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Remote Sensing for Archaeological Applications: Management, Documentation and Monitoring

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Additional information is available at the end of the chapter

1. Introduction

Archaeology is defined as the systematic approach for uncovering the human past and its environment. Archaeology involves not only systematic excavations and surveys, but also analysis of the data collected in the field. In a broader term, archaeology is an interdisciplinary research. Modern studies in archaeology engage a series of other sciences such as geology, information systems, chemistry, statistics, etc. In recent years, remote sensing has received considerable attention since it can assist archaeological research, along with other sciences, in order to extract valuable information to the researchers based only on non-destructive and non-contact techniques.

Remote sensing is the acquisition of information about an object or phenomenon without making any physical contact with the object (Levin, 1999; Parcak, 2009). According to Sabins (1997), remote sensing involves all the methods that allow the use of electromagnetic radiation in order to identify and detect various phenomena. Based on this definition, many techniques such as satellite remote sensing, aerial photography, geophysical surveys, ground spectroscopy or even terrestrial laser scanners, are considered as remote sensing techniques (Johnson, 2006).

Remote sensing has opened up new horizons and possibilities for archaeology. For example, oblique or vertical aerial photography can detect phenomena on the surface associated with subsurface relics, while the use of infrared and thermal electromagnetic radiation can be used in order to detect underground archaeological remains (Bewley et al., 1999; McCauley et al., 1982). Moreover, remote sensing as a non-destructive technique can con-

tribute to the investigation of an archaeological site before, during and after excavation periods. At the micro-level scale, geophysical surveys and ground spectroscopy can provide information about subsurface relics, while at the macro-scale, aerial photographs and satellite remote sensing can identify traces of the human past. Concurrently, these techniques can monitor the surroundings of a cultural heritage site and record any changes due urban expansion and/or changes of land use (Rowlands & Sarris, 2007; Masini & Lasaponara, 2007; Hadjimitsis et al., 2009; Ventera et al., 2006; Negria & Leucci, 2006; Cavalli et al., 2007; Altaweel 2005; Aqdus et al., 2008; Bassani et al., 2009).

Satellite remote sensing has become a common tool of investigation, prediction and forecast of environmental change and scenarios through the development of GIS-based models and decision-support instruments that have further enhanced and considerably supported decision-making (Ayad, 2005; Douglas, 2005; Hadjimitsis et al., 2006; Cavalli et al., 2007). By blending together satellite remote sensing techniques with GIS, the monitoring process of archaeological sites can be efficiently supported in a reliable, repetitive, non-invasive, rapid and cost-effective way (Hadjimitsis and Themistocleous, 2008).

This chapter presents a brief overview of the evolution of remote sensing in archaeological research. Several applications of applied remote sensing techniques, including satellite remote sensing, GIS, laser scanning, atmospheric pollution, spectroscopy, webGIS and geophysical prospection will also be examined through different case studies in Cyprus and Greece.

2. Satellite remote sensing in archaeology

This section introduces current remote sensing satellite data which are available for archaeological research along with a historical background of remote sensing applications in archaeology. As well, satellite sensors, such as Landsat, EO – Hyperion, QuickBird, IKONOS, etc., are also briefly outlined.

2.1. Historical review

The first aerial photographs used for archaeological purposes were taken just before the beginning of World War I in UK and Italy (Capper, 1907; Parcak, 2009; Bewley et al., 1999; Riley, 1987). Mesopotamia and the Levant were traditionally photographed until the 1940s (see Keneddy, 1925; Crawford, 1923, Glueck, 1965, Keneddy, 2002). After the end of World War II, new archaeological sites were explored due to aerial reconnaissance during the war. The scientific interest has been currently shifted to the Middle and Far East, as well as other areas in Europe and America (Parcak, 2009). During the Cold War in the 1960's, several satellites, including CORONA, Argo, Lanyard and COSMOS, were used for military purposes. However, these data were only accessible after their declassification in 1995 (Parcak, 2009).

Spatial resolution of CORONA spy images taken during the Cold War could reach up to 0.6m (Lock, 2003). Fowler & Fowler (2005) explored the potentials of CORONA images for

archaeological purposes and concluded that such images can be used as an alternative way in many European archaeological sites, where traditional aerial photography is very limited. Grosse et al., (2005) used CORONA images for mapping geomorphological features in NE Siberia. The combination of ASTER and CORONA images in northern Mesopotamia was also studied by Altaweel (2005).

KVR-100 images from the Russian space program have been available since 1987 and have a high spatial resolution of 2-3 m. Such data are valuable in areas where the landscape has changed dramatically as a result of human activity, such as urban expansion. Even though KVR-100 has been used by several researchers (Fowler and Curtis, 1995; Comfort, 1997), their application is still limited due to their high cost (Parcak, 2009). CORONA and KVR images have been also used to monitor cultural heritage sites in Iran (Kostka, 2002).

Since the 1970s, the launch of new satellite systems coincided with the technological progress of the sensors. In 1972, the Landsat space program was initiated and was followed by the launch of other satellites, including the SPOT satellite in France (Parcak, 2009; Sarris, 2008). The Landsat sensor has been in continuous orbit since 1972 and provides multispectral data for archaeological research. Despite the medium spatial resolution (from 15-80m) Landsat images have a relatively low cost while covering a large area (180 x 180 km) in both the visible - infrared and thermal wavelengths. Landsat images were used to study archaeolandscapes in many archaeological projects and surveys. Vaughn and Crawford (2009) used predictive models in order to identify new areas with potential settlements of Mayans. Barlindhaug et al., (2007) found that Landsat satellite images can be used for monitoring purposes of archaeological sites. Neolithic settlements in Greece were detected using archive Landsat images (Alexakis, 2009; Agapiou et al., 2012a; 2012b). Landsat images were also used for monitoring purposes of the surroundings of monuments in Cyprus (Hadjimitsis et al., 2009; 2008).

During the 1980's, thermal and radar sensors were also added to satellite sensors (Bewley et al., 1999). In the late 1980's, India launched the IRS 1A, 1B, 1C, 1D and IRS P2 sensors (Tripathi 2005a). Although these data have been used for archaeological purposes in India, such as the identification of the mythic site *Dvaraka* (Tripathi 2005b) and the observation of *Hampi* site (Raj et al., 2005), their use is very limited in other regions.

From the 1990's, remote sensing and Geographical Information Systems (GIS) have been used systematically for archaeological research and newer satellites with higher spatial resolution are now available. Indeed, Quickbird, IKONOS, WorldView and GeoEye are capable of providing satellite images with spatial resolution up to 0.5 m.

In addition to the above, hyperspectral images, such as those from EO-HYPERION, have recently made their appearance. Hyperspectral remote sensing analysis is performed over hundreds of narrow bands. The key characteristics of hyperspectral images are its fine spectral and radiometric resolution. Hyperspectral data provides a variety of spectral information, which can be used for the identification of archaeological remains. Alexakis et al., (2009) stated that these new technologies can support the detection of archaeological sites,

although it is not always possible to extract a unique archaeological spectral signature due to the heterogeneous presence of vegetation and soil.

Lasaponara and Masini (2007a) highlighted the potential benefits of high resolution satellite images in order to detect subsurface monuments through the use of vegetation indices and edge detection techniques. Cavalli et al., (2007) introduced the use of airborne hyperspectral scanner Multispectral Infrared Visible Imaging Spectrometer (MIVIS) for the detection of subsurface monuments based on spectral anomalies. The study found that the detection of subsurface monuments is possible employing both visible and near infrared part of electro-magnetic radiation, and can concurrently detect anomalies using the thermal infrared spec-trum. Using QuickBird satellite imagery, Lasaponara and Masini (2007b) examined the Metaponto archaeological sites in the South of Italy, using sophisticated spectral techniques such as the Tasselled Cap Transformation and Principal Component Analysis. The combina-tion of hyperspectral data and several remote sensing processing techniques (Principal Component Analysis, vegetation indices, etc.) for the detection of subsurface monuments in eastern Scotland was also presented by Aqdus et al., (2009).

Beck (2007) and Beck et al., (2007) conducted a detail study of the archaeological site of *Homs* in Syria, using CORONA and IKONOS images. The results indicated that areas with archaeological interest tend to have different spectral signatures from the surround-ing area. Rowlands and Sarris (2007) used airborne hyperspectral scanners (Airborne Thematic Mapper –ATM and Compact Airborne Spectrographic Imager -CASI) and LI-DAR data in order to study the Hellenistic settlement of *Itanos* in Crete. The data were post-processed using object-oriented analysis. Although the study found several difficul-ties in relation to the identification of archaeological remains, the continuing use of such methods and applications along with other remote sensing techniques such as geophysi-cal surveys was recommended. In the ancient city *Sagalassos*, Laet et al., (2007) applied object-oriented techniques and several satellite images (ASTER, SPOT, IKONOS) in order to identify archaeological remains. The results from investigations , in the Piramide Nar-anjada in Cahuachi (Peru), based on high resolution satellite imagery, geomagnetic sur-veys and Ground Probing Radar was recently presented by Lasaponara et al., (2011). Currently, several archaeological investigations are carried out using combined remote sensing techniques, such as satellite images, aerial photographs, ground geophysical sur-veys, and LIDAR measurements. The next section provides an outline of the characteris-tics of the most important satellite data available today for archaeological research.

2.2. Satellite image data

Currently, there is a plethora of satellite images which may be used for supporting archaeo-logical research. However, these images have different resolutions depending on the sensor characteristics. Moreover, many of these satellite systems are nowadays inactive, but their data can be still be used for research. Table 1 summarizes some of the general characteristics of several satellite data regarding spatial, spectral and temporal resolution. As indicated in Table 1, as a result of the space race, satellites have been able to monitor Earth since the

1960's. The Landsat program, which began in 1972 and continues to today, is considered a significant component of remote sensing applications in archaeology.

