ENVIRONMENTAL MONITORING IN CENTRAL DALMATIA

Vincent Gaffney
University of Birmingham, United Kingdom
Krištof Oštir, Tomaž Podobnikar and Zoran Stančič
Centre for Scientific Research of Slovenian Academy of Sciences and Arts, Slovenia

Commission VII, Working Group 6

KEY WORDS: Cultural Heritage, Multispectral Classification, Land Use

ABSTRACT

Following the early seventies, when satellite imagery became widely available, a wide range of professionals have attempted to utilize satellite images in environmental sciences. The study discussed here has been carried out in the central Adriatic where an international team of archaeologist, historians, geographers and other specialists has been studying the archaeology of the Central Dalmatian islands (Croatia) for more then a decade. The natural environment data for the research — when available — was largely supplied as thematic maps which were frequently unsuitable for detailed analysis. Satellite imagery seemed to be an adequate alternative source for such data. The island of Šolta was chosen to be presented in this paper as it is a relatively small island and therefore all image processing can be done quickly even with small personal computers and with low–cost software. The study has two important implications. First, the land use map of Šolta was produced, and second, the possibilities of a simple and non–expensive image processing system for this kind of analysis have been demonstrated to local planners and decision makers.

INTRODUCTION

In the area of central Adriatic an international team of various scientists has been studying the Central Dalmatian islands (Croatia) for more then a decade (see Figure 1). The research has included the analysis of settlement patterns, colonization, contacts, land use and economy of the prehistoric, protohistoric, Greek and Roman communities who lived in the area. The archaeological data for this work was gathered through field surveys of the islands and extensive archive research. The natural environment data — when available — was largely supplied as thematic maps which were sometimes quite detailed but sometimes also unsuitable for any analysis. These contrasts are exemplified by the situation relating to soil maps in the area. The one for the island of Hvar was extremely detailed with a refined classification and plotted at a scale of 1:25.000 (Gaffney and Stančič, 1991). Unfortunately no other island, with the exception of Brač, possessed such maps, so the situation clearly limited comparative analysis between the islands. Satellite imagery seemed to be an adequate alternative source for such data. The island of Šolta was chosen to be presented in this paper as it is a very small island (with a total area of 52 km^2) and therefore all image processing can be done quickly even with both low–cost personal computers and software (IDRISI).

THE CENTRAL DALMATIA PROJECT

The Mediterranean landscape in the Eastern Adriatic is an extremely fragile ecosystem. Although changes in the natural environment were always apparent, they have never been more dramatic than in the last 50 years. It is essential that such changes should be seen in a long–term perspective as this will allow the identification and understanding of both environmental and socio–cultural causes of landscape degradation. Although many states of Eastern Europe often have specialized thematic data, these are mostly out of date (i.e. not suitable for modern analytical approaches) or user–restricted. Newer technology should be applied to data–collection and analysis. The use of remote sensing and GIS coupled with modeling techniques and an emphasis on the human–environmental co–evolution could help us gain an insight into the extent and causes of soil degradation in Slovenia, Croatia and other countries, and to serve as a basis for monitoring such degradation in the future. Concretely, our aims were:

- to encourage application of the new technology in collecting and analyzing the natural and social environmental data in Slovenia and Croatia;
- to develop a new methodological framework of evaluating changes and degradation of the landscape based on the long–term observation of the human–environment relationship;
- to provide the relevant background for decision–making in regional planning for Mediterranean areas which aims at minimizing the environmental damage.

The island communities in the region of Central Dalmatia, especially on the islands of Hvar and Brač were in the focus of our study. In these islands, the very fragile karst environment has in recent decades been placed under heavy stress from popular tourism, and a reevaluation was opportune. The analysis could provide us with a deeper insight into the role of tourism, as well as an indication in which direction development could be steered once normal circumstances prevail, and tourism resume. Also, these islands have been the subject of intensive data–gathering on the topic in the last years before the present hostilities; this included data on the long–term evolution of vegetation, soils and settlement pattern.

