ATHENA

Remote Sensing Science
Center for Cultural Heritage

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Contributor(s):	**Athos Agapiou, Vasiliki Lysandrou, Diofantos Hadjimitsis, Gunter Schreier**	
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Summary

The current deliverable is an overview of the most common remote sensing technologies in use today for archaeology and cultural landscape investigations. Human activities produce landscape alterations and environmental changes that can be recognized also after centuries and millennia even if deposition processes and/or alluvial phenomena tend to mask them continuously. Albeit the traces of “human induced” alterations are generally subtle still they can be revealed by aerial or satellite observations.

One of the main advantages of remote sensing techniques is their capability to provide a huge amount of information in a non-invasive, non-destructive way, also protecting and preserving cultural heritage.

This report includes also an annex that is a chapter published in a book in press entitled "Sensing the Past" edited by Mansini N., Soldovieri F. (Springer Publisher).

1. Introduction

In the last fifteen years, the application of Earth Observation (EO) techniques has exhibited great potential for archaeological investigations, so that it has accounted for a number of important archaeological discoveries and has provided manifold capabilities from the detection of cultural remains to the documentation, monitoring and preservation. The significant increase of Remote Sensing in Archaeology is confirmed by the scientific interest in terms of publications between 1999 and 2005 as showed by Agapiou and Lysandrou (2015) (see Fig. 1)

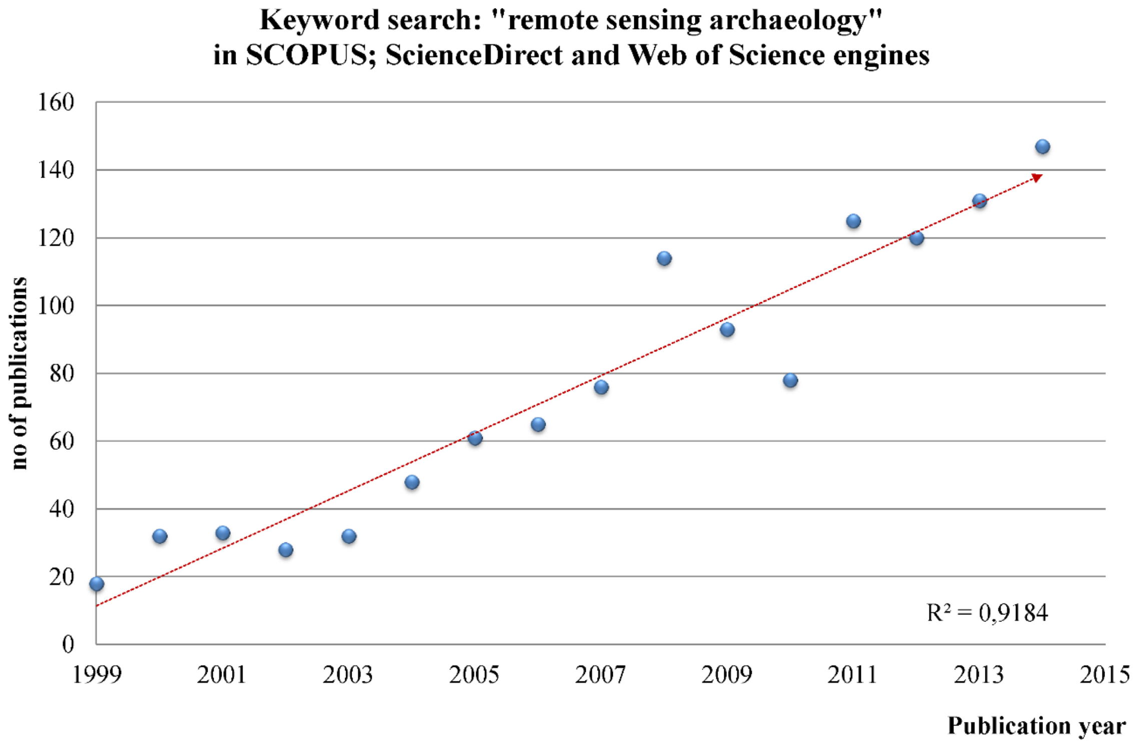

Figure 1 - Trend of publications from 1999 to 2015 from the Scopus; ScienceDirect and WoS engines, considering as keyword search "remote sensing archaeology" (drawn by Agapiou & Lysandrou 2015).

One of the main advantages of remote sensing techniques is their capability to provide a huge amount of information in a non invasive way. The remote sensing tools today available for archaeological application enable us to get extremely precise results speeding up the work during the diverse phases of archaeological heritage management ranging from survey, mapping, excavation, documentation, monitoring at diverse scales of interest, moving from small artifacts to architectural structures and landscape reconstruction. Data acquired by active and passive satellite, aerial and ground sensors and tools such as GIS, virtual and augmented reality have opened new possibilities, unthinkable only a few years ago. As an example, it is possible to integrate archaeological information with reconstruction of ancient environment, obtainable from satellite data, with mapping of past flora and fauna and anthropological aspects.