Prior to the Landsat program, satellite sensors such as CORONA and Zenit 2-8 sensors acquired only panchromatic photographs. These satellites were characterized by non-periodicity; therefore, some areas of archaeological interest may not have been photographed by these sensors. In contrast, the Landsat program has given further capabilities for research since the sensor is able to recover information in the visible, infrared and thermal part of the spectrum. Furthermore, the sun-synchronous orbit of the Landsat satellite enables researchers to study many archaeological sites and monuments in a systematic way. From the beginning of the Landsat program until the end of the century, new multispectral satellite sensors were launched from different countries, including the USA, USSR, France, and Japan, and the spatial resolution of the images was significantly improved. In 1999, the first high-resolution satellite imagery with a spatial resolution of less than 4m was available through the IKONOS space program. The IKONOS satellite was the first satellite operated by a private organization (Space Imaging). In 2000, NASA launched the first hyperspectral receiver, the EO-1 Hyperion, which had the ability to record electromagnetic radiation into 220 different spectral bands.

In the decade that followed, new satellites with higher spatial resolution were available to the scientific community and other countries became actively involved in space technology. Brief descriptions of different satellite sensors characteristics are highlighted in Table 1 and more specific information related to the most popular satellite platforms used in archaeological research are provided in the paragraphs below.

Landsat (MSS / TM / ETM +): The Landsat program was the result of the combined efforts of NASA and USGS to monitor Earth from space using remote sensing techniques. The first satellite launch was performed in 1972 (Landsat 1) and, since then, another 6 satellites were sent into orbit. According to Parcak (2009), the Landsat satellite program is the most well known satellite used for archaeological purposes due to its relative low cost, global coverage of the satellite data and access to archive data since the 1970's. Landsat satellite images cover an area of about 185 x 185 km. The multispectral bands of the sensor cover both the visible and infrared region of the spectrum while one sensor is able to produce thermal images. The panchromatic band of an ETM+ Landsat image has a spatial resolution of 15 m, while for the rest of the bands the resolution is set to 30 m with the exception of the thermal region (60 m). Landsat data can be obtained via FTP upon request from USGS (http://glovis.usgs.gov/).

CHRIS Proba: The Proba satellite belongs to a relatively new space program of the European Space Agency (ESA). The Compact High Resolution Imaging Spectrometer (CHRIS) sensor was launched on 2001 and provides hyperspectral images from 63 separate bands at a spatial resolution of 18 m. The objective of the CHRIS Proba is to evaluate new technologies for supporting future satellite sensors (experimental satellite) and to use the data for environmental purposes. The satellite data are acquired in HDF format after approval of ESA committee. A single satellite image covers an area of 13 x 13 km.

Satellite	Sensor	Acquisition period	Spatial resolutions		Spectral Resolution (nm) (only VIS-VNIR are listed)	Temporal Resolution
			Pan	VIS-NIR		
ALOS	PRISM	2006-Today	2.5	10	420 -890	46 days
CBERS	HRCC	2003-Today	20		450 - 890	26 days
CORONA		1960-1972	1.8 – 12		Panchromatic	
CARTOSAT-1		2005-Today	2.5		Panchromatic	116 days
EO-1	ALI	2000- Today	10	30	433-890	under req.
EO-1	Hyperion	2000-Today	10		356-996	under req.
FORMOSAT-2		2004-Today	2	8	450 -900	under req.
GeoEye-1		2008-Today	0.41	1.65	450 -920	under req.
IKONOS		1999-Today	1	4	450 -950	under req.
IRS	Cartosat-1 (IRS-P5)	2005-Today	2.5		Panchromatic	under req.
IRS	Cartosat-2B	2010-Today	1		Panchromatic	under req.
IRS	Resourcesat-1 (IRS-P6)	2003-Today	5.8	23.5	520 -860	under req.
IRS	Resourcesat-2	2011-Today	5.8	23.5	520 -860	under req.
IRS	1C / 1D	1996/7-Today	5.8	23.5	520 -860	under req.
KOMPSAT-2		2006-Today	1	4	450 -900	under req.
Kometa	KVR-1000	1981-2005	2-3		Panchromatic	
Kometa	TK-350	1981-2005	2-3		Panchromatic	
Landsat 4	MSS	1982-1993	60		520 - 900	
Landsat 5	TM	1984-Today	15	30	450 -900	16 days
Landsat 7	ETM+	1999-Today	15	30	450 -900	16 days
Orbview-3		2003-Today	1	4	450 -900	under req.
Pleiades-1		2011-Today	0.5	2	430-950	under req.
Proba	CHIRS	2001-Today	17-34		415-1050	under req.
QuickBird	-	2001-Today	0,60	2,4	450 -900	under req.
RapidEye		2008-Today	5		440 - 850	under req.
SPOT-1	HRV	1986-2003	10	20	500-890	
SPOT-2	HRV	1990-2009	10	20	500-890	
SPOT-3	HRV	1993-1996	10	20	500-890	
SPOT-4	HRVIR	1998-Today	10	20	500-890	under req.
SPOT-5	HRG	2002-Today	5	10	500-890	under req.
Terra	ASTER	1999-Today	15		520-860	under req.
Kometa	KVR-1000	1981-2005	2-3		Panchromatic	
TK-350			2-3		Panchromatic	
WorldView-1		2007-Today	0.5		Panchromatic	under req.
WorldView-2		2009-Today	0.5	1.8	400-1040	under req.
Zenit	2-8	1961-1994	15-2		Panchromatic	

Table 1. List of available satellite sensors for archaeological purposes.

EO-1 HYPERION: HYPERION was the first satellite of a new generation space program which was launched by NASA in 2000. The satellite's main objective was to collect experimental data for future receivers. The main feature of the HYEPRION satellite was the acquisition of hyperspectral data (a total of 220 separate bands) at a spectral range from 356 nm to 2577 nm. The spatial resolution of the data was 30 m. HYPERION data can be obtained via FTP upon request from USGS (http://glovis.usgs.gov/).

IKONOS: IKONOS is a commercial satellite with high spatial resolution. It was sent into orbit in 1999 and can provide images with spatial resolution up to 1m for panchromatic images and 4m in multispectral bands. The spectral resolution of the sensor extends from the visible to near infrared. Although IKONOS images are widely available to the research community, they are not recorded on a regular basis. The radiometric resolution of the satellite is 11 bit and a single image can cover an area of about 13 x 13 km. IKONOS satellite can provide stereo images in order to support the production of Digital Terrain Models and Surface Terrain Models (DEM, DSM). IKONOS data are available from GeoEye upon request (http://www.satimagingcorp.com/).

QuickBird: Quickbird is owned by the commercial satellite company DigitalGlobe and was sent into sun-synchronous orbit in 2001. The satellite is currently one of the few satellites with the highest spatial resolution (e.g. OrbView-2, OrbView-3, WorldView-1, WorldView-2 and GeoEye-1). The spatial resolution is up to 0.60 m in the panchromatic wavelength while multispectral bands are acquired at a resolution of 2.4 m. The spectral capacity is equivalent to the IKONOS satellite (visible and near infrared). Moreover, QuickBird images cover a ground area of 16.5 x 16.5 km. QuickBird data is available from DigitalGlobe after request (http://www.digitalglobe.com).

WorldView: WorldView satellite were launched in 2007 (WorldView -1) while a second sensor followed a few years later (WorldView-2). These sensors have a very high spatial resolution (0.5m). The WorldView-2 sensor provides a high resolution panchromatic band and eight Multispectral bands; four standard colors (red, green, blue, and near-infrared) and four new bands (coastal, yellow, red edge, and near-infrared). WorldView data is available from DigitalGlobe upon request (http://www.digitalglobe.com).

GeoEye-1: GeoEye is the latest high spatial resolution satellite that was sent into space (2008). The spatial resolution of the satellite is 0.41 m and 1.65 m (panchromatic / multispectral bands). The spectral resolution is limited to visible and near infrared wavelength. A GeoEye-1 image covers an area of 15 x 15 km.

CORONA: From 1960 until 1972, the CORONA satellite acquired over 860,000 panchromatic images for US Intelligence. The photographic capsule from the spy satellite was dropped to earth with the help of parachute and then was collected by a special aircraft (Figure 1). The CORONA images were declassified in 1995, and are now available in digital form upon request.

Remote sensing has been able to assist archaeological research in several ways during the past years, including detection of subsurface remains, monitoring archaeological sites and monuments, archaeolandscapes studies, etc. The next section presents recent developments

and applications of several remote sensing techniques for supporting archaeological research. The section includes detection of subsurface remains at the Thessalian plain based on both satellite and ground spectroradiometric measurements. Moreover, remote sensing and GIS analysis as means for monitoring purposes in the area of Cyprus are also examined. Geophysical surveys from various archaeological sites are also presented as well as the results of a study aiming to analyse the impact of atmospheric pollution on archaeological sites. The section ends with discussion of low-altitude airborne systems, as well as 3D laser scanner documentation of cultural heritage site.

Figure 1. Film capsule of the CORONA satellite collected from aircrafts. (Photos from Wikipedia and CSNR collection)

3. Monitoring archaeological sites using satellite remote sensing and GIS analysis

In many areas of the world, cultural heritage sites and visible monuments are monitored mostly with on-site observations, including data collection, periodic observations for archaeological sites and multi-analysis risk assessments. In this way, on-site observations are time consuming and not cost-effective.

Hadjimitsis et al., (2011) highlighted the beneficial integrated use of satellite remote sensing with GIS for exploring the natural and anthropogenic hazard risk of the most significant cultural heritage sites in Cyprus. In order to proceed to overall risk and vulnerability assessment of the archaeological sites in Cyprus due to anthropogenic and natural impact, a risk index was attributed to each different factor such as urban activity, minimum distance of urban activity in the vicinity of an archaeological site, seismic PGA and air pollution impact. They found that, concerning the seismic risk assessment, that significant monuments are located within the spatial limits of the most seismic prone areas in Cyprus. Additionally, regarding sea erosion, the study proved that 50% of the sites examined in the study, are within a distance of only 500 m away from the coastline making them vulnerable to related coastal hazards such as sea water erosion. The creation of buffer zones in GIS environment around CH sites explored the signifi-

cant problem of extensive urbanization in the vicinity of cultural heritage sites. Almost 50% of the CH sites are under severe urban pressure and a percentage of 37.5% of the sites are within a radius of 500m from the urban centers. In similar studies, Carlon et al., (2002) and (Alexakis and Sarris, 2010) used both anthropogenic and natural factors to create a risk assessment model concerning archaeological monuments in Venice and Western Crete respectively. Moreover, Urhus et al (2006) emphasized the human driven agents, such as camping, hunting and woodcutting, for assessing the modern threats to heritage resources and Lanza (2003) addressed the potential threat that is posed at the historical center of Genoa in the case of failure of the urban drainage system.

