A Web-based Digital Archaeological Map of Lasithi, E. Crete.

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Abstract: Digital archaeological spatial databases can contribute significantly to the management and protection of archaeological resources, as well as to the effective use of the environment. The diffusion of these data through the Web has also major advantages in terms of modelling the past usage of the landscape as well as in the future preservation of sites within the general framework of large-scale construction works.

In the absence of a detailed archaeological registry, the Laboratory of Geophysical-Satellite Remote Sensing & Archaeo-environment of the Institute for Mediterranean Studies/Foundation of Research & Technology, Hellas (FORTH) undertook the creation of a Web-based GIS platform mapping of the known archaeological sites (more than 900) of the wider region of Lasithi, located in E. Crete (http://www1.ims.forth.gr/maps/website/imslasithi2001). The research project was carried out under the framework of Applied Research program of the Prefectorial Functional Program of Crete (1994-1999) and was funded by the Prefecture of Crete, through the European framework of Development-II.

The final product consists of an integrated archaeological geographical database of the cultural resources of the Lasithi district, based on the principles of a Geographic Information System. The background layers of the digital archaeological map of the region consist of a complete map mosaic (topography, geology, landuse, land capability maps, DEM), SPOT and Landsat satellite images, which are used for a better presentation of the distribution of archaeological sites. The geographic database contains a catalogue of the known archaeological sites of the Lasithi district, environmental information, chronology, general information, references and photographic material from the archaeological sites. The Geographical Information System offers the capability of synthesis of different information layers and the creation of thematic maps of the archaeological sites in the region. In this way, this project can be considered as an initiative for the development of a digital archaeological cadastral registry of Crete. It has the dynamic potential of a tool in the decision making process of the development of the region and constitutes a detailed research guide of the cultural resources of the region, with direct consequences in the protection, conservation and management of the ancient environment.

Through the mapping of the geomorphological and archaeological variables of the region, the system can be used for the development of settlement pattern models, the enhancement and management of cultural resources (protection zones, archaeological parks, conservation risk areas), the protection of monuments and the parallel economic and tourist development of the region.

Key words: Web, GIS, Lasithi, Crete, digital archaeological map, satellite, GPS, CRM.

Introduction

In the last years, the profile of cultural resources management (CRM) has changed due to the large construction works, the increase of tourist industry and the requirements for a different city planning and a sustainable development (Sarris 2000). This development has been intensified through the expansion of the communication networks and the new advances of information technologies.

The turning of the century and the millennium is mostly characterized by the exponential creation of digital data that have a major impact on all sectors of society. Culture is one of them. Cultural resources need a special approach as they belong to the boundary that distinguishes technology from art, development from preservation, digital from archaeological information. Although the above fields may entail certain contradictions, it is possible to interact in favor of each other (Sarris 2001:2).

Geophysical prospection, satellite remote sensing and GIS are considered 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 protection zones of known archaeological regions. The recent developments in satellite remote sensing and Geographical Information Systems (GIS) have offered new standards to both historical and archaeological research and the management and protection of cultural and natural resources (fig. 1).

Innovative satellite sensors of high spatial and spectral resolution, along with the use of high accuracy Global Positioning (GPS) systems and enhanced image processing systems offer great possibilities in the mapping of archaeological sites. In addition, the combination of the above technologies with other databases, which contain archaeological and environmental information and with socio-economic models has direct consequences on our knowledge of use of cultural space in antiquity as well as on management policies of archaeological sites today.

Moving one step further, Geographical Information Systems could be used for integrating archaeological data, together with satellite and aerial images, topographic and geological maps and other digital environmental and cultural information. 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. 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 the proper accommodation of large amounts of funds.

The need to develop of 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.). 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. 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 settlement patterns of a region, locating and outlining high probability archaeological candidate sites, studying the communication or defence networks, specifying cost surface regions used for the exploitation of natural resources, etc. The creation of electronic thematic maps that present various cultural and environmental information simultaneously, 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.

A priori condition for any project dealing with the protection, promotion and management of archaeological sites, as well as with archaeological landscape and settlement modelling, is the accurate mapping of sites and their correlation with the corresponding environmental information. Such an endeavor was undertaken by the Laboratory of Geophysical-Satellite Remote Sensing & Archaeo-environment of the Institute of Mediterranean Studies – FORTH aiming towards the creation of a Web-based digital archaeological map of Lasithi district in east Crete, operating on a GIS platform (Sarris et al 2000). The following actions and activities took place in the course of the project (fig. 2):

- Retrieval of published archaeological information, maps and field surveys. Emphasis was given on Prehistoric to Roman times.
- Construction of an archaeological database, which was implemented in the GIS. The database was also installed on a different platform, having the potential of updating the current information and querying through its data, without being necessarily within the GIS environment. Within the GIS environment, thematic maps can be produced based on simple or combined queries (eg. type, chronology, etc.).
- Construction of the Digital elevation model (DEM) from SPOT orthophotos and thematic maps modelling slope, aspect, inclination and shading.
- Digitization of 7 geological maps of the Institute of Geological and Mineral Exploration (IGME), 8 landuse and 8 forestry capability maps of the Ministry of Agriculture and other topographic data (coastline, villages, main and secondary road network, caves, quarries, etc) covering the same area of interest.

- Processing of satellite imagery taken by Landsat Thematic Mapper (30m resolution) and SPOT satellite (10 & 20m resolution). Real color and pseudocolor images were also produced by the synthesis of the different spectral bands.
- Construction of archaeological thematic maps representing sites as dots, lines and polygons (depending their extent and outline of them in cases where GPS readings were taken). All sites were connected to the corresponding archaeological database.
- DGPS mapping of more than 200 archaeological sites. Reduction of all GPS readings, satellite and aerial imagery and digitized maps to EGSA'87 coordinate system. In this way it is possible to overlay the data of the estate registry on the digital archaeological map or vice versa.
- Design and construction of a web site, which hosts the GIS-based digital archaeological map along with the rest of the results of the project. The web site is serving both the digital map within a GIS environment and the database. Thus, the user, accessing an HTML viewer, is able to define the map layers he wants to view. At the same time he has full access to the archaeological database for searching and printing the registered information. The web site includes additional information regarding the research project, such as general information, research team, coding information, technical reports regarding digitization of maps, GPS mapping and retrieval of archaeological information, together with other useful links that can be found in the net. The database and most of the technical reports are bilingual (greek and english).

The following sections analyze in detail the above activities.

Archaeological Database

A relational database was constructed for the registration of the archaeological information that was retrieved from the published references. The format and general design of the database was based on the principle of compatibility with the rest modules of the Web-based GIS platform and the possibility of expanding the project within the wider region of Crete, or even in other areas of Greece. The database was initially constructed in Access and then it was transformed to DBF and SQL formats. The DBF format of the database included the coordinates of the sites and it was connected to the rest geo-referenced maps. The SQL format of the database was used for querying the archaeological information and producing reports of the sites of interest.