One of the most important points is that all these technologies are available at different costs for different purposes and needs, even with a small budget it is possible to implement a very effective solution. Moreover, we already live in an age of a growing availability of free data and open access software tools that can also enhance a powerful link between in situ investigations and computer-based analysis thus offering a new opportunity for the operational exploitation of archaeological results.

The impact of digital technologies for archaeology (Lasaponara & Masini 2016) regards researchers, professionals as well as end-users and even if today they are underexploited it is expected that is in the next future, they will have a larger diffusion also in the cultural heritage fruition and exploitation including the touristic sector, serious game etc. (see Figure 2). This is clearly evident thinking about, for example, the new portable devices, as tablets and smart-phones, nowadays equipped with integrated (Global Position System) GPS, very powerful processors and video cards, which will permit us to enjoy virtual reconstructions and an increasing amount of information available “exactly on site and on time”.

Figure 2 Lidar based virtual reconstruction of an abandoned medieval village near Matera. On the basis of the virtual reconstruction a serious game has been developed (Gabellone et al. 2016)

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2. Airborne remote sensing

Historically, aerial photography has been the first remote sensing tool extensively used in archaeology for surveying emerging archaeological remains, as well as for detecting underground archaeological structures through the reconnaissance of proxy indicators traditionally known as crop/soil/damp/shadow marks (Crawford 1929; Dassie 1978; Masini and Lasaponara 2007).

Soil marks are changes of colour or texture due to the presence of surface and shallow remains. Crop marks frequently appear as differences in height or colour of crops which are under stress due to lack of water or deficiencies in other nutrients caused by the presence of masonry structures in the subsoil (Fig. 3). Crop marks can also be formed above damp and nutritious soil of buried pits and ditches. Such marks are generally visible only from an aerial view, especially during the spring season. Damp marks occur when archaeological deposits, such as buried walls, filled ditches and pit etc., induce local changes in the drainage capability of the soil. Finally, shadow marks are caused by microrelief which are the residues of eroded shallow remains and earthworks viewable from above when the sun is low in the sky.

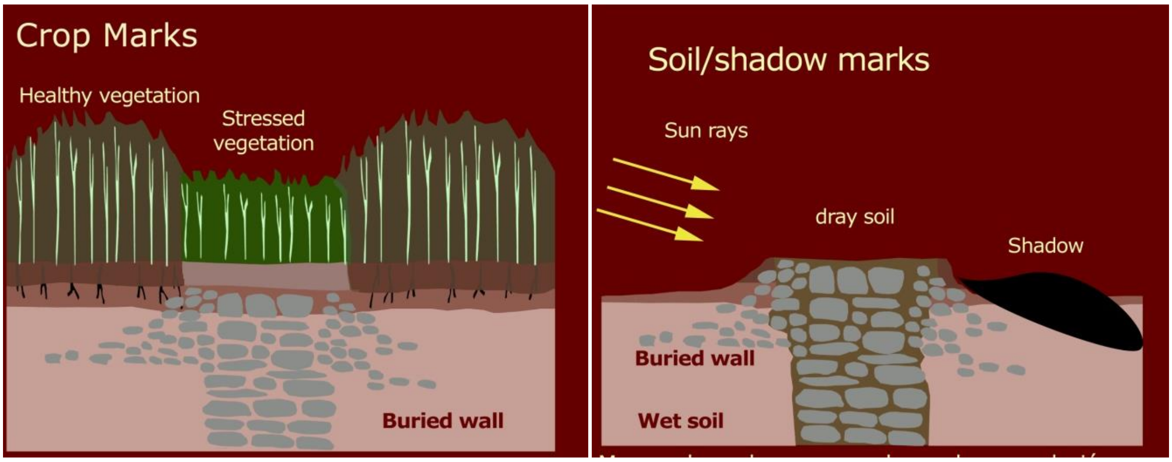

Figure 3 - Sketch of crop, soil and shadow-marks from Masini N., Lasaponara R. (2016), 'Sensing the Past from Space: approaches to site detection', in "Sensing the Past. From artifact to historical site" (Masini N., Soldovieri F. (Eds), Springer, in press.

The visibility of those proxy indicators as result of the physical interaction between soil, vegetation and archaeological deposits has a significant intra- and inter year variability due to changes in vegetation types and crop phenology, soil moisture content and other parameters among them soil type (compactness/pedology), climate and meteorological conditions, and, the nature (walls/ditches) and material of remains (stone, rammed earth)

Additionally, the visibility of micro-topography of cultural interest depends on many other factors, such as off-nadir viewing angle of the collected imagery, time of image acquisition, view geometry, sun angle.

The micro-relief of cultural interest can be better identifiable by high detailed digital models derived from photogrammetrical methods using aerial images taken from unmanned air vehicle (UAV), airplanes and LiDAR surveys. The latter is also able to 'remove' the vegetation cover making possible the survey of archaeological features, from exposed to microrelief, not visible from optical remotely sensed data.

Airborne Hyperspectral and Thermal sensors have been also exploited in archaeology (see for example Cavalli et al. 2013) even if less than multispectral data. Up to now, the impact of Hyper spectral and Thermal data in archaeological investigations has been still limited due to the high cost of the sensors compared to the improvement achievable and to other lower cost technologies.