This section presents the contribution of remote sensing for monitoring the surroundings of archaeological sites in order the managing authorities or governmental related bodies to be able to conduct a risk assessment analysis of cultural heritage sites in Cyprus. Figure 2 presents some of the most indicative threat parameters. Special attention in this section is given to urban expansion during the past 50 years. Anthropogenic factors, such as urban expansion and air pollution contribute significantly to the destruction of cultural heritage sites. Remote sensing and GIS provide synoptic views of cultural heritage sites which enable policy makers to make appropriate decisions regarding the preservation of cultural heritage sites.
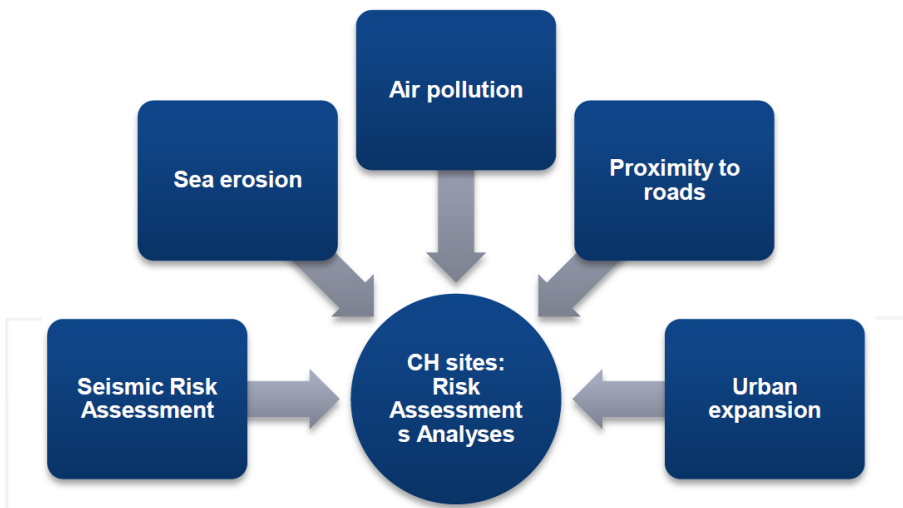
Figure 2. Risk assessment analysis for cultural heritage sites (Hadjimitsis et al., 2011)

3.1. Urban expansion and other hazards as a threat to archaeological sites

In order to study and map urban expansion, a number of significant archaeological sites of Cyprus were examined. These cultural heritage sites are located in the southern coast-

al part of the island (from west to east): *Tombs of the Kings, Nea Paphos, Palaepaphos (Old Paphos)*, and *Amathus*. Urban expansion was monitored with the extensive use of time-series multispectral and aerial dataset. All images were both geometrically and radiometric corrected in ERDAS Imagine 9.3 software. Moreover, atmospheric correction was also performed based on the Darkest Pixel algorithm (see Hadjimitsis et al., 2009, 2002; Agapiou et al., 2011). Post-processing techniques included histogram enhancement, computation of vegetation indices, band ratios, principal component analysis and photo-interpretation of the results.

The results showed a dramatic increase in urban expansion of main cities of Cyprus (Limassol and Paphos) during the last 50 years. For example, in the case of the *Palaepaphos* site (Figure 3), the entire east area of Kouklia village (*Palaepaphos*) is still undeveloped, while at the west area the urban expansion has been increase dramatically (Agapiou et al., 2010a).
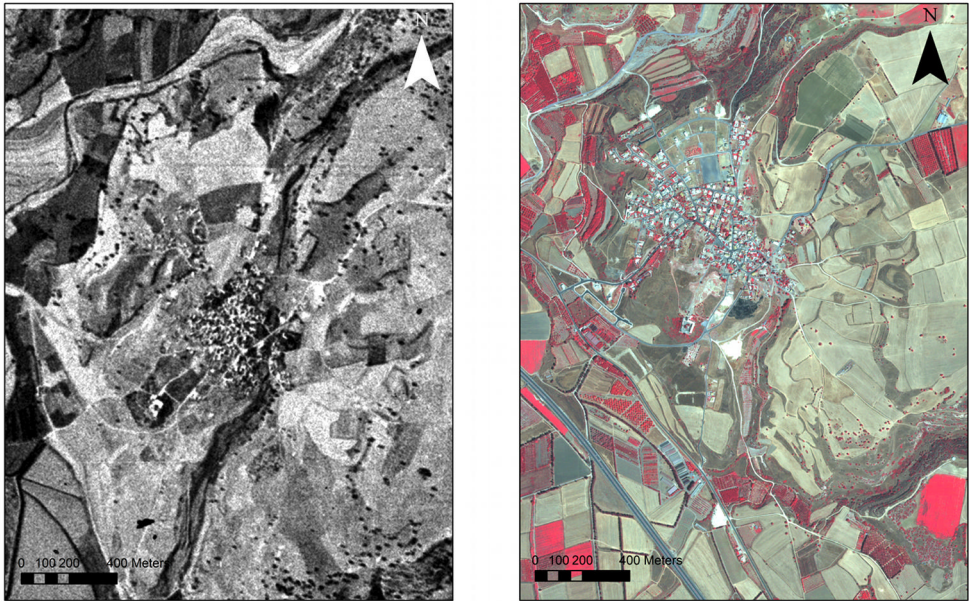
Figure 3. Palaepaphos archaeological site in 1963 CORONA image (left) and 2004 QuickBird image (right) (Hadjimitsis et al., 2010)

Urban sprawl has been recorded also in the broader area of Paphos during the last decades. Extensive construction and building development has taken place and areas with significant archaeological interest are now affected from urban expansion. Thus, the land use and land cover region of the area was examined to monitor and map the size of urban expansion in the vicinity of the archaeological sites of Tombs of the Kings and Nea Paphos during the last half century. Aerial photos of the study area, acquired in 1963 and 2008 were provided from the Department of Lands and Surveys of Cyprus. Initially, aerial photos were georeferenced

in a GIS environment with the use of ground control points (GCP's). The digitization of all the buildings in the broader area of Nea Paphos and Tombs of the Kings was performed for both time periods. Their direct comparison enabled the researchers to map the extent of urban development during the last years and revealed the impact of urbanization on the preservation of archaeological sites (Figure 4).
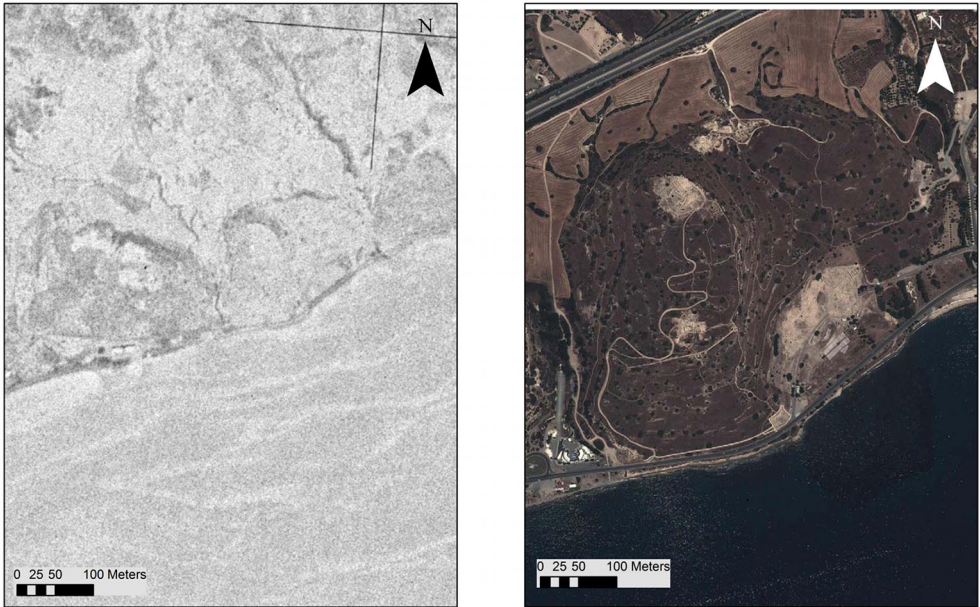

Figure 4. Urban expansion near the archaeological sites of *Nea Paphos* and *Tombs of the Kings* during the last 50 years (3D view).

CORONA satellite images have also indicated the growth of the urban activity around the *Amathus* archaeological site, including the highway that passes 100 m north of the site (see Figure 5) (Hadjimitsis et al., 2010). Several satellite images were used to examine the threat of urban expansion around the *Amathus* archaeological site located just east from the outskirts of the city (Figure 6). The dataset includes Landsat TM/ETM+ images from 1987 until 2009. As shown in Figure 6, urban expansion is clearly observed though interpretation of the images.

