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Vegetation mapping of Žumberak – Samoborsko gorje Nature Park, Croatia, using Landsat 7 and field data

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A vegetation map of Žumberak – Samoborsko gorje Nature Park with a minimum mapping unit of 2.25 ha (22500 m^2) was created during 2003. A Landsat ETM+ satellite image (acquired in the year 2000) and the results of field sampling were combined as mapping method. Given the constraints of the minimum mapping unit chosen, 17 classes were identified in the field and designated to corresponding polygons created by the classification of satellite image. Thirteen classes were plant communities or their combinations, while remaining four denoted various types of land cover (coniferous plantations, mixed rural landscapes, settlements and quarries). In the overall area of the Nature Park (344 km^2), the most frequent type of cover was *Lamio orvalae – Fagetum* forest (38.4 % of total area), while the most frequent non-forest community was *Bromo – Plantaginetum mediae* (7.9%). According to this research, as much as 77.3 % of Park area is covered with forest, which is a significant increase compared to the old data of 61 % of forests. Analyses of mapped polygons showed that almost a quarter of all polygons has an area equal to, or just little bigger than the minimum mapping unit, while more than three quarters of all polygons have their area smaller or equal to 9 ha (corresponds to 300 x 300 meters square). Such an extreme mosaic landscape structure in conjunction with the constant depopulation of Park area causes further natural forestation of park and hence decreases in biodiversity. The overall accuracy of map was 65%, forest vegetation being mapped with higher accuracy (70%) than non-forest vegetation (61%).

Key words: Vegetation, remote sensing, nature protection, mapping, Croatia

Introduction

The use of spatially organised databases has proved to be suitable and very efficient in the management of protected areas (e.g. TURNER et al. 1994, WELCH et al. 1995, MENON and BAWA 1997, RAO et al. 2002). This has been recognized and adopted in some Croatian national and nature parks as well. Žumberak – Samoborsko gorje Nature Park (Fig. 1) is among them. Its vegetation cover is one of the bases of its natural richness.

Having accurate and precise information about its distribution is crucial for proper management of the Park itself. Since such information for the complete area of the Nature Park did not exist, a need for a vegetation map compatible with already existing GIS data-

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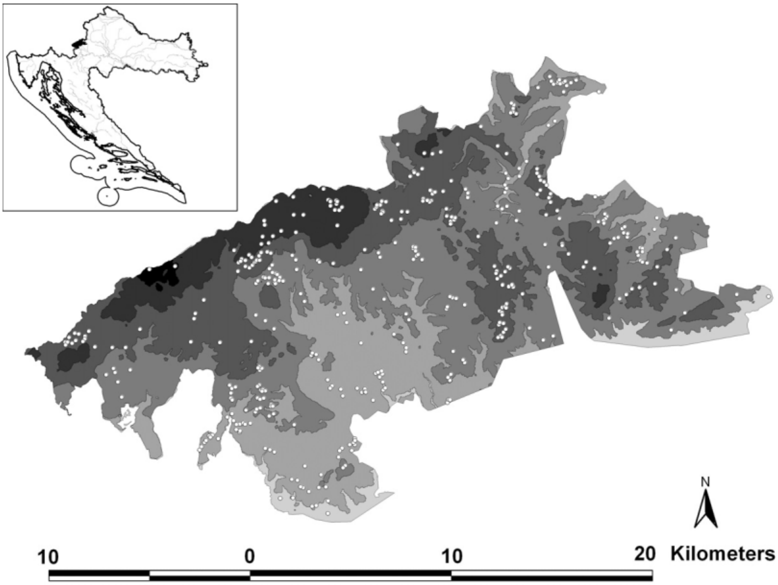

Fig. 1. Position of Žumberak – Samoborsko gorje Nature Park in Croatia (upper left part of the figure – black polygon). Nature Park with altitudinal belts stretched in grey scale (darker indicating higher altitudes) and field samples (white dots) used for vegetation mapping.

base arose. Mapping with the use of remotely sensed data is becoming standard for the mapping of vegetation or physiognomic land cover types (e.g. MARSHALL and LEE 1994, CHERRILL et al. 1995, MENON and BAWA 1997, LILLESAND and KIEFER 1999). In addition to this, taking into account the area of the Nature Park and its very complex orography, there would be a great discrepancy between the use of traditional mapping methods and the usual time and budget spans of surveys conducted for Nature Park management. Consequently, use of remote sensing data was chosen as the only feasible option for this mapping survey to be done in one year.

