SPACE TECHNOLOGIES IN ARCHAEOLOGICAL RESEARCH & CRM OF SEMI-ARID & DESERTIFICATION AFFECTED REGIONS. EXAMPLES FROM CHINA & GREECE

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ABSTRACT/RESUME

Geographical Information Systems and Satellite Remote Sensing techniques were used as detection and monitoring means in the archaeological research and cultural resources management in semi-dry and desertification affected regions. Two pilot study areas were chosen, Lasithi district in Greece and Zhouyuan in China, in order to take in account the diverse nature of monuments and sites (with respect to the area coverage, building materials, conservation status, etc), and the environmental setting of the surrounding regions. Satellite and aerial imagery was mainly used to identify hidden cultural features. Archaeological and environmental data were merged together in a GIS to define the archaeological areas in risk due to natural and anthropogenic causes [1].

1. THE CULTURAL RESOURCES OF THE LASITHI DISTRICT, CRETE, GREECE

The recent mapping of the archaeological sites of Lasithi district (almost 1000 sites dated mainly to the Neolithic-Roman period) through digitization and high-accuracy GPS (differential static mapping with 2 sub-cm Ashtech Z-12 double frequency receivers) and the design of a digital Web-GIS archaeological map (http://www1.ims.forth.gr/maps/website/imslasithi2001) [5] [6], introduced a new input for the management of cultural resources in the region. The need for the development of a CRM model is of critical value, since Lasithi is one of the less-developed and remote districts of the E.U. and at the same time one of the most archaeologically investigated areas in Greece. One of the directions of the current research is devoted in the risk assessment of the archaeological sites, taking in account natural and environmental hazards, such as earthquake activity, fires, soil erosion, landuse practices, geological characteristics, climatic conditions, population and tourist pressure, etc. SPOT and Landsat TM images were used for extracting the spectral signatures of the archaeological sites. GIS processing was carried out based on the geomorphological, geological and cultural characteristics of the sites in order to define archaeologically sensitive locations having a variable index of conservation due to the environmental variables.

2. LASITHI: CULTURE & ENVIRONMENT

The archaeological database contains 972 records, the largest percentage of which (67.59%) is sites dated to the Minoan period, followed by those of the Roman period. 182 out of 972 sites have resulted from excavation research, while 667 sites have been located by surface survey techniques. The abovementioned sites were divided in 9 typological categories: habitation sites (29.63%), sites of unknown typology (26.13% - derived mainly from survey publications, where there is no detailed description of the typology), burial sites (20.16%), isolated buildings (11.21%), religious sites (10.80%), fortifications (7.20%), caves (7%), other categories (5.45% - containing sherds' concentrations, cisterns, roads, etc.) and production sites (4.73%). The main purpose of the above classification scheme was to specify a different conservation factor (or risk factor) for each type of site.

Although 320 out of the 972 archaeological sites were visited during fieldwork activities, site verification was achieved in just 209 of them. Thirty of these sites are fenced, 89 are well preserved, 96 are poorly preserved and 46 have been found destroyed.

The spatial correlation between the archaeological sites and geological/landuse maps indicated that the largest quantity of sites (37.24%) is located on tertiary deposits, followed by a percentage of 34.30% of sites located on hard limestone. About 61.51% of the sites are located on rounded summits, followed by 28.59% located on middle or lower slopes. A high percentage (34.73%) of sites were found to be in risk due to intensive agricultural activities.

Fire incidences recorded for the period of 1923-1997 by the Department of Forestry of the Ministry of Agriculture indicated a rising trend of forest/agricultural fires (an increase of more than 200% with respect to the early 1900s). Due to the lack of detailed data concerning the outline of the area of disaster, circular buffers representing the total area affected were created around the location of the corresponding villages, close to the epicenter of the fire location. Thus, a number of thematic maps were created indicating the size of the burned areas and the number of fires per modern settlement (fire frequency).

