Advances on Remote Sensing for Archaeology and Cultural Heritage Management

Edited by
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CD–Rom included
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Preface

In the last two decades, the increasing development of ground, aerial and space remote sensing techniques and the tremendous advancement of Information and Communication Technologies (ICT) have focused a great interest in the use of remote sensing and ICT for supporting cultural heritage applications. In particular, the improved spatial and spectral capability of active and passive sensors has opened new challenging prospective for the use of EO (Earth Observation) technologies not only for the investigation but also, for the management and valorisation as well as for the monitoring and preservation of cultural resources. Additional challenges to this field of research are related to the crucial importance of the integration of remote sensing with other traditional archaeological data sources, such as aerial photo, field surveys, trials, excavations and historical documentation. Such an integration requires great efforts aimed at creating a strong interaction among archaeologists, scientists and managers interested in using remote sensing and ICT for supporting cultural heritage applications. Moreover, the impact of the past human activity upon the environment is an important issue not only in the field of archaeology, but, also for botany, forestry, hydrology, soil and geo-science. Thus, the knowledge on ancient landscape and human settling provides invaluable information for better understanding human-environmental interaction, climate change, and Earth’s system.

The continuous collaboration among scientists working in different fields of Cultural Heritage can contribute to take benefits from the new sensors, techniques and methodological approaches for a wide range of investigation and application fields. A constructive and complementary multidisciplinary approach can open a revolutionary scenario unthinkable several decades ago.

In this cultural framework, in 2007, representatives of two Italian research institutes (IMAA, and IBAM) of the National Council Research (CNR) created the EARSeL Special Interest Group (SIG) on Remote Sensing for Archaeology and Cultural Heritage (Re.Se.Ar.C.H.). The SIG was formally launched in June 2007 at the annual EARSeL Symposium held in Bozen. Since then, the group has tried to foster interaction among archaeologists, scientists and managers interested in using remote sensing data (from ground, aerial and satellite) and Information Technologies to improve traditional approach for archaeological investigation, protection and management of Cultural Heritage.

In the context of the EARSeL Re.se.Ar.C.H. activities we have been pleased to organize the 1st International Workshop “Advances in Remote Sensing for Archaeology and Cultural Heritage Management”. The event has been carried out with the patronage of UNESCO and MiBAC (Italian Ministry of Cultural Heritage and Activities), and the sponsorship of ESA, BELSPO, ASI, CNR, BNL and the private company Geocart srl.
During the four days of the workshop more than 100 papers will be presented and discussed by over 244 authors coming from 25 different countries. A fascinating and rich variety of issues, applications and study cases emerges from the papers.

The Proceeding book includes 93 papers divided in 9 sections which focus the following topics:

- Aerial archaeology from the historical photographs to multispectral and hyperspectral imagery.
- Data processing issues and new perspectives of use of active airborne data (lidar, SAR);
- Multi-scale satellite imagery processing aimed at identifying, observing and interpreting archaeological features for different surface characteristics;
- Detection and spatial reconstruction of sub-surface remains by using GPR, magnetic and electrical tomography
- Opportunities and limits in the integration of space/air borne and ground remote sensing techniques.
- 3D visualization and Virtual reconstruction of landscape and sites.
- Landscape archaeology and palaeo-environmental studies based on Remote sensing, GIS and ICT.
- The integrated use of RS, GIS and ICT, for the management of cultural and natural heritage, rescue archaeology.
- The role played by the international archaeological missions in the development of new methodologies and the encouraging a widespread use of the new technologies within the archaeological community.

Rosa Lasaponara

EARSeL Re.Se.Ar.C.H. SIG Chair

Nicola Masini

EARSeL Re.Se.Ar.C.H. SIG Co-Chair
Presentation

I would like to express my warm thanks to the organisers of the “Advances in remote sensing for Archaeology and Cultural Heritage and Management” International Workshop, promoted by the Italian National Research Council through IBAM – Institute for Archaeological and Monumental Heritage (Cultural Heritage Department) and IMAA – Institute for Environmental Analysis Methods (Earth and Environmental Department).