Unlike CARPENTER et al. (1999), OHMANN and GREGORY (2002) and KRISHNASWAMY et al. (2004) whose research efforts were focused on the methodology and its accuracy, we focused on the end results i.e. a vegetation map at association level, with the aim of achieving as consistent results as possible throughout the complete area of the Nature Park. Afterwards, we performed spatial analyses with respect to map unit sizes and rough accuracy assessment.

Methods

A combination of interpretation of Landsat ETM+ satellite image and field sampling was used as a mapping method. One of the main driving forces in choosing the methodology of this mapping survey was the constraint imposed by budget and the limitation of time to just a single season. A LANDSAT ETM+ satellite image, with a 30-meter spatial resolution of multispectral bands and a 15 m spatial resolution in the panchromatic band from the year 2000, was available and used in this survey. A minimum mapping unit (MMU) of 2.25 ha (corresponding to 150 m sided square) was chosen as appropriate for the following reasons:

1. this MMU approximately corresponds with its spatial resolution to maps in 1:25000 scale, that is the optimal resolution given the area of Nature Park, which is over 300 square kilometres (i.e. having enough detailed information, and yet not so detailed as to decrease the practical usage of the maps for field work and management)
2. it sets a limitation of the minimally 25 grouped pixels of satellite image to which certain vegetation class will be assigned. This increases consistency in the interpretation of temporary codes (see further text for explanation), and decrease error induced by generalization to the chosen MMU
3. it suits the amount of fieldwork that could be performed during one vegetative season, and in the framework of the project. Smaller MMU would significantly increase the amount of fieldwork needed.

After standard pre-processing procedures (i.e. geo-referencing, enhancing contrast of particular combinations of spectral channels, calculated Normalised Difference Vegetative Index – NDVI), as well as correction of scenes with relief data and actual sun positions synchronised with the time of satellite image acquisition, satellite image was interpreted in following steps:

- Unsupervised classification using ISO (Iterative Self Organising Data Analysis Techniques) data clustering (TOU and GONZALES, 1974) into 39 classes
- Identification of extracted classes based on: field data, expert interpretation knowledge and thematic maps into six distinct land-cover classes (agriculture; forests; non-forest vegetation; water; quarries; settlements) and three classes representing combinations of non-forest vegetation; agriculture, settlements and water, with different proportions of them in each combination
- Creation of masks, based on the nine classes created in the previous step
- Unsupervised classification of scenes composed of all bands from spring and autumn sets and calculated NDVI-s using optimization of number of classes with developed mathematical algorithm of each nine classes separately into a maximum of 30 subclasses
- Assigning a temporary unique code to each subclass

All nine spatial layers (i.e. classes) were merged into a single layer and further processed in the sense of filtration of all groups of pixels smaller then 25 (representing the MMU chosen). Those pixels were assigned to neighbouring larger groups. Finally, the grid thematic layer was converted to a polygon vector thematic layer used for overlaying on topographic maps and preparation of fieldwork. All satellite image processing was done using ENVI© (RSI) software, while preparation of field maps and further spatial analysis was performed using ArcView© (ESRI) software.

Fieldwork was done systematically, visiting at least 5% of the polygons of each class following the recommendations from the CORINE LC technical guide (BOSSARD et al., 2000), anticipating an error rate similar to that obtained in vegetation mapping by DIRNBOCK et al. (2003). Field routes were planned across the whole area of the Nature Park, with emphasis placed on areas with a larger number of different classes. Respecting the project budget, 437 field points were sampled and geo-referenced using GPS (Fig. 1), in period from May to October that took 52 man/days, and over 5000 kilometres driven.