The database consisted of 17 basic tables (fig. 3) which included various types of information, such as name of the sites, accessibility, nearest village, type of site, chronological periods, information regarding the excavation or surface survey, excavator/surveyor, bibliography, geophysical prospection techniques, archaeo-environmental data, present environment, bibliography, photographs, plans, GPS coordinates, general comments, a.o. The tables were related to each other through a common coding system, so that they guaranteed the successful

retrieval of information through possible queries. The main tables of the database referred to the sites and the corresponding bibliography or references. Other tables contained the full path name of the files that referred to the images or topographic plans of the sites.

Every table or form of the database required the completion of different types of information (fig. 4). Macros were included to make easier the movement from one form to the other or the change of the language (greek or english) used for filling the fields that exist on the forms. In a few cases, look-up tables, numerical elements and predefined tick boxes were used to minimize the time and errors of the data entry process, automate the updating of both the Greek and English versions of the database and avoid possible errors that could be caused due to the discrepancies of terminology, such as in the case of chronological periods. In other fields, the user was able to enter additional comments in text format. The above design guaranteed the uniformity of the database that was necessary in establishing a connection to the GIS environment.

Different tables were created to distinguish the sites that were topographically mapped through a GPS survey from the sites that were mapped through digitization of maps or diagrams. A similar table was created containing the centroid of the sites instead of the total number of coordinates that was taken in the specific location and which was related to the extent of the sites or the outline of the architectural remnants.

The database was implemented in the GIS, which was used for the digital map. The database was also installed on a different platform (SQL), having the potential of updating the current information and querying through its data, without being necessarily within the GIS environment. The Web user is able to search the database by specifying either the full name or part of the letters that form the name of the site. If more than 1 match is encountered, all of the site names that satisfy the query parameters are listed and the user can decide which one is the proper site that he is interested in. Querying can be also carried out in the GIS platform through a number of tools or Boolean operators. Based on the query results, thematic maps can be produced based on simple or combined queries (eg. type, chronology, etc.). The user has also the ability to print specially designed reports for each site, even through the WEB. The reports of the sites were used for the better presentation of the information that is included in the database (fig. 5). All the site reports pull information through the database and one is able to print them either in Greek or in English.

Topographic mapping of archaeological sites through the use of Global Positioning Systems (G.P.S.)

Accurate mapping of the most important archaeological sites of the Lasithi district was carried out using 2 sub-cm geodetic GPS receivers (Ashtech Z-12 double frequency receivers) with a static differential mapping procedure (choke ring and 700718'_Geo.III L1/L2 antennas were used for the particular purpose).

Prior to the topographic mapping, a catalogue containing all

the sites and important relevant information about their location and type was created. The approximate location of the sites was marked on the 1:50,000 topographic maps of the Geographical Service of the Hellenic Army, according to the descriptions and maps found in the relevant bibliography. The fieldwork (fig. 6) was mainly contacted in 6 periods, covering a total period of about 80 days, within which more than 200 sites were mapped of a total of 900 that have been registered in the database. Data collected prior to the initiation of the project were also incorporated to the database.

Static differential positioning technique (Leick 1990, Kaplan 1996) was systematically employed in all stages of the research project. The base station receiver, connected to a Choke Ring antenna, backed up by both a 12V battery and electric power, so as to prevent loss of data in case of power failure, was recording every 10-30sec. The base stations were different for each survey period and always within a distance of 30km from the surveyed sites. The coordinates of the base stations were established in the beginning of each survey period, by taking measurements for a period of over one hour at 2-3 close-by army datum points and comparing them with their known coordinates. During fieldwork, the rover receiver was transported at the sites of interest, where it recorded for a period of approximately 10-20 minutes, with a mask angle of 15°, so as to be able to locate from 4 to 9 satellites. Each measurement was coded with a distinct 4-digit code name, while a small draft plan of the site marked the locations that were measured.

The selection of points recorded each time varied according to the case and type of the archaeological site. In the case of surface distribution of sherds or visible architectural remnants, measurements were taken to define the extent of the site or the outline of the architectural features. Generally, more than one measurement were taken in each site (in a few instances a few dozens of readings were taken), aiming towards the definition of the limits of the settlements. If a topographic plan of the site was available, specific points of the features were recorded and assigned on the plans. In the case of caves, one point close to the entrance of it was measured. Similar strategies have been followed for similar features such as isolated tombs, houses, peak sanctuaries, etc. Besides the archaeological sites, GPS measurements were also taken in Ground Control Points (GCPs), in locations visible in airphotos and satellite images, which were used for the georeference of the images and their registration to the national coordinate system (EGSA'87).

Processing of the data was conducted daily, so as to evaluate the results and the accuracy of the measurements. Every measurement was processed and corrected (using Ashtech Office Suite software) according to the data recorded by the base. GPS measurements were recorded in WGS'84 and they were later transformed to the EGSA'87 coordinate reference system. A comparison of the measurements taken at specific datum points with those provided by the Geographical Service of the Hellenic Army resulted to an average percentage error of less than 10cm.

The use of accurately defined coordinates is of critical importance in a Geographic Information System.

Measurements can be used for the necessary geometric corrections and transformation of all data in a common reference system. Furthermore, the accurate mapping of sites can refine the subsequent spatial analysis of the data, resolving problems related to the viewshed analysis, the precise definition of buffer zones (such as protection areas) and the accurate correlation of sites with the underlying environmental layers, especially critical for the derivation of the spectral signatures of sites (Topouzi et al 2001).

References & Bibliography used for Archaeological Data Retrieval

The information that accompanies the digital archaeological map of Lasithi was retrieved by a number of Greek and foreign journals and books. Emphasis was given to sites spanning from Prehistoric era to Roman period. The more recent monuments and sites (Byzantine and later period) were selectively mapped. The following information was retrieved for each archaeological site (depending on the availability of data):

- Name of the site/settlement
- Municipality – province in which it belongs to, nearby town or modern settlement
- Information concerning excavation (systematic, rescue, test, illegal)/ survey method
- Name of the excavators/researchers
- Year/years of survey or excavation
- Extent or area coverage of the archaeological site/ settlement
- Chronological periods of occupation or usage
- Type or category of the site at the particular chronological period or at other chronological periods (settlements, industrial site, religious site, burial site, cave, etc.)
- General remarks, based on bibliography, describing the general characteristics of the archaeological site.
- Important references and bibliography

The above information regarding the sites was registered, provided that systematic research had been carried out and results of this research had been made public (fig. 7). In specific cases, such as a) when surface survey was taken place without excavation, b) when excavation was not yet completed and c) when the study of the ceramics, finds or other structural features was not published, it was not possible to provide a full record of the above information.

When evidence was not sufficient to support the definition of a specific chronology or category of site, a more general date (e.g. LM instead of LMIIIC) and type (e.g. archaeological site instead of settlement, town, village, metallurgical site, shrine, sanctuary, cemetery, isolated building, farmstead, villa etc.) was provided. Since there are also arguments, of archaeological ground, concerning the type and chronology of sites, especially when sites have not been excavated yet or systematically studied, the adoption of different terms or contrasting suggestions (e.g. farmstead instead of country house or villa, or LMIA instead of LMIB) were mentioned in the comments.

