A NEW METHOD APPROPRIATE IN ENVIRONMENTAL IMPACT ASSESSMENT STUDIES FOR NATURAL ENVIRONMENT LAND COVER DATA ELABORATION

ADRIANOS RETALIS[1], FREDERIC BENDALI[2], MARIANTHI STEFOULI[3], ELENI CHAROU[4] AND GEORGE VAVIZOS[2]

[1] Institute for Space Applications & Remote Sensing
National Observatory of Athens
Metaxa & Vas. Pavlou, GR 152-36, Palaia Pendeli, Athens
GREECE
[2] Eco-Consultants S.A.
Aetideon 5, GR 15561, Holargos, Athens
GREECE
[3] Institute for Geology & Mineral Exploration
70 Messogeion Ave., Ampelokipi, GR 115-27, Athens
Greece
[4] Institute of Informatics Telecommunications
National Centre of Scientific Research "Demokritos"
P.O. 60228, GR 153-10, Agia Paraskeui, Athens
GREECE
adrianr@space.noa.gr http://www.space.noa.gr/~adrianr
info@eco-consultants.gr stefouli@igme.gr http://www.igme.gr/
exarou@iit.demokritos.gr http://iit.demokritos.gr/cil/members/cil_mem_exarou.htm

Abstract: - The Greek and EU legislatives' prescriptions in Environmental Impact Assessments Studies (EIA) impose habitat dynamic assessment and maps at large scale. Such studies need to exploit already accessible data as the ones from the Natura 2000 network. These data are insufficient to assess the habitat dynamics unless combining them with other characteristics such as soil potential. In this paper we present a classification of a Landsat-7 satellite image using Neural Network with training set combining Natura 2000 types of habitat references from Natura 2000 site map and from soil potential corresponding map. This resulted in a vegetation land cover map extrapolated from Natura 2000 map to the extend of the soil potential map (9000 to 60000 Ha). Correspondence between vegetation classes and soil potential have been assessed by statistics and explanations have been given for the study area on how edaphic characteristics can be limiting in habitat dynamics.

Key-words: - Environmental Impact Assessment, Landsat, Natura, Soil Potential, habitat, neural network

1 Introduction

Due to Greek and EU legislatives' prescriptions [8], in Environmental Impact Assessments Studies the possible changes of the natural environment caused by a projected activity should be predicted not only on the base of the environmental status prior the works start, but also on the base of a future status.

It is necessary then to estimate the state of the dynamics in which this environment is prior the works starts and the state in which it will be in a future date (15 years at least) in a "do-nothing" hypothesis. Also, the limitation in which EIA are conducted are stressing considering time and money.

Consequently, to state the dynamics of types of habitats within the purpose of EIA we should have access to already gathered data from further studies.

A category of existing data in Greece is the standard data form of "Natura" program [6].

The question risen is what criteria could be used for defining both habitat types inside the "Natura" zones and the natural habitats outside these sites within the same typology system, leading to conclusions on their dynamics. Furthermore, what criteria should be used for habitat description that would reveal the limiting factors [1, 10, 12] at the proper scale.

The dynamics of "natural" environment must be studied through selection of adequate descriptive criteria and quantitative measures of this environment. These criteria must be chosen following these constraints:

- They should be map able, first because EIA prescriptions refer to maps; furthermore at large scale (1:5000), and second to use the numerous data offered by geographic information, especially from remote sensing for phenomenon-factor causal analysis through GIS treatment. The interpretation of satellite images can also permit us to monitor evolution of the environment described by the proper criteria in future dates.
- They should have maximum correlation with discriminating and limiting factors of the environment, defined at the prescribed perception scale.
- They should correspond to ease in gathering data for field verifications and training sets for extrapolation from field units.

The Natura 2000 data cover widely the Greek territory (17%). In quite natural zones it should not be reasonable to over cross these data, even if the study area do not include a Natura site [16, 17].

Terrestrial European natural habitats described in the Natura 2000 network are classified and mapped according to phytosociological criteria [4, 7]. Other criteria are used but not systematically.