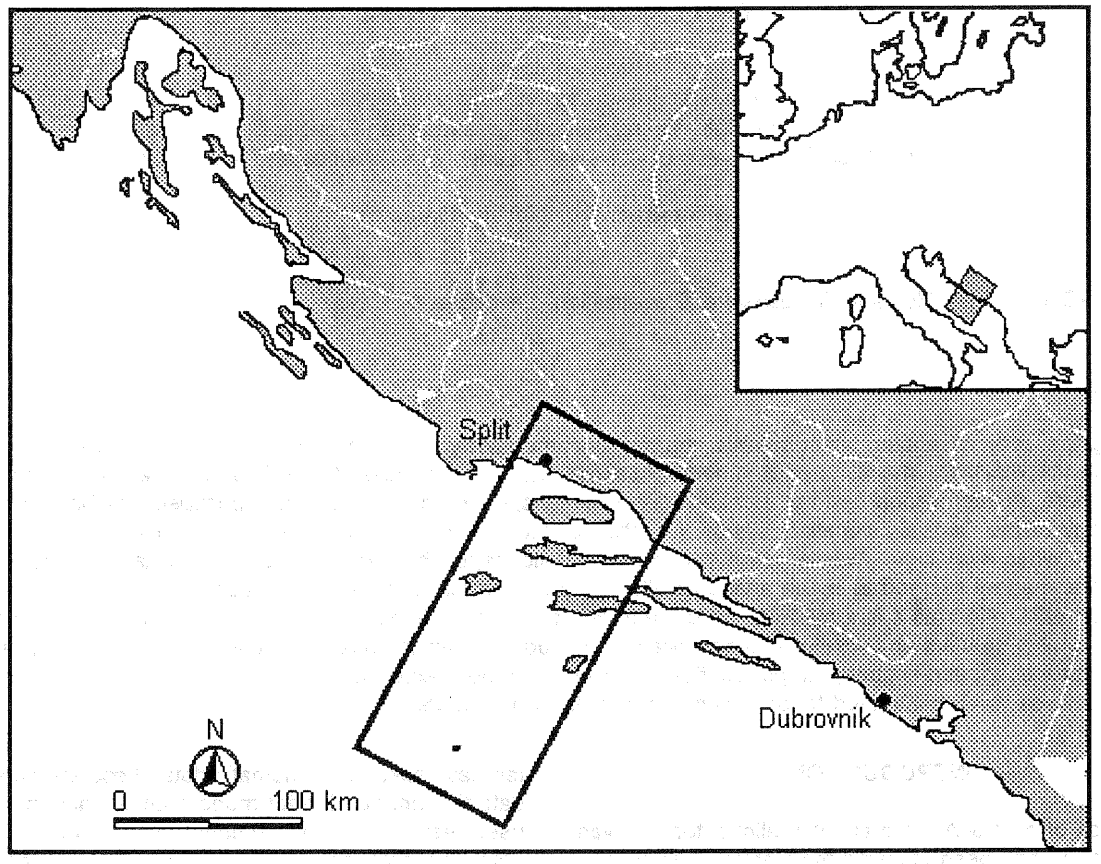

Figure 1: The study area.

Despite well known problems in Eastern Europe, many areas are beginning to anticipate reconstruction. The region of Dalmatia (Croatia) is one such area. Dalmatia, formerly one of the most popular tourist resorts in Europe, has suffered severe environmental and economic damage. Despite this, local planners regard the situation as one which allows major reevaluation of local development procedures.

The Adriatic and especially the Dalmatian karst are very sensitive environments and demand careful monitoring. In the past, this occurred via local development plans, supplemented by a series of United Nations development studies (United Nations, 1968). Unfortunately the documents produced were frequently based upon inadequate information. Consequently, development was uncontrolled and damage to environmental resources was commonplace. This situation was exacerbated by the development of mass tourism associated with pressure on water and land, increased erosion, pollution and levels of damage to cultural resources.

Local planners wish to avoid the repetition of such a situation when economic development recommences. The lack of access and experience in new technologies related to development data is a serious handicap in preventing further environmental miss–management. There is a continuing reliance upon traditional paper–based thematic maps as a source for data which could be applied more efficiently via satellite imagery.

