CREATION OF A LAND COVER MAP OF CRETE, USING SPOT SATELLITE DATA

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ABSTRACT

The aim of this work was to create a Land Cover map of Crete on a cartographic scale of 1:50,000 using SPOT4-Xi images. Supervised classification was employed and the CORINE standards were followed.

The task proved to be complicated due to the wide heterogeneity and the undulating nature of the Cretan landscape. One of the classification images was tested for its accuracy, which was estimated to be lower than 50%; however, after enhancement based on ancillary data it increased to 70%.

KEY-WORDS: LANDSCAPE OF CRETE, SPOT-XI IMAGES, SUPERVISED CLASSIFICATION, LAND COVER MAPPING.

INDTRODUCTION

It has been widely recognized that information about land cover is a basic requirement for the management of the environment and natural resources. Land cover mapping has become an integral part of the CORINE (Co-ordination of Information on the Environment) Programme, which was initiated in 1985 by the European Commission Directorate General XI (now known as DG Environment) with the main aim of compiling consistent and compatible information about the environment for Member States of the European Union [Buttner et al., 2001].

Within the CORINE frame, computer assisted visual interpretation of satellite images has been chosen as the preferred technology for mapping [Buttner et al., 2001]. According to the CORINE standards, LANDSAT-MSS, LANDSAT-TM or SPOT-HRV imagery are all suitable for CLC (CORINE Land Cover) mapping. Although data from second-generation sensors (TM/HRV) are easier to interpret, purchasing costs are higher and processing times are longer, while MSS data - which are less costly and are more quickly processed - take longer to interpret and involve a greater systematic use of ancillary documentation, particularly aerial photographs [European Commission - JRC, 1997]. Greece is a participant in the CORINE project and the Greek team produced the CORINE Land Cover map of Greece on a scale of 1:100,000 (CLC100 map) using LANDSAT satellite imagery [European Commission - JRC, 1997].

Soon after the satellite's launch in 1998, SPOT-4 data was recognized as fulfilling the geometric, as well as the thematic specifications of CLC50 (CORINE Land Cover mapping on a 1:50,000 scale). This was attributed to the 20/10 meter pixel size in Multi-spectral (XI) and Panchromatic (PAN) modes, and the availability of a short-wave infrared band in the Xi mode [Buttner et al., 2001].

The **aim** of this work was to create a Land Cover map for the entire island of Crete on a cartographic scale of 1:50,000 using Remote Sensing and GIS. This aim was defined in an INTERREG-IIC project, entitled "Space allocation of existing land uses and natural resources in the island of Crete by employing Geographical Information Systems and Remote Sensing". Assuming the lowest size limit of an object that can be usefully shown on a paper map to be 0.5 mm as a rule of thumb, then for a scale of 1:50,000, an effective resolution of 25 m is needed [Goodchild M.F., 1993]. Since SPOT satellite data (20 m resolution) fulfill the conditions necessary to achieve a result on the aforementioned scale, this particular data was chosen for this work.

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More specific objectives of this work were: 1) the construction of a CLC50 map of Crete using SPOT4-Xi, in contrast to the existing official Land LCL100 based on TM satellite data, 2) an evaluation of how the difficulties of the Cretan landscape affect land cover mapping and the results thereof, and 3) the creation of a 3-Dimensional representation of the map to be created by its overlay onto a 20x20 m DEM of Crete. A 3-Dimensional representation of the Earth's surface can generate new information and insights about the study area that would otherwise be impossible using 2-dimensional tools alone; surface views can provide a substantial amount of information and can be a powerful vehicle for conveying geographic information to various kinds of interested parties.

The basic hypothesis of the work was that SPOT data could be able to ascertain the reality of the Cretan landscape, due to their medium-high resolution and their new (in SPOT4) MIR band.

STUDY AREA

The study area comprised the entire island of Crete. Crete is located in the eastern part of the Mediterranean Sea, (between 34°55' and 35°41' latitude and 23°30' and 26°19' longitude). The total surface area of the island, including the surrounding small islands, is 8.336 Km^2. However, the small island of Gavdos was not considered, because it was not included in the satellite images acquired.

Ecologically, the predominant flora consists mainly of *Maquies*, *Garrigues* and *Frygana* with small extents of coniferous, chestnut and plane forest. Olive groves are the most extended crops with vineyards, greenhouses, fruit plantations and vegetables completing the agricultural sector. Goats are the predominant species of fauna and at the same time the main cattle-raising animals, found especially in the highlands.

METHODOLOGY

The methodology was chosen in accordance with the CORINE standards.

The basic digital data used in this study were 6 SPOT4-Xi (multi-spectral, spatial resolution 20 m) satellite images for the year 1998, which in total covered the entire island.