One problem is that there is not very often (especially in Mediterranean countries) clear correlation between the phytosociological criteria and the environmental factors that determine these types of habitats [17]. In such cases it is difficult to know what habitat criteria will change and how much it will change in case of a value change of an environmental factor. This is important not only in prediction of changes, but also in extrapolation outside the Natura site.

Another problem is that type of habitat description criteria adopted for Natura 2000 network in Greece, that are basically the vegetal association levels, do not often allow to map at large scale (how is it possible to map a vegetal association which characteristics are non dominant species?).

To take advantage of Natura 2000 data and to extrapolate them to overriding zones (in some kind of kriging), we propose to classify a satellite image using Natura geographic references on types of habitats for constituting training sets included, partly included or nearby the study area.

Thus, attention should be given in searching for the limiting factors of the habitat types, comparing the Natura based cartography with other geographic information, in order to ensure that spatial and temporal extrapolation will be done on rational bases.

The imbedded statistic programs in most GIS can help to support the establishment of the above relationship and to extrapolate the Natura data to extended surface.

2 Material and methods

To test the proposed method, we chose an area in which much data are available from previous studies (Fig.1). This area is in the Pindos Mountain in site of Acheloos dams [3, 9, 13, 15].

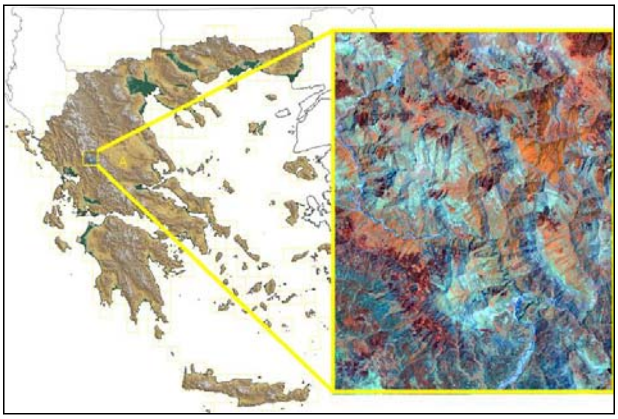

Figure1. Pilot project area

Besides existing Natura site (GR2110003, area 9082 Ha) and bibliography on this site including maps of types of habitats at 1:20.000 [6] we dispose a soil potential map at 1:50.000 (Ministry of Agriculture) and a land cover map at 1:20.000 issued by remote sensing from Landsat and IRS image. The study area covers then a surface of 59416,5 Ha.

The Natura site chosen has a good position on the limit between two bioclimatic zones: The eu-mediterranean in its south and the sub-mediterranean on its north part, so the training set that it can constitute can takes account of the two kind of correspondent vegetation [5, 11].

A LANDSAT–7 satellite image acquired in 2000, the same year that the land cover map has been created, was chosen for classification.

The soil potential maps have a large coverage in all Greece and represents a very good geographic layer to stratify the field for sampling. They have petrographic, geomorphologic, soil, artificialisation characteristics and references to vegetation stories.

We applied on the extend of the soil potential map two forced satellite image analysis using back propagation neural network. One analysis concerned vegetation characteristics and the other concerned both vegetation and soil potential characteristics.

Artificial neural networks (ANN) are computational systems whose architecture and operation are based on our present knowledge about biological nervous systems. By analogy to these systems, ANNs consist of a set of suitably positioned simple processing elements (nodes) representing the neurons. Each node receives signals X_i from a fixed number of other nodes and determines its activation V as a function of these signals and the strength of the synaptic weights W_i. The response Y of each node is a function of its activation $Y=g(V)$.

Different ANN models can be constructed by suggesting different ways of connecting processing elements. An example is the multi-layered feedforward network that consists of an input layer, intermediate or "hidden" layers of nodes and a layer of output nodes, with each node receiving inputs only from nodes in the previous layer. Depending on the number of layers and nodes in each layer, as well as on the values of the synaptic weights, a multi-layered feed forward network can realize any arbitrarily complicated, generically non-linear functional relationship between its inputs and its outputs by superposition of the elementary node functions. This relationship can be continuous or discrete (e.g. in a classification problem with two classes: All inputs belonging to one class correspond to output equal to 1, while those belonging to the second class correspond to output equal to 0).

