Cultural Resources Management Through the Application of Ground-Based & Satellite Remote Sensing and Geographic Information Systems: A New Digital Cultural World.

A. Sarris

Laboratory of Geophysical-Satellite Remote Sensing & Archaeo-environment,
Institute for Mediterranean Studies, Foundation for Research & Technology, Hellas (F.O.R.T.H.),
Nik. Foka 130, P.O. Box 119, Rethymno 74100, Crete, Greece,
Tel. ++30-831-56627, 25146, 56628, fax. ++30-831-25810, asaris@ret.forthnet.gr

Abstract

The current pressure applied by large construction works, the increase of tourist industry, the requirements for a different city planning and a sustainable development, together with the need of expanding the communication networks, coupled to the new advances of information technologies, the need of dissemination of information and protection of cultural heritage has altered the profile of cultural resources management. Socio-economic growth and development has been re-defined through the parallel preservation of cultural resources, which together with the natural resources constitute the continuum of our environmental context.

The turning of the century and the millennium is mostly characterized by the exponential creation of digital data that have a major impact in all sectors of the society. Culture is also one of them. On the other hand, cultural resources need a special approach as they belong to a fragile boundary that distinguishes technology from art, development from preservation, digital information from architectural monuments. Although the above fields may involve certain contradictions, it is possible to co-exist in harmony and in favor of each other.

Geophysical prospection, satellite remote sensing and GIS can be considered as important modules for acquiring digital information regarding the cultural topography and landscape. Geophysical prospection techniques constitute a valuable tool in the mapping and management of archaeological sites during the course of large development works. Aerial and satellite images can contribute to the detection of new archaeological sites and the outline of the protection zone of known archaeological regions. The recent developments in satellite remote sensing and Geographical Information Systems (G.I.S.) have created new standards to both historical and archaeological research and the management and protection of cultural and natural resources. Innovative satellite recording systems of high spatial and spectral resolution, along with the use of high accuracy Global Positioning Systems (GPS) and enhanced image processing systems offer great possibilities in the mapping of archaeological sites. In addition, the combination of the above technologies with other digital databases, which contain archaeological and environmental information, and with socio-economic models has direct consequences to our knowledge of the use of cultural space in antiquity as well as to the management policies of archaeological sites today.

The above manifest the use of new remote sensing (RS) and information technologies (IT) in the preservation, conservation and cultural resources management (CRM). The final products of this approach may be accessible to the interested parties through the WEB, assisting the planning and state authorities, supporting the local and regional growth, enhancing the tourist and cultural industry and offering a multidimensional and integrated solution to a number of problems encountered in the management of cultural heritage. Examples will be drawn from various parts of the world, with emphasis in the Mediterranean

and the Aegean region, to indicate the potential use and contribution of geophysical mapping, satellite remote sensing and GIS in particular applications, such as the outline of the limits of archaeological sites and the mapping of the subsurface relics, the reconstruction and modelling of the ancient settlement patterns (archaeological risk areas) and the development of GIS for the management of archaeological monuments (protection zones, archaeological parks, conservation risk areas).

Ground-based Prospection Techniques

The contribution of geophysical techniques in archaeological research is quite obvious, if we consider the limitations imposed prior or during an excavation of a site, the questions generated in the course of a surface survey and the ultimate exploitation of areas that belong to a general cultural continuum. Geophysical techniques spanning from ground based mapping to underwater survey or satellite remote sensing can provide valuable information regarding the type, extent and depth of architectural relics. They can be applied with a relative flexibility to different environmental conditions, including rural and urban environments, and they generate a bulk of information in a fast and economic way. Due to the above factors, as well as the technological developments both in terms of instrumentation and data processing techniques, these methods have been adopted as an inseparable component of archaeological research. On the other hand, the application of geophysical prospection techniques in the Mediterranean has been modified appropriately to respond to the diverse environmental conditions (such as arid environments and desertification phenomena), the frequent presence of sites with multiple occupation layers, the complex geomorphology of the terrain accompanied by intense erosional effects, and the increasing pressure to the cultural relics by large or even small scale construction works.

In order to place the geophysical prospection techniques within a more generalized reasearch context, we need to recognize 4 different (and overlapping) dimensions as they are defined by the corresponding goals of archaeological activities:

TABLE 1: General Applications of Geophysical Surveying (Sarris & Jones 2000)

APPLICATION	*FUNCTION*
In planned (i.e. non-rescue) excavation.	To guide the archaeological strategy in advance of, and during the process of excavation, at a particular locality.
In rescue (salvage) archaeology.	To provide rapid assessment in advance of building or other development in urban, rural and marine contexts (eg. Construction of national roads or large tourist units).
In archaeological exploration at the landscape/regional level.	To support regional archaeological surveying, locate occupation areas and contribute to settlement pattern analysis.
In building/monument conservation and cultural resources management (CRM).	To explore the condition, or structural integrity of individual buildings (e.g. churches) or monuments. Excavation may not be involved. Management of Cultural Resources Outline definition of archaeological parks Examination of conservation and protection conditions.