In the field, we did not make the phytosociological relevés that one might expect in a survey dealing with the mapping of vegetation. Instead of that, we assigned the dominant vegetation or land cover type to every polygon visited. To each temporary code, the type of vegetation or land cover was assigned that was dominant among polygons (i.e. field points) from that code. Based on those results, the final joining of temporary codes and polygons was performed, resulting in a vegetation map of the Nature Park with MMU of 2.25 ha. Distribution of vegetation map elements (i.e. polygons) was analysed with respect to their size.

Standard accuracy assessment (e.g. KHAT) as described in CONGALTON and GREEN (1999) was not carried out. In this survey it was the end result that was of primary concern, hence we used all field data for interpretation of temporary codes without leaving any as an independent test data set. However, we checked 25% (i.e. 109) randomly selected field points and tested to what extent they correspond to data acquired from the final vegetation map as a rough estimate of achieved accuracy. The number of used field points was chosen arbitrarily, bearing in mind two goals: to have a test data set sufficiently large to ensure credibility of results, and yet to prevent over-fitting of results using the same data for classification and accuracy assessment.

Results

Given the constraints of the minimum mapping unit chosen, 17 classes were identified in the field (Tab. 1) and assigned to the corresponding polygons created by classification of satellite image creating the final vegetation map of the Nature Park (Fig. 2). Thirteen

Tab. 1. Areas of mapped classes, their portions in the complete area of the Nature Park, mean area and standard deviation of polygons in each class.

mapped classes	area (ha)	portion (%)	mean area	s.d.
Epimedio – Carpinetum betuli	5521.406	16.04	13.18	29.97
Lamio orvalae – Fagetum sylvaticae	13232.080	38.43	41.35	228.68
Luzulo – Fagetum sylvaticae	6266.869	18.20	32.64	84.40
Querco – Castaneetum sativae	430.784	1.25	4.79	3.55
Ostryo – Quercetum pubescentis	839.034	2.44	11.49	13.24
Robinia / Epimedio – Carpinetum betuli	31.724	0.09	3.97	0.76
Coniferous plantations	291.891	0.85	7.12	6.06
Pteridio – Betuletum	43.485	0.13	6.21	4.52
Arrhenatheretum elatioris	1361.845	3.96	6.45	5.43
Bromo – Plantaginetum mediae	2720.521	7.90	7.64	10.28
Arrhenatheretum / agriculture	407.169	1.18	5.46	3.96
Bromo – Plantaginetum mediae / agriculture	116.692	0.34	3.76	2.00
Bromo – Plantaginetum mediae / Pteridio – Betuletum	841.523	2.44	4.98	4.03
Bromo – Plantaginetum mediae / Genisto – Callunetum	90.530	0.26	3.62	1.17
Mixed rural landscapes	1847.232	5.36	7.00	5.64
Settlements	368.764	1.07	5.27	3.91
Quarries	22.040	0.06	4.41	2.36
TOTAL	**34430.793**	**100.00**	**14.62**	**89.55**

classes were plant communities (syntaxonomically harmonised with ŠUGAR 1972, HORVAT et al. 1974 and VUKELIĆ and RAUŠ 1998) or their combinations, while the remaining four denoted various types of land cover (coniferous plantations, mixed rural landscapes, settlements and quarries). In the overall area of the Nature Park (34430 ha) *Lamio orvalae – Fagetum* forest was most frequent (38.4 % of total area), while the most frequent non-forest community was *Bromo – Plantaginetum mediae* (7.9%). According to this research, as much as 77.3 % of Park area is covered with forests, which is a significant increase compared to old data of 61 % of forests (data from the leaflet issued by Nature Park).