The solution of a problem by an ANN is achieved in two stages. In the supervised *training* stage, the network is provided with a "training set" of examples (input plus desired output) of the relationship to be learned, and by implementing specific algorithms, usually iterative in nature, the values of the synaptic weights change until the network becomes able to reproduce these examples. Once the training stage has been completed, the values of the synaptic weights are fixed and the *testing* stage can begin. A "test set" of new examples (not contained in the training set) are presented to the ANN. In this way, we can test whether the ANN can *generalize*, i.e. realize the correct associations using data not previously encountered. The back propagation algorithm [14] is the most widely used training algorithm.

The training set has been created, choosing vector points on the satellite image with reference from the Natura type of habitat map and vectorized soil potential map. Each point is referred by a type of habitat code and a unique soil potential code.

In the both vegetation and soil potential characteristics analysis, the process examines the set of input raster values for each cell location, then assigns each unique set of values to a distinct arbitrary cell value in the new combination raster. An attached CELLVALUES table (Table1) details the actual combinations: it has a record for each cell value in the combination raster and fields containing the corresponding source raster cell values, as well as the count of cells having that combination. By analyzing this table, the degree of correlation between soil potential and vegetation classes can be identified. The raster has been converted in vector format. Accurate statistics can be derived, for example to know the area of each new vegetation and soil potential combined class. An option is provided to transfer additional attribute tables from the input rasters to the combination raster. These tables retain their original structure and have attachments from the combination raster cell values to the corresponding records as needed. This feature allows to further integrate information from the different input rasters. A similar approach can be followed for comparing the multi-temporal satellite images.

The statistics employed for class relation were tree classification.

Table 1. Combinations of Soil Potential and Vegetation classes, along with the area that has been estimated from counting the number of cells for each unique combination.

Soil Potential	Vegetation	Area (km^2)
"B8-991-4EEB8-9" (Bare rocks)	"934A" (Clear Kermes oak maquis)	10722600
""	"8250" (Low vegetation)	104517000
""	"119A" (Unvegetated Sand Bed)	62418600
"C1C4-828-3QQ" (Calcareous upper part of rocky summits)	"92D0" (Plane)	14004000
""	"934A" (Clear Kermes oak maquis)	295740000
""	"8250" (Low vegetation)	447321600
""	"5150" (Bracken Fields)	55180800
"R5R7-225-1BNR5" (Middle & low part of argylic flysch slopes)	"925A" (Mixed hornbeam & Kermes oak pseudo maquis)	92847600
""	"92D0" (Plane)	176784300
""	"5150" (Bracken fields)	10603800
""	(Beach)	96764400
"F5-474-1BN" (Mixed flysch)	"925A" (Mixed hornbeam & Kermes oak pseudo maquis)	17667000
""	"9280" (Fir)	254874600
""	"5340" (Eastern garrigues)	23590800
""	"934A" (Clear Kermes oak maquis)	16831800
""	"9340" (Mixed deciduous and evergreen forests)	349198200
"R3R7-262-3BN" (Rounded summits & down parts of argylic flysch)	"934A" (Clear Kermes oak maquis)	84688200
"R2R7-248-3NB" (Intense slope & down parts of argilic flysch)	""	25813800
Class not belonging to any soil potential category (i.e. water surfaces, shadowed areas)	"9280" (Fir)	4948200
""	"5340" (Eastern Garrigues)	11196000
""	"934A" (Clear Kermes oak maquis)	330795000
""	" 00" (Water)	165150000
""	"9340" (Mixed deciduous and evergreen forests)	24541200

3 Results and discussion

The classification using vector points as training set with only vegetation characteristics permitted to distinguish most its structure (height and density), with distinction between evergreen and deciduous vegetation (Fig. 2 and 3).

More precisely, the first distinction (separability 82,8 %) is between low vegetation of rocky slopes and summits ("Natura" habitat types classification code no 8250), almost not in the Natura site, and taller vegetation of forests, clear forests, maquis and clear maquis.

