THE USE OF SATELLITE REMOTE SENSING FOR THE MANAGEMENT OF CULTURAL HERITAGE SITES IN CYPRUS

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ABSTRACT:

Earth observation from space has given us a new perspective of our planet and has become an essential technique for the understanding and monitoring of changes at various scales from local to regional and global. Numerous applications have been developed, in particular for land management, such as agriculture, forestry, land use and land cover and the management of cultural and natural heritage areas. The satellite images provide the only possibility for the mapping of the heritage areas because of their instant availability and high resolution. This paper presents the preliminary results obtained from the application of satellite remote sensing techniques to monitor cultural heritage areas in Cyprus using high resolution satellite imagery. Indeed, an IKONOS pan-sharpened 1m resolution and Quickbird 0.62m resolution satellite images acquired in 2000 and 2003 respectively have been used for the Paphos District area to identify, survey and investigate possible land-cover changes near the cultural heritage areas. The resulting database is an essential tool for decision-making in heritage management. Methodology to locate, monitor and map cultural heritage sites is suggested in this paper.

1. INTRODUCTION

The use of satellite remote sensing technology in conjunction with the use of GIS can provide an efficient tool for locating the existing cultural heritage sites by coding and establishing a comprehensive database so as to assist the management and monitoring of such sites in the Cyprus region in an effective way.

Spatial data is a necessity for anyone involved in planning development and in protecting natural and historic resources. Spatial data is also the foundation of a GIS. A GIS uses layers of data, taken from maps or other sources of information. These layers are built on a digital base-map, usually including topographical data, political boundaries and road infrastructures. When building a database for a GIS, the first step is to determine the high priority needs for the base-map. This involves setting accuracy standards, graphic standards, and deciding on the scale and geographic area to include. A sample of available spatial data sources includes the following information: *Satellite imagery, Aerial Photographs/ Images*, *Government Printed Paper Maps and GIS Maps*. Satellite remote sensing imagery can be beneficial tools for assisting monitoring and planning strategies of cultural heritage sites as a part of an overall methodology (using GPS, GIS and remote sensing techniques).

2. A BRIEF HISTORY OF CYPRUS

Cyprus has played a leading role in the history of the Eastern Mediterranean. Her history is one of the most ancient in the world. The oldest remains of civilisation go back more than 8000 years. Cypriot prehistory dates from the beginning of the 6th millennium BC.

Figure 1: The island of Cyprus in the Mediterranean: Surrounded by Greece, Turkey, Syrian, Lebanon, Israel, Palestine and Egypt.

The discovery of copper on the island in the third millennium BC brought wealth and trade to Cyprus. The settlement of Myceneans and later Achaeans in the 15th century BC resulted in the development of the island into an important centre of Greek civilisation. The Achaeans founded Greek kingdoms in Cyprus on the Mycenean model, and introduced the Greek language and religion as well as the Greek way of life. The institutions of these kingdoms were maintained until the Roman period. Cyprus was very well known to the ancients for her copper mines and her thick forests. Her natural wealth and her strategic position made her the bone of contention between the powers of the Eastern Mediterranean in antiquity. She was conquered in turn by the Assyrians, Egyptians, Persians, Romans, Byzantine, Ottoman and British rule. Nevertheless, Cyprus managed to preserve her language and cultural heritage intact.

3. ROLE OF SATELLITE REMOTE SENSING FOR MONITORING AND MANAGING CULTURAL HERITAGE SITES

3.1 Remote Sensing

Remote sensing covers all techniques related to the analysis and use of data from environmental and earth resources satellites and from aerial photographs. Remote Sensing is the science of deriving information about an object from measurements made at a distance from the object (ergo, without actually coming in contact with it) (Lillesand and Kiefer, 1994; Mather 1999, Jensen, 2000). With their continuous development and improvement, and free from national access restrictions, satellite sensors are increasingly replacing surface and airborne data gathering techniques. At any one point in time, day or night, multiple satellites are rapidly scanning and measuring the earth's surface and atmosphere, adding to an ever-expanding range of geographic and geophysical data available to help us manage and solve the problems of our human and physical environments. Remote Sensing is the science of extracting information from such images.

Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) and MSS, SPOT satellite images are widely used for deriving information about the earth's land. Moreover, the operational availability of *high-resolution satellite imagery*, (i.e. Quickbird, IKONOS), opens up new possibilities for investigating and monitoring natural resources. Compared with traditional survey techniques, satellite remote sensing is accurate, timely and cost-effective. These data offer a number of advantages (Hadjimitsis *et. al*., 2003):

- Provide synoptic coverage and therefore give an extensive view of vast areas at the same time.
- Images can be acquired for the same area at a high rate of repetition (two to three times a month), thus permitting selection of the most appropriate seasonal data.
- Satellite images are recorded in various wavelengths, visible and non-visible, which provide accurate information on ground conditions.
- They can be obtained for any part of the world without encountering administrative restrictions.