Within the above domain, ground-based prospection techniques could address much more specific problems related for instance to the extent of an archaeological site and the definition of protection zones with direct consequences to the future construction and development planning of a region, or to the examination of the presence or absence of architectural remains with a potential cultural development of a region. The extension of the 2nd highway route of the National Road connecting Thessaloniki to Katerini is one such example, where construction works met the relics of a neolithic settlement, in Makrygialos, Pieria (Greece). The site, which turned out to be the largest neolithic settlement in Greece, was threatened due to construction activities carried out in the wider area. Although a large portion of the site was destroyed, an area of 80,000m^2 was mapped using magnetic and resistivity techniques. The results of the geophysical survey were able to locate a system of three curvilinear trenches, which belonged to the defensive system of the site during the Neolithic period. The Slingram EM method and measurements of the magnetic susceptibility provided additional information, including the stratigraphy of the defence trenches (Tsokas, *et al*, 1997). In a similar project, in the area of Aerino, in Thessaly, geophysical mapping was carried out at selected sites identified to contain large concentration of sherds, prior to the construction for the extension of the National Road. Instead of detecting archaeological relics, magnetic, resistivity and electromagnetic methods located the gas pipe of the Greek Airforce, running parallel to the existing road (Fig. 1). Aside from the profound consequence of this project, the absence of any architectural traces of archaeological origin in the specific region acted in favor for the operation of a modern quarry, to be used for providing construction material for the national road. In some much more complex situations, geophysical techniques are employed as the ultimate solution, with careful and sophisticated approaches which involve the examination of the signal registration by predefined theoretical models. The recent investigation of the Old Jewish Cemetery at the center of Alexandria in Egypt (Fig. 2) or the exploration of the Bronze Age Tumuli in Thrace (Fig. 3) (Sarris, *et al*, 2000) constitute such examples.

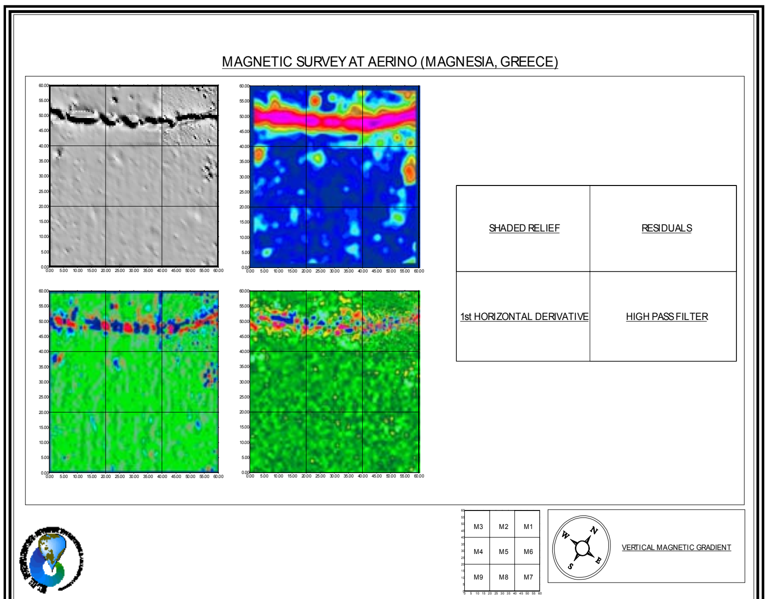

Figure 1. Aerino (Thessaly, Greece). Vertical magnetic gradient survey indicated the presence of a military gas pipe running in a direction parallel to the national road Athens- Thessaloniki.

Caught in the middle of extreme archaeological conditions and practices and limited by a number of environmental boundaries, geophysical survey has introduced a different perspective to archaeological research, notably in its contribution to cultural resources management and conservation. Geophysical survey has much to offer archaeological research as well as to the planning authorities. Recognition of the potential of geophysical prospection in archaeology came to be acknowledged during the 1980s at a formal level in parts of the Mediterranean, for instance in Egypt (Moussa and Dolphin 1977), Spain (Ministerio de Cultura 1992) and Italy (CNR 1991). Yet, no national directives have been forthcoming on the manner in which either geophysical prospection should be employed or its results utilised in potentially resolving conflicts between state archaeological services and developers. It has to be mentioned that although geophysical techniques constitute a non-destructive approach for the exploitation of archaeological sites, they cannot become a substitute of the