Thematic maps regarding the mean and mean maximum temperature, the mean relative humidity, and the mean and mean maximum rainfall levels, on a yearly basis, were created based on the archives of the National Meteorological Service of Greece. Climatic data have been collected by 12 meteorological stations located all over Crete for the period of 1931 up to 2000. Data were averaged per decade period and mapped through krigging interpolation processes to show the trends that exist throughout the island. Among other results, data clearly indicate the decrease of the rainfall levels and the corresponding increase of the mean temperature, which are critical factors in the desertification process (Fig. 1).

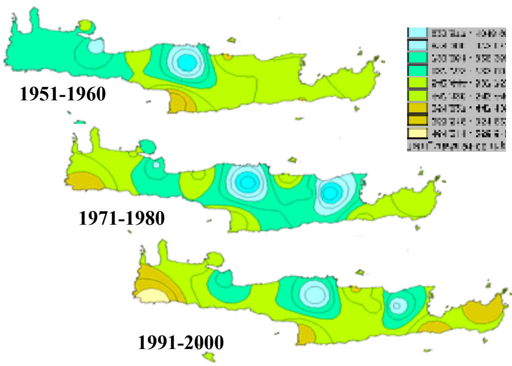

Fig. 1. Total rainfall levels for different decades (1951-2000).

Historical data concerning the earthquake activity before 1950 were collected by [2] & [3]. Data include the date, epicentre and magnitude of earthquakes before the 1950's. Data for earthquakes after 1950 were obtained by the web site of the Institute of Geodynamics of the National Observatory of Athens (http://www.gein.noa.gr/services/cat.html).

Only earthquakes with magnitudes larger or equal to 4.5 R were included in the database, in order to emphasize the macro-scale effects. The geographic coordinates of their epicenter (latitude, longitude) were transformed into Easting and Northing of the Greek Geodetic Reference System 1987 (EGSA'87). Earthquakes were classified in 8 main categories, based on their magnitude (4.5 - 4.9 R, 5 - 5.4 R, 5.5 - 5.9 R, 6 - 6.4 R, 6.5 - 6.9 R, 7 - 7.4 R, 7.5 - 7.9 R and >7.9 R). A simplified model showing the areas affected by the earthquakes was created by constructing circular buffers of different radii for each category of magnitude. For example, 3 buffer zones, 5km in width (a total of 15km from the earthquake's epicenter) were created for earthquakes of magnitude 4.5-4.9R. Buffer zones helped to distinguish the specific earthquakes that affected the archaeological sites at Lasithi. Examination of the 1st buffer zone (buffer zone A or high-risk area) around each epicenter indicated that 76,67 % of the sites fall within the high-risk zone. Buffer regions were also spatially joined with the location of the archaeological sites, in order to examine the type of sites mostly affected by the earthquake activity in the last century.

For a better refinement of the above-simplified model and the enhancement of the seismic risk analysis, the strong ground motion parameters (such as peak ground acceleration, velocity and displacement – PGA, PGV & PGD) were calculated based on the empirical attenuation relations of [4]. According to the specific relations, PGA is a function of the moment magnitude (M_W), the epicentral distance (R) and the ground conditions (S). For our purpose, PGA was calculated for 4 epicentral distances (R=5 km, 10 km, 50 km and 100 km), taking in account shallow depth earthquakes (0<h<60km) of the mainland of Crete and the UBC [7] ground classification scheme (3 classes B, C and D with corresponding S values of 0, 1 and 2) (Fig. 2).

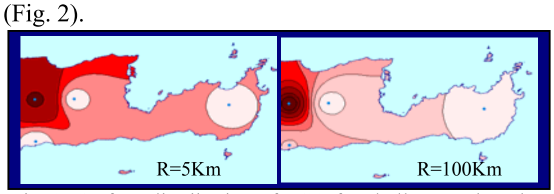

Fig. 2. Surface distribution of PGA for shallow earthquakes.

Finally, the proximity of the archaeological sites to modern topographical features was examined through the creation of buffer zones of different width along the main and secondary road network, the coastline, the modern villages, the certain and possible fault lines, etc.