The second distinction is for three groups of land cover at 48,7 % separability. The first one is deciduous vegetation of beech forests (not in the Natura site), other deciduous forests (mainly oaks, code no 924A), mixed hornbeam and Kermes oak pseudo maquis (code no 925A) and bracken (code no 5150). The second group is essentially constituted of Kermes oak clear maquis (code no 934A), and the third group of fir (code no 9280) and mixed deciduous and evergreen forests, including Quercus ilex (code no 9340) in the south part of the study area. Let's say that there is great extent of mixed vegetation of fir and *Quercus ilex* in the study area, supposed being part of separate stories in the vegetation classification Natura system in Greece [6]. In the previous study [9], it was quite impossible to distinguish *Quercus ilex* both from fir and Kermes oak by maximum likelihood classification of a Landsat image.

At this stage of the work, it is possible to say that the classification with Back Propagation

Neural Network permit us to map quite all the land cover Natura 2000 types of habitat from a 9082 Ha united surface sample to 59416,5 Ha. It is satisfactory in comparison with the land cover map from the previous study that has field verification [9]. But, as it appeared in the late study, pure *Quercus ilex* forests (code no 9340) does not exist in the study area, unlike it is referred on the Natura site map [6]; type "Eastern garrigues" (code no 5340) dominated by *Phlomis fruticosa* seems that is not extended at all of the low vegetation of upper part of the slopes.

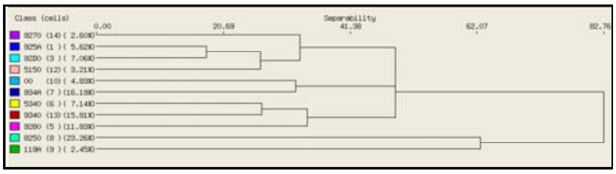

Figure 2. Statistics of the classification result (vegetation). Classes with similar spectral properties join near the left side of the Classification Dendrogram.

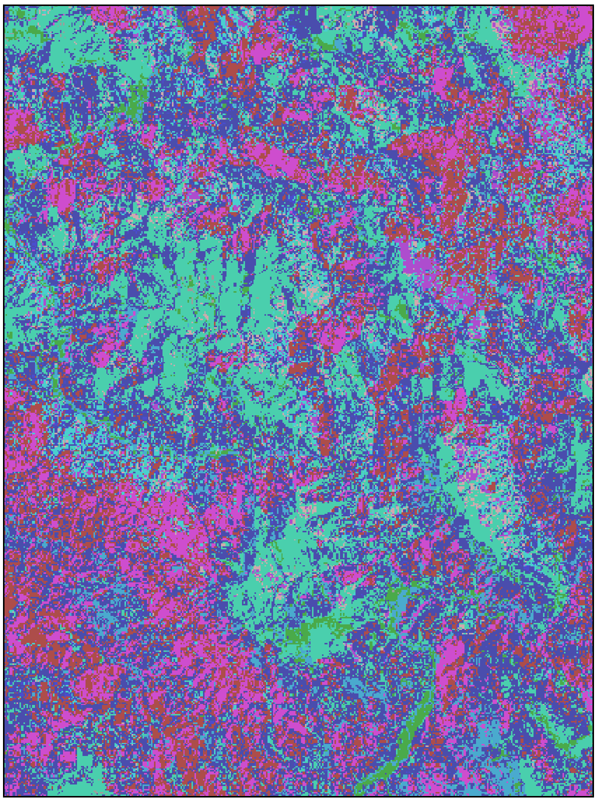

Figure 3. Classification result for vegetation

The classification using vector points as training set with both vegetation and soil potential characteristics did not permitted to a better distinguish of land cover than only with vegetation characteristics (Fig. 4 and 5). Nevertheless, the soil potential characteristics in the study area are well discriminating variables, and all vegetation classes have been automatically included in soil potential classes except vegetation class of clear Kermes oak maquis that had been regrouped with river, since they have similar spectral signature (Table 1). This is explained by the fact that clear Kermes oak maquis are the most common vegetation type in the study area (16,19%).

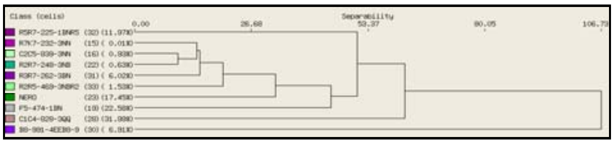

Figure 4. Dendrogram of the classification for soil potential. Class pairs that join together near the left edge of the diagram are closely related in their spectral properties, and the degree of relatedness decreases to the right.