Digitization of Maps and Photographic material

Topographic & Archaeological Maps

AutoCAD14/2000, connected with a CalComp DrawingBoard III digitizer, was employed in the digitization process of maps. A number of archaeological and topographic features were digitized to be included in the thematic map list that can be activated in the final product. Topographical data included the coastline, the main and secondary road network and about 344 caves, 90 quarries and 338 village polygons (outline of village limits). The digitized data were treated similarly, together with the rest GPS measurements, while a number of geometrical symbols were used for mapping the archaeological sites and features. More specifically, point symbols were used for mapping the archaeological sites, based either on the GPS measurements or the calculation of the centroid of a group of measurements that defined the approximate limits of the archaeological site. In other cases, polygons, cirles or lines were used for describing some particular details (table 1) (Para-schakis, *et al* 1991, Hoffman 1992). In the case of polygons, the database included site names, estimated area and perimeter of the polygon. The following convention (table 1) includes the cases that were taken in account in the symbolism defini-tion within the digitization process.

Table 1: Digitization convention.

Digitization of Topographic Elements	Digital Mapping of Archaeological Sites
Lines: ♦ Coastline (Lasithi district)	**Polygons:** ♦ Outline of buildings ♦ Estimated extent of sites ♦ Quarry pits (eg. Kalamaki quarry)
Lines: ♦ Main Road network	**Circles:** ♦ Tomb ♦ Cave entrance ♦ Estimated extent of sites, defined by 2 points
Lines: ♦ Secondary road network / dust roads	**One Point:** ♦ Approximate centroids of sites ♦ Sites not found-coordinates taken in the approximate vicinity of the site ♦ Sites discovered through surface survey
One Point: ♦ Caves (Total = 344)	**Two Points:** ♦ Approximate site limits (ex. Agia Fotia – necropolis)
One Point: ♦ Quarries (Total = 90).	**Lines:** ♦ Walls and roads
Polygons: ♦ Village polygons/Modern towns & villages (Total = 338)	

Different layers were created in order to provide the capability of separation of the cartographic products. Different colours were assigned to each layer. The topographic features that were digitized from the 1:50,000 scale maps are presented in fig. 8. For the wider Palaikastro area (north of the village of Palaikastro), 4m contour lines were digitized from 1:5,000 scale maps.

Geological, land use and land capability for forestry maps

A similar procedure was followed in the digitization of the geological and landuse maps of the region. The different formations of the corresponding maps were represented by closed polygons. Thus, digitization of double lines was prevented, avoiding problems that would have arisen in assigning the formation attributes. Each one of the above environmental maps was placed in the same layer (fig. 9).

Following the digitization of the maps, georeferencing of them was performed with TNT Mips software, by choosing specific GCPs in the corresponding maps and the digitized costline. Later on, the relevant attributes were filled in the corresponding database.

The geological attributes included a polygon consecutive number, the geological formation code similar to the one assigned by the Institute of Geology and Mineral Exploration (e.g. "al" for alluvium), a general type and description of the geological formation, the corresponding geological chronological period (e.g. upper cretaceous/lower Eocene) and the coding of the digitized map sheet. The accompanied database, consisting of 99 distinct geological formations, included also information related to the area (in square meters and acres) and the perimeter of each formation polygon. Discrepancies in the coding due to the different year of map design and production were also taken into account. Formations with different codes between new and old maps were registered as being the same when description and geological period were identified as the same. In the case of an overlapping region between new and old maps, the most recent and more detailed description was recorded, coded appropriately to refer to the corresponding map. The following table (Table 2) summarizes the maps that were digitized and were implemented in the Geographical Information System database.

Table 2: List of topographic, landuse and geological maps that were digitized for the purposes of the project.

Topographic Maps Geographic Service of the Army (scale 1:1,5000 – 50,000)	Soil Maps (Land use & Land capability for forestry) Ministry of Agriculture Scale 1:50,000	Geological Maps Institute of Geological & Mineral Exploration (IGME) Scale 1:50,000
DIONYSADES, 1994	DIONYSADES, 1996	
PALAIKASTRO, 1994	PALAIKASTRO, 1996	ZIROS, 1959
SITEIA, 1994	SITEIA, 1996	SITEIA, 1959
KATO CHORIO, 1994	KATO CHORIO, 1996	IERAPETRA, 1993
IERAPETRA, 1994	IERAPETRA, 1996	IERAPETRA, 1959
AGIOS NIKOLAOS, 1993	AGIOS NIKOLAOS, 1996	AGIOS NIKOLAOS, 1987
MOCHOS, 1993	MOCHOS, 1996	MOCHOS, 1989
ANO VIANNOS, 1994	ANO VIANNOS, 1996	ANO VIANNOS, 2000

The registered attributes of the landuse and land capability for forestry are listed in Tables 3-4, defining approximately 365 different landuse categories.

Table 3: Recorded attributes of the Landuse maps

Landuse Attributes
• Surficial Geology (hard limestones, tertiary deposits and conglomerates, schists, alluvium, mixed flysch, limestone colluviums, dolines, deposition cones)
• Physiography (flat areas, steep summits, escarpments, cliffs, rounded summits, upper slopes, middle slopes, terraces, lower slopes, open valleys, closed valleys)
• Soil Depth (deep, deep and shallow, shallow and deep, shallow, shallow and bare, bare and deep, bare and shallow, bare)
• Erosion (none, none and moderate, none and severe, moderate and none, moderate, moderate and severe, severe and none, severe and moderate, severe)
• Slope (gentle, gentle and moderate, gentle and steep, moderate and gentle, moderate, moderate and steep, steep and gentle, steep and moderate, steep)
• Ecological land region (broadleaved evergreen zone, pinus brutia, oak zone, pseudoalpine zone)
• Degree of artificilization of vegetation/ Human provoked vegetation (nil, moderate, severe, no vegetation, grassland, phrygana, agriculture)
• Aspect (north, north and south, variable, south and north, south, nil, nil and north, nil and south, north and nil, south and nil, variable and nil, nil and variable)
• Code of the map sheet.

Table 4: Recorded attributes of the Land capability for forestry maps

Land Capability for Forestry	
Field	Name Description
Category 1:	Lands without limitations for timber growth
Category 2:	Lands with slight limitations for timber growth
Category 3:	Lands with moderate limitations for timber growth
Category 4:	Lands with severe limitations for timber growth
Category 5:	Lands with extremely severe limitations for timber growth.

Photographic material

Photographic images were taken from all the archaeological sites that were mapped with GPS units. The photos were scanned with a Hewlett-Packard ScanJet 4c scanner, with 150dpi resolution, and they were saved in jpeg format, to be easily retrieved by the database by specifying the path of the directory of the photographic registry. In a few cases, such as peak sanctuaries, Photopaint 9 was employed for creating panoramic views of the wider area surrounding the archaeological sites (fig. 10).

Satellite Remote Sensing – Digital Elevation Model.

SPOT and Landsat TM images have been georeferenced using the coastline and the SPOT derived DEM (resolution of 50m). All images were georeferenced to the Greek Geodetic reference system (EGSA' 87), with a Transverse Mercator projection and a WGS84 datum. All images were compressed with MrSid encoder down to a factor of 75-90%, resulting in images of total size less than 800KB, which were easily served in the Web. All images were processed through the application of contrast enhancement techniques and high pass filtering. Due to the limited surface information, classification of the images produced poor results.