The ancillary data used included:

- 24 sheets of the 1:50,000 topographic map (source: Hellenic Army Geographical Service - GYS), transformed into digital form, through scanning.
- 24 sheets of the 1:50,000 geological maps in hard copy form, (source: Hellenic Institute of Geological Studies – IGME).
- A large number of 1:5,000 digital ortho-photographs (partial cover of the island – part of Iraklion and Lasithi prefectures) (source: Greek Ministry of Agriculture).
- A 20X20 m DEM of Crete created by 4 SPOT2 stereopairs (source: private company).

Firstly, the geometric correction of the multi-spectral images was carried out in a UTM/WGS84 projection system, based on the 1:50.000 topographic map and with a Root Mean Square Error (RMSE) on average fewer than 2.5 pixels, (less than 50 m on the ground). Secondly, the appearance of the multi-spectral images was enhanced by manipulating their Look-up tables (LUT). Thirdly, the NDVI and PCA images were produced. Forthly, the aspect and slope maps were acquired from the DEM. The aim of the production of all these new images was to assist in the visual interpretation. The raw multi-spectral images were then topographically normalized using the DEM to remove the shadow effect from them and thus to improve their spectral credit. However, the adopted procedure (the Lambertian Reflection Model) proved to give very uncertain results, due possibly to the very undulating relief of the landscape. Therefore the use of the non-normalized images was eventually preferred.

The 6 images were classified separately since every image was acquired on a different date (between 22-04-98 and 08-06-98). In order to make the classifications, field work was conducted, during which the sample parcels were collected. In the course of this field work, it was observed that the land cover was extremely heterogeneous due to the considerable variety of alternating thematic features (vineyards, olive groves, fruit plantations or greenhouses interspersed with residential areas or other constructions, as well as natural land mixed with areas with cultivated land) (Picture 1). Concerning the geology of the island, the karstic character appeared to be the predominant, evidenced by the presence of many gorges, even at the shorelines.

The structure of the spectral signatures input in the classification was based on the CORINE nomenclature, which consists of 3 item levels. In two cases, a 4th level was added to the classification scheme, namely "Greenhouses" in class "2.1.1–Non irrigated arable land" and "Citrus plantations" in class "2.2.2-Fruit trees and berry plantations". The Bayesian technique (Maximum Likelihood with use of probabilities) was applied to the images and a total of sixteen classes were identified in the classified maps (different number of classes in each scene).

Picture 1. A characteristic aspect of the considerably heterogeneous landscape of Crete (Omalos plateau).

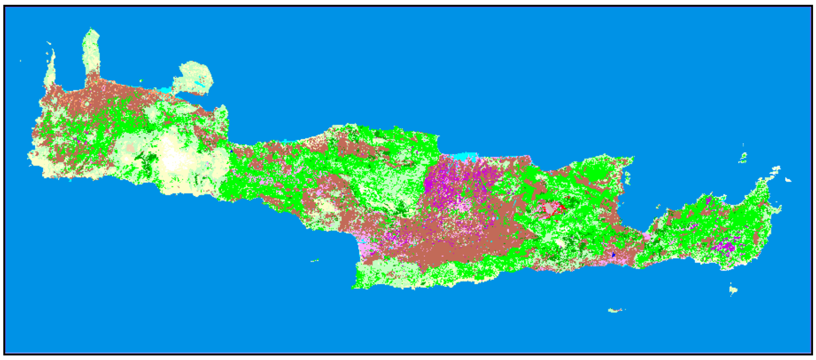
The mapping unit, which was determined by geographical analysis (namely, the local variance method), was set at 0.4 ha, approximately 10 pixels of SPOT4-Xi images [Cao C., and Siu-Ngan Lam N., 1997]. The variance images created by 3x3, 5x5, and 7x7 moving windows were tested and showed the 3x3 (9 pixels) image to have the largest variance value. Such a small mapping unit was in accordance with the particular landscape of Crete.

At this stage, one of the images (the image covering the area of Rethymnon) was experientially assessed for its accuracy: a field trip was conducted and the credit of the classified image was evaluated by observations in situ. Since the accuracy proved to be very low (less than 50%), the result was improved by manually recoding pixels of certain classes and areas (using polygonal "Areas of Interest"), relying on the information provided by the GYS topographic map. The class items that were mainly modified by this recoding were "Olive groves", "Sclerophyllous vegetation", "Water bodies", "Forests", and "Bare rocks". Eventually, using sampling points collected in the course of a new field survey (3 points per each of the 10 class items of the image – in total 30 points) the final accuracy of the classified image was estimated to be 70%. The image of Rethymnon was a guide for the recoding of all the remaining 5 images. However, due to the lack of time, no other images were accuracy assessed.