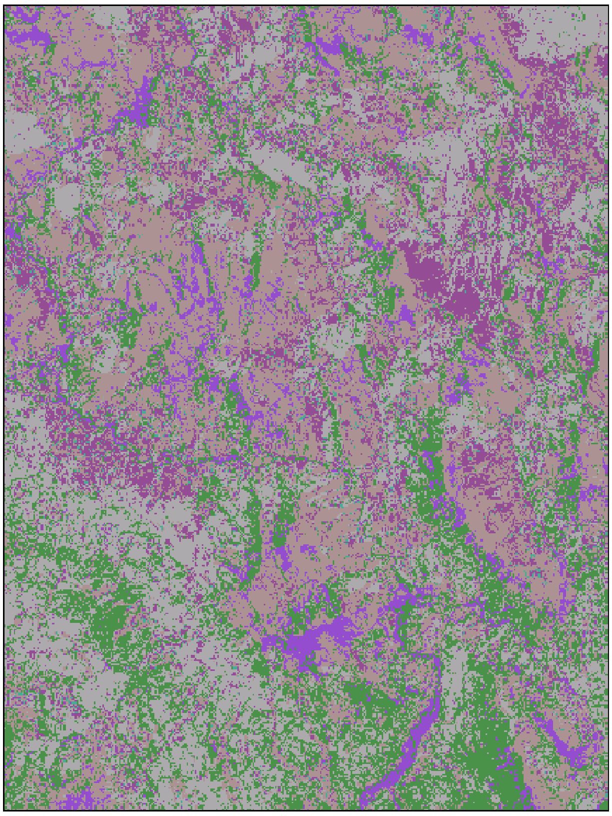

Figure 5. Classification result for soil potential

The soil classes that appear to discriminate the land cover in the study area are:

- ➢ The river bed, composed of bare stones (code no B8, separability 106,7), which is a characteristic that includes also the bare rocky slopes.

- The calcareous upper part of rocky summits (code no C1C4, separability 61,85), that are covered by clear Kermes oak maquis, but also by most of bracken fields in the study area. They are also covered by fryganes, low vegetation dominated most by *Phlomis fruticosa*. This vegetation is not normally limited to limestone, so it appears that the geomorphologic characteristics discriminate more than the petrographic one.
- The middle and low part of argylic flysch slopes (code no R5R7, separability 50,9) that are covered by deciduous vegetation (plane trees, hornbeam pseudo maquis, beech forests and other deciduous forests and bracken fields, all with 100% soil coverage.
- The middle slope mixed flysch (argylic and psammitic, code no F5, separability 44,9) covered by fir and *Quercus ilex*. It is to be noted that on the map resulting from the classification with only vegetation criteria, the limit between pure fir population and mixed fir and *Quercus ilex* corresponds to the limit between psammitic flysch (pure fir) and mixed flysch (mixed fir and *Q. ilex*). Mixed flysch is also covered by maquis, pseudo-maquis and frygana, when artificialisation degree is higher, but this is not frequent in this kind of soil potential category.
- Less distinguished categories between argyllic flysch from upper parts of the slopes, most covered by Kermes oak.

4 Conclusions

Our extrapolation of vegetation data from Natura 2000 site to greater geographic extent using image classification is satisfactory regarding the large extend on which it have been done.

The major problems encountered in classifying the image only with vegetation criteria is that some vegetation types are difficult to separate, as fir from *Quercus ilex*, plane from bracken and deciduous trees among them. Only field verification can avoid such problems.

The addition of edaphic characteristics to classify land cover permitted us to characterize types of habitat with criteria that have influence on vegetation and can help first to stratify the field for better field verification, and second to find limiting factors important in habitat dynamics. For instance, we can say that in our study area fir is more frequent on mixed flysch than on argyllic flysch or limestone. That is explained by the fact that psammitic flysch (mixed with argyllic) is better for soil water reserve than the two other kinds subsoil. Also deciduous forest and clear forests with hornbeam pseudo maquis are more frequent on low part of the slopes, having more soil water reserve than on the upper parts, where Kermes oak or frygana remain dominants. This explains the vegetation story inversion at large scale: deciduous trees at the down part of the slopes and evergreen oaks at the upper part, in contrary of vegetation storage at smaller scale, conformably to the bioclimatic classification where evergreen oaks are in lower altitude than deciduous [2, 11].