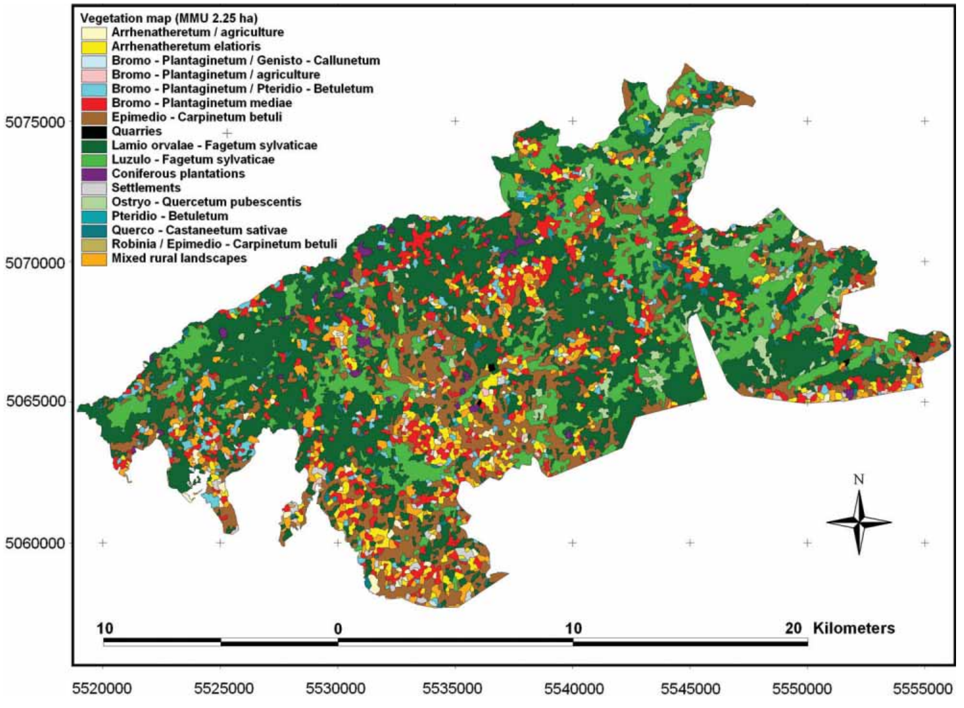

Fig. 2. Vegetation map of Žumberak – Samoborsko gorje Nature Park with minimum mapping unit of 2.25 ha.

Almost a quarter of all polygons has its area equal to, or just little bigger than the minimum mapping unit, while more than three quarters of all polygons have their area smaller or equal to 9 ha (corresponding to 300 meter sided square) (Fig. 3). Further, only four forest classes have a mean area of polygons larger then 10 ha (Tab. 1), while the mean area of all polygons is 14.62 ha (s.d. = 89.55 ha). All these indicate an extreme mosaic landscape structure.

Out of 109 tested field points, 65% had identical vegetation observed in the field, and extracted from the final vegetation map. Forest vegetation had higher accuracy (70%) than non-forest vegetation (61%).

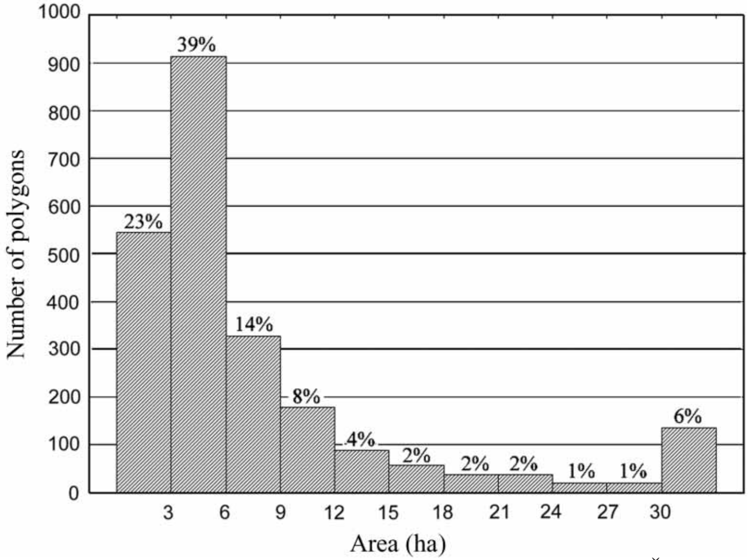

Fig. 3. Number and proportions of mapped polygons from vegetation map of Žumberak – Samoborsko gorje Nature Park, with minimum mapping unit of 2.25 ha, distributed over area classes with 3 ha step. Left skewed distribution indicating extreme mosaic landscape structure (i.e. large number of small polygons).