It is very important for researchers to understand the dramatic changes that have occurred due to human activity during the last decades. Figure 7 highlights the potential risk of the archaeological sites due to urban expansion of the city of Limassol. Using archive satellite images, the researchers can map this expansion with great detail and accuracy based on classification techniques.
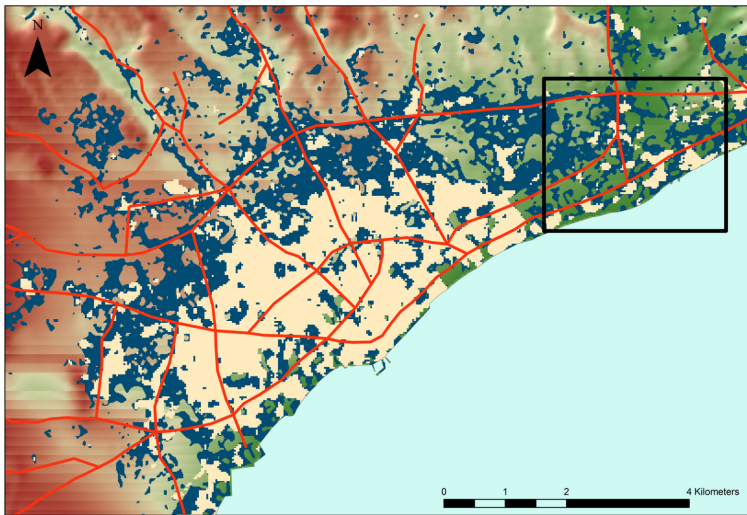
Figure 5. Amathus archaeological site in 1963 CORONA image (left) and 2010 Google (right).
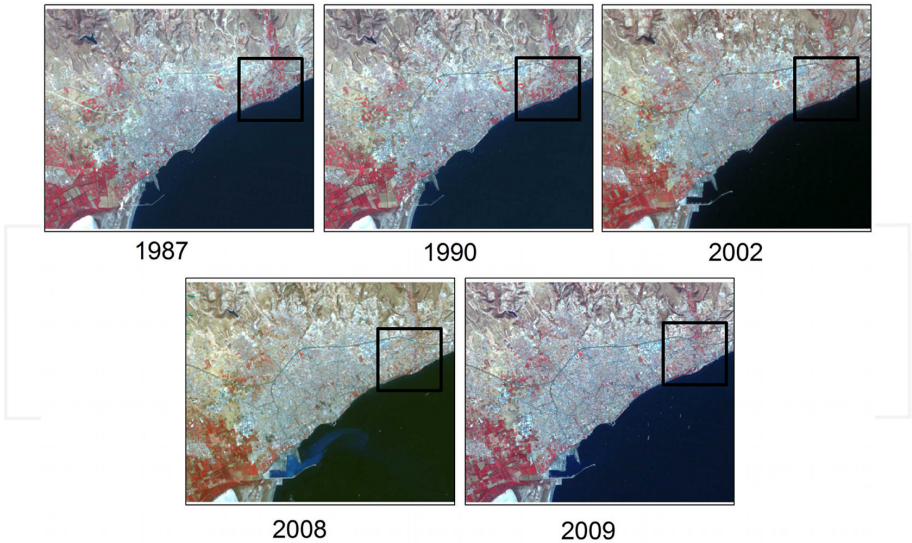
Figure 6. Landsat images used for mapping the urban expansion of Limassol town during the last 30 years. *Amathus* archaeological site is indicated in a square.

Figure 7. Urban areas of Limassol town in 1987 (red) and in 2009 (pink). The *Amathus* archaeological site is indicated in a square.

Vegetation indices are also a key parameters that can be used for monitoring dramatic land use changes over time (e.g. urban activities). The Normalized Difference Vegetation Index (NDVI, with range -1 to +1) was applied to the entire dataset (Figure 8). High values of NDVI (indicated with green in Figure 8) are present vegetated areas while low NDVI values (indicated with yellow) are recorded for areas with no vegetation. Since NDVI values may vary throughout time due to the physical phenological changes of the plants, similar periods of Landsat images were examined.

NDVI values were used along with classifications results in order to record NDVI differences in urban classified areas. Figure 9 demonstrates the results of the NDVI difference for the period 1987-2009. Although many areas have indicated no dramatic changes, some other areas represented in yellow and red colour (Figure 9) indicate dramatic transformation of the initial landscape. Indeed, such changes have been recorded in a very close proximity of the archaeological site of *Amathus* (see Figure 9 in black square).

Further anthropogenic and natural hazards (e.g. landslides; sea erosion; earthquakes etc) can be monitored in a systematic basis using remote sensing data and GIS spatial analysis. Different studies (Hadjimitsis et al., 2010; 2011) have shown the potential of using such methodologies for cultural heritage risk assessment.

Contemporary technological means such as GIS and satellite remote sensing provide efficient and detailed maps of the region of CH sites in the island of Cyprus. This specific study revealed the different kinds of natural and anthropogenic hazards that threaten the preservation of valuable CH sites.
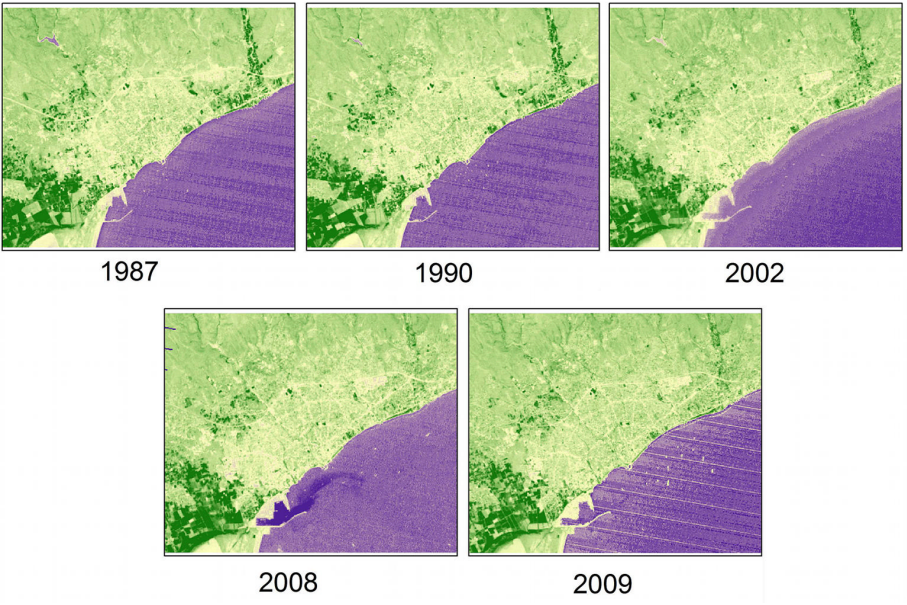
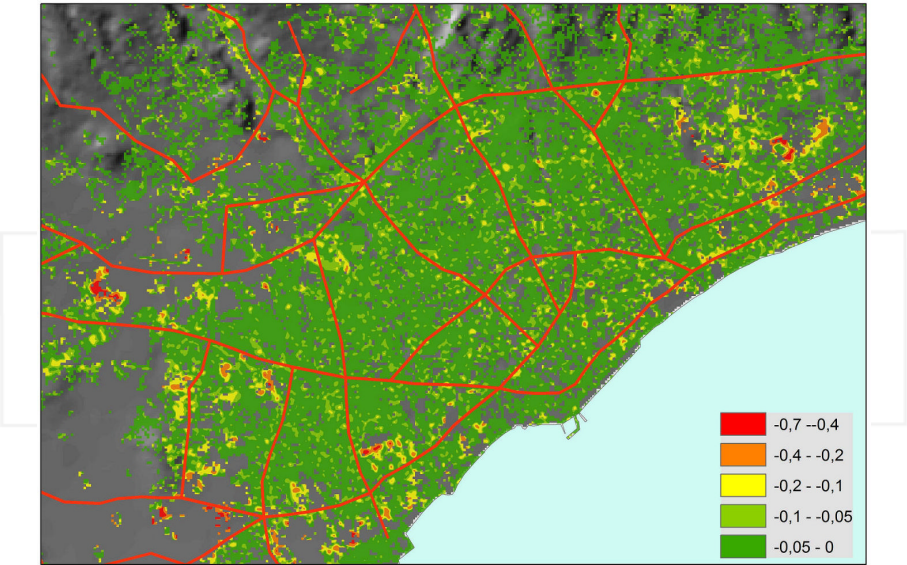**Figure 8.** NDVI maps produced from Landsat dataset.

Figure 9. NDVI difference from 1987 until 2009. The *Amathus* archaeological site is indicated in a square.

3.2. Monitoring air quality in the vicinity of archaeological sites based on satellite and ground measurements

Although cultural heritage sites are documented and preserved, there has been limited monitoring and documentation of how cultural heritage sites are affected by air pollution. Themistocleous et al., (2012a) introduced a new approach for monitoring air pollution near cultural heritage sites. By using a variety of tools, including satellite images, sun-photometers, PM_{10} monitors, and laser scanners, the level of air pollution and its effect on cultural heritage sites can be determined. The cultural heritage sites were documented, and using GIS tool, any significant areas of air pollution, including urban areas, industrial areas, and roads were determined. The algorithm proposed by Themistocleous (2011) was applied to retrieve the aerosol optical thickness (AOT) from Landsat TM/ETM+ satellite images in order also to cross-validate the AOT values found from MODIS and sun-photometers.

Spectral variations recorded by satellite sensors are indicators of aerosol particles and, therefore, air pollution. The key parameter for assessing atmospheric pollution in air pollution studies is the aerosol optical thickness. Aerosol optical thickness (AOT) is a measure of aerosol loading in the atmosphere (Retalis et al., 2010). High AOT values suggest high concentration of aerosols, and therefore air pollution (Retalis et al, 2010). The use of earth observation is based on the monitoring and determination of AOT either direct or indirect as tool for assessing and measure air pollution. Several studies have shown that satellite data can be used to monitor air pollution and air pollution effects. Tømmervik et al., (1995) compared vegetation cover maps and air pollution emissions data over a 15 year period and found major changes in the environment as a result of high air pollution values. Nisantzi et al., (2011) used MODIS satellite data to analyse the relationship between the aerosol optical thickness (AOT) and the PM_{10} as indicators of pollution. Satellite remote sensing can be used to assist in air quality monitoring and identify the need to protect cultural heritage in urban areas from air pollution (Hadjimitsis et al., 2002; Kaufman et al, 1990; Retalis, 1998; Retalis et al., 1999). Pollution not only deteriorates cultural heritage sites but may also cause irreversible damage that prevents the proper salvation of the monument (Skoulikides, 2000). Therefore, improving air quality is critical for the preservation and maintenance of cultural heritage sites.