The fact that I have chosen to express my appreciation in this presentation has nothing conventional or ritual about it – because, among other reasons, these words are written in Hierapolis-Pamukkale in Turkey, where I am involved in managing the Italian Archaeological Mission. Here a complex project for the study and recovery of cultural heritage is being conducted in one of the most extraordinary archaeological sites in the Mediterranean, where the monuments of the ancient city are set in the natural context of white travertine formations.

As well as archaeologists and architects, traditional figures in a site that is most typical of classical archaeological contexts, Hierapolis is currently playing host to a multidisciplinary team of scholars. Their research makes constant use of Geographical Information Systems, geomatics, satellite images enhanced by orthographic projection, and GPR-assisted geophysical prospections; the marble decorations of the Roman theatre are being surveyed with manual laser scanners (Handyscan); the territory surrounding Hierapolis, with its farms, sanctuaries and aqueducts, is being revealed by traditional surveys, even in the most rugged terrain, where however the use of GPS technology enables precise positioning of the archaeological items.

IBAM researchers are playing an important role in these activities, characterised by real and extensive interaction between “humanistic” and scientific expertise, thereby re-establishing the unity of research, too often fragmented as a result of “academic” practices in which disciplinary boundaries serve merely to ensure the self-replication of groups, and have little to do with the need for scientific openness and innovation.

The Atlas of Hierapolis, edited by myself, Giuseppe Scardozzi (IBAM, CNR) and Antonia Spanò (Politecnico of Torino), and recently published by Ege Yayınları of Istanbul, is a concrete example of what a multidisciplinary strategy can contribute to the study of an ancient city and its surrounding territory.

In the Conference held in Rome on Remote Sensing, Nicola Masini made a fundamental contribution in both scientific and organisational terms. The variety of methods proposed, the broad participation of international research bodies and the application of technology to the study of cultural heritage in all countries (Perù, Yemen, India etc.) all served to fulfil the prospect of a
“Global Archaeology” encompassing all cultures of the planet. The participation of UNESCO was thus of great importance, since it can now avail itself of these technologies in order to promote the conservation of the world’s natural and cultural heritage, increasingly threatened by uncontrolled development. Today, working to combat the forces that tend to annul cultural diversity, to prevent unauthorised excavations driven by the venal interests of the illegal market in works of art and to conserve historic landscapes involves the use of geophysical prospections, multispectral and hyperspectral sensors and satellites images; all of which are technologies that were originally developed for military purposes and subsequently transformed into tools for the study and safeguard of cultural heritage.

Lastly I would like to stress another positive contribution of this Convention, regarding the 3D Visualisation and Virtual reconstruction of landscape and sites. The Iraq Project, promoted by Roberto De Mattei and conducted by researchers from IBAM, is a good example of how the reconstruction of items that were damaged during conflict plays such an important role in the recovery of cultural heritage and the recognition of its true value. Technology must also contribute to the diffusion of knowledge to the wider public and raise public awareness in support of cultural heritage: the digital reconstruction of landscapes and monuments obliges researchers to step out of their “specialist” confines and illustrate the results of their labours.

Today, communication technologies represent the most innovative aspect of many scientific disciplines, and this is especially true of the Cultural Heritage sector, where there is a growing demand from the public, at the local community level, for education and the management of cultural heritage with a view to tourism. The Acts of the Conference take account of all these aspects and, in the variety of the many contributions, make up a fascinating and complex mosaic.

Francesco D’Andria
Director of IBAM – CNR

Hierapolis – Pamukkale (Turkey)
Firstly I want to thank Earsel that promoted this workshop and the Organizing Committee for the successful job they made.

This workshop is successful not only for the number of participants and the quality of talks but overall because it offered different scientific communities the chance to meet and to discuss actual achievements and future challenges and perspectives.

In my opinion new observational technologies can play a key role in the discovery, assessment, monitoring and management of cultural heritage. This workshop is the forum where researchers engaged in cultural heritage management and the ones engaged in earth observation meet each others both to present recent results and to put the basis of a tighter cooperation.

My personal background is mainly the development and use of earth observation techniques both satellite and airborne and ground based. In last years there was an exceptional improvement of our observing capability, that is based on the development both of new sensors and computing capabilities. By this way new frontiers of applications are opened and they will be further enlarged by new missions and sensors that have been scheduled or are going to be developed and will become operational in next decade.