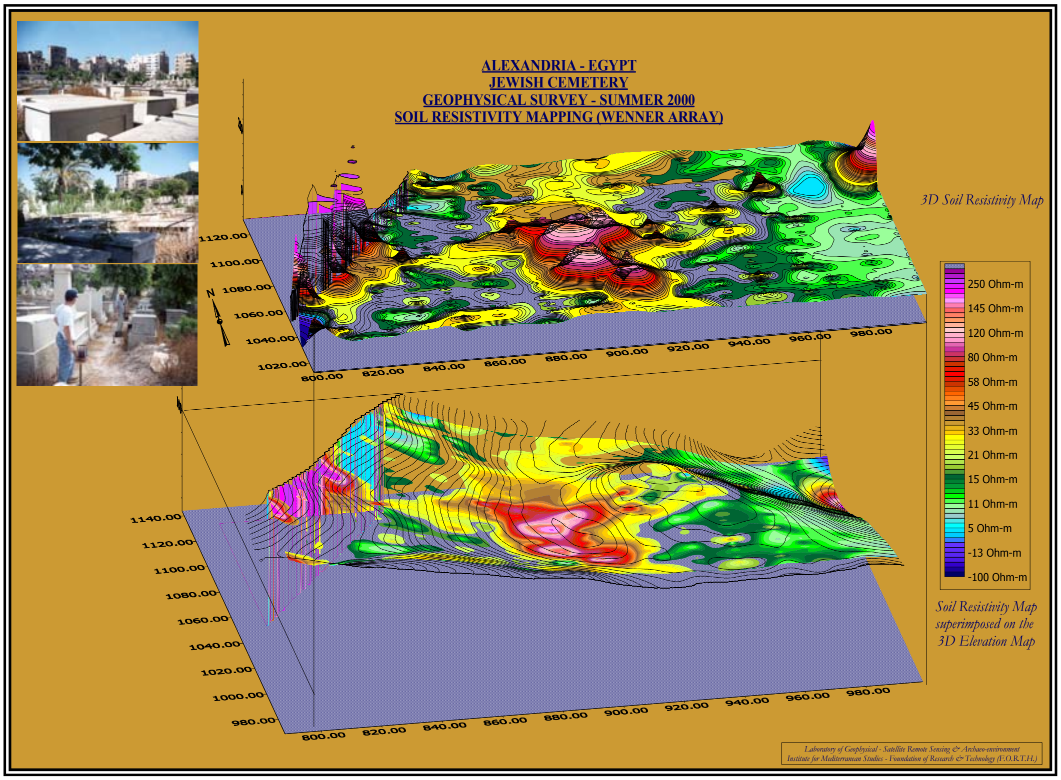

Figure 2. Geo-electrical subsurface mapping of the Old Jewish Cemetery at the centre of the city of Alexandria, Egypt.

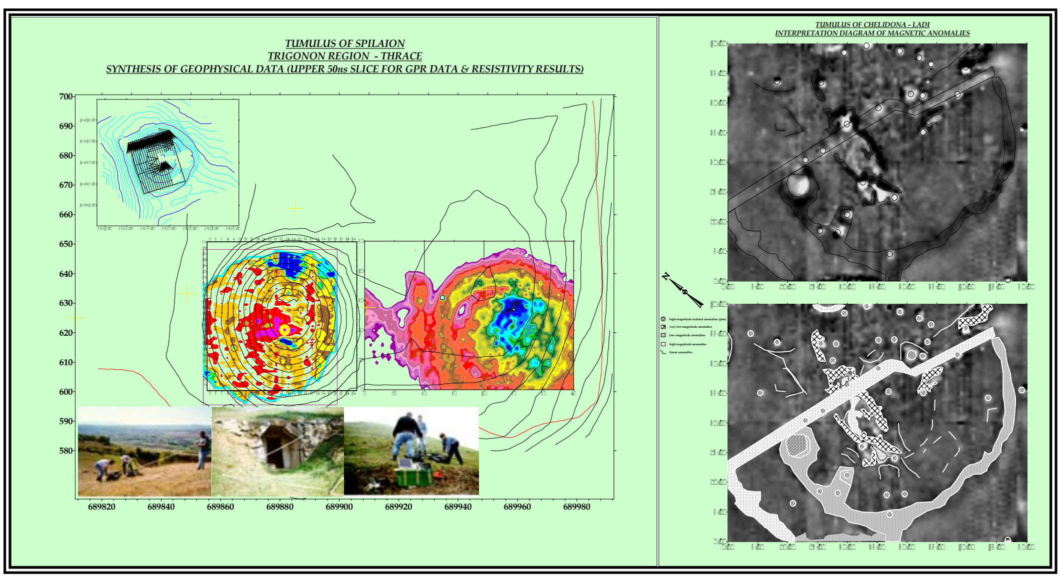

Figure 3. The prospection of Thracian Tumuli was carried out by combination of soil resistivity, magnetic and ground penetrating radar techniques as an alternative method or complementary to excavations, which in most cases had to remove the bulk of the soil of these monumental mounds, whose dimensions could reach 30-50m diameter and 10-15m height.

archaeological excavation. On the other hand, the adoption of prospection techniques in archaeological research serves as a cohesive medium between archaeological research and technology, responding in the best possible way to the need of moving from the traditional object-oriented approach to the construction of a more integrated and holistic representation of monuments and sites, challenging the traditional methods of revealing the past.

