REMOTE SENSING IN ARCHAEOLOGY. A NEW APPROACH TO KNOWLEDGE OF THE INTERACTION HUMAN/TERRITORY

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ABSTRACT:

A remote sensing approach to address the archaeological reserches for reconstructing old settlement models and locating in them exactly the sites is illustrated. Tese models are fondamental to recover the historical memory of humanity through the reconstruction af the relation human-territory.
The methodology of the approach makes use of satellite, aerial and remote sensing images, analysed in sequence and interpreted in multispectral bands.

KEY WORDS: archaeology, territory, human settlement, remote sensing application, multispectral.

INTRODUCTION

Traditional archaeology has not yet developed a particular method for searching for sites and individual buried remains, that could become an element of an experimental settlement model.
At present, they are identified in the territory partly through the interpretation of historical texts or information received and they are only located through field observation, thus they are limited by the capacity for visual observation. Consequently, the location of sites is always somewhat uncertain and they are often discovered through chance information and this means that the models outlined may contain errors.
These limitations are reflected in the fact that it is impossible to reconstruct the fundamental human/territory relationship that must be discerned if we are to correctly rediscover the vicissitudes of human history.
Thus, knowledge of the history of the territory is of prime importance for archaeology. A history which can be reconstructed through still perceptible signs, both the dynamic geomorphological signs and those produced by human intervention which are found in the surface topsoil and upper subsoil.
What one obtains from this, is a model of past territory in which the elements of the past are placed coherently, a model that permits the complete historical reconstruction of monuments of the past, one which is supplemented by the more direct and traditional research methods (excavation).

THE APPROACH TO ANALYSIS OF THE TERRRITORY

Analysis which has the above as its aim must, in its approach, offer an applied methodology for interdisciplinary use, one which will enable a comprehensive territorial model to be delineated in a short time.
Modern techniques for the acquisition, interpretation and study of satellite, aerial and low altitude images, used in sequence, meet the conceptual requirements outlined above and enable the procedure that the Authors have called the "Systemic Territory Approach" (STA) to be used.

Analysis of Satellite images

This analysis uses satellite products, preferably on the 1:100,00 scale which, experience has shown, is the best for accurate analysis and interpretation given the current technological characteristics of the systems used to acquire it (Landsat TM and Spot).
What is obtained is a picture of a synthesis of information about the territory, which facilitates achievement of the aim, which is the reconstruction of models of anthropic settlements, though on a small