No matter if data is gathered through traditional or advanced techniques, it is the analysis that really makes the difference between right decisions and miss–management. Therefore, for the purposes of local decision making, GIS technology should be applied. Observing the changes in the natural and social environments on a long–term scale and especially isolating catastrophic events in the past compared to general trends would be of extreme importance. Some environmental changes have been monitored for nearly 100 years. However, it is apparent that earlier historic and prehistoric data should also be considered. Only this can enable a relevant evaluation of changes in the environment as well as the building of a model representing the dynamic system of human–environmental interaction and their transformation.

The research in Central Dalmatia is comprised of two parts. In the first part our aim is to integrate present natural environment data. The established database includes extensive information on the current status of soil, surface geology and the terrain. All these data is incorporated into the GIS providing a technological framework for the analysis. Thematic map data is then compared to the Landsat satellite images thus enabling the evaluation of the conventionally produced thematic maps. The natural environment data — when available — was namely supplied as such maps which were frequently unsuitable for detailed analysis. In the second part of the Project we want to analyze the cultural and environmental resources of the islands. The cultural environment data, especially the archaeological data, is integrated with the natural environment data. The process of archaeological data collecting was limited to the islands of Brač and Šolta. The results are used to model the possible impacts of human intervention on the environment

and for the re–analysis of the most recent modern local development plan which was compiled for the Hvar Commune in 1990.

ŠOLTA ISLAND THEMATIC MAPPER DATA CLASSIFICATION

The island of Šolta has a relatively poor natural environment database compared to other islands in the area of Central Dalmatia. The major goal of the research was to obtain data on the current land use for the entire region and compare it with the historical data. However, we wanted to use a low–cost image processing system, one which would be readily available for local authorities without major software and hardware investments. An important issue in the choice of the test image processing system was also the easy integration with the other existing geographic data. It would be of great importance if powerful analysis within the system could be performed. Thus it was crucial to find a system that is easy to use and has a good and friendly user interface. After an extensive search, IDRISI, which is a grid based spatial data analysis and image processing system, was used in this part of the research (Oštir, 1995).

The image selected was a Landsat TM quarter scene (90 by 90 km), acquired on July 31, 1993. Preprocessing of the image, including georeferencing, was performed with EASI/PACE (PCI, 1994). After the initial stage the satellite data for the island of Šolta was only transferred to IDRISI on which the processing was continued. Processing comprised of two steps. In the first stage, unsupervised classification of satellite imagery with some general information of the land use was obtained. The process continued with more refined supervised classification using different statistical techniques. Results of both methods will be presented in the following text.

Unsupervised classification

IDRISI, despite being a relatively powerful system, has certain limitations in image processing. Unsupervised classification could be performed simultaneously on three spectral bands only (Eastman, 1995). This might represent a significant drawback if more bands were needed in the process of classification. However, after initial inspection of the image with seven spectral bands, it become apparent that quite good results could be achieved if bands 3, 4 and 5 were used.

Spectral band 3 is useful for our application as it enables easy distinction between vegetation and nonvegetation, while bands 4 and 5 are very important in the vegetation analysis. It was our hope that these bands would contain enough data for effective unsupervised classification. IDRISI requires, as a first stage in unsupervised classification, the creation of a composite image containing data from all three bands selected (Eastman, 1995). The frequency distribution of classes in this composite image suggested that the maximum number of classes in the unsupervised classification could be more than 30. However, after the inspection of the composite image it was decided that an initial 15 classes cluster analysis of the image would be performed. The resulting image produced very detailed information on

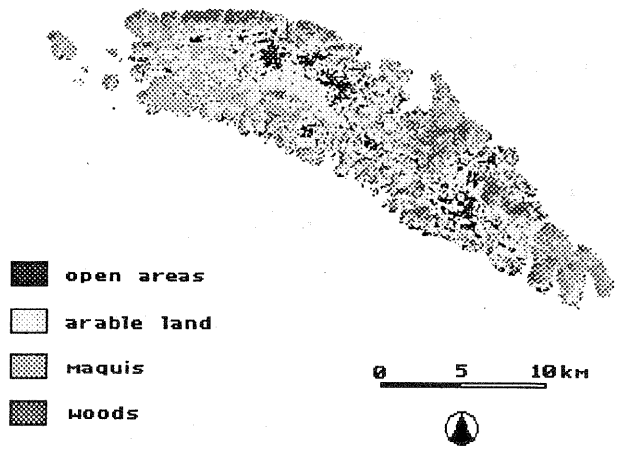

Figure 2: Results from the unsupervised classification with seven classes.