Discussion

This vegetation map does not represent a check list (or census) of all vegetation types present in the Nature Park. There are two reasons for this:

1. limitation set by the size of the MMU used. There are plant communities that are present in the Nature Park that have areas smaller then 2.25 ha or simply were not found during field work. Yet, they are very important for overall diversity like *Arnico – Nardetum strictae* or *Seslerietum kalnikesis*. Furthermore, ruderal and weed communities, usually linear spatial features, could not be mapped here.
2. limitation of the method used with respect to the assumed rarity of a certain plant community, although it covers areas larger then MMU. In consequence, no such plant community was found during the fieldwork, and it was not sufficiently different in spectral channels reflectance from some other widely distributed plant community. An example of such a community is *Lathyro – Quercetum petrae* cited by Šugar (1972) for the area of the Nature Park, but not identified in this project.

An extended list of vegetation present in the Nature Park could be compiled from papers by BEVILACQUA (1959), ŠUGAR (1972, 1973), GAŽI-BASKOVA et al. (1983), FORENBACHER (1995) and VRBEK (2000).

Bearing in mind the extreme mosaic landscape structure observed, it is expected that in the Nature Park there are significant numbers of areas smaller than the MMU that were assigned to some neighbouring larger group of pixels, which could be of a completely different land cover type (e.g. many small areas with grassland vegetation were assigned to the forest polygons). Although this could be the cause of the observed increase in the areas under forest associations, the main reason for the present forestation trend lies in the constant depopulation of the Nature Park. Based on achieved accuracy (65% of tested data) this vegetation map could be criticized for its accuracy. However, a significant part of error can be explained as follows:

- GAŽI-BASKOVA et al. (1983) observe transitions of *Arrhenatheretum elatioris* and *Bromo-Plantaginetum mediae* to each other depending on human impact intensity. Having in mind the extreme dry season during the field work, it is very likely that grassland communities was not developed in their optima, increasing the difficulty of identifying those two associations when they are not in their characteristic stage
- Generalization inevitably leads to certain amount of error. This is fact even with traditional mapping methods. The area of usual relevés is from 1 to 400 m^2 (depending on the type of vegetation). We can consider them actually as point data. If we want to produce vegetation map, we have to interpolate those data, which will inevitably lead to certain amount of misclassified space regarding the present vegetation cover.
- Another limitation of vegetation mapping in general is that in many cases we use discrete presentation of the variables (i.e. present vegetation) that are actually continuous. Resolving the very complex continuum/discontinuum controversy as in GLAVAČ et al. (1992) is, however, far beyond the scope of this paper.
- Accuracy assessment is very dependent on the level of spatial resolution i.e. level of discretization of land cover classes, as can be best seen from following examples: 69.4% of accuracy achieved at community level in DIRNBOCK et al. (2003); 54 to 100% of accuracy at habitat type level in JENSEN at al. (2001); 82% of accuracy at U.S.A. National Vegetation Classification Standard at the Formation level (e.g. Short temperate annual grassland; Mixed broad-leaved evergreen – cold-deciduous open tree canopy) and 99.5% at forest vs. non-forest classes in DE COLSTOUN et al. (2003).

From all this, we can conclude that the vegetation map produced by this survey is sufficiently accurate in the spatial sense and it represents the most accurate existing vegetation map covering complete area of Žumberak – Samoborsko gorje Nature Park. As it is, it can be used for management purposes in the Nature Park, which should tend to lead to the preservation of all plant communities present in the Park. Naturally, this map should be combined with additional data coming from surveys targeted to rare, small and more linear plant communities.

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