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2.1 UAVs system use

Undoubtedly, compared to traditional aerial archaeological, the UAVs offer several advantages, particularly low cost and ability to cover large areas in a short time. A traditional aircraft must take off from an airport, sometimes far from the work area, while a drone, particularly rotary wing, can be transported in the area of interest and take off directly from there in a few minutes. The reason of the success of the UAV’s is also the innovative vision, the very high-resolution of the obtainable products (orthophoto, digital elevations models) and the availability of easy tools of image processing based on Structure from Motion (SfM). (Neitzel & Klonowski 2011; Nex & Remondino 2013). SfM is a range imaging technique which allows to estimate three-dimensional objects from two-dimensional image sequences which may be coupled with local motion signals. Respect to conventional photogrammetry which requires a single stereo-pair, SfM needs multiple, overlapping photographs as input to run the feature extraction and 3-D reconstruction algorithms. In SfM the geometry of the scene, camera positions and orientation are solved simultaneously using a highly redundant, iterative bundle adjustment procedure, based on a database of features automatically extracted from a set of multiple overlapping images. Moreover, the usefulness of UAV-based investigations has been also given by its prompt integrability with other remote sensing data including geophysics, optical and satellite (see for example Fig. 4).

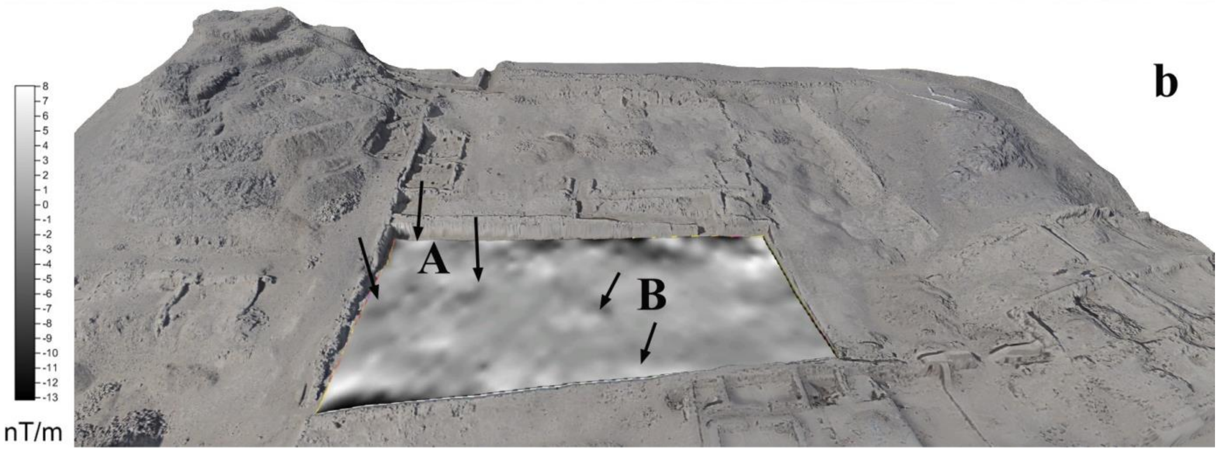

Figure 4. Inka site of Paredones near Nasca (Peru). Integration of magnetic results with 3 D model obtained from the SfM based processing of aerial images taken from a low cost drone.

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2.2 Lidar in Archaeology

LiDAR provides direct range measurements of the earth’s topography, by using two different types of ALS sensor system: (i) conventional scanners or discrete echo scanners and (ii) full-waveform (FW) scanners. The first, generally, delivers only the first and last echo, thus losing many other reflections. The second is able to detect the entire echo waveform for each emitted laser beam, thus offering improved capabilities especially in areas with complex morphology and/or dense vegetation cover. Airborne laser scanning (ALS) systems are generally composed of different components which contribute to the final accuracy of the range data. All the components should be accurately calibrated and integrated.

The measurements are mapped into 3D point clouds and very detailed digital terrain models which allows us a precise characterization of geomorphological features and microtopography of archaeological interest.

To this aim, it is crucial to:

1) process the point clouds and classify terrain and off terrain objects by applying adequate filtering methods such as Morphological, Surface based and Segment based filtering, Progressive densification and Spline interpolation filtering (Axelsson 2000; Vosselman, G. 2000) and

2) to use and 'manipulate' the DTMs with appropriate techniques of visualization aimed at emphasizing changes of landscape morphology linked to the human presence, such as relief shading procedure, Slope gradient, local relief model (Hesse 2010) and Sky view factors (for an overview of visualization techniques of LiDAR-derived relief models see Stular et al. 2013).