The study area was the Limassol Castle, located in the center of Limassol, Cyprus. The study utilized a variety of remote sensing tools to measure air pollution. Landsat TM/ETM+ and MODIS satellite images, as well as the GER 1500 spectro-radiometer, were used to directly or indirectly retrieve AOT, as were ground measurements using the Microtops II handheld sunphotometer and the Cimel sun-photometer located at the Cyprus University of Technology, which is part of the AERONET program. Air particles' measurements were correlated to the AOT levels to verify the level of pollution. Last, visual observation of the Limassol Castle identified the damage caused by air pollution and laser scanning to document and monitor the damage was conducted. Results from satellite remote sensing identified that the centre of Limassol contains high levels of air pollution, with values of AOT higher than other surrounding areas. Determination of AOT measurements using MODIS and Landsat satellite images found that the centre of Limassol, where the Limassol Castle is located, experiences the highest level of AOT values (Figure 10). A PM_{10} /$PM_{2.5}$ in situ measurement campaign in the area of the Li-

massol Castle found that for the majority of the time periods, the PM_{10} readings exceeded the limit value (50 μg/m3), indicating a high level of air pollution in the area.

Figure 10. AOT levels in the Limassol area. High AOT levels are noted in the area near the Limassol Castle.

A similar approach was followed for the Paphos town using daily MODIS AOT data. The results have shown that 54% of the measurements for air quality was above the threshold of AOT 300 (AOT 0.300) (see Figure 11). This analysis suggest that cultural heritage sites near the Paphos town (e.g. *Nea Paphos, Tombs of the Kings* etc) are exposed to air pollutants half the time.
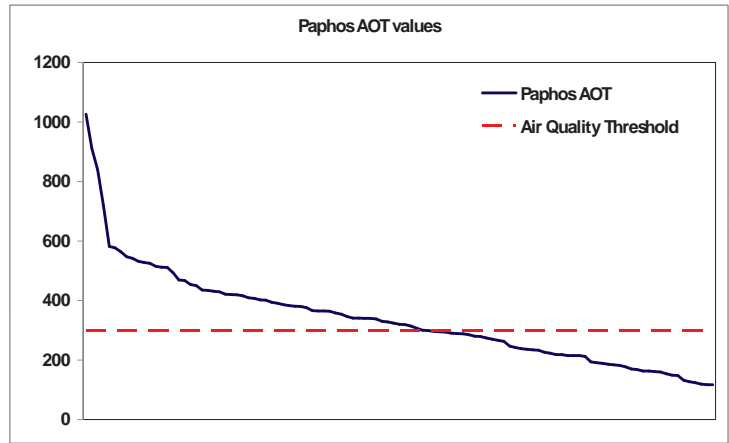
Figure 11. Paphos AOT values (sample = 109 measurements) in blue. In red circle is the threshold air quality limit of 300 (AOT 0.300). In the y-axis, AOT value is multiplied by 1000 (to match MODIS data) (Themistocleous et al., 2012a).

## 4. Detection of archaeological sites based on remote sensing techniques

Several Neolithic settlements ("magoules") are located in the Thessalian plain in central Greece. These sites are typically found as low hills raised up to 5-10 m. Alexakis et al., (2009; 2011) has recently shown that the detection of several unknown sites is possible based on remote sensing and GIS analysis. The study aimed to combine several types of remote sensing data (e.g. Landsat TM/ETM+, ASTER, Hyperion, IKONOS) and DEM in order to improve the detection of these subsurface remains (Figure 12). The satellite data were statistically analyzed, together with other environmental parameters, to examine any kind of correlation between environmental, archaeological and satellite data. Moreover, different methods were compared for the detection of Neolithic settlements. The results of the study suggested that the complementary use of different imagery can provide more satisfactory results.

Further to the Alexakis study, Agapiou et al., (2012a) argued that the detection of the settlements is possible based on ground spectroradiometric measurements. Several spectroradiometric measurements have indicated that each magoula has its own spectral characteristics related to its own morphological characteristics. The study has found that the highest peak of the magoula tends to give high NDVI and SR values (similar to the flat – healthy regions) while the slope of the magoula has lowest NDVI and SR values (and for the other indices as well). The extraction of each magoula requires further analysis and enhancement techniques in cases where the spatial resolution of the satellite image used is low. Local histogram enhancements can identify magoules as a small difference of NDVI values at the same parcel (Figure 13).


Figure 12. Magoula *Neraida* using ASTER image (left). Magoula *Melissa 1* using IKONOS image (RGB - 321) (right).

Similar results were found following the application of the Tasselled Cap algorithm (Figure 14 to a series of Landsat TM/ETM+ multispectral images. The Tasselled Cap transformation is used to enhance spectral information for Landsat images, and it was specially developed for vegetation studies. The first three bands of the Tasseled Cap algorithm result are characterized as follow: band 1: brightness (measure of soil); band 2: greenness (measure of vegetation); band 3: wetness (interrelationship of soil and canopy moisture).
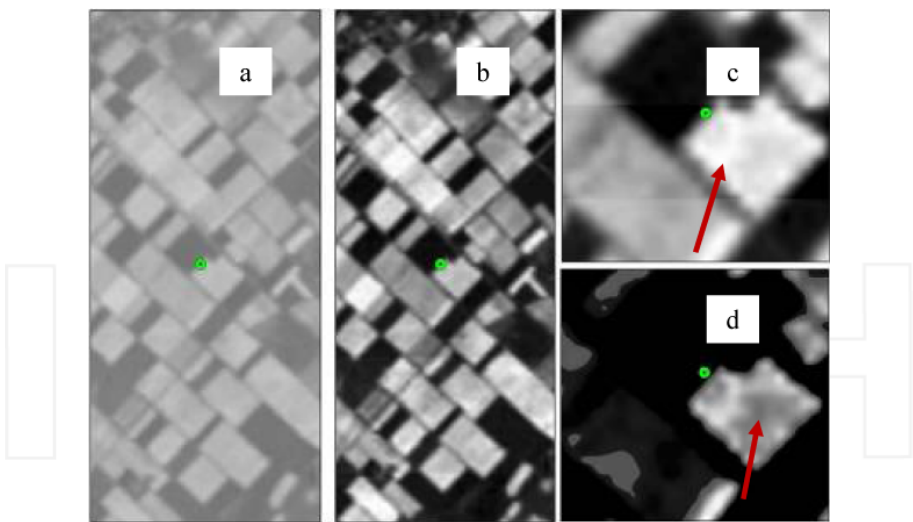
Figure 13. NDVI results for *Prodromos II* site (in green circle). (a) Raw satellite image without any radiometric enhancements, (b) satellite image with a linear max-min enhancement applied to all image, (c) max-min enhancement applied to the area around *Prodromos II* and (d) modified max-min enhancement applied to the area around *Prodromos II*. The magoula is indicated with the red arrow (Agapiou et al., 2012c).
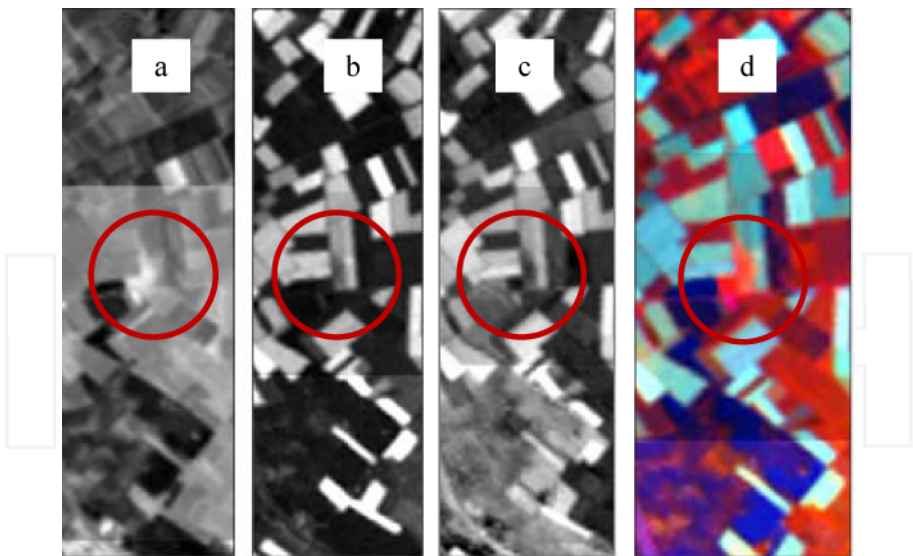
Figure 14. Tasseled Cap results for *Nikaia 16* site (in red circle), (a) Brightness, (b) greenness, (c) wetness and (d) RGB of the first three components of the T-K algorithm (Agapiou et al., 2012c).