the urbanization of the island; however, distinction between maquis, wooded areas and arable land was rather difficult. Therefore some additional tests with a smaller number of classes were performed. The best results were achieved with the cluster analysis of the image giving seven classes only. This image produced very clear built areas and therefore open land, including the coast, could be easily distinguished from arable land, maquis and two types of woods. The later two probably represent two different covers of vegetation which resulted either as a different vegetation type or vegetation density. For the purpose of presentation only, the landcover map has been simplified to present four classes only. The coast and open land have been combined in a single class and the woods as well have been joint in a unique class. The resulting image is presented in Figure 2. If the number of cluster classes is reduced to six or five, much data is lost and image classification gives no useful information.

Supervised classification

The results of the unsupervised classification were very promising, however, some rather unexpected results occurred. The signal from the coast was, though geographically easily defined, very mixed. Thus it was decided to try a supervised classification which would include following classes: open areas, arable land, woods, coast and maquis. For each land use type a training area was selected and digitized on–screen. Each digitized polygon contained 60 to 70 pixels which had to be very homogeneous. Figure 3 presents the spatial position of the training areas. As mentioned five different classes were selected:

- Open areas. The spectral signatures of urban and open areas were very similar. It was hoped that urban areas and areas of bare rock would be classified in the same class. The training area was selected in the centre of Grohote, the largest village on the island. It contained houses, paved roads and squares.

- Arable land. The largest arable field on the island was selected as a training area. However, the sample needed to contain different vegetational cover, from different vegetables through to cereals.

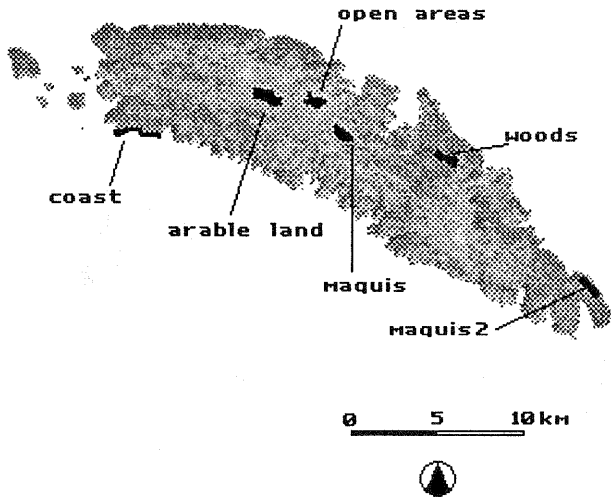

Figure 3: Position of training areas selected.

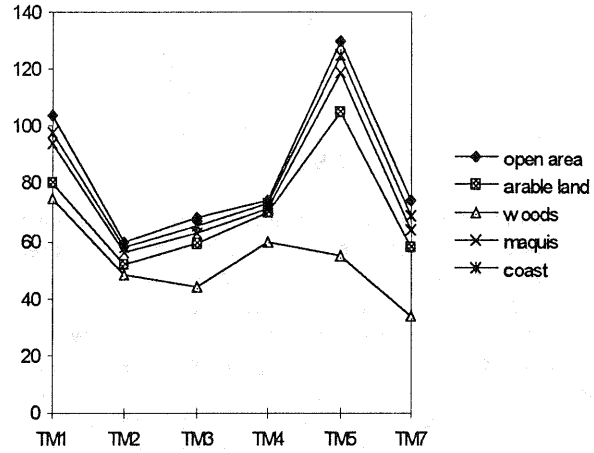

Figure 4: Mean reflection values of signatures of corrected samples.