An Ortho Pan Spot image was used as the basic background layer of information, having a resolution of 10x10m and a georeferencing accuracy of +/-12m. Three more panchromatic Spot images were used in the map registry, having a less degree of georeferencing accuracy (+/-13-170m). Similarly, a Spot multispectral image (resolution of 20m) was used for creating a pseudocolor image, emphasizing mainly the vegetation of the area of interest (fig. 11).

Finally, six of the seven bands of the Landsat Thematic Mapper (30x30m) were used for constructing false color composites (combinations 1-2-3, 3-4-5, 4-5-7). TM images were initially resampled to 10m cell size, achieving a georeferencing accuracy of less than 5 meters.

The construction of the digital elevation model (DEM) was based on 14 level 1A Spot images. The resolution of the DEM was 50m and its accuracy after georeferencing was of the order of 35m. A lookup table was formed for associating the grey scale of the original image (0-255) to the actual altitude values (0-2084). Different colors were assigned to each altitude class (every 10m for altitudes 0-100m, 50m for altitudes 101-1000m and 100m for altitudes 1001-1084m).

Surface modeling was carried out through processing of the DEM, including the construction of the 50m-elevation contour map of the region, together with a slope map (0-90°), an aspect map (0°:N, 90°:E, 180°:S, 275°:W) and a hillshade map (external light source with azimuth: 315°, elevation: 45°). These images (fig. 12) can be useful in the further study of the archaeological sites and the settlement pattern analysis.

Dissemination of results. Creation of the Web-based digital archaeological map of Lasithi.

For the better dissemination of the results of the project, it was decided to serve all the information layers through the Web. In this way, the user was provided access not only to colourful static maps, but instead he was allowed to interact with the system, activating any number of information layers at any time at his own will.

Still, transferring data of different type, format and size to the cyberspace needed to take into account the size of files to be served (and thus the speed of data presentation), the Web publishing support, the client software support, software and hardware compatibility and the reliability (and security) of data serving within a user-friendly environment. ESRI's ArcIMS (version 3) proved satisfactory for the above requirements, providing handy tools within an Arcview-like environment.

ArcIMS was installed on a Windows NT 4.0 (SP4, 5, 6A) server. IIS was used as the Web server environment, together with a servelet engine, which was employed for the connection to ArcIMS map server. The manager facility of ArcIMS provided a Web-based interface supporting three main operations: author mapping, web page design and administrator services. The server side component of ArcIMS contains modules for processing the client's request and serving the spatial data (image or feature files), monitoring the requests' traffic and the automatic initialization of map services. On the other hand, from the client side, Java viewers (standard and custom) or HTML viewers are both capable on presenting the results of a request that has been processed by the server. Taking in account the advantages and disadvantages of the two viewers, it was decided to employ the HTML viewer as the client viewer. Although the HTML viewer does not exploit all the functions of ArcIMS, it covers all web browsers, it has a relatively simple interface, and it does not require any additional modules to be downloaded or installed. On the other hand, the Java viewer (~5MB) needs to be downloaded by the client and it requires the installation of JRE, without having full support by the Netscape browser.

Web publishing of large size (>100MB) satellite images was also made possible through the use of MrSid Image Server (http://www.lizardtech.com/), which was supported by ArcIMS. Prior to publishing, satellite images were compressed down to approximately 700-500KB using the corresponding compressor (MrSid Compressor). In this way, it became possible to incorporate a number of SPOT and Landsat images, together with the digital elevation model and its secondary products, as different information layers of the GIS platform, upon which the user is capable to overlay any other raster or vector format layer to obtain a visual comparison or correlation of the spatial data. A specific scale-dependent renderer was set to establish a minimum display scale for the satellite images (1:3,000), above

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which images rasterize the screen of the client.

The initial web page of the digital map is presented in a very simplistic form, consisting just of the coastline and the main and secondary road network. The user can activate any layer and query information included in the menu. The query results that satisfy the criteria of the client are presented at the lower portion of the screen, consisting of all the descriptive and spatial information that the administrator has allowed to be accessible by the client (fig. 13).

A number of tools are also available for the navigation of the map. They include zoom in and zoom out buttons, zoom to full or active extent, pan movement (top, bottom, left, right), overview map window, distance measure tool, unit definition, selection by line/polygon or rectangle, a query builder and identify tool. The user can print our any portion of the map resulting by a combination of layers or query result.

Future prospects

The next step of the project will be devoted to the analysis of the spatial information and the study of the diachronic settlement pattern analysis of Lasithi. Having accurate topographic and environmental information, the archaeological data will be processed through different GIS analytical techniques, such as viewshed analysis, spatial patterning and distribution, least cost surface analysis and site prediction. The incorporation of the satellite images could also lead to the spectral signature recognition of archaeological sites of the area.

A joint research and technology programme between the Institute for Mediterranean Studies - FORTH and the Institute of Archaeology - Chinese Academy of Social Sciences has been also initiated, aiming towards the study of archaeological sites and their management in semi-arid and desertification affected regions. The project will make use of the digital archaeological map of Lasithi and it will compare the environmental conditions of the location of the sites and their preservation status with those in the Xinjiang district in west China. A similar collaboration with the Université Catholique de Louvain, aiming towards the study of the Minoan cultural landscape resulting from the spatial characteristics of the peak sanctuaries, is under progress and will produce similar results for the whole island of Crete (Soetens *et al* 2001).

The digital archaeological map of Lasithi constitutes the first step towards a more systematic plan for the management and preservation of the cultural resources of Greece. The expansion of the project can be easily achieved, following similar steps to those that were used for the Lasithi district. The final product of this approach could 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. As all archaeological artifacts, from ceramics to megalithic monuments and from surface 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 that concerns the protection and preservation of cultural resources. Within the current era of digitization, the construction of a digital cultural world will broaden cultural policy frameworks & will strengthen the design of cultural policies (Sarris 2001:2).