Phenological studies of crops for the detection of buried archaeological remains were also evaluated (Agapiou et al., 2012b) It was found that the phenological cycle of crops for 'archaeological' and 'non archaeological areas' can be used as a "remote" approach in order to locate buried architecture remains. In Figure 15, the phenological cycle of an archaeological site (*Almyros II*) and the phenological cycle of a healthy site (Site 3) are examined. A small NDVI difference is evident (Case A, Figure 15) which is associated with buried archaeological remains. This is due to the fact that soil over the archaeological remains seems to have a different moisture content compared to their surroundings. Therefore, although there exist similar climate characteristics and crop cultivation techniques, there is a difference in amplitude of the NDVI cycle of the archaeological and non-archaeological areas.
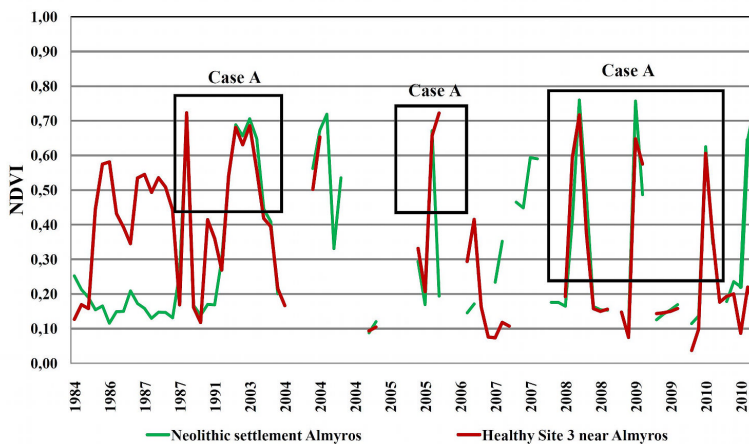
Figure 15. Phenological cycle of the Neolithic settlement (solid line) and the healthy site 3 (dashed line) (Agapiou et al., 2012b)

5. Documentation of cultural heritage sites using remote sensing techniques, GIS and laser scanning

Contemporary techniques and methods such as computer graphics, virtual reality, multimedia technology, and information technology can be integrated in Web GIS technologies, in order to act as a uniform digital tool for documentation, protection and preservation of cultural heritage (Agapiou et al., 2010c; Hadjimitsis et al., 2006). In order to document and map known archaeological sites and monuments, several techniques may be used, including laser scanning, 3D modelling and GIS. In this section, applications from several monuments in Cyprus are presented.

5.1. Integrated use of GIS and remote sensing: a pilot application at the archaeological sites of Paphos

Local cadastral maps were used to support the documentation of cultural heritage sites in the Paphos district, SW Cyprus. In general, each monument may be located in a different sheet /plan; therefore, spatial analysis from such data is a very difficult task.

In order to overcome such limitations, a GIS geodatabase was developed using the ArcGIS 10 software. A GIS system is a computer system (software) that collects, stores, manages, analyzes and visualizes spatial information and upgrades to other information systems. Therefore, GIS can be used as a tool for modelling and analysis of complex research and as a system that supports decision making. Important advantages of GIS include: (a) The data can be stored in a small digital space, (b) Both the storage and the recovery can be achieved with lower costs than traditional ways, (c) Analysis can be carried out much faster, (d) GIS allow synthetic analysis of data without any particular problems and (e) GIS offers the digital environment for an integrated process, where the collection, analysis and decision process are in a continuous flow.
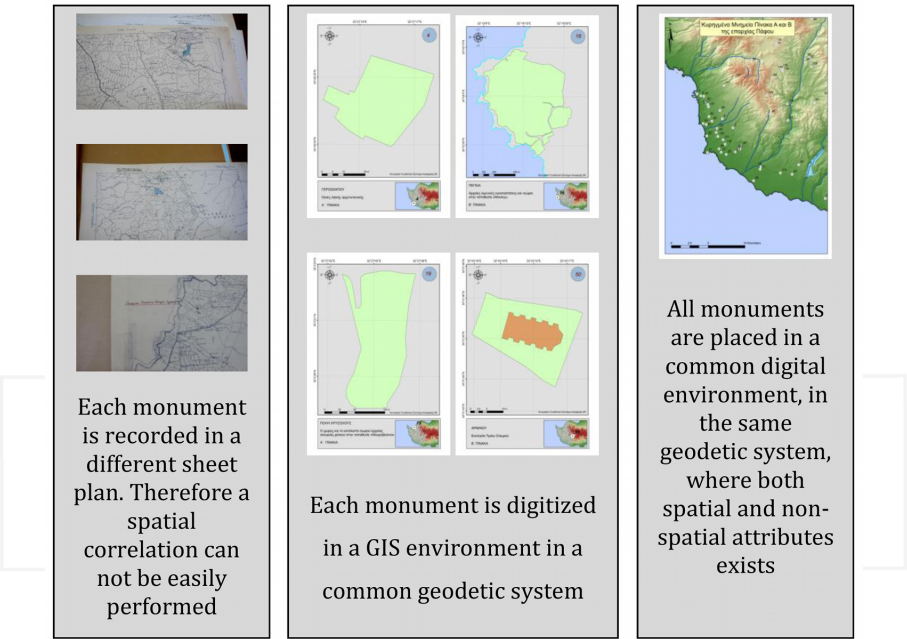

Figure 16. Methodology of mapping the archaeological sites

The most important advantage of the GIS environment is that it can connect both spatial information (e.g. place, coordinates) along with a-spatial (non-spatial) information (e.g. type

of the monument, chronology etc). In this way, further spatial analysis can be performed (Figure 16).

For each monument listed by the Department of Antiquities of Cyprus (200 monuments belonging to the Paphos district), the relative sheet plan was found and digitized. All monuments were georeferenced in a common geodetic system (WGS 84, 36N) (Figure 17). The overall map created (Figure 18), can assist risk assessment analysis. Such kind of an integrated CHM/GIS system has been recently implemented to be used for the efficient manipulation of information regarding the ancient monuments and movable antiquities of Cyprus (Kydonakis et al 2012).
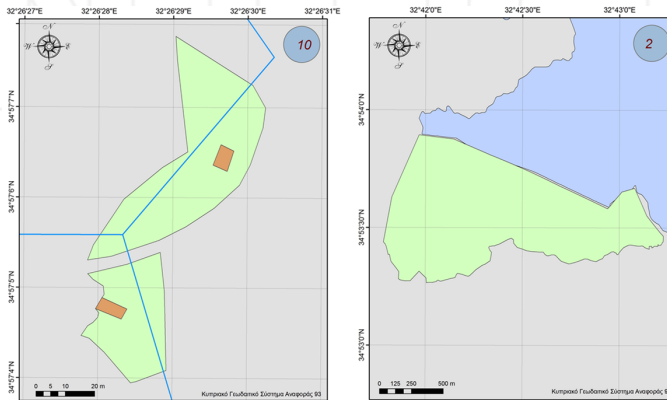
Figure 17. Example of the mapping procedure using the GIS software.
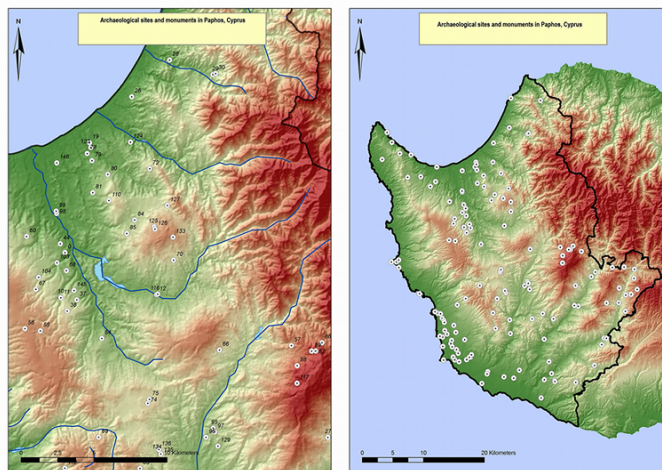
Figure 18. Archaeological sites and monuments of the Paphos District.

5.2. Terrestrial laser scanning for documentation, reconstruction and cultural heritage structural integrity

Due to their high data acquisition rate, relatively high accuracy and high spatial data density, terrestrial laser scanners are increasingly being used for cultural heritage recording, architectural documentation studies, research of cultural heritage with photogrammetric methods and engineering applications that demand high spatial resolution. Terrestrial laser scanning process can be considered as a part of remote sensing methods. In this section, the results from three different cases studies are presented: *Saint Theodore, Tomb I* at the *Tombs of the Kings* and the *Church of Kyrikos and Ioulitis*

For the documentation of the church of *Saint Theodore* in Idalion village, central Cyprus, the 3D laser scanner Leica C10 was used (Figure 19). Pre-processing of the point clouds was performed at the Cyclone software. The latest includes the noise removal of the initial point clouds and the registration using scan targets (Agapiou et al., 2010b).


Figure 19. Data collection from the church of *Saint Theodore* in Idalion village (left). Registration of the point clouds for *Saint Theodore* in Idalion village. All point clouds are transformed into one coordinate system (right) (Agapiou et al., 2010b).

A single scan station was also used for the interior of the *Tomb I*, located at the *Tombs of the Kings*, archaeological site. The data were then processed at the Cyclone software. The initial point cloud of the Tomb I was further analysed and a 3D mesh was finally created (Figure 20). Using the 3D mesh several sections can be drawn in order to study in detail the architecture of *Tomb I.*

The third example is the *Saint Kirikos and Ioulitis* church. Specific laser scans were acquired from the exterior and the interior of the church. The use of laser scanner can provide accurate geometric documentation of such buildings through time and monitor them. One such example is the crack presented in the background of fresco of Christ in the church of Saint Kirikos and Ioulitis (Figure 21). Repeated accurate measurements of the order of magnitude of a few mm can identify if the crack is gradually increasing in size.