In my opinion one the most challenging frontier of Earth Observation is the application of new observational techniques in the field of cultural heritage. The exploitation of these capabilities requires a common work to be performed by people involved in observing techniques with people dealing with archaeology and cultural heritage management.

This is one of the main reasons that make this workshop so interesting. This is an important stone along the road of a cooperation that has to be straightened and stabilized.

In my opinion it is necessary to give continuity to this workshop scheduling it at a fixed periodicity, so to enlarge the research community involved in the share different competences and experience in the field of cultural heritage management.

If such a decision will be assumed, just now IMAA-CNR feels engaged to support future workshops.

Vincenzo Cuomo
Director of IMAA – CNR
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Satellite imagery for archaeology: data processing methods and study cases
Following O.G.S. Crawford
satellite images and field archaeology in Sudan

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ABSTRACT.

The Middle Nile Valley is rich in fortified settlement remains. In the region between Abu Hamed and Atbara they date from the time of the Meroe Kingdom (richly described by Herodotus) to the British–Egyptian condominium. One of the few who did try to examine these territories was O.G.S. Crawford whose reports fill two monumental works published in the 1950s (Castles and churches of Middle Nile Region; Fung Kingdom of Sennar) which are for many scholars the only source of data for this part of the world. Although aerial photography was Crawford’s specialization he had no opportunities for this in Sudan although he underlined its necessity and usefulness in his publications.

More than 50 years has past and knowledge about the archaeology of this region has not changed much. One of the objectives of our project was to record the remains of fortresses which lie on both sides of the Nile. Documentation includes photo galleries, sketch maps and plans showing arrangements of fortresses, detailed descriptions of walls and the character of each fort’s location. Due to administrative restrictions as well as a lack of access to light aircraft we were not able to follow Crawford’s idea to carry out aerial survey there. Instead we decided to use the satellite images available on the Internet. A detailed interpretation of them within the fortresses’ catchment areas allowed us to discover/identify plenty of archaeological sites (some of them described by Crawford but most not mentioned at all).

We achieved a very good correlation between the results of the satellite image interpretations and field walking. The experience we already have allowed us to interpret better the features visible on the satellite images.

Our project shows the usefulness of satellite images in archaeological research in such difficult, barely accessible regions. The rapid economic development in Sudan in recent years raises a lot of new problems with the management and protection of archaeological heritage. Access to satellite images (and with better resolution at our disposal more sites may be identified) might be a good solution for all working in the management and protection of archaeological heritage there as well for an archaeologist carrying out ‘pure’ research. But it is important to note, based on our experience (and not only), that effective interpretation of satellite images needs archaeological knowledge of the area under review. It is necessary to study the results of previous archaeological surveys and excavations in particular. Also one needs some knowledge about the current farming practices of local communities which leave traces in the landscape.

1 INTRODUCTION

The Middle Nile valley is rich in fortified settlement remains. In the region between Abu Hamed and Atbara they date from the time of the Meroe Kingdom (richly described by e.g. Herodotus) to the British–Egyptian condominium. However, regardless of such archaeological resources this region has never been under close archaeological investigation. The first reports of well preserved fortresses, churches and vast cemeteries were made as early as in the 19th century (e.g. Caillaud, 1826), but these spectacular descriptions did not manage to raise more interest in the archaeology of the region. The first archaeologist who was seriously interested in the middle Nile river was O.G.S.Crawford. His initial visits to Sudan were connected to his involvement in excavations led by Sir Henry Wellcome in 1913–1914 (at sites in Jebel Moya and Abu Geili – Crawford 1955). His fascination with Sudan returned when he retired – and Crawford visited Sudan in 1950, in 1951–1952 he worked on a project financed by the British Academy (e.g. Arkell, 1959). He published two books dedicated to selected aspects of archaeology in Sudan: Castles and Churches in the Middle Nile Region (1953a) and The Fung Kingdom of Sennar (1951). His articles – Field Archaeology of the Middle Nile Region (1953b) and Christian Nubia: a Review (1947) – are likewise extremely valuable. Crawford’s work, in a systematic way, presented the archaeology of the Middle Nile region, particularly sites dating from the ‘Christian’ period and the Fung Kingdom.