Satellite Remote Sensing

The recent advances in remote sensing recording systems and image processing techniques, together with the development of high accuracy Global Positioning Systems have nominated the above techniques as a valuable tool for the retrieval of archaeological information and the management of monuments and sites. Archaeological research incorporates satellite remote sensing aiming at the identification of environmental parameters and their association to the topography of archaeological monuments and the assessment of the spectral signatures of archaeological sites with the ultimate goal of developing predictive archaeological models. In this way, satellite remote sensing constitutes a method of archaeological information retrieval, without the use of excavation or intensive survey procedures. In such an example, SPOT and Landsat imagery of the Baux Valley in France revealed a detailed plan of the ancient landuse and of the communication network of the region. SIR-C/X-SAR images from the space shuttle Challenger, together with Landsat imagery, were also used by a team from the Jet Propulsion Laboratory (JPL) and the California Institute of Technology for studying and mapping the traces of ancient caravans, resulting to the discovery of the ancient town of Ubar (the so-called "Atlantis of the Desert") (Williams 1992). Similarly, in Egypt, the imaging of the Nile river by the synthetic aperture radar SIR-C/X-SAR of the space shuttle Endeavour contributed to the definition of the boundaries between the desert and the urban residential region, as well as to the study of the diachronic landuse in antiquity. Finally, the incorporation of KVR (2m), Corona (8m), SPOT (10m), and Landsat (30m) images from the wider region of the Birecik dumb, on the river Euphrates in Southern Turkey, aims at the detection of subsurface archaeological relics and it will contribute in the archaeological investigations of the ancient town of Zeugma, which together with other cultural monuments and sites, is under the threat of an imminent destruction after the construction of the dumb.

The Nikopolis project in NW Greece was one of those multidisciplinary projects that have integrated geophysical survey with remote sensing techniques. Among the goals of the project was the study of the diachronic settlement patterns of the region (c. 800 km^2), examining the interaction between human occupation, environmental variation, adaptation through time and land resources (Wiseman 1993). In four survey seasons more than twenty sites were investigated through the use of geophysical prospection, balloon photography and satellite remote sensing techniques, exemplifying the integration of the newer technologies in archaeological research. Surface surveying data and geological coring indicated that the coastline along Phanari bay (at the mouth of the River Acheron) extended in antiquity c. 3-4 km inland. Although analysis of the cores suggested that the Holocene marine transgressions extended up to the mountain ridges, sites of higher elevation, such as those in the plain of Grammeno, were not flooded during this period; instead, as the combined field walking and geophysical surveys indicated, there was intense level of settlement. Satellite (SPOT) remote sensing techniques, such as multispectral image classification, employed specifically to correlate landscape features with archaeological sites, identified several exposed deposits of Plio-Pleistocene sediments ('red beds') associated with Paleolithic sites (Stein & Cullen: in press; Sarris *et al*. 1996). In another pilot study, the use of sub-cm accuracy GPS was effective in the accurate mapping and georeferencing of the cultural, environmental and geophysical features on the aerial and satellite images of Itanos, in E. Crete, an area close to the palm forest of Vai, threatened by the local tourist development (Fig. 4) (Sarris 1998; Sarris *et al*. 1998a). Finally, issues such as mapping accuracy are of vital importance especially in the case of geographical registration of images and G.I.S. processes, as indicated by the viewshed analysis of Classical/Roman towers in Amorgos, Greece (Sarris *et al*. 1998b) or the site catchment analysis and settlement pattern modelling in the islands of Hvar and Brac, Yugoslavia (Gaffney & Stancic 1990; Stancic *et al*. 1997).