The combination of 3D model and WebGIS applications was also presented by Agapiou et al., (2010c). The "Digital Atlas of Byzantine and Post Byzantines churches" application consists of a WebGIS tool, using the ArcGIS Server software. The WebGIS includes a detail 3D reconstruction of the surrounding area of the monuments using grayscale high resolution orthophotos, a digital elevation model (DEM) of a high accuracy of (± 2m) and

3D digital "light" models of the monuments, produced in Google SketchUp software, after applying topometric methods for measurements. Moreover, the application includes non-spatial information about the monuments, such as relevant bibliography, photos of the interior and exterior of the monuments and also audiovisual data. Finally, this digital tool provides to the end-users a brief, time-stamped, historical background information about the Byzantine and post-Byzantine monuments of central Cyprus (www.byzantine-cyprus.com).
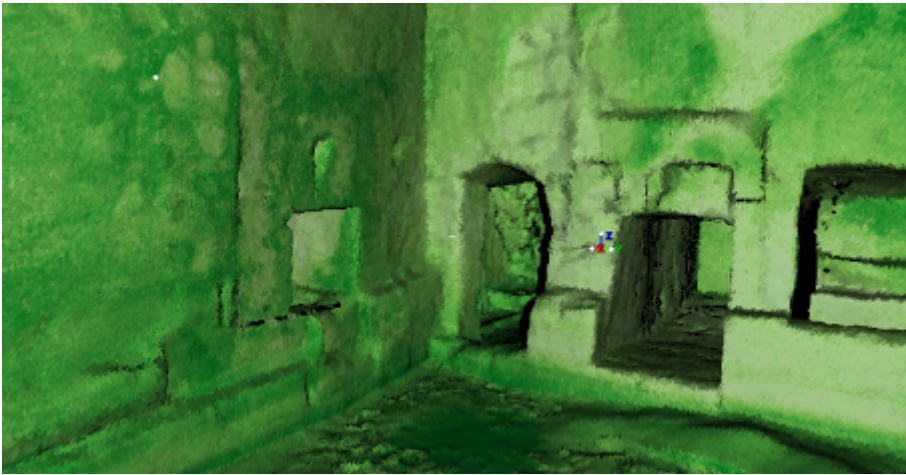
Figure 20. Mesh documentation of the interior of the *Tomb I, Tombs of the Kings* archaeological site.
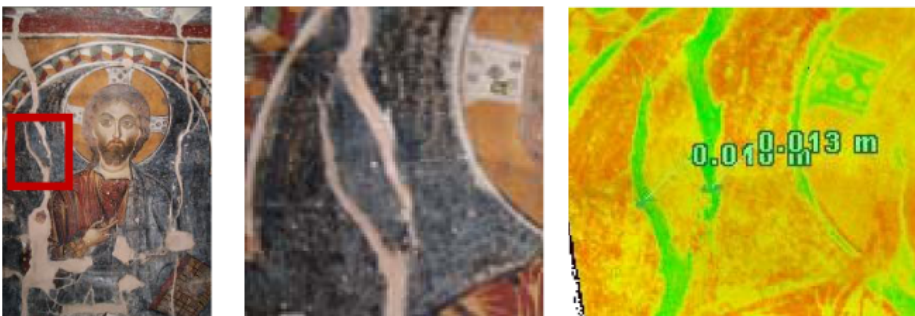

Figure 21. Monitoring the crack (see square in the first image from the left) of the background of the fresco at Saint Kirikos and Ioulitis through Laser Scanners (Agapiou et al., 2010b).

Figure 22. Models for Byzantine and Post Byzantine churches of Cyprus using topometric measurements and GIS tools (Agapiou et al., 2010c).

Moreover, laser scanners can be used for monitoring purposes as shown by Themistocleous et al., (2012a). In order to monitor the effects of air pollution, the Limassol Castle is being documented every year with the 3D laser scanner. Areas of the castle which show deterioration on the 3D laser scanner will have samples taken to determine the chemical analysis of the surface to establish if the deterioration was caused by air pollution or natural causes. Photographs of the castle were also taken and applied to the 3D laser scanned point cloud. A direct visual comparison between the intensity of the laser scanner and close range photographs of the cracks in the Limassol Castle indicate that observation of intensity values can indicate the presence -or not- of possible cracks in the monument. (Figures 23 and 24). Similar conclusions can be drawn when laser scanner intensity is compared with ultrasonic measurements.
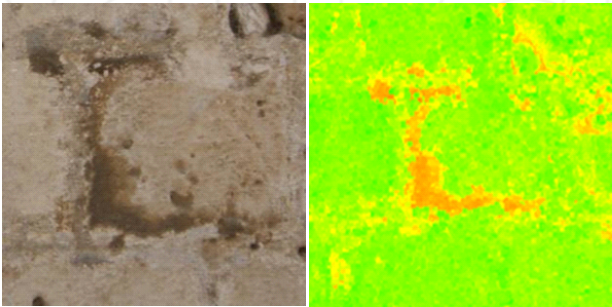
Figure 23. Visual comparison of the laser intensity and close range photographs near a crack
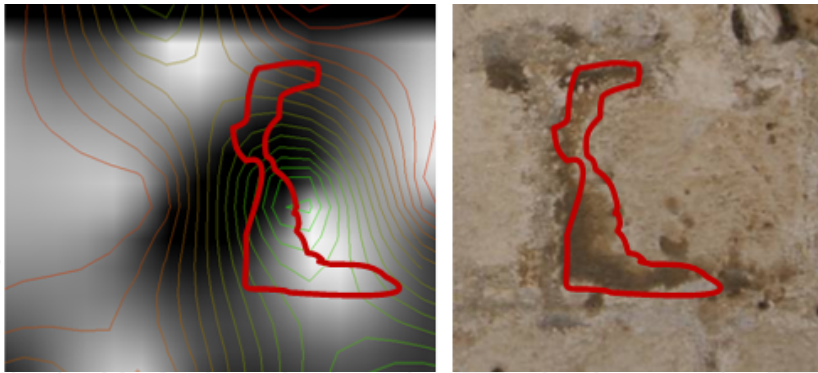
Figure 24. Visual comparison of the ultrasonic measurements and close range photographs. The polygons are drawn as common areas for each set of figures.

6. Geophysical prospection techniques: From mapping to CRM

In terms of ground based remote sensing, there is a wide range of surveying techniques that are focus targeted towards the shallow or medium mapping of the subsurface antiquities or even of the deeper geological layers that may have covered the cultural strata. The various methods, including magnetometry, soil resistance or electromagnetic methods (EM), ground penetrating radar (GPR), and seismic, are based on the measurement of different physical quantities and the complementary application of them (the manifold approach) produces datasets that can match each other and maximize the information content of the geophysical interpretation (Sarris, 2012). Depending on the method and the configuration of the techniques, it is also possible to have different penetration depths and operation in diverse environmental settings (rural or urban) to address a various topics related to the mapping of archaeological sites and archaeo-environment, the preservation of monuments, e.t.c. Geophysical approaches can be applied in planned excavations, rescue archaeology, archaeolandscape studies, building conservation and cultural resources management (Sarris & Jones 2000).

In general, magnetic techniques using the measurement of the total geo-magnetic field intensity or of the gradient of it or one of its components can be helpful in identifying architectural relics or residues of habitation and workshop activities. Magnetometry techniques have been successfully used to map the relics of settlements and reveal the town planning system. Mud brick foundations of Late Neolithic houses together with pits and other details were recorded around the tell of *Sceghalom-Kovácshalom* in E. Hungary. The organic material gathered in the pits was responsible for the enhancement of the magnetic susceptibility, resulting in the good registration of the pits from the measurements of the vertical magnetic gradient. Even stronger was the magnetic signature of the foundations of the fired daub foundations and walls of the farmsteads that were recorded as thermal targets, but which at the same time were not able to register to the GPR measurements due to the high conductiv-

ity of the soils (Monahan & Sarris 2011, Sarris, 2012) (Figure 25). The same type of thermal signature is shown in the investigation of workshops and kilns belonging to different chronological periods. In other cases, such as in *Sikyon*, Peloponnese (S. Greece), the difference of the construction materials of the structural remains of the Hellenistic/Roman city in terms of the magnetic minerals they contained was responsible for providing an accurate plan of the ancient city. Due to the soil conditions and the preservation of the site, the magnetometry survey specified the street layout and the city quarters, tracing numerous monuments inside and outside the agora limits, including temples, porticoes, a basilica, street lines, houses and industrial installations (Sarris et al., 2009; Gourley et al., 2008).

Similar is the operation of the EM and soil resistance methods, which, together with the GPR, are considered ideal to resolve features related to structural remains, champers, voids and tombs. These methods are considered to be active measuring techniques. The particular methodology has been used successfully in resolving the foundations of buildings, road networks, and funeral residues. Of particular interest is their ability to operate in different frequencies (EM and GPR) or configurations (soil resistance) allowing a larger or smaller penetration depth. In this way, it is possible to provide valuable information regarding the subsurface stratigraphy. For example, the decrease of the GPR antenna frequency can provide a larger penetration to the soil strata. In addition, the multiple reflections of the GPR electromagnetic signals originating from adjacent (usually parallel) transect can create images of the subsurface layers (of various widths) by increasing depth (depth slices) (Figure 25). In a similar way, vertical electric soundings measure resistivity variations with depth by increasing gradually current electrode separation while the center of the electrode configuration, remains stationary. Based on the same principle, the electrical resistivity tomography provides information for both the lateral and vertical variations in the resistivity of the soil and, based on 2D or 3D inversion algorithms; it can produce a 3D reconstruction model of the subsurface (Papadopoulos et al., 2011, Sarris 2008).

The use of the EM, electrical resistivity tomography (ERT) and seismic techniques is more appropriate for the deeper mapping and their employment is usually applied in archaeolandscape studies. This was the case of *Priniatikos Pyrgos*, where the integrated application of ERT and seismic tomography techniques processed by 3D inversion algorithms were capable to contribute to the archaeoenvironmental reconstruction of the *Priniatikos Pyrgos* at Istron, E. Crete, providing indications regarding the ancient harbor of the nearby settlement (Shahrukh et al 2012). The particular methods were the only solution to provide information about the deposits that exist in the coastal area of *Priniatikos Pyrgos*: carstic formations of medium to high permeability and alluvium deposits of variable permeability, probably originating by past landslide episodes and periodic flooding of the Istron River, have covered the ancient harbour at depths varying from 20-40m below the current surface. Similarly, electromagnetic and soil resistance measurements revealed the movement of the older Istron River branches, which appeared to be directed to the sea from both sides of the settlement, leaving probably a small path to the mainland from the SW direction. The above results were also supported by the sedimentologi-

cal analyses and OSL dating of cores taken from the region and the use of geophysical techniques in the study of the dynamics of the landscape evolution (Sarris et al 2012) (Figure 26).