3. ARCHAEOLOGICAL RISK ASSESSMENT. NATURAL & ANTHROPOGENIC FACTORS.

Modelling of the archaeological risk areas was performed through the use of simple Boolean operations and weighted procedures. The available data were classified in different groups, each defining a specific parameter of "risk", such as anthropogenic, erosional, seismic, etc. Data were statistically analysed and weights of influence were defined for each parameter and group of variables, depending their contribution in the archaeological risk. For example, soil erosion was defined based on the slope, land use, parent material, soil depth, rainfall levels, proximity to the coastline and water reservoirs, etc. Weights of influence were based on various tests and the outcome of each process was always analysed with respect to the actual data, namely, the observed preservation status of each site, especially those falling in the high-risk category. Further research is under progress in an effort to include as many parameters as possible in an effort to refine the risk-zone definition model and depart from the simplistic approach of other similar studies (Fig. 3).

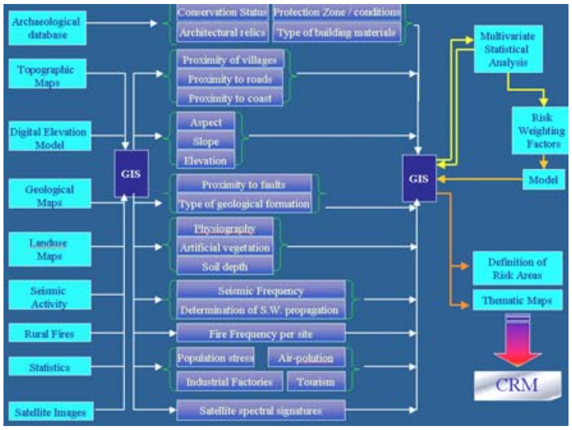

Fig. 3. Design of a sophisticated archaeological risk-area definition model, based on a GIS approach.

4. ARCHAEOLOGICAL IMPLICATIONS OF THE ZHOUYUAN SITE, CHINA.

Zhouyuan site is located on the western part of Shaanxi province, China. The site is limited by Qi mountain in the north and the Wei river in the south, while the Qi river is running through the site. Under the threat by the Rong and Di national groups, the Zhou people fled from their hometown Bin to the wider region of Zhouyuan, which remained the political center of the Zhou people, until king Wen moved his capital to Feng in the late period of his reign. During the western Zhou dynasty (11-7B.C), Zhouyuan kept a special political position as the holy capital.

It is in Zhouyuan that the Zhou's political power spread quickly and developed into a main adversary of Shang dynasty during the reign of three generations of kings, namely Gugong, Jili, King Wen and the defeated Shang dynasty. Since the 1950's, several decades of surface surveys and excavations have identified the extent of the site and the distribution of main vestiges of Zhou culture. Zhouyuan site covers roughly 56 sq km, 7.5 km in length and 7.5km in width.

Pre-Zhou cultural remains (relics of houses, pits, and a cemetery attributed to the culture of king Gugong, Jili period) are mainly situated in the western part of site, such as Wangjiazui Village, Hejia Village and Licun village. Liujia Cemetery includes 20 tombs dated to the late period of Shang dynasty. These remains are the most important material, used to study the transformation of the Zhou culture.

In the Zhouyuan site there are a lot of group foundations of superior western dynasty buildings, such as Zhuangbei, Shaochen, Qizhen, Yuntang, Qijia, Fengchu, etc. These building remains include earth-trampled platforms, foundations of pillars, stone aprons, stone roads, cover tiles, bed tiles, and other structural characteristics. These buildings probably belong to the royal or high rank nobles.

The Fengchu foundation of group A consists of an earth-trampled platform, 45.5m in length, 32.5m in width, with a total area coverage of 1469m^2, including a hall, houses, a forward yard, back yards, corridors and guard houses. The two pits, in which the important Zhou oracle-bone inscriptions have been found, are located in the second house of the western section.