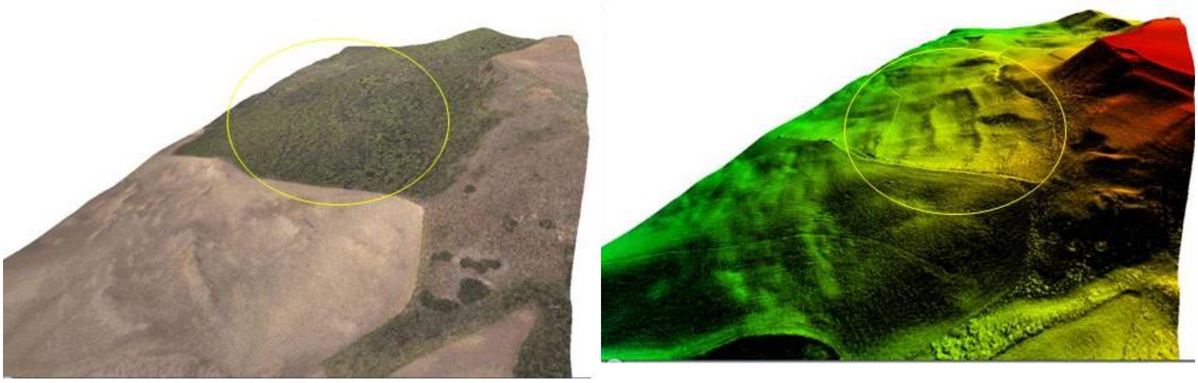

Figure 5 Airborne laser scanning survey aerial photo (left) and DTM (right) obtained after the removal of vegetation cover

Nowadays ALS is regarded as a well-established tool used to depict micro-topographic earthworks in bare ground sites (Lasaponara & Masini 2009) and for detecting archaeological heritage in wooded areas (Devereux et al. 2005; Doneus et al. 2008).

They can penetrate vegetation canopies (see Fig. 5) and model accurately underlying terrain elevation. The recent discoveries of Evans (Evans et al. 2013) in Angkor and of Chase in Belize (Chase et al. 2012) demonstrate the effectiveness of this technology for archaeological research. Recently ALS has been also used for underwater archaeological even if the majority archaeological studies make use of LiDAR for land investigations throughout the world in Europe, Central America, Canada and limited locations in North America including the United States.

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3. Passive Satellite Remote Sensing

During the last twenty years, the use of space technologies in archaeology and cultural landscape has been strongly increasing for several reasons: i) the improvement of spectral and spatial resolution of satellite sensors; ii) the availability of user-friendly software and routines for data processing and analysis; iii) the interests of archaeologists to study the dynamics of human frequentation in relation to environmental changes.

Moreover, archaeologists are ever more aware of the benefits of remote sensing applications for their investigations, such as: i) reduction of costs, time and risk associated with archaeological excavations; ii) creation of site strategies addressed to conservation and preservation.

The multispectral capability of satellite images can improve the identification of differences in texture, moisture content, roughness, topography, various types of terrain, vegetation cover, lithological and geological composition and other information used in archaeological studies.

For example, using multispectral images crop-marks can be detected by spectral variations in specific channels more sensitive to vegetation (as near infrared) or spectral indices (i. e. mathematical combinations of different spectral channels) as NDVI, etc (see Fig. 6)

Damp-marks, linked local changes in the drainage capability of the soil, can be revealed by spectral variations in specific channels more sensitive to moisture or spectral indices (i. e. mathematical combinations of different spectral channels) as NDWI etc.

Finally, shadow marks are micro/medium-micro-topographic relief linked to archaeological remains, as artworks, platforms, ditches and shallow remain, and they can be revealed by changes in colour or texture due to the presence of shadow.

Early applications of satellite for studies on past human activities were attempted starting from the eighties using the Thematic Mapper (TM), which was the highest (thirty meter) spatial resolution sensor available at that time for civilian applications. Using TM data, some success was achieved in landscape archaeological investigations, for example, the finding of old roads, ancient land divisions, Roman centuriation, relict agricultural systems (Clark et al.1998, Sever 1998), and also in palaeogeographic environment studies (Parry 1992, White & El Asmar 1999). Moreover, these early studies highlighted the need to set up proper image processing techniques and modeling to predict areas of potential archaeological interest.

The subsequent availability of the ten meters resolution of the Spot imagery of French satellites was a missed opportunity for archaeological utility, because they were much more expensive than TM and offered a "coarse" spatial resolution still not enough to detect smaller features of archaeological interest.