3.2 Satellite remote sensing in support of cultural heritage management

It was found from the literature that satellite remote sensing offers many useful and sometimes essential data for the mapping, monitoring and management of world cultural heritage sites, either natural sites such as parks or cultural sites such as archaeological sites and monuments (Arnaud, 1993; Van Hooff, 1994). By blending together satellite remote sensing techniques with GIS, the monitoring process of such sites can be efficiently supported in a reliable, repetitive, non-invasive, rapid and cost-effective way. Indeed, satellite remote sensing can assist the achievement of the following:

- Create up-to-date digital maps
- Assist in the identification and precise location of sites in the world that have certain characteristics so that they could become World Heritage sites if the associated country so desires.
- Help to delimitate management zones for conservation purposes
- Monitor land cover changes
- Assess damages caused by natural and/or human hazard.
- Assist the development of stereoscopic views so as to permit and obtain a digital elevation model of the landscape or some three-dimensional measurements of monuments through the use of satellite images and ground control points (obtained from GPS). Indeed, digital maps can be better realized.

In some areas in which an absence of recent maps of World Heritage sites exists and where such areas are often not easily accessible, recent satellite image coverage can be useful to produce new GIS layers providing the required information for a beneficial protection management of the site.

4. METHODS AND MATERIALS

4.1 SATELLITE IMAGERY

Cloud-free satellite images acquired on the 3rd of June 1985 (Landsat-5 TM) and 11th of May 2000 (Landsat-5 TM) were used to detect the coastline and land-use change of Paphos District area. High resolution satellite images acquired on 14th of March 2000 (IKONOS 1m resolution) and 23rd of December 2003 (Quickbird 0.62 m resolution) were used in this study.

4.2 METHODOLOGY

Methodology is based on the combination of several techniques to extract information from satellite remotely sensed data so as to reach the following objectives:

- To *map* and *monitor* land-cover changes nearby the cultural heritage sites so as to assist the decision makers for future planning (e.g. open access to the cultural heritage sites through the construction of new road infrastructure). This will help in the preservation planning, which is perhaps the most effective use of a GIS and remote sensing, since careful planning can prevent some threats to World Heritage sites before they become problems. One of the most important uses of a GIS and remote sensing for the World Heritage would be in the planning of tourism. Tourism is both a friend and foe of historic and natural sites. Indeed, careful preservation planning for the heritage sites is needed for assisting the sustainable tourism development local strategies.
- Create up-to-date digital maps using up-to-date high-resolution satellite images
- Obtain all the required information from the satellite imagery so as to assist the GIS procedures.

To reach the above objectives, all the satellite imagery must be *pre-processed following the following steps as explained by Hadjimitsis et. al. (2003)*: *geometric correction*, *radiometric correction* (conversion of DN to units of radiance and reflectance, removal of atmospheric effects)

4.3 CASE STUDIES

Land-cover changes in the nearby cultural sites:

Unsupervised classification was carried out using ISODATA method (Hadjimitsis *et. al*., 2003). This method uses spectral distance and iteratively classifies the pixels, redefines the criteria for each class, classifying again, so that the spectral distance patterns in the data gradually emerge. The aim of this step is to identify homogeneous spatial elements on satellite images automatically. Figure 2 presents the unsupervised classification results. Seven classes were defined. Red colour depicts the urban like areas and green-yellow colours depict the agricultural /soil areas. Differences are evident in the classification results, highlighting the land use/cover changes around the coastline (from the Paphos Airport up to Peyia area). The increase of red colour on the image acquired on 30th of May 2000 (see Figure 2 and figure 3) indicates the rapid expansion of the real estate between 1985 and 2000 period in which several tourist development activities (e.g. hotels, apartments, villas, road infrastructure) have been found near the coastline.