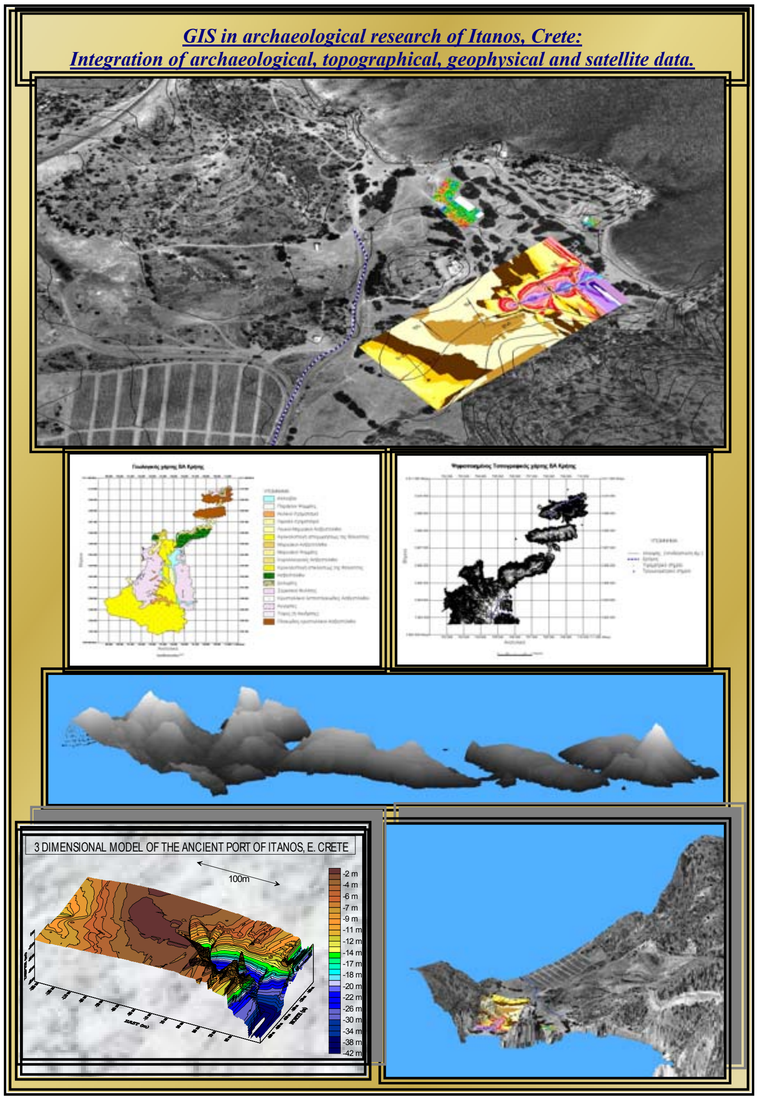

Figure 4. GPS measurements were used for the registration of the archaeological sites of the wider region of Itanos and the georeference of satellite images, aerial photos and digital topographic maps. Based on these data, it was possible to overlay the different layers of information on a common topographic background.

The above indicate that the systematic integration of geophysical prospection and aerial/satellite remote sensing in the general framework of regional archaeological studies can contribute significantly in site catchment and settlement pattern analysis, as well as the management and monitoring of cultural monuments within their environmental context. Geophysical surveying is capable of providing a detailed picture of the subsurface and distinguishing areas of different habitation activities. Together with coring and other analytical techniques, geophysical and remote sensing techniques are critical in the reconstruction of the ancient environment, in a way that no other field method could provide. Finally, aerial photography and satellite remote sensing constitute our unique windows of capturing the mosaic of large-scale regional phenomena, such as settlement distribution, land use patterns, communication modelling, etc. (Sarris & Jones, 2000).

Cultural Geographic Information Systems

If satellite remote sensing is mainly employed for the detection and mapping of natural and cultural resources and the environmental changes of the past, the processing of the corresponding information can be successfully managed through the use of Geographic Information Systems (GIS). Such an example can be found in the MARS project of the Royal

Commission on Historic Monuments of Great Britain, which aimed at the study of the corrosion conditions of archaeological sites using photographic archives and aerial photos (Bell & King 1995). In another case, the overlay of digitized topographic maps and architectural plans of ancient Corinth constituted the background information for the study of the landuse systems of the past in the surrounding region (Romano 1998).

Moving one step further, Geographical Information Systems can be used for integrating archaeological data, together with satellite and aerial images, topographic and geological maps and other digital environmental and cultural information. Up to now, GIS has been mainly used for landscape applications aiming towards the reconstruction of the ancient environment (e.g. Acheloos Delta, S. Greece (Fouache, 1997)) and settlement pattern analysis (e.g. Corinthia, S. Greece (Kardulias *et al*. 1994, Dann & Yerkes 1994), Guadalquivir Valley, Maresme, and Tarragona, Spain (Massagrande 1995), Hirbet el Hamra, Jordan (Menotti 1999)). One of the most important applications of the Geographic Information Systems is the development of predictive models for archaeological site assessment based on image and statistical processing techniques of satellite imagery and environmental information. These methods are aiming to the management of cultural resources and the decision making process in large development works. Prediction models are based on the hypothesis that the spatial distribution of archaeological sites is a function of environmental parameters that exist in the specific region of interest. As an example, along the course of the project entitled "Science and Technology for the Safeguard and Exploitation of Cultural Heritage" in Lucania (S. Italy) (Jacoli & Carrara 1995) GIS was developed for detecting candidate archaeological sites in the region of Lucania, and was applied within an area of 1300 sq. km, resulting to 22 new archaeological sites spanning from the Middle Palaeolithic to the Roman Era. Avoiding high-risk areas, namely areas that have a large probability to contain archaeological sites, it is possible to insure the protection of monuments, a better planning of the development works and proper accommodation of funds.