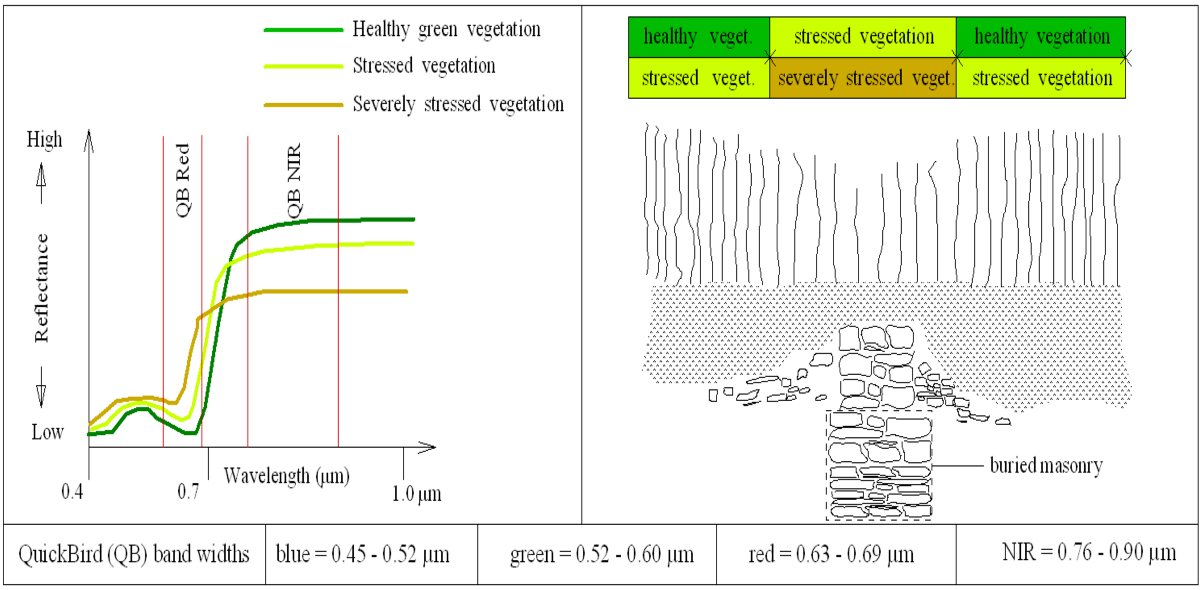

Figure 6 - Spectral response by QuickBird imagery of archaeological crop marks

A larger use of satellite data in archaeology was achieved later, after the end of the Cold War, when in the 1990s, Russian and American intelligence satellite photographs were made commercially available for civilian purposes.

Russian declassified KVR-1000 imagery were exploited by Fowler (1996) to detect archaeological features such as crop and soil marks in the surrounding of Stonehenge, and by Comfort (1997) for archaeological investigations in the Greek and Roman city of Zeugma on the Euphrates in Turkey. Russian Soyuz Kate-200 images have also been explored for studying ancient irrigated and cultivated areas in Yemen (Marcolongo & Morandi Bonacossi, 1997)

The American declassified Corona images were used by Fowler (1997) for detecting archaeological features near a hill fort in Hampshire, dating back to the Iron Age and by Kennedy (1998) to investigate the Euphrates valley (Turkey).

Ur (2003) used Corona to identify ancient road systems dating from the Early Bronze Age in the Upper Khabur basin (North-eastern Syria). Another important contribution comes from the study and documentation of the archaeology of the Altai Mountains by Goossens et al. (2006). Altalweel (2005) integrated CORONA with ASTER multispectral satellite imagery at medium spatial resolution. Beck et al. (2007), used Corona along with Ikonos imagery for studying tell settlements and field systems in Western Syria.

The availability of VHR satellite data since the 1999 with the launch of IKONOS (and the following commercial high resolution satellite data) has determined an increasing use of satellite data in archaeology and opened new perspectives in the field of archaeo-geophysics. As an example, Figure 1 shows the increasing number of papers based on the use of satellite data which were published in the most important journals of Remote Sensing and heritage science, some of them dedicated special issues on the use of remote sensing for archaeology and cultural heritage management, such as the Journal of Archaeological Science (vol. 38, issue 9, 2011), Archaeological Prospection (vol. 16, issue 13, 2009), Journal of Cultural Heritage (vol. 10S, 2009), Archaeological Prospection (2013), Remote Sensing (2014), Remote Sensing (2016).

The distribution policy and access to VHR satellite images is different, depending on the satellites owners, in the case of private companies such as IKONOS, QuickBird and GeoEye images are well distributed. A good distribution network also exists for SPOT, the Indian Satellites and EROS data (see table 1).

Satellite data	Launch	Country	Pan	Ms
IKONOS 2	1999	USA	1 m	4 m
QuickBird	2001	USA	0.6 m	2.4 m
TES	2001	India	1 m	
OrbView 3	2003	USA	1 m	4 m
Cartosat 1	2005	India	1 m	2.5 m
Kompsat 2	2006	S. Korea	1 m	4 m
Resurs DK2	2006	Russia	1 m	2:3 m
EROS B	2006	Israel	0.7 m	
WorldView-2	2007	USA	0.5 m	2 m
Cartosat 2	2007	India	0.8m	
RapidEye	2008	Germany	5 m	5 m
GeoEye-1 *	2008	USA	0.41/0.5 m	1.65/2 m
Pleiades 1a-1B	2011-12	France	0.5 m	2 m
Spot 7	2014	France	1.5 m	6 m
WorldView-3	2014	USA	0,31-0,34m	1.24-1.38

Table 1. List of optical VHR satellite data.

Currently also the availability in Google Earth of free of charge satellite pictures, opened new strategic challenges in the field of remote sensing in archaeology. According to the outputs from several papers (see Lasaponara & Masini 2012 and references therein quoted) the main concern is the lack of correspondence between the great amount of remote sensing image and effective data processing methods capable to reliably enhance and automatic extract the subtle traces of archaeological remains still present in the modern landscape.

