sylvatica*, *Acer opalus* subsp. *obtusatum*, *Corylus avellana*, *Fraxinus ornus* subsp. *ornus*
ChCs Co	*Cyclamino hederifolii-Castaneetum sativae* var. a *Carpinus orientalis* subsp. *orientalis*	Arenaceous	N	400-600	20-30	*Castanea sativa*, *Carpinus orientalis* subsp. *orientalis*, *Lonicera etrusca*, *Viburnum tinus* subsp. *tinus*	*Castanea sativa*, *Fraxinus ornus* subsp. *ornus*, *Carpinus orientalis* subsp. *orientalis*, *Acer opalus* subsp. *obtusatum*, *Ostrya carpinifolia*, *Hedera helix*, *Cornus sanguinea*

SFs mt	*Solidagini-Fagetum sylvaticae moehringietosum trinerviae*	Arenaceous	N	1200-1450	10-40	*Fagus sylvatica* subsp. *sylvatica*, *Ilex aquifolium*, *Laburnum anagyroides* subsp. *anagyroides*, *Euonymus latifolius*	*Fagus sylvatica* subsp. *sylvatica*, *Prenanthes purpurea*, *Geranium nodosum*, *Rubus hirtus*, *Cardamine bulbifera*
SFs ls	*Solidagini-Fagetum sylvaticae luzuletosum sylvaticae*	Arenaceous	N	900-1200	15-40	*Fagus sylvatica* subsp. *sylvatica*, *Castanea sativa*, *Luzula sylvatica*, *L. forsteri*	*Fagus sylvatica* subsp. *sylvatica*, *Hieracium murorum*, *Luzula sylvatica*
SFs ap	*Solidagini-Fagetum sylvaticae aceretosum pseudoplatani*	Arenaceous	N-NW-NE	1000-1200	50-70	*Fagus sylvatica* subsp. *sylvatica*, *Acer platanoides*, *Acer pseudoplatanus*, *Tilia plathyphyllos* subsp. *plathyphyllos*, *Ulmus glabra*	*Fagus sylvatica* subsp. *sylvatica*, *Acer platanoides*, *Acer pseudoplatanus*

2.2 Data collection and analysis

Field and floristic data are obtained from phytosociological tables published in CATORCI et al. (2008); bioindication values are inferred from PIGNATTI (2005).

Statistical analysis was carried out using the PODANI (2001) software:

- Principal Coordinates Analysis (PCoA), more particularly two data matrix were outgoing respectively using field and floristic data.
- Principal Coordinates Analysis (PCoA), using a data matrix based on bioindication values.

3. Results

The PCoA diagram related to field data analysis (Fig. 2) show 2 groups of coenoses (A and B), which are clearly separated in two clouds placed respectively in the left and right panels, relatively to the origin of the ordmation axes. Each cloud presents a gradient along the y axis. The first ordination axis (x) explains the 25% of total variability, while the second axis (y) explains the 20%.

In the PCoA diagram related to floristic data analysis (Fig. 3) the plant communities (represented with a cloud and a letter) are disposed again along gradients respect to the axes. The first ordination axis (x) explains the 21% of total variability and the second axis (y) explains the 16%.

In the PCoA diagram, relative to bioindication values (Fig. 4), the distribution of syntaxa along the x axis (explaining 90% of total variability) and the y axis (explaining 6%) is shown.

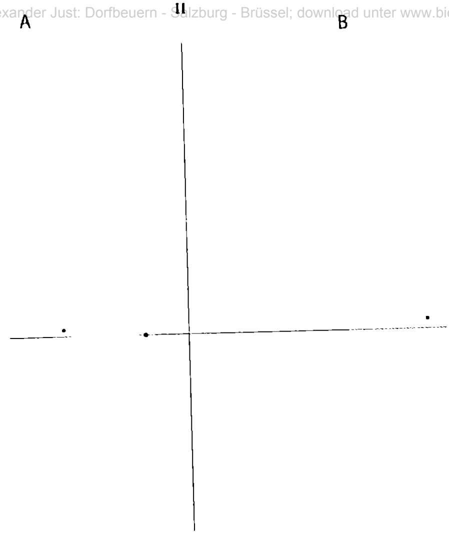

Fig. 2: PCoA analysis performed using field data from phytosociological relevés: A - Southern slope woods; B - Northern slope woods.