The need to develop a Geographic Information System of Cultural Resources, with capabilities of processing and modelling digital images, is actually imposed by the effort of accommodating funds, due to the high cost of surface surveying and archaeological site registration and assessment during or prior the course of large scale construction works (e.g. highway or railway construction, expansion of rural estates, exploitation of coastal areas, construction of waste dump areas, a.o.). For example, the Department of Antiquities of Israel together with the GIS Section of the municipality of Haifa have developed a system for the processing of underwater and coastal measurements with the ultimate goal to create thematic maps that will be used for the preservation of antiquities with emphasis to the archaeological site of Tel Shiqmona, threatened by the harbour construction activities (Breman 1999). In Greece, the overlay of the digital archaeological map of Amorgos, on the digital elevation model (DEM) of the island, and the subsequent processing through viewshed analysis helped the reconstruction of the communication network between towers of the historical period and the diachronic settlement modelling of the region (Sarris *et al*. 1998b). Similar studies, such as the analysis of the defensive network of the wider Mantineia region and the detection of new outposts in the region (Topouzi *et al* 2000) (Fig. 5) and the study of the Minoan peak sanctuaries aiming to the modelling of cultural topography of Crete are also in progress. Soon, the Laboratory of Geophysical-Satellite Remote Sensing & Archaeo-environment of the Institute for Mediterranean Studies/F.O.R.T.H. will launch a WEB site that will host the results of a project dealing with the development of a GIS for the management of archaeological monuments and the mapping of archaeological sites of Lasithi region in Crete. The database of the system consists of digitised geological, topographic and landuse maps, roads and village spots, SPOT and Landsat imagery, accurate location of sites (achieved by a systematic GPS survey) and their visible extent and DEM products, accompanied by a dynamic data base regarding the archaeological information of each site, including photographic material and bibliography (Fig. 6). The data will be further analyzed for recognizing the environmental parameters of the archaeological sites and their effect in the conservation of the monuments, enhancing the decision-making process for the management of cultural resources, since the final products of the project can be also considered as the necessary infrastructure for the construction of a state registry for archaeological sites and monuments.

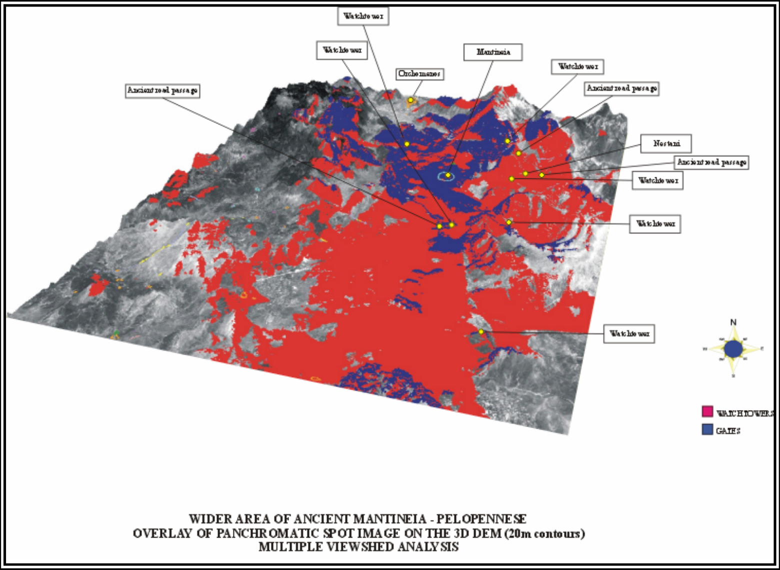

Figure 5. The study of the defensive network of the wider Mantineia region and the investigation of the presence of new outposts in the region was carried out by vieshed techniques based on the digital elevation model.

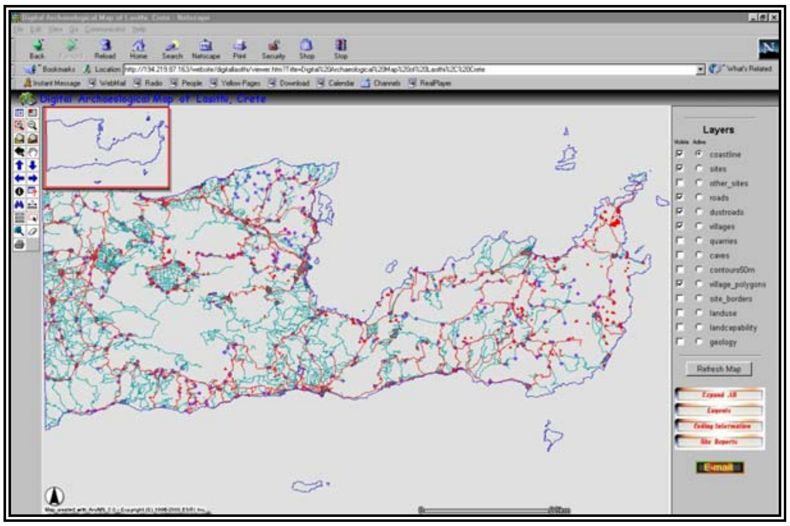

Figure 6. WEB – based platform serving data of the digital archaeological map of Lasithi, Crete. The synthesis of environmental and archaeological data will contribute to the decision-making process for the conservation, protection and management of cultural resources of the region.