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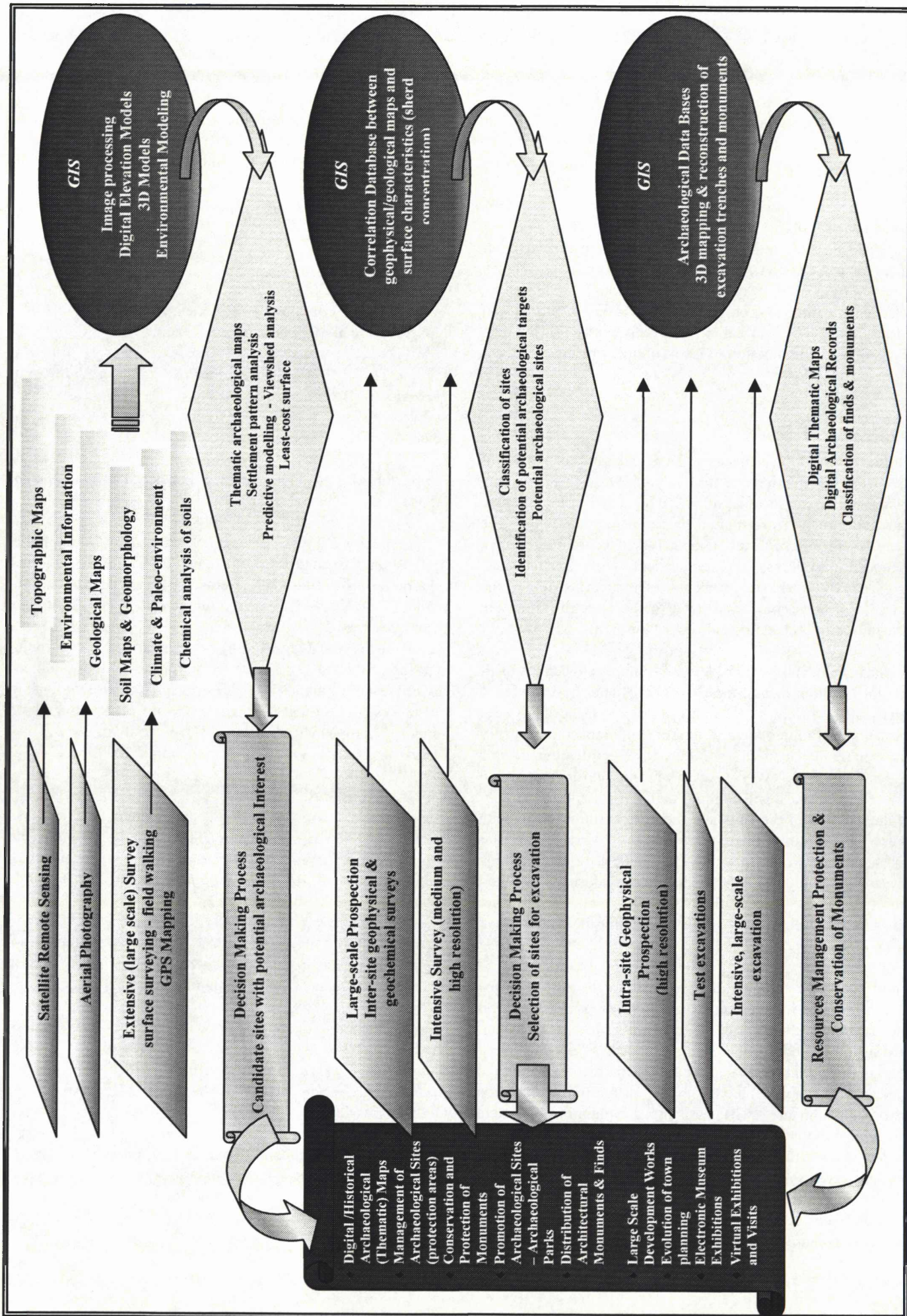
GIS
Image processing
Digital Elevation Models
3D Models
Environmental Modeling

GIS
Correlation Database between geophysical/geological maps and surface characteristics (sherd concentration)

GIS
Archaeological Data Bases
3D mapping & reconstruction of excavation trenches and monuments

Topographic Maps
Environmental Information
Geological Maps
Soil Maps & Geomorphology
Climate & Paleo-environment
Chemical analysis of soils

Thematic archaeological maps
Settlement pattern analysis
Predictive modelling – Viewshed analysis
Least-cost surface

Classification of sites
Identification of potential archaeological targets
Potential archaeological sites

Digital Thematic Maps
Digital Archaeological Records
Classification of finds & monuments

Satellite Remote Sensing

Aerial Photography

Extensive (large scale) Survey
surface surveying - field walking
GPS Mapping

Decision Making Process
Candidate sites with potential archaeological interest

Large-scale Prospection
Inter-site geophysical &
geochemical surveys

Intensive Survey (medium and
high resolution)

Decision Making Process
Selection of sites for excavation

Intra-site Geophysical
Prospection (high resolution)

Test excavations

Intensive, large-scale
excavation

Resources Management Protection &
Conservation of Monuments

- Digital /Historical Archaeological (Thematic) Maps
- Management of Archaeological Sites (protection areas)
- Conservation and Protection of Monuments
- Promotion of Archaeological Sites – Archaeological Parks
- Distribution of Architectural Monuments & Finds
- Large Scale Development Works
- Evolution of town planning
- Electronic Museum Exhibitions
- Virtual Exhibitions and Visits

Figure 1: Macro, medium and micro scale applications of Geographical Information Systems (G.I.S.) in archaeological research and CRM.
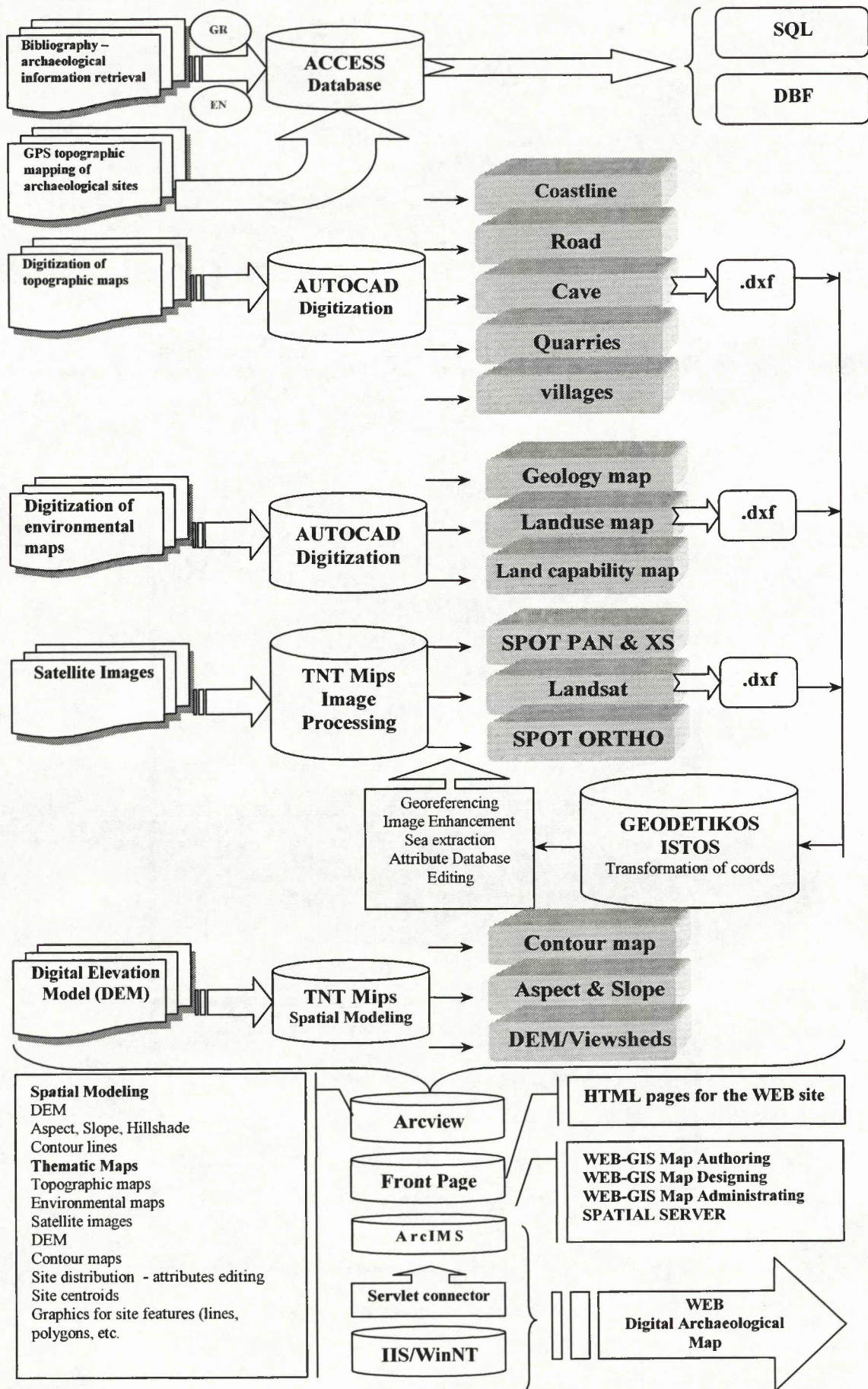
Bibliography – archaeological information retrieval