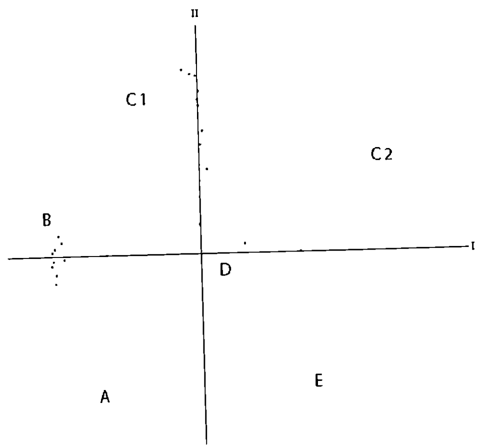

Fig. 3: PCoA performed using floristic datum from phytosociological relevés. A Woods formed by *Quercus pubescens* (s.l.) (*Roso sempervirentis-Quercetum pubescentis ericetosum arboreae* and *Erico arboreae-Quercetum pubescentis ericetosum arboreae*); B - Woods of *Ostrya carpinifolia* (*Hieracio murori-Ostryetum carpinifoliae hieracietosum murori*); C 1 e C 2 - Woods formed by *Castanea sativa* (C 1 - *Cyclamino hederifolii-Castaneetum sativae teucrietosum siculi* and *Carpinus orientalis* subsp. *orientalis* variant; C 2 - *Cyclamino hederifolii-Castaneetum sativae fagetosum sylvaticae*); D - Woods of *Quercus cerris* (*Aceri obtusati-Quercetum cerridis fagetosum sylvaticae*); E Wood constituted by *Fagus sylvatica* subsp. *sylvatica* and brushes of

Betula pendula or *Populus tremula* (*Solidagini-Fagetum sylvaticae moehringietosum trinerviae, Solidagini-Fagetum sylvaticae aceretosum pseudoplatani, Solidagini-Fagetum sylvaticae luzuletosum sylvaticae*; Grouping to *Betula pendula*; Grouping to *Populus tremula*).

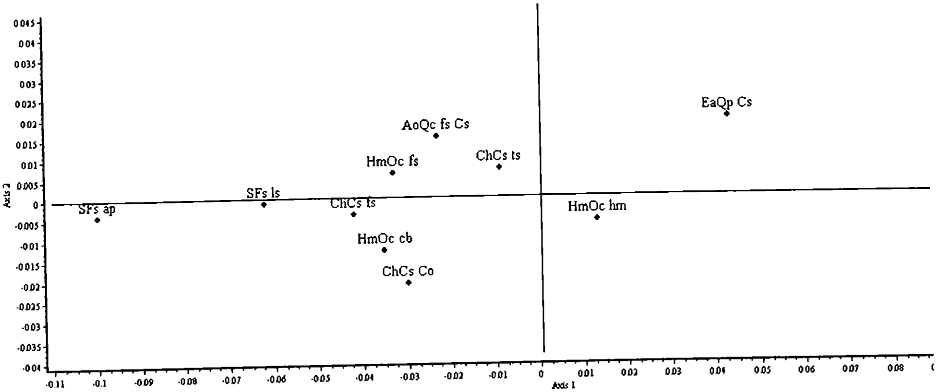

Fig. 4: PCoA with biondication values (PIGNATTI 2005) of each syntaxon: L - light need; T - temperature; C - continental climate; U - moisture or water availability; R - soil reaction; N - nutrients.

4. Discussion

The diagram relative to the field data analysis (Fig. 2) shows two groups of coenoses, A and B, which are distributed along an exposure gradient on x axis (from Southern, on the left side, to Northern facing slopes, on the right one), while, along y axis, a double gradients act: the first is relative to slope (that decreases upwards) and the second concerning the altitude (decreasing downwards).

Also PCoA analysis based on floristic data (Fig. 3) shows an exposure gradient along the x axis and an altitude gradient on the y axis.