2 O.G.S. CRAWFORD’S FIELD ARCHAEOLOGY

O.G.S. Crawford was never a conventional archaeologist for whom archaeological excavations were one of the most important stages of the investigation. From the start of his professional career he emphasised the need to develop field archaeology. Such an approach in the first half of the 20th century was understood as study of archaeological sites though it did not include excavations (Daniel, 1978). The study of archaeological sites was supposed to be based on the search for and discovery of a site, followed by in-depth documentation, measurements, sketches and mapping. Detailed maps of sites were one of the most important
achievements of British field archaeology. Various methods were introduced into the study of sites e.g., phosphorus, resistivity method and ground penetrating radar and, in the 20th century, aerial photography. Photographs provided very precise information regarding the spatial structure of a site, its location and environmental context. A very important aspect of field archaeology was the fact that the methods were complementary, many different methods together gave a better overall picture of the site.

O.G.S. Crawford’s experience in field archaeology started at the beginning of the 20th century. Hikes and bicycle tours across Salisbury Plain in the search for archaeological sites and their recording as one field archaeology method led Crawford to consider the difficulties and bonuses of this method of field prospection. He believed that for archaeological analysis the location of a site is especially important, as is its precise description and identification of its spatial structure. In the realisation of his research project in Sudan in 1951–1952 he decided to use this method in order to, in a relatively short period of time, get as much complete information about the sites as possible. Crawford also wanted to show that the application of this method could bring good results there, as in Great Britain (Crawford, 1953b). He also suggested ways to extended the range of research tools in Sudanese archaeology in contrast to the dominant model based mainly on excavations.

The publication of Crawford’s research results has enabled his method to be refined. In Sudan Crawford travelled on both banks of the Nile visiting numerous sites. An important element in his work was interviews with local communities which gathered a lot of information. The foundation of his documentation was a detailed description which contained information about recorded artefacts as well as the geological-geomorphic conditions. He also analysed natural processes which occurred in the past and therefore affected the preservation of a particular site. The chronology of archaeological material was also recorded. Detailed sketches/plans and photographs of a site were likewise a vital element in the documentation. Thanks to this material it is now possible to locate these sites in the field (Crawford did not have suitable maps at his disposal), to review their current condition and ascertain the factors which affected a site. At many sites Crawford mentioned (e.g. Crawford, 1953a) that the descriptions would have been more precise he had appropriate aerial photographs to his disposal.

O.G.S. Crawford did not utilise the whole range of methods that field archaeology actually encompasses in his project. This is due to two reasons. Firstly, it was impossible to incorporate all methods, i.e. aerial survey. Secondly, his project lasted only a short period (11.12.1951–3.03.1952). We can suppose that the first survey of the terrain could have become, in time, the basis for the realisation of further, more detailed projects. As history shows no detailed archaeological surveys in the area were undertaken, and any further publications (e.g. Edwards & El-Amin, 2000; Wiewióra, 2007) were based on data and material published by Crawford.

3 FOLLOWING O.G.S. CRAWFORD

O.G.S. Crawford’s approach to archaeological survey and his findings from the middle of the 20th century became the inspiration for the project entitled Fortresses of Sudan: following O.G.S. Crawford (http://knsa.archeo.edu.pl/sudan). The aim of the project was to ascertain the current state of the fortresses which dated from the Christian period and to record archaeological sites in their catchment areas. In following Crawford’s footsteps various techniques were used: the land was surveyed using GPS and Laser Distance Meter, photographic documentation was made, descriptions recorded and interviews with local communities were carried out. The plan of the project included aerial photography. However, due to numerous organizational and financial problems aerial reconnaissance was not accomplished. Therefore, as Crawford, neither did we have aerial photographs at our disposal. In an effort to fill this gap we decided to investigate the potential of the satellite images available on Google Earth.

4 POTENTIAL OF SATELLITE IMAGES FOR FIELD ARCHAEOLOGY IN SUDAN

Satellite images have been used in archaeology since the 1970s (e.g. Ebert, 1989). However, poor image resolution limited their use in this field whilst the satellite images currently available show the Earth’s surface in much higher resolution. Their usefulness in archaeology likewise is increasing all the time.