GR

EN

ACCESS Database

SQL

DBF

GPS topographic mapping of archaeological sites

Digitization of topographic maps

AUTOCAD Digitization

Coastline

Road

Cave

Quarries

villages

.dxf

Digitization of environmental maps

AUTOCAD Digitization

Geology map

Landuse map

Land capability map

.dxf

Satellite Images

TNT Mips Image Processing

SPOT PAN & XS

Landsat

SPOT ORTHO

.dxf

Georeferencing
Image Enhancement
Sea extraction
Attribute Database
Editing

GEODETIKOS ISTOS
Transformation of coords

Digital Elevation Model (DEM)

TNT Mips Spatial Modeling

Contour map

Aspect & Slope

DEM/Viewsheds

Spatial Modeling
DEM
Aspect, Slope, Hillshade
Contour lines
Thematic Maps
Topographic maps
Environmental maps
Satellite images
DEM
Contour maps
Site distribution - attributes editing
Site centroids
Graphics for site features (lines, polygons, etc.

Arcview

Front Page

ArcIMS

Servlet connector

IIS/WinNT

HTML pages for the WEB site

WEB-GIS Map Authoring
WEB-GIS Map Designing
WEB-GIS Map Administrating
SPATIAL SERVER

WEB Digital Archaeological Map

Figure 2: Flowchart of the actions and the activities that took place for the construction of the digital archaeological map of Lasithi district, together with the software modules that were employed.
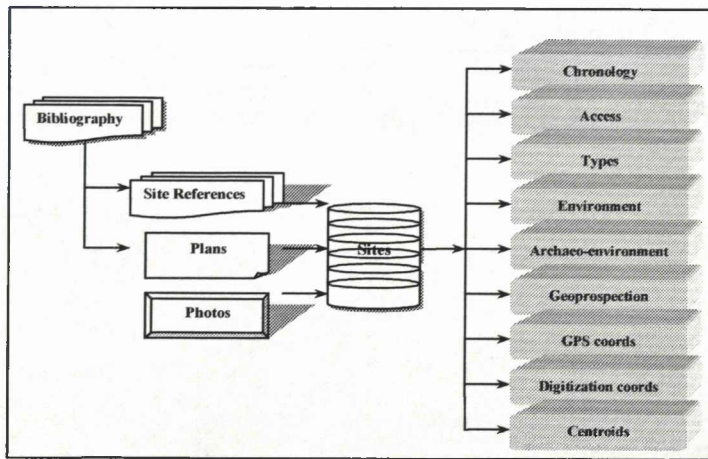
Figure 3: Analysis of the basic tables of the archaeological database, which was integrated in the GIS of the digital archaeological map.

Figure 4: Samples of the Access database forms that were designed for the registration of the archaeological information.
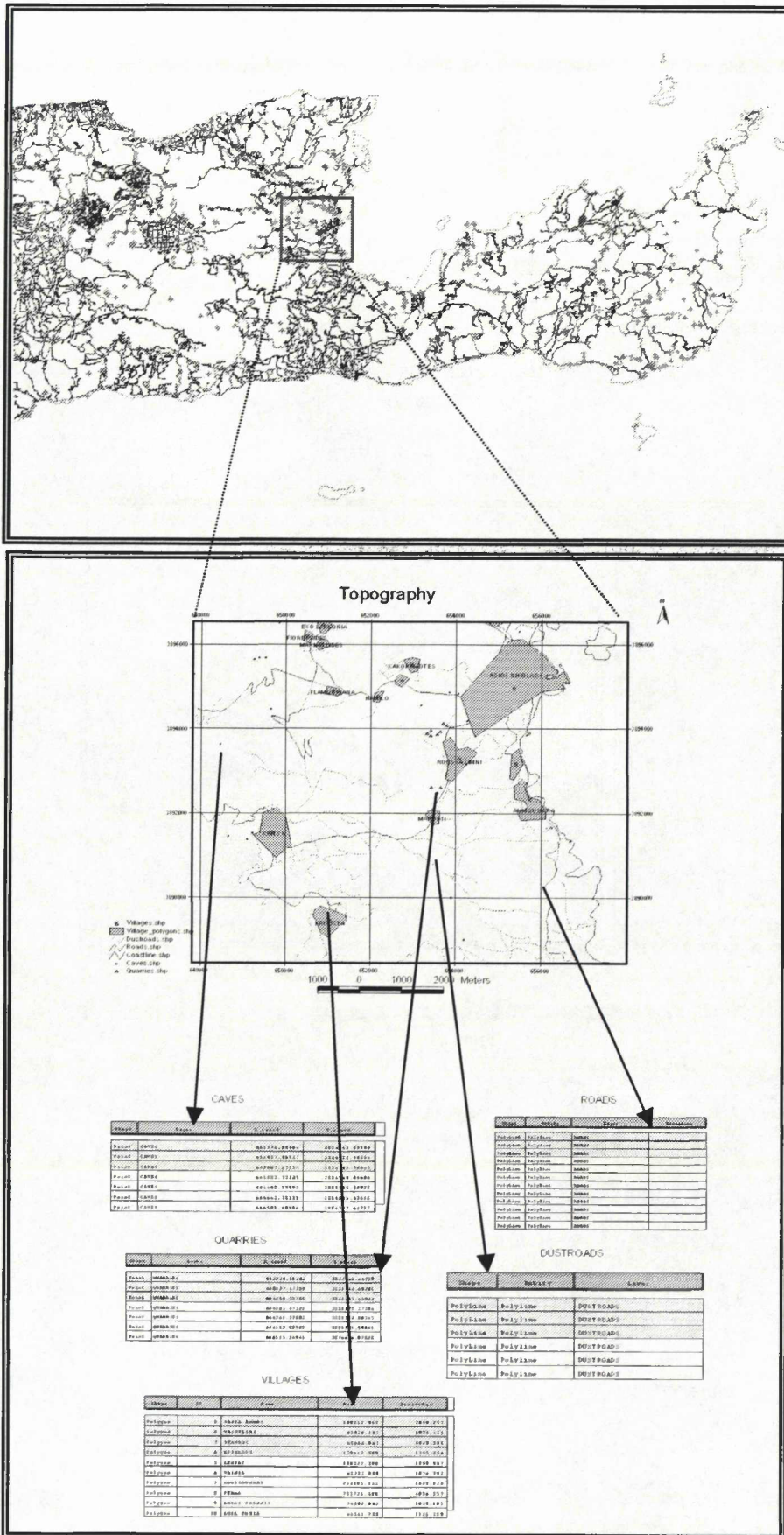
Figure 5: Site querry and the corresponding archaeological site report that the user can print for his own use.