The adoption of such a system has direct consequences in enhancing the current inventory systems and electronic databases and in upgrading the current models of protection and the general strategy of management of cultural resources (Fig. 7). A further advantage of GIS lies in their ability of updating their geographical information index in a continuous and interactive mode, processing and storing large volume of diverse origin data and creating thematic maps based on specific inquiries. The above can be used in archaeological research for modelling the diachronic settlement patterns of a region, locating and outlining the limits of high probability archaeological candidate sites, studying the communication or defensive networks, specifying cost surface regions used for the exploitation of natural resources, etc. The construction of digital thematic maps that present various cultural and environmental information, could be extremely useful in solving problems resulted by the environmental and development plans, suggesting specific solutions for the protection, preservation and management of ancient monuments.

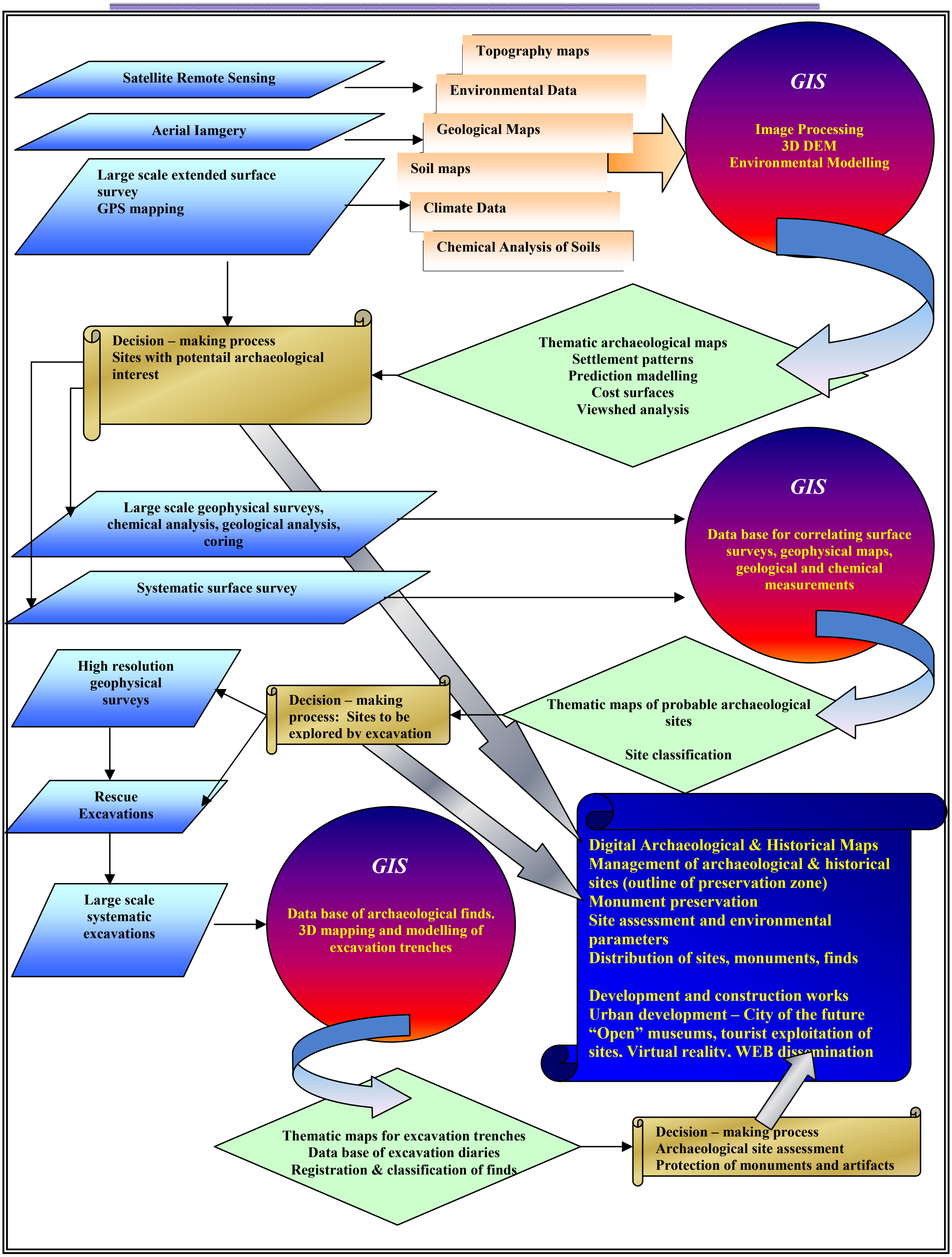

Figure 7. Geographic Information Systems in Archaeological Research & Cultural Resources Management