In his analysis of the current application of satellite images in archaeology Rog Palmer proposed the distinction of two models of action. The first is connected with an in-depth computer analysis of the data which uses tools such as datafusion, edge detection, edge thresholding, edge thinning, line extraction etc., to characterise individual pixels. The appropriate procedures permit an objective interpretation of archaeological resources in the context of their environment. The second model is based on experience gathered so far aerial photography interpretation and is limited to looking at the satellite image of the Earth’s surface, in the same way one would view an ordinary aerial photograph.
The first model requires sophisticated knowledge in the field of computer analysis of data recorded via particular sensors and the appropriate software. It is quite difficult then to see how it could be used by the majority of archaeologists. The second model however requires archaeological knowledge of the chosen region and a certain level of experience of photograph interpretation. It was due to this perspective that the second model was used in our project.

Before the field walking stage of the project satellite images of selected forts and their catchments which were available on Google Earth were analysed. In this way we were able to identify various archaeological sites including: burial mounds, cemeteries, the stone foundations of buildings and numerous traces connected to current farming practices (the remains of irrigation systems, areas where harvested crops could be dried, kraal for livestock etc.), roads.

5 PRELIMINARY RESULTS OF THE PROJECT

In February 2008 within the framework of the project selected fortresses from the ‘Christian’ period with numerous signs of equally intensive use later were investigated. 12 fortified architectonic features were chosen (figure 1). Analysis of satellite images beforehand enabled their fast identification in the field (in Sudan access to detailed maps is still a problem). Measurements were made as were detailed descriptions and photographic documentation, beds of raw materials used in the construction of the fortresses were identified, information acquired earlier was compared to the current situation, interviews with local communities were carried out and questions were asked on how the sites were viewed in contemporary culture. The comparison of earlier information on the forts and their current state enabled the determination of quite obvious physical deterioration and not only. Worth noting is the fact that Crawford’s documentation is, to a large extent, still relevant (even allowing for the destruction suffered over the last 50 years), this is not true of plans which were made later.

As mentioned earlier, in the preparatory stage, on the basis of satellite imagery, we identified approximately 100 points as potential archaeological sites within the catchment areas of the selected fortresses. As we knew their exact location (having the satellite images and geographical coordinates instead of maps) verification in the field was made possible. The results of this procedure were startlingly positive, as the majority of the points did turn out to be traces of past human activity (figures 2, 3). Part of the ‘archaeological sites’ visible on the satellite images turned out to be traces of current farming practices in the zone bordering the desert. Of the sites described by Crawford (not including the forts) only part were verified in the field – the remainder had been destroyed (e.g. the cemetery in El Koro).

![Figure 1. Map of Middle Nile Valley between Abu Hamed and Atbara – the project area](image)

6 CONCLUSIONS

The results of the project so far have enabled many different scientific conclusions and assumptions to be made. From the perspective of the application of the method used by Crawford at the start of the 1950s we can say that it is still extremely useful under Sudanese conditions and permits further investigation into past Sudanese landscapes. By enriching the method with high resolution satellite imagery it is possible that change will occur in Sudanese archaeology. This particularly concerns speedy recognition of archaeological
resources in regions under threat from planned investment. We observed many examples where the construction of vast irrigation canals cutting across the desert resulted in the destruction of many archaeological sites (mainly cemeteries). Currently under final review is the proposed construction of a dam near the 4th cataract. Shortly, a vast area of the Middle Nile Valley will be flooded. Thousands of small archaeological sites, which are not under close archaeological investigation will be destroyed without any, even basic, documentation being made. The reason for this is the short time left for archaeological action and the attitude of the local people (of the Manasir tribe) towards all activities related to the construction of the dam. As our experience gained during the project shows, by using satellite imagery with a good level of resolution (at least slightly better than that available on Google Earth) it is possible to quickly record traces of the past which are soon to be totally destroyed.

Figure 2 (left). Fortress at El Koro. Top: north–west corner (Photo: O.G.S. Crawford, 1952); bottom left: western tower (Photo: Ł. Banaszek, 2008); bottom right: satellite image, 2003 (© Google Earth). Figure 3(right). Cemetery at Wadi Dam et Tor. Top: view from the North (Photo: W. Rączkowski, 2008); bottom left: robbed grave (Photo: W. Rączkowski, 2008); bottom right: satellite image of a site, 2003 (© Google Earth)

7 REFERENCES