Figure 6: Details of the GPS fieldwork activities. Recording at the site of Monastiraki – Katalimata (left) and Modi (right).

Figure 7: Archaeological site of Gournia

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Figure 8: Digitizing and mapping of topographic features of the Lasithi district.

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Geology Map
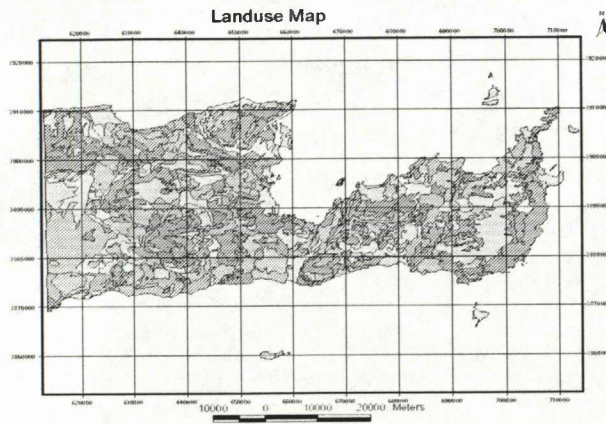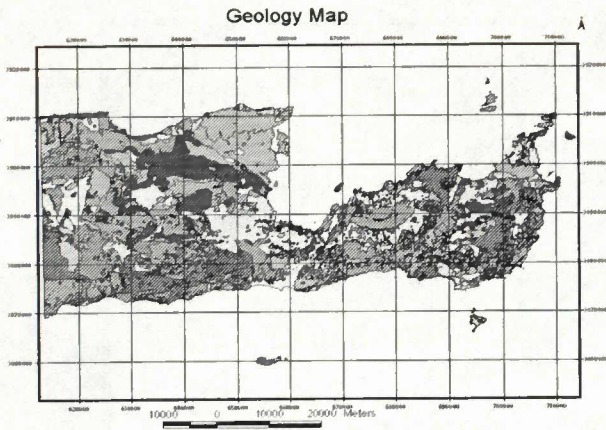
Landuse Map

Figure 9: Digital thematic maps. Geological map (above) and landuse map (below) of the Lasithi District. Different colors represent distinct formations.
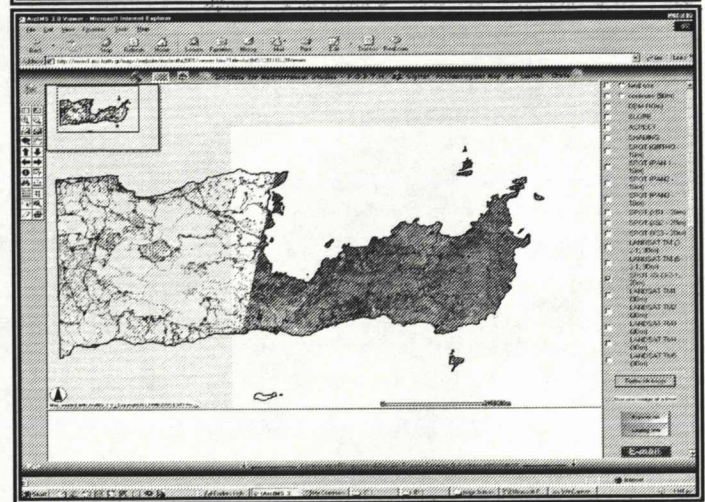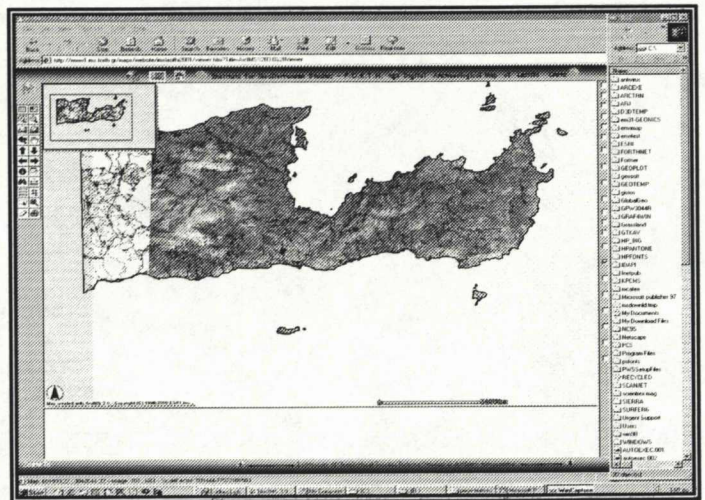
Figure 11: Real color (RGB: 3-2-1) Landsat satellite image (above) and pseudocolor SPOT XS image (below).
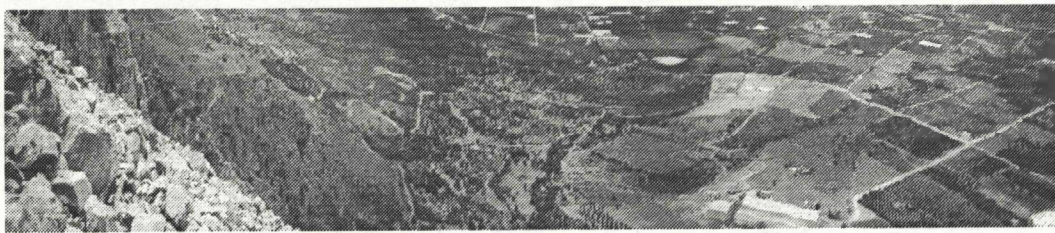