Yuntang foundations of buildings were excavated in 1999-2000. Foundations F1, F2, F3, F8, F5, with high earth-trampled platforms and a circle wall, integrate into a group of closed, symmetrical buildings. Among them, the outline of F1 looks like a "V"-shape, 22m in length and 16.5-13.1 in width. A hall, surrounded by some houses, is located on the center of the platform. There are steps at the different sides of the platform (one step at the east, west and north fringes and two steps at the south). F2 and F3 are located SE and SW of F1 correspondingly, having a length of 11.6m and a width of 8.5m. A janitor's room is located in the middle of the southern rim of the forward yard. A "U"-shaped stone road connects the main platform with the gate and janitor's room in the yard. F5 is located west of F1. The group of buildings suggests that it is probably related to an ancient temple.

Some cemeteries are scattered in Licun, Qijia, Yuntang, Zhuangbei and Huangdui villages. Bronze ritual vessels, weaponry and precious jades have been found in some large size tombs, while only pottery has been found in small size tombs.

In Zhouyuan site, roughly 70 hoards were discovered, including more than 600 bronze vessels, dating from early to late period of western Zhou dynasty. All the hoards can be dated back to the late period of western Zhou. The appearance of the bronze hoards can be related to the escape of bronze-owners during the invasion of Quanrong nation from northwestern and the resulting collapse of western Zhou dynasty.

These bronze vessels were made exquisitely and they are well preserved. They include a lot of important inscriptions that constitute the main documentary of western Zhou dynasty, such as the inscription of Shiqiang plate, recording the main political affairs of 6 kings of the early western Zhou dynasty and the history of 7 generations of the Weishi family.

5. ZHOUYUAN: SATELLITE IMAGERY & GIS IN ARCHAEOLOGICAL RESEARCH

Landsat TM imagery and aerial photographs were systematically employed for the detection of archaeological relics and photogrammetric mapping of the region. In the Zhouyuan site, all the building foundations and tombs are made of rammed earth, which is very dense and has smaller moisture content than the rest of the soil. Since almost all the crops on the Zhouyuan site have been harvested by middle October, leaving the ground mostly exposed, near and middle infrared Landsat TM images (bands 4, 5, 7) could distinguish the tiny differences in humidity of the surface layers of the soil. Other false colour combinations (bands 7, 5, 4) and image enhancement techniques were also used to identify a number of linear features of high reflectivity. Many of the brighter linear features found on the autumn TM images, were produced by archaeological remains (rammed earth structures of building foundations or tombs), since the rammed earth is drier than the rest of the soil (lower absorption of the infrared bands).

GPS geodetic stations were used to obtain high accuracy GCPs (Ground Control Points), which were ultimately used to create photogrammetrically a new map of the Zhouyuan region. The GCPs' coordinates were used together with stereo aerial photographs to create a 3-dimensional imagery model of the site. The different topographic layers (elevation contours, rivers, roads, modern villages and orthographic aerial images) were imported to a GIS platform to create an interactive Zhouyuan archaeological information system. Finally, TM images were also georeferenced and resampled in order to be fused with the orthographic aerial image (Fig. 4). In this way, the TM images and the orthographic aerial images were combined together to form an image of high ground resolution and wide spectral resolution, which was used in the interpretation of the surface characteristics of the landscape. At the end, all the geographically referenced information and data were used as an input to a GIS system for further analysis.

Fig. 4. Synthesis of aerial and Landsat TM imagery.

6. REVEALING THE INVISIBLE

Processing of the above data and photo-interpretation of the images was able to detect a number of cultural features in the Zhouyuan site, including some important palace foundations, two of which were excavated, bringing to light important archaeological features (Fig. 5). Photogrammetric techniques were also used to merge the low-resolution Landsat TM images with higher resolution orthophotos, enhancing the analysis of the landscape of the region.

Fig. 5. A set of palace foundations, closed by some palace walls, with white circles representing pole bases.

Further analysis is under progress, including the spatial analysis of the distribution of the tombs, palace foundations, bronze hoards etc., in an effort to infer the locations of other remains which will contribute to building a more synthetic image of the cultural landscape of the Zhouyuan site.

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