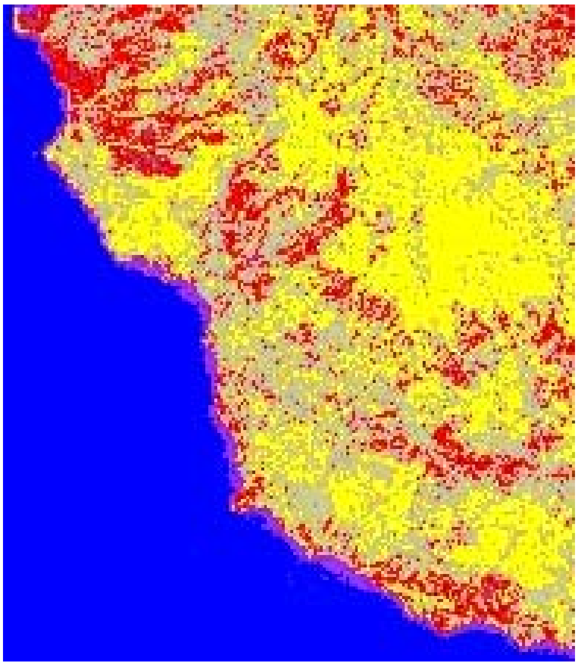

Figure 2: Landsat TM image dated 03.06.1985

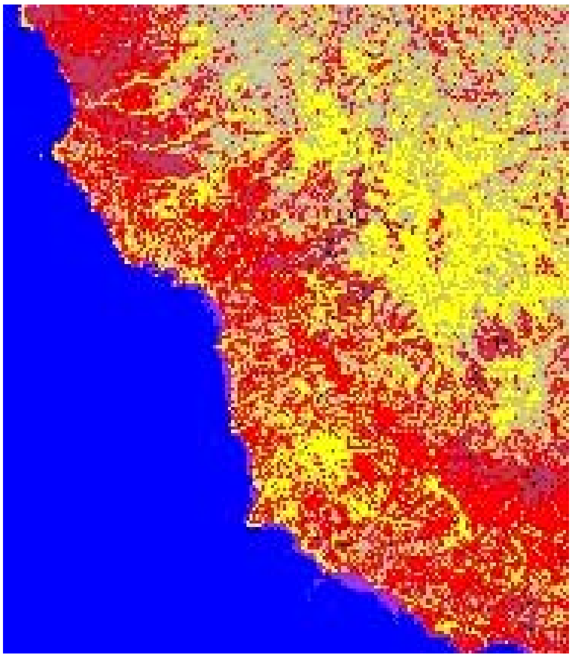

Figure 3: Landsat TM image dated 30.05.2000

In comparing the two satellite images acquired at different periods as shown in Figures 4 and 5 and Figures 6 and 7; using image processing overlay technique, it can be possible to identify any land change in the area nearby the archaeological sites under investigation. Indeed, possible land-use changes can be further analysed to delineate possible effects of their topology and soil conditions. Further research with multi-temporal imagery acquired in different years in conjunction with more consistent data such as GPS and elevation data, make the derivation of more consistent information possible. By using a GIS system, we can identify and categorize all changes and physically compare them with archaeological sites.

Figure 4: IKONOS -1m resolution image of Paphos harbour area acquired on 14-3-2000 (castle and House of Dionyssos area).

Figure 5: Quickbird- 0.6m resolution image of Paphos harbour area acquired on 23-12-2003 (castle and House of Dionyssos area). (© eurimage)

Mapping of physical changes that have occurred as a result of natural phenomena such as rain, floods etc, as well as landscape changes due to tourism activities, is possible using NDVI (Normalised Difference Vegetation Index) and image differencing techniques (Mather, 1999; Hadjimitsis *et.al*., 2002).

Figure 6: IKONOS satellite image of Tombs of the Kings (Paphos-Cyprus)

Figure 7: Quickbird satellite image of Tombs of the Kings (Paphos-Cyprus) (© eurimage)

Image Differencing involves the subtraction of two images acquired on different dates on the condition that these images are registered. Data transformations were confined to these bands because they are considered to be the most useful for discriminating forest canopy and vegetation alterations.

Figure 8: IKONOS satellite image of Ilatis monument area acquired on 14-3-2000.

Figure 9: Quickbird satellite image of Ilatis area monument acquired on 23-12-2003 (© eurimage)

The Normalized Difference Vegetation Index (NDVI) is used to transform multi-spectral data into a single image band which represents vegetation distribution. The NDVI values indicate the amount of green vegetation present in the pixel. *Higher NDVI values show more green vegetation*. NDVI's were computed according to the standard algorithm as described from several textbooks (Mather, 1999; Lillesand and Kiefer, 1994)

In comparing the two satellite images shown in Figures 8 and 9 using image processing software to overlay the two images and adjusting the scale, we can observe any changes that have occurred in the area during the past three years. It should be noted that a new roadwork is currently being constructed at this site. Following the road construction, an up-to-date series of images have already been acquired and further results will be published in the near future. By comparing the images before and after the construction roadworks, we can estimate the changes in the landscape of the Ilatis monument area. Future planning and development of the area should take into consideration how tourists will access the site through the new roadworks.

5. CONCLUSIONS

This paper highlights the beneficial use of satellite remote sensing for the monitoring of cultural heritage sites in Cyprus. The methodology adopted for the cultural heritage sites monitoring uses precise location of such sites, assesses nearby land-cover changes and produces up-to-date information, which is presented here. Future steps consist of the use of GPS for in-site campaigns in conjunction with the current and past high resolution images for producing stereoscopic views of the heritage sites including natural or cultural sites (e.g. ancient monuments)

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