From the methodological point of view, in many cases the main problem is the enhancement of the subtle archaeological features generally known as crop, soil, damp marks namely spatial discontinuities or variations induced by archaeological remains in the reflectance values (i.e. tones or colours) of vegetation and soil surface (Crawford1929; Wilson 1982; Beck 2007; Lasaponara & Masini 2007; Grøn et al. 2011; Traviglia & Cottica 2011; Rowlands & Sarris 2007; Agapiou & Hadjimitsis 2011; Agapiou et al. 2013).

Even if the number of publications , in terms of papers, books and special issues is increasing in the last ten years, the use of Remote Sensing in archaeological practice is still underexploited and, still today the use of satellite data is generally reduced to a mere visual interpretation exercise.

Up to now, investigations have been mainly based on approaches aimed at enhancing archaeological features using spectral indices, RGB composition, Principal Component Analysis, Tasselet Cup Transformation, edge detection (Argote-Espino and ChaVez, 2005; Lasaponara & Masini 2006; Garrison et al. 2008; Traviglia & Cottica 2011; for a more complete bibliography see Lasaponara & Masini 2012).

A few investigations have been addressed to the extraction of information using automatic or semi-automatic tools as, for example, De Laet et al. (2007) who compared the performance obtained from the application of pixel based and object based classification (using eCognition tools), edge enhancement and visual interpretation for a test site in Turkey, which was characterized by the presence of emerging scattered remains made up of quite big stones. On the basis of the results obtained the authors considered the visual interpretation better than the other considered approaches.

Trier et al., (2009) developed a satellite based automatic approach to extract circular crop/soil marks linked to buried features in Norway, but the rate of success was unsatisfactory. Recently, Lasaponara et al (2014) successfully applied an unsupervised classification to satellite imagery, previously processed by using the LISA (Local Index of Spatial Autocorrelation), to extract circular traces of illegal excavation in Peru. Luo et al (2014) reliably extracted the circular archaeological tops of Qanat Shafts automatically from Google Earth Imagery by using a new method consisting of a combination of the circular Hough transform followed by mathematical morphological processing and the Canny edge detector. Recently Lasaponara et al.2016 proposed an automatic method for extracting features related to ancient farms near Hierapolis exploiting the geometric patterns and object oriented approach.

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4. Satellite SAR

Compared to passive optical data, SAR offers a number of advantages. They can operate night and day and are less influenced by atmospheric effects and can penetrate into the soil according to the specific frequency.

Early studies based on satellite microwave radiation provided unexpected insights for archaeological applications. For example, they enabled the discovery of subsurface features related to dry channels and rivers in the eastern Sahara (McCauley et al. 1982) with subsequent important implications in the geo-archaeology of prehistoric environments of this region (see also El-Baz et al. 2007). The use of SIR-C data allowed to find a portion of the Great Wall of China (Xinqiao et al. 1997) under sand, and to discover the City of Ubar in the desert of Oman (http://visibleearth.nasa.gov/view_rec.php?id=536).

Other discoveries have been made in the famous site of Angkor, Cambodia. A vast water management system was identified under tropical forests using radar images taken from a NASA Space Shuttle (Moore et al. 2007). Later, other discoveries in the urban area of Angkor have been made by Evans et al. (2007), using JPL AirSAR data, along with other remote sensing data. Nevertheless, the relatively low spatial resolution of radars (in L and P bands), the complex interpretation of radar-based products, and the difficulty to access low-cost data sets (such as SIR-A, SIR-B, and SIR-C) have strongly constrained their use in archaeological studies (El-Baz et al. 2007). Still today, the application of imaging radar such as the German Terra SAR-X and the Italian Cosmo-Skymed SAR-X with high spatial resolution is quite limited due to the relatively high cost of data and their limited penetration capability being them acquired in the X band. Moreover, radar data processing requires sophisticated data processing, noise suppression, and other advanced data interpretation techniques.

One of the most useful and used radar-based products is the DEM obtained from the Shuttle radar topographic mission SRTM data. SRTM-DEM products at 30 m resolution are available free of charge via the internet for almost 80% of the Earth’s surface. The nearly global availability of the SRTM offers the archaeologists the possibility to have a prompt virtual survey of large areas, for the detection and mapping of huge archaeological features, such as settlement mounds and tells. Several studies were conducted mainly in the Middle East and Near East, using also declassified satellite data (Menze and Sherratt 2006). Using the Canadian SARSAT data Richason III & Hritz (1998) investigated settlements and river systems in the lower Mesopotamian Plain (Iraq).

SAR data were also successfully used in Southeast Asia for archeological exploration. The use of SAR data is mandatory here as the utility of optical imagery is quite limited by the frequent cloud cover and dense forest canopy (Supajanya et al., 1994). In Northern Thailand, Wara-Aswapati (1995) identified remains of numerous moated cities Moreover, SAR data enabled also the detection of large canals, which improved the understanding and the identification of the urban area its chronological evolution (Supajanya et al., 1994, 1995).