- Woods. Spatially well defined and clearly seen as darker areas on infrared bands of the TM image.
- Coast. Also spatially well defined, but has very mixed signal — probably due to different coast types resulting in the geology, proximity of vegetation etc. It was hoped that inclusion of coast in the classification would facilitate classification of open areas.
- Maquis. Probably the most problematic sample. Most of the maquis has developed on abandoned pastures and can be very dense in some cases. Sometimes even recently abandoned grasslands and pastures could be included in it. As most of the problems were predicted in this class, two samples were taken.

Following the initial inspection of the training area samples it was decided to use only bands 1, 2, 3, 4, 5 and 7 in the analysis. Band number 6 was excluded due to its large pixel size which resulted in the significant loss of data. During the more detailed inspection of sample signatures it became apparent that some of them overlap and therefore they had to be modified. In Figure 4 the mean values of corrected signature samples are plotted. It is evident that in general the bands do not overlap.

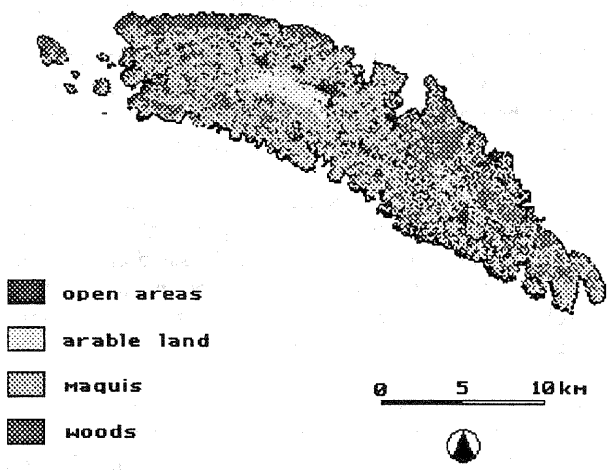

Figure 5: Results from the supervised classification.

Several methods of classification were used in the classification procedure. Since the parallelepiped method is very simple and robust, the results obtained were inappropriate (Mather, 1989; Sabins, 1986). Thus minimum distance and maximum likelihood methods were tested. They are both provided as an integral part of the IDRISI software package. As expected, the best results were produced when maximum likelihood method was applied (see Figure 5). The results of the classification were compared with the 1:25,000 map produced in 1981. Though recent air photographs should have been used for quality control, the only available comparable sources were maps. There was evidence of the growth of maquis in all areas where agriculture has not been so intensive. Abandonment of arable land followed between the 1981 till 1993. It seems that all the abandoned arable land has been covered by maquis. The wooded areas seem to be constant.

CONCLUSIONS

The study has two important implications. First, the land use map of the island of Šolta was produced. The island of Šolta probably has the worst spatial data on the natural environment in the whole region of Dalmatian islands. All other islands, especially the island of Hvar and the island of Brač, have soil and geology maps of some relevance. In the study an accurate land use map was produced, despite serious problems with the satellite imagery applied in the Mediterranean environment. These problems are (Gaffney et. al., 1995):

- Extreme polyculture of the Central Dalmatian agriculture; on a single land parcel a wide variety of crops may be grown together, along with subsidiary tree crops.
- Arable areas on the island are typified by the use of very small fields. Sometimes up to 45% of the fields can be smaller than 30 meters.
- Last but not least, field boundaries are composed of masses of cleared stones and stone terraces which may be several meters wide and up to 3 meters in height.

The second implication of the study is the demonstration of the possibility of a simple and low–cost image processing system for this kind of analysis. Local planners avoid satellite images due to the cost of hardware and software needed for effective processing of such a large amount of data. That forces them to rely on old or inadequate spatial data which may result in poor decision making. We hope that it has been proved that even low–cost systems can help to provide up to date information on environment and land use changes. Most of the analysis could have been done on the hardware already available at the local government planning offices with small investments in software. The only problem remains in the appropriate training and education of local specialists.

ACKNOWLEDGEMENT

The project was sponsored by the Commission of the European Communities, Directorate General XII, and EOSAT. The attendance at the conference was possible with financial help of the Austrian Institute for Eastern and Southeastern Europe and the University of Ljubljana Knafelj's foundation.

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