The single classified images were finally used to create a uniform classified image of entire Crete, using a mosaic procedure. The united image was then smoothed by statistical filtering (majority filter).

Erdas Imagine 8.4 was employed for the whole image processing and the analysis. The raster classified image of Crete was finally converted to vector format using ESRI ArcView3.2 (Picture 2).

RESULTS



Picture 2. The final CLC50 map of Crete in vector format.

The end result was a map of the entire island of Crete on a cartographic scale of 1:50,000 and the respective legend. The 1st level of the nomenclature was selected in two cases (1-Artificial surfaces and 5.Water bodies) in order to keep the number of classes low (Figure 1).

Using raster or vector viewing software, the screen display of the map in a 3-dimension space is possible, with zoom-in/zoom-out and information about the class and the area of each polygon facilities (Picture 3).

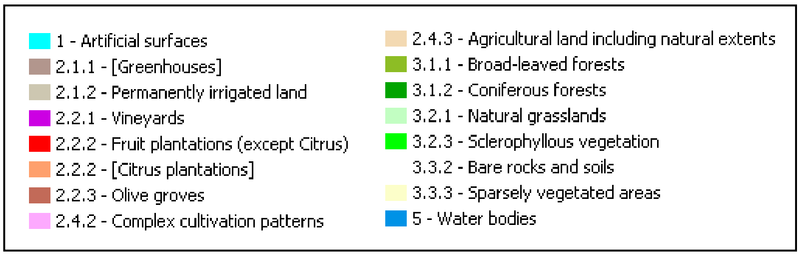
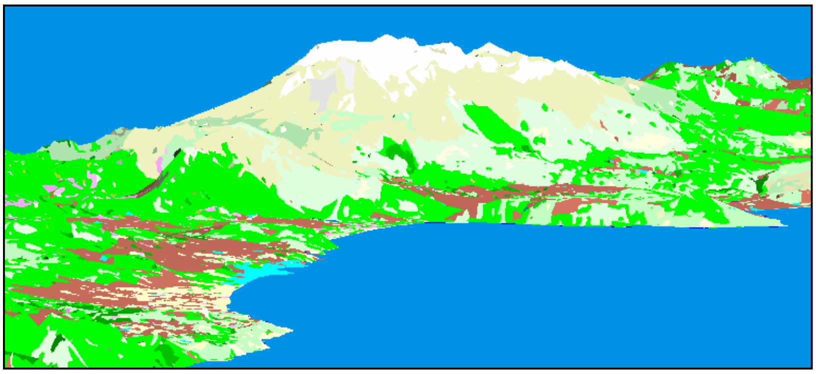


Figure 1. The CLC50 map of Crete legend (based on the CORINE nomenclature).

DISCUSSION AND CONCLUSIONS

In the course of the classification procedure and the results assessment, the following difficulties were encountered:

- Identification of the classes in the field during the classification sampling; careful clarification to which class item each sampling parcel should be assigned was needed, due to the considerable land fragmentation.



Picture 3. An aspects of the 3-D representation of the CLC50 map of Crete (Rethymnon area).

- Inability to identify most of the classes in the field with the setting of the mapping unit at 4 ha according to the CORINE standards [Buttner G. et al., 2001] due to the considerable fragmentation of the land especially the agricultural areas (see above). Therefore, a lower value needed to be set as a mapping unit; after geographical analysis and inspection of the area during the field work 0.4 ha was determined to be a more appropriate mapping unit. This was an aspect of the study that eventually was not in accordance with the CORINE standards.
- Discrimination and classification of areas located in shadows in the images was impossible due to the very undulating nature of the relief (Mean height: 1,164 m / Standard deviation: 671 m). Normalization with ERDAS Imagine (Lambertian Reflection Model) [ERDAS Imagine, 1982-1999] yielded images with not meaningful pixel values in the shadow areas and it was canceled thereof.
- Spectral confusion in various thematic classes, such as young “Olive groves” with “Vineyards”, “Olive groves” with “Sclerophyllous vegetation”, and “Sclerophyllous vegetation” with “Coniferous forests”, was noticed due mainly to the significant interference of the soil background in the spectral response in

the first case, and the limited number of spectral bands in the second and third cases. Similar confusion was reported with "Artificial surfaces" / "Bare rocks-soils" / "Greenhouses" and "Sclerophyllous vegetation" / "Forests" (Coniferous or Broad- leaved).

The basic hypothesis of the work was not confirmed. The SPOT satellite data used in this work and treated with conventional classification methods did not provide reliable results for the landscape of Crete, without significant assistance by ancillary data.

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