Dore et al. 2013 investigated the UNESCO Cultural Heritage sites of Samarra (Iraq) and Djebel Barkal archaeological area (Sudan) by means of polarimetric products of the Japanese satellite ALOS PALSAR. Patruno et al. 2013 focused on the comparison of ALOS (Advanced Land Observing Satellite) PALSAR (Phased Array type L-band Synthetic Aperture SAR) L-band satellite with SARSAT-2 C-band satellite in order to identify the most suitable method for the detection of ground anomalies due to the presence of shallow underground archaeological structures. Link et al. 2013 compared Terra SAR data with results of geoSAR survey in order to assess the penetration capability of the SAR X band at a test site of a Roman fortress in Syria. Stewart et al. 2013 focused on the archaeological site of Pelusium in the north-eastern edge of the Nile Delta, Egypt, using PALSAR data. The aim of the investigation was to assess the potential of PALSAR, acquired in various polarimetric modes, to identify buried archaeological structures. Cigna et al. used SAR amplitude information from ENVISAT C-band Advanced SAR (ASAR) to analyze the cultural landscape of the Nasca region, Southern Peru. The processing method based on SAR amplitude information was also used also by Tapete et al. 2013 to extract the backscattering coefficient (σ0) from ENVISAT Advanced SAR (ASAR) scenes to investigate ancient pyramids and mounds, and identify areas affected by looting in the area around Cahuachi, in the Nasca region (Peru). Finally, Morison (2013) proposed a new scheme for mapping sub-surface features with synthetic aperture SAR (SAR) at large stand-off distances applicable to airborne and satellite measurements.

The advent of the “2000” generation of space-borne SAR sensors, such as ENVISAT/ASAR (2002-2012, C-Band dual), ALOS/PALSAR (2005-2011, L-Band), SARLupe (2006, X-band), Cosmo SkyMed (2007, X-Band Dual), TerraSAR-X, 2007, X-Band quad), SARSAT-2 (C-Band quad, 2007) has provided improved data acquired by multiple polarization modes. The current SAR technology offers a greater flexibility in the selection of the incidence angle range as well as advanced imaging modes like ScanSAR or Spotlight.In particular, the launch of VHR space-borne SAR sensors offered advanced mapping capability in the scale of one meter, thus opening new prospects for archaeological applications.

The launch on 3 April 2014 of Sentinel-1 started a new era for the free availability of SAR data. Sentinel-1, based on a long-standing heritage from the ERS, Envisat and Radarsat missions, operates in C-band and offers two acquisition modes (StripMap and Extra Wide Swath) with the possibility to sense data up to 5 x 5 m resolution. Finally, ALOS2, launched on May 24, 2014 with onboard PALSAR-2, opened a new era providing full polarization and high resolution data in L-band.

In order to obtain significant results for archaeological prospecting it is important to know the surface to be investigated in order to process SAR data taking into account the key parameters of the radar energy – target interaction that are the: 1) surface roughness, 2) moisture content and electrical properties, and 3) radar viewing and surface geometry relationship. The most recent application of SAR in Archaeology put in evidence the need to integrate this technology with optical (airborne and spaceborne). Examples of SAR and optical data integrations are related to the Phoenician and Roman town of Sabratha in Libya (Chen et al. 2014), the Greek town of Metaponto and its surrounding in Southern Italy (Lasaponara & Masini 2015), the ancient town of Pelusium in Northern Egypt (Stewart et al. 2013; Lasaponara & Masini 2015; see Fig. 7).