Finally, the results emerged from PCoA of bioindication values data set (Fig. 4) highlight that the gradient along x ordination axis is linked to the parameters temperature (T) and humidity (explaining great part of total variability), while is clear that, referring to y axis and moving upwards, an increase in Nitrogen content in the left panels and pH variation (R) from neutral-basic to acid in the right panels.

Considering the fact that, in a same bioclimatic belt, temperature and humidity are influenced by field factors such as altitude, exposure and soil depth (closely related to slope steep) (CREMASCHI & RODOLFI 1991, ALLEGREZZA et al. 2005, PIERUCCINI 2007), is possible to state that exposition and slope represent the factors explaining the analyzed variability in all the three studies conducted

(25% on PCoA related to field data; 21% on PCoA related to floristic data; 90% on PCoA related to bioindication values). This evidence emphasizes that soil factors act at a lower hierarchical level, while bioclimatic features act at a higher hierarchical level.

On the basis of these results is possible to generate a model (Fig. 5) that highlights the hierarchical importance of the considered environmental parameters, showing the relationship between each of them.

Altitude and, inside each bioclimatic belt, aspect are the main factors influencing the forest coenoses distribution on homogeneous substratum; in fact, they determine temperature (consequently the length of growing period) and solar radiation (consequently evapotranspiration). At a lower hierarchical level soil physical factors (as deep and texture that joint to slope and aspect determining the soil AWC - Available Water Content) act; at last, soil chemical factors (pH and N content) complete the scheme outlining the floristic characterization of plant communities.

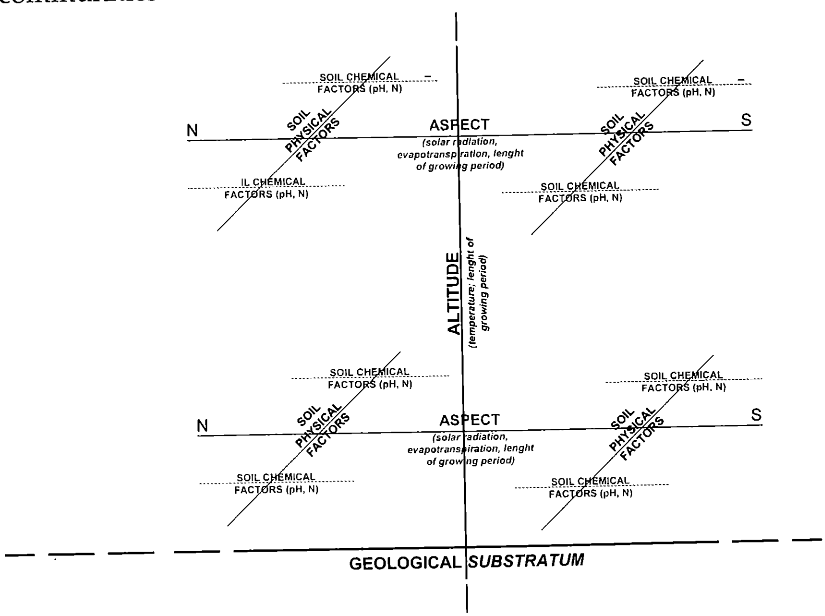

Fig. 5: Model of hierarchy of ecological factors affecting the distribution of forest types.

5. Conclusion

This work allowed to point out how, at the landscape scale, the distribution of different syntaxa relatively to a geologically homogeneous territory can be modelled by only three parameters: altitude, exposure and slope angle. In a first approximation, the expression of such factors includes also the main pedological characteristics to which the floristic biodiversity within each plant communities is related.

Actually, is clear that in order to create predictive models, field parameters were not taken into account singly, but rather in the entirety of their possible combinations. In fact, a single ecological factor is not enough to characterize a point of the topographic surface from an ecological point of view and consequently the vegetation which covers it, but only the combination of all of them takes part in defining the amount of radiation on the soil (mainly aspect and slope angle) and the meteoric waters flow trend (mainly morphology and slope angle) (AMATO et al. 2004). Therefore, the ecological model outing from this work will be an useful tool for future research project, because it will allow to insert field environmental features, as soil chemical and physical properties, undergrowth light intensity or forest management in a hierarchical framework. This will enable a better comprehension of the influence of each of them on the species richness and diversity.

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7. Literature

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