GPR and soil resistance techniques (including ERT) also can be used in an urbanized context in contrast to the rest of the geophysical approaches (Sarris 2008; Linford 2006). Due to a high level of ambient noise from the background anthropogenic activities and the high disturbance of the upper soil layers, the particular techniques can be adapted to resolve a number of issues in question (Sarris & Papadopoulos 2011; Papadopoulos et al., 2009). Thus, the above methodology can be used during the course of private construction activities but also for even larger civil construction works that can deal with highways, squares, pedestrian roads, etc. In a number of instances they can even be applied within historical structures and monuments to conclude on the integrity status of the monuments. The geophysical techniques can also contribute to a more generalized risk assessment model, since it can provide information for the tectonic regime and the classification of geological strata either in terms of their resistivity (ERT), velocity of propagation of acoustical waves (seismic techniques) or even the seismic amplification factor (micro-noise horizontal to vertical spectral ratio - HVSR) (Sarris et al., 2010).
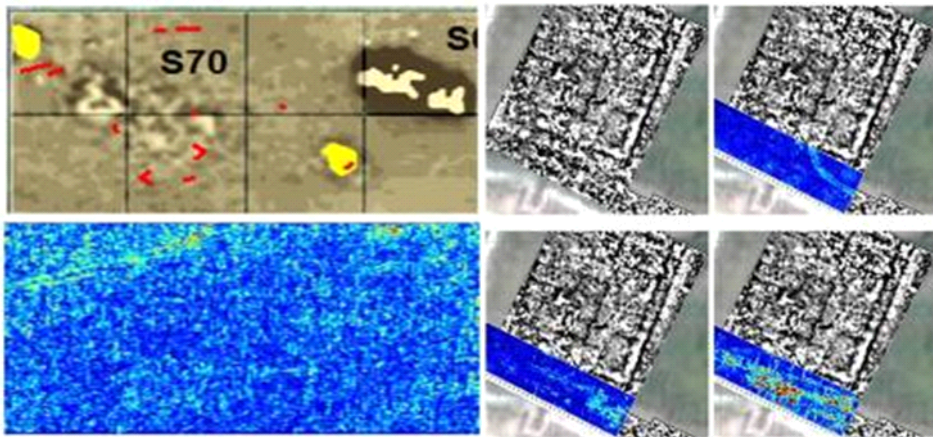
Figure 25. Left: Comparison between magnetic and GPR prospection above structural remains of the flat settlement at *Szeghalom* site in East Hungary. Even though the foundations of the daub constructions are registered clearly to the magnetic data (left top), the high conductivity of the soils has attenuated strongly the GPR electromagnetic signals masking completely the particular area (left bottom) (Sarris 2012). Right: Comparison between magnetic and GPR prospection at the corner of the Palaeochristian fortifications of *Nikopolis*, *Epirus* (Greece). The color maps represent the GPR horizontal slices of 0.1m width for depths of 0.5 (top right), 1 (bottom left) and 1.5m (bottom right) approximately. The remains of a structural complex are obvious in the magnetic data. The GPR managed to register reflectors originating from various depths, such as a curving path at the top layers and a section of decumanus maximus at the lower bottom of the surveyed area. The latter was not clearly resolved in the magnetic data as the high surface concentration of sherds created a uniform magnetic background masking of the area of interest.
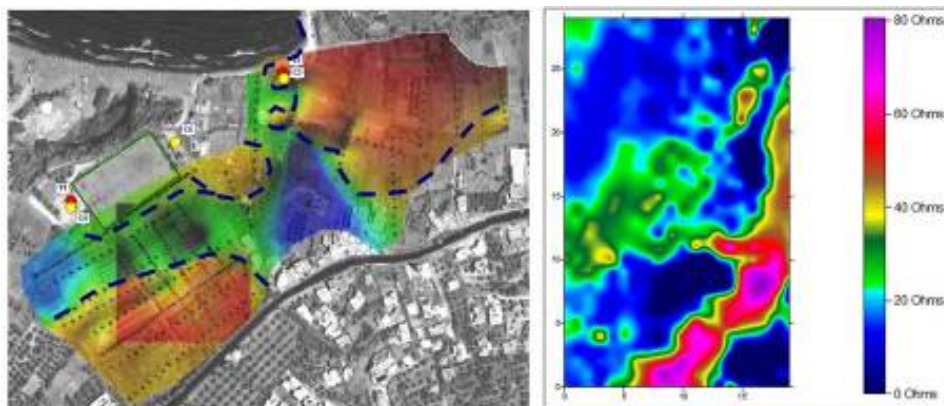
Figure 26. Left: A 2-D view of the bedrock depth in the area of the harbour of *Priniatikos Pyrgos* resulting from the seismic refraction survey. The bluish colors indicate the deeper level of the bedrock and the dashed lines indicate the proposed location of the depression of the ancient harbour. Right: The soil resistance survey to the south of the prom-ontory of *Priniatikos Pyrgos* indicated a 5m wide high resistance linear anomaly that extends in a SW-NE direction and is probably related to one of the older branches of the Istron River running towards the east side of the promontory. (Sarris et al 2012)

Although current trends have emphasized the fast reconnaissance of the archaeological sites through multi-sensor, multi-electrode or multi-antenna systems, the manifold approach, which is the amalgamation of multiple geophysical techniques, as well as the fusion of the geophysical data with other types of remote sensing techniques, such as satellite imagery, LIDAR or laser scanning and orthophotos aiming towards a better and more holistic visualization of the area and a better reconstruction of the underground monuments will continue to be of crucial importance in the geophysical prospection of archaeological context (Sarris 2012).

7. Low altitude systems for supporting archaeological investigations

Further to satellite and ground investigations, research has indicated the need for a low altitude airborne imaging systems in order to support archaeological research. This is due to the fact that such systems of low cost, with a stable platform for imaging sensors and have the ability to lift a payload equivalent to sensor equipment (Patterson & Brescia, 2008; Voerhoeven, 2009; Kemper, 2012; Nebiker et al., 2008; Bento, 2008; Georgopoulos, 1982; Hailey, 2005). In this study, several technologies were merged to create an innovative low altitude airborne system supporting remote sensing and photogrammetric applications, which includes the ability to conduct spectroscopy and aerial photography using a helium filled balloon. The complete low altitude airborne system is shown in Figure 27.

Figure 27. Right- ground control mechanism and aerial platform. Left-Low altitude airborne system including air balloon, spectro-radiometer, and researcher wearing ground control mechanism with harness (Themistocleous et al., 2012b)

A helium-filled balloon with a 3 m. diameter was used which was able to be raised to a height up to 200 m with a payload of up to 6kg. The Spectra Vista GER 1500 spectroradiometer was attached to the aerial platform and operated remotely. The balloon was raised to varying heights and spectroradiometric measurements were taken of the same target at different elevations. Concurrent to the spectroradiometric measurements, aerial photographs were taken using two digital cameras, one with infrared filter. The integration of the various techniques was used in order to detect subsurface archaeological remains by examining ground anomalies identified through spectral signatures. Previous campaigns in Cyprus found that field spectroscopy can support the detection of archaeological crop marks based on the retrieved spectral signatures over agricultural areas which are characterized as archeological areas (see Agapiou and Hadjimitsis 2011). Possible identification of subsurface archaeological remains is based on spectral signatures anomalies. Such anomalies are observed in crops when the vegetation is under stress due to subsurface relics. Therefore, spectral signatures anomalies are expected in the red and VNIR part of the spectrum.

The low altitude airborne imaging system was tested at the Agricultural Research Institute in Paphos, Cyprus, where a simulated archaeological test field was constructed. Spectroradiometric measurements and photographs in the visible and infrared range were taken over

the target area. Preliminary results found that there were no significant differences in the spectral signatures in the visible range, while there was a significant difference among the spectral signatures in the NIR range as the balloon was moving up-wards (Figure 28). The study found that the spectral signature of the target can changed as a function of altitude, with higher reflectance indicated as the elevation increased.
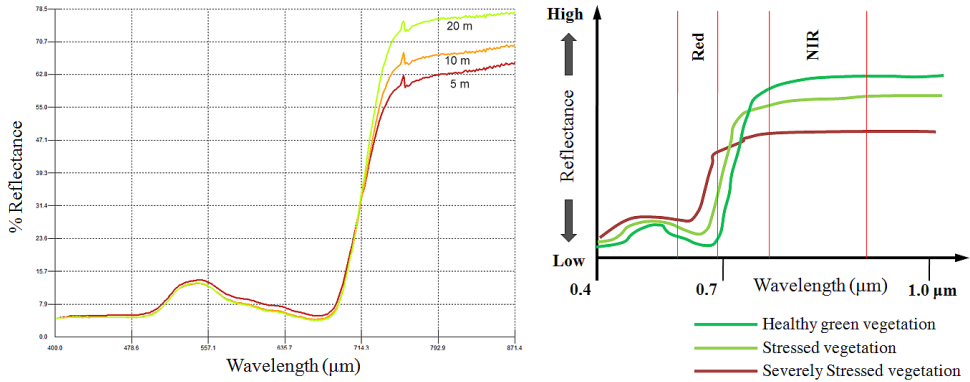
Figure 28. Right-Spectral signatures of vegetation at 5, 10 and 20 meters. Left-spectral differences between healthy and stressed vegetation (Themistocleous et al., 2012b)

8. Conclusions

Remote sensing can contribute in several ways to archaeological research. This chapter presents some results from different cases studies in Cyprus, Greece and Hungary using several techniques of remote sensing, including satellite images, archive aerial images, geo-physical surveys, 3D terrestrial laser scanners, ground spectroscopy, atmospheric pollution, WebGIS and GIS analysis for monitoring purposes.

The results have shown the potential use of satellite remote sensing and ground spectrosco-py for the identification of buried archaeological remains through crop marks. Moreover, monitoring archaeological sites and risk assessment can be performed for several threats in-cluding urban expansion and air pollution. As demonstrated in this chapter, a dramatic land use change has taken place in several archaeological sites during the last decades. Such in-vestigations are very important for studying archaeolandscapes since can provide valuable for information for areas that are nowadays vanished. Furthermore, the potential use of ground geophysical surveys for the detection of subsurface remains was also demonstrated through several applications in Greece and Hungary, was also demonstrated. Documenta-tion, mapping. 3D modelling and WebGIS applications for archaeological sites and monu-ments are also demonstrated in this chapter.

Acknowledgements

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