Even, as admitted, the interaction between landscape topography and environment on the one hand and people on the other is mediated by human perception, GIS cannot be considered as a simplistic typological representation of cultural information (Gillings & Goodrick 1999). Archaeologists today have certain doubts regarding the effectiveness of the representation of cultural complex landscapes through GIS, mainly due to the type of data and the processing and interpretation process. Yet, GIS and remote sensing techniques have a dynamic potential for further development through the flexibility of its processing tools and the adoption of other technologies such as virtual reality of 3D digitization. Issues such as neural networks, virtual reality interfaces and artificial intelligence have been continuously enhancing the latest developments of GIS technology and are expected to make a significant contribution to archaeological applications. It is this particular synergy of digital information technologies that may provide a cohesion space allowing different degrees of freedom in the formation of the environmental domain of cultural monuments and the management of natural and cultural landscapes.

Geographic Information Systems offer a unique mode of representing the ancient environment and its settlement patterns through the reconstruction of monuments and the ancient landform, modelling of geomorphology and hydrology, viewshed analysis and statistical processing and correlation between natural and cultural variables. This type of approach should not remain static. Instead, it should be continuously transformed through a constant feedback and updating of geographic and cultural information, in order to meet the challenges generated by the increase of archaeological information, the extreme environmental pressures (desertification, erosion, forest fires, etc.) and the development works. Projects such as "Science and Technology for the Safeguard and Exploitation of Cultural Heritage" in Lucania (S. Italy) (Jacoli & Carrara 1995), "Long-term Degradation of the Mediterranean Landscape" of the University of Cambridge (Stancic *et al*. 1997), and "Carta Archaeologica del Rischio Territoriale" in Italy (Guermandi 1999) clearly manifest the above tendency.

Final Remarks

It has been demonstrated that ground-based remote sensing can contribute considerably to the mapping of subsurface archaeological relics and the geomorphological characteristics of the terrain of the wider region of archaeological sites, leading excavations at specific areas of interest and indicating archaeologically sterile regions that could be safely offered for development works. Satellite images and GIS are used for capturing the wider area of archaeological sites, offering the possibility of comparison and classification of multispectral information and the reconstruction of cultural landscapes. These techniques constitute a forward answer to the demands that are created during the organization and planning stage of either excavations or large development works, contributing essentially to the decision-making process regarding the preservation and management of cultural resources. The adoption of these techniques by local authorities, specialists and other relevant sectors of cultural resources management reflects the tendency of archaeology, as well as of society, towards the creation of an advanced cultural policy based on digital information technologies.

The question that remains to be addressed is at what level the above would contribute to the construction of a sustainable environmental context which will incorporate policies in both cultural heritage conservation and regional economic growth, or in a different way, how sustainable are the cultural assumptions of the current development models? In practice, the problem focuses, for example, on how a site can become a wealthy tourist attraction or which sites should be destroyed in order to expand a town planning or in order to construct a national highway? Obviously, the ideas of both sustainability and development need to be reassessed by broadening their theoretical and practical concepts from pure economic growth to preservation and management of cultural resources. This does not mean that we should attach an environmental or cultural determinism to development, or vise versa, namely a developmental determinism to culture. The ideas of reversibility and maximum entropy should be much stronger in all aspects of development than sustainability since the cultural values subject to change according to the standards of the society. In other words, how are we going to take the decision to expose an archaeological site through an excavation, which is by all means an irreversible and destructive process? How can we propose that a particular archaeological region, belonging to a wider cultural continuum, should be destroyed in favor of a large-scale construction work? The vision of synergy between culture and development needs a re-consideration by changing the structure of their interaction. In such a case, both of them need to be placed in a common platform that will be open to adaptation by local, regional and temporal changes of the society.

As all archaeological artifacts, from lithic artifacts to megalithic monuments and from concentrations of sherds to natural landscapes, play an integral role in the reconstruction of cultural heritage, the need of technological means to record and disseminate the corresponding information to all sectors of society is more urgent than ever, in order to provide the necessary knowledge framework that will enhance the decision-making and policy-making process, according to the demands of the development plans and the protection of cultural resources.

Obviously, the above represent a shift of the archaeological research towards developing new cultural strategies based on information and digital technologies. Yet, there are two main challenges that need to be faced in the immediate future: firstly, the development of a common strategy regarding the management of antiquities, the creation of homogeneous and unified databases and the integration or modification of the existing management systems and secondly, the dissemination of information and knowledge resulting by interdisciplinary archaeological and technological approaches aiming towards the better exploitation and enhancement of the Cultural Geographic Information Systems (C.G.I.S.). Within the current era of digitization, the construction of a digital cultural world will broaden cultural policy frameworks & strengthen the design of cultural policies investing in this way to the archaeology of the future or to the future of archaeology.

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