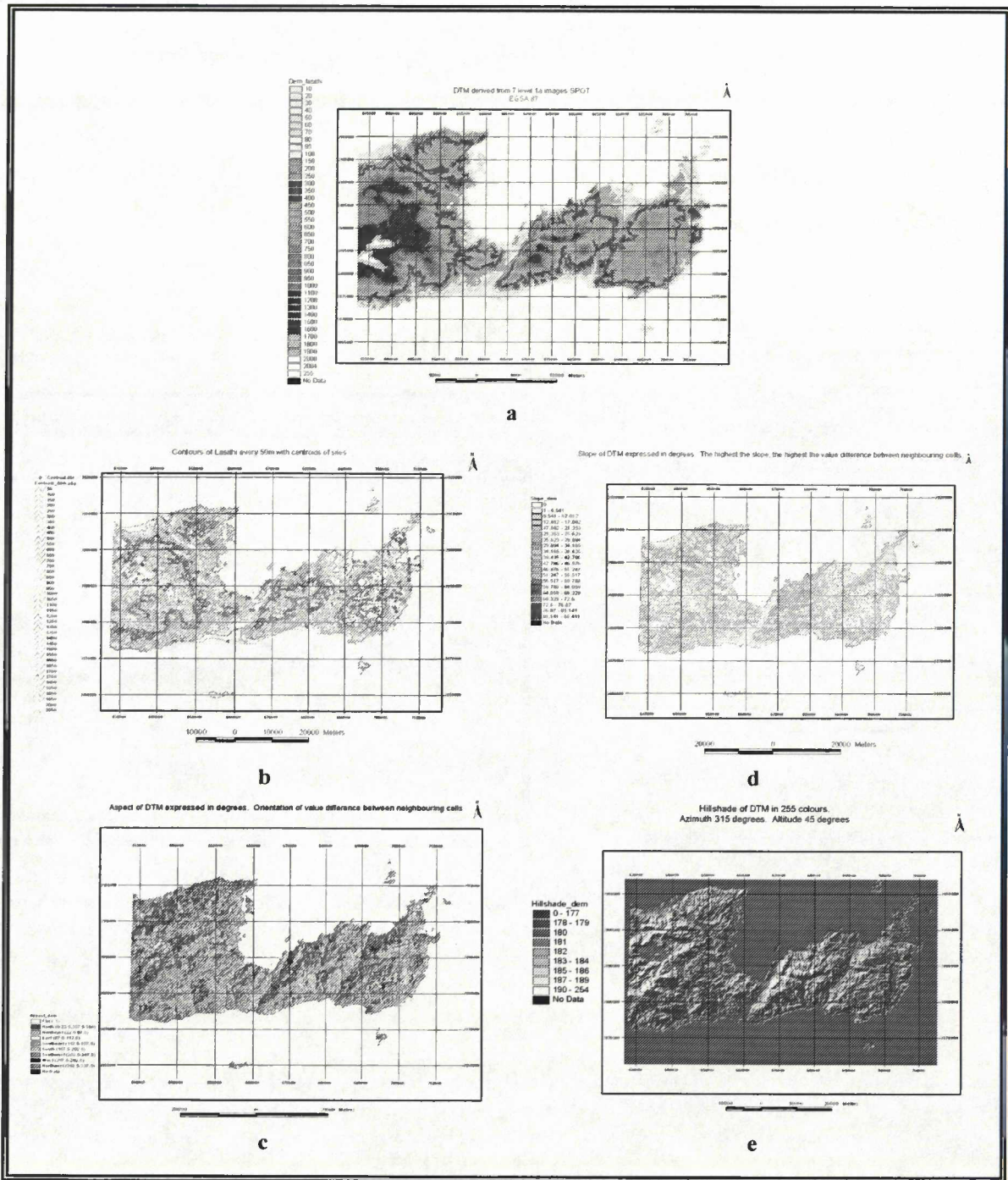*Figure 10: Panoramic view from Monastiraki Katalimata.*

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Figure 12.   a.   *Digital elevation model (50m)*
                             b.   *Elevation map (contours of 50m)*
                             c.   *Slope map*
                             d.   *Aspect map*
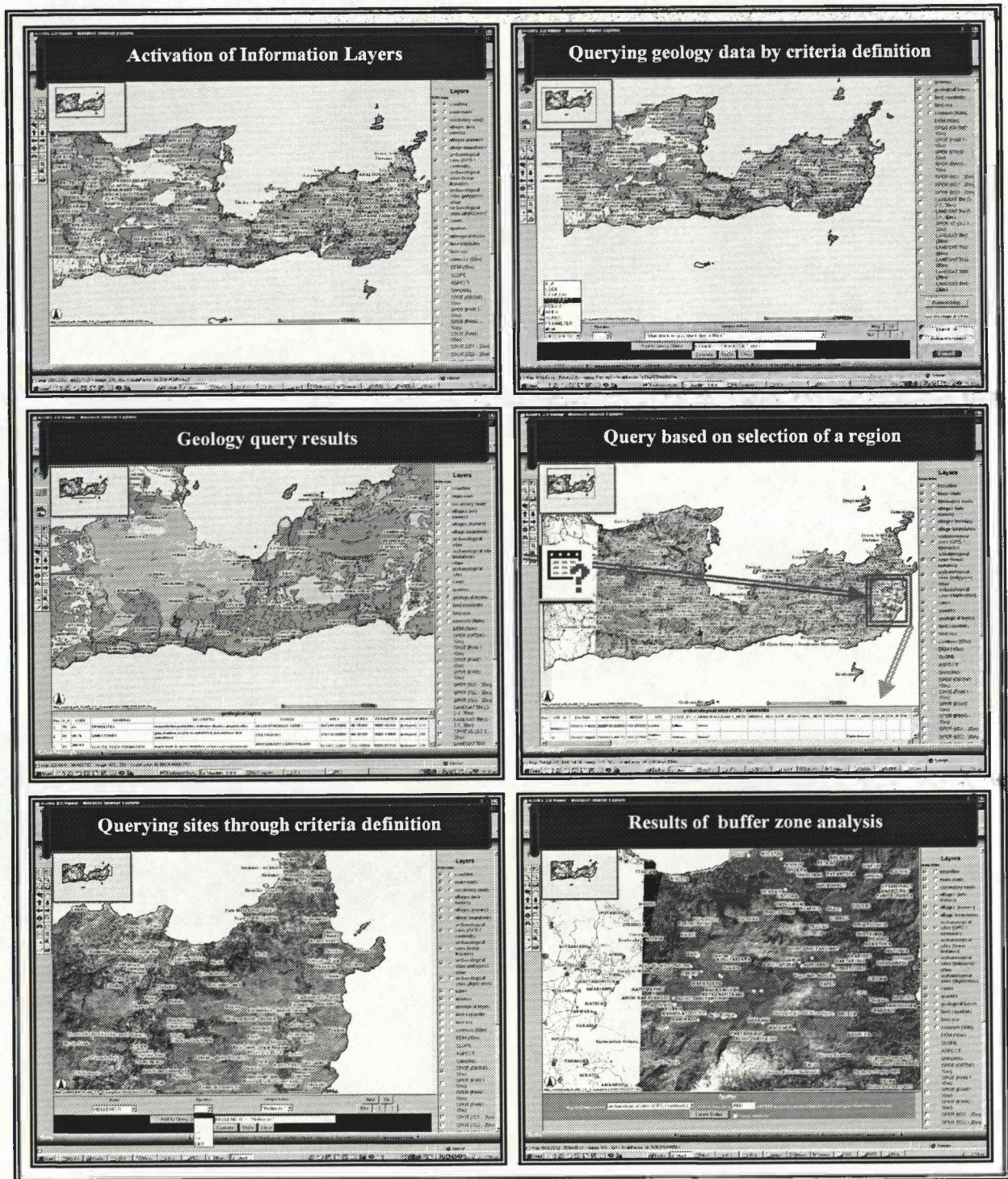   e.   *Hillshade map*

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Figure 13: Screens showing different functions of the Web-based digital archaeological map of Lasithi. The user is able through the GIS Web server to activate any number of information layers, perform queries based on criteria definition or selection of a region and even perform simple spatial analysis, such as the construction of buffer zones around archaeological sites. The results of the queries are displayed on the lower part of the screen, consisting of all the fields that the site administrator has allowed to be visible.