The authors aim to further extent this work by applying this method to a set of multi-temporal imagery in order to verify the dynamic trends of our types of habitats, separating edaphic effect from artificialization effect. Furthermore, this method will be applied to other parts of Greece, taking advantage of the large coverage of soil potential maps and adding climatic parameters to enhance the method of mapping for impact assessments studies necessities, permitting application of Natura 2000 data in practical cartography.

References:

[1] Aronson J., Floret C., Le Floc'h E., Ovalle C., Pontanier R., 1993, Restoration and Rehabilitation of Degraded Ecosystems in Arid and Semi-Arid Lands. I. A view from the South. *Restoration Ecology*, 1 (1), pp.8-17.

[2] Barbero M., Quezel P., 1976, Les groupements forestiers de Grèce Centro – Méridionale, *Ecologia Mediterranea,* 2-1976.

[3] Bendali F., Spanidis N., Vavizos G., 2002, Mapping natural habitats for environmental impact assessments in Greece, *Proceedings of the 6th Protection and Restoration of the Environment International Conference,* Vol.1, pp. 539-547, July 1-5 2002, Skiathos, Greece.

[4] Braun-Blanquet J., 1952, *Les groupements vegetaux de la France mediterraneenne*, Macabet Freres, Maison la Romaine.

[5] Emberger L., 1955, Une classification biogeographique des climats. *Rev. Trav. Fac. Sci.* Montpellier, 7, 3-43.

[6] Georgiadis Th., 2001, *Identification and Description of Habitat Types in Sites of Conservation Interest (Mapping of Habitat Types),* Ministry of Public Works and Environment (YPEXODE)

[7] Georgopoulos D., 2001, *Management and monitoring of the survey and description of*

habitat types studies program in zones of interest for nature conservation, Ministry of Public Works and Environment (YPEXODE).
[8] Greek Ministry of Environment and Public Works (YPEXODE-1), 2001, *New prescriptions for the EIA* (in Greek).
[9] Greek Ministry of Environment and Public Works (YPEXODE-2), 2001, *Complementary environmental impact assessment for the derivation of the Acheloos river to Thessalia* (in Greek).
[10] Krebs C. J., 1994, *Ecology: the experimental analysis of distribution and abundance,* (4th Ed) Harper Collins College Publ.
[11] Mavrommatis G., 1980, *Le bioclimat de la Grèce; relations entre le climat et la végétation naturelle. Cartes bioclimatiques,* Institut de Recherches Forestières d'Athènes.
[12] Odum E. P., 1993, *Ecology and Our Endangerd Life-Support Systems,* (2nd Ed). Publ. Sinauer Associates Inc.Sunderland, Massachusetts.
[13] Retalis A., Bendali F., Vavizos G., Vozikis E., Petrogonas I., 2002, Mapping Natural Habitat for Environmental Impact Assessment, *2nd National Conference of the Hellenic Geographic Information Systems Society,* February 28 - March 1, 2002, Athens, Greece (in Greek).
[14] Rumelhart D. E., Hinton G. E., and Williams R. J., 1986, Learning representations by back propa-gating errors, *Nature*, 323, pp. 533-536.
[15] Spanidis N., Vavizos G., Bendali F., 2001, Application of Multifactorial Analysis and GIS: Study on factors that influence vegetation in the zone of Acheloos derivation works, *11th Arc/Info Users Meeting,* November 9-10, 2001, Athens, Greece (in Greek).
[16] Vavizos G., Zannaki K., 1998, *Ecological Theory and Practice in Environmental Studies*, Papazissis Ed. Athens (in Greek).
[17] Vavizos G., Mertzanis A., 2003, *Environmental Impact Assessment Studies*, Papassotiriou Ed. (2nd Ed), Athens (in Greek).