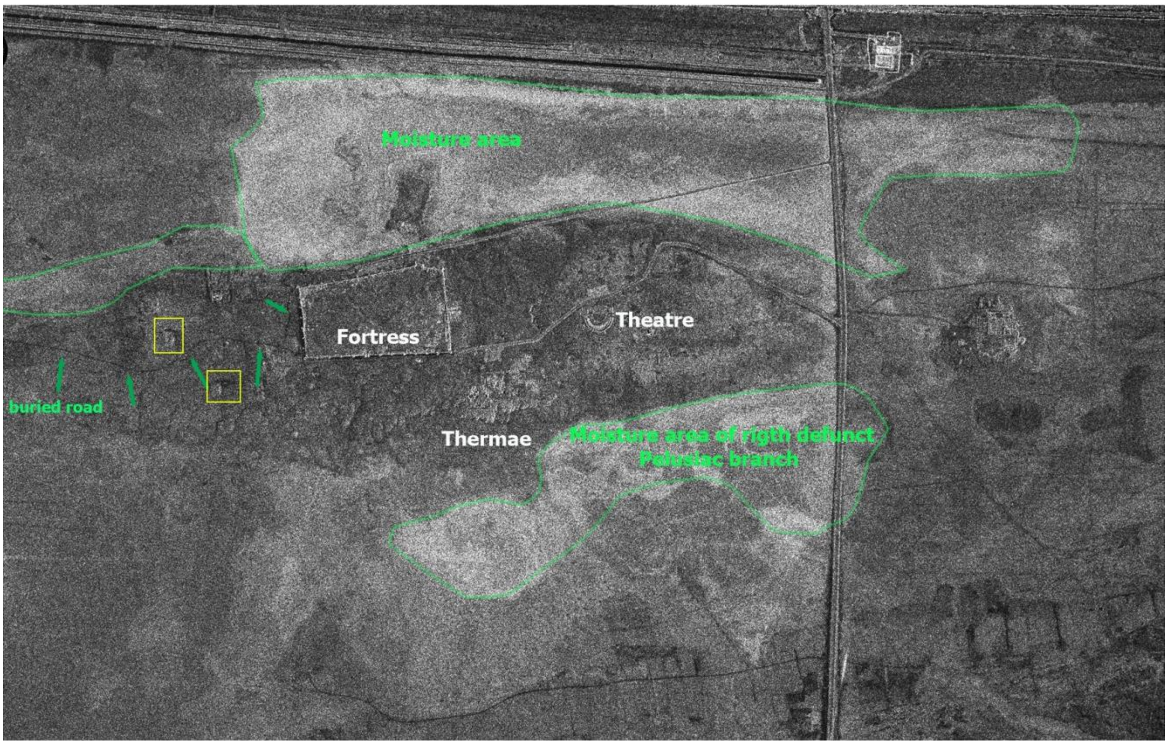

Figure 7 - Pelusium (Egypt): new information provided by processing x-band Cosmo SkyMed data

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5. Ground remote sensing

Geophysical prospecting is a non-destructive technique for subsoil investigation, which consists of the measurement of some physical properties of soil (as anomalies in magnetic, electric or radio signal) that can reveal its structure, as well as the presence of buried objects. In particular, magnetometry detects magnetic anomalies in the vertical component of the earth's magnetic field providing useful information for the detection of archaeological deposits as burnt areas, kilns and hearths, building remains, and even pits and ditches. Resistivity is based on a small electrical current which is passed through the earth. The differences in relative resistance is used to map features including ditches, pits, voids and structural features such as wall footings, garden features, platforms, paths, tracks and roads. Compared to magnetometry, resistivity is more time consuming.

Ground Penetrating Radar GPR is based on radio signals. Sub-surface features and objects can be profitable identified on the basis of the recording reflections. The time of the transmitted and received signal provides information on the presence and depth of structural features.

Magnetometry, resistivity, ground penetrating radar are very popular technologies for archaeological investigations, today, considered as high powerful subsurface imaging tools that can provide detailed evidence of past occupation and activities not visible in surface. Obviously Magnetometry, resistivity, ground penetrating radar survey must be implemented using adequately configured survey equipment, with properly data sampling strategies and appropriate post survey data processing.

Geophysics has over the past five decades been successfully employed in the investigation of numerous archaeological sites in Europe and beyond (e.g. Aitken, 1961; Scollar et al., 1990; Becker, 1995, Conyers and Goodman, 1997; Neubauer, 2001; Leckebusch, 2003; Linford, 2006; Campana and Piro, 2008; Gaffney, 2008; Schmidt 2013; Leucci & Negri 2006; Leucci et al., 2012). The driving force behind the development of archaeological geophysical prospection in many other countries has often been linked to development schemes and national ancient monument protection laws.

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6. Data Integration

The full exploitation of data provided by diverse sensors (from aerial, space and ground acquisition) the usage of 3D models, acquired from airborne and terrestrial laser scans, impose the integration of all the available information (in digital and non digital format) within a GIS environment and software technologies which provide effective solutions for the management, integration, elaboration, full exploitation and publication of heterogeneous data sources provided by excavation reports, geophysical prospection, cartography, aerial and satellite photogrammetry.

GIS environment or web-based GIS environment tools allow a new and more effective way to conduct archaeological research, storing handling and sharing geospatial data from heterogeneous sources in a collaborative way.

The huge amount of data (big data), the increasing needs of data integration, archiviation and processing along with the necessity to make cost effective and easier available these GIS based technologies require new approaches and concepts in the development of infrastructures. These issues can be reliable and effectively addressed by a WebGIS platform, based on and built with open source components, i. e. open standards, metadata and open source (OSS) architectures.

In the mid and late nineties, the terms GIS and Internet indicated two distinct and separate fields. Today the combination and the increasing use of these systems in regards to archeological applications is clear in the rapid spread of archaeological webGIS, leading to the creation of many platforms with interfaces and functionality, oriented at both specialist and non-specialist audience"

A webGIS architecture provides flexible tools for the diverse needs, applications and “usage phases” ranging from data collection phase to the system fruition. In fact, in recent years the development of open webGIS source tools has played an important role with regard to different aims as, for example, (i) publication of the results of an excavation, (ii) placement of archaeological evidence in the territory, (iii) inclusion of archaeological data in broader national geoportals aimed at landscape protection (iv) the inclusion in projects for dissemination also to an audience of non-specialists.

The critical point is therefore to create easy access tools that can suitably face (i) domain expert needs, such as archaeologists, remote sensing community, manager, museums, and laypersons (ii) interested in the cultural assets of the area for educational or tourist purpose(https://rometheimperialfora19952010.wordpress.com/tag/descriptio-romae-webgis/) (iii) effective interchange among computer platforms, i.e., interoperability i.e “the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units”

ANNEX A – book chapter

Masini N., Lasaponara R., "Sensing the Past from Space: approaches to site detection", in *Sensing the Past* (N. Masini and F. Soldovieri (Eds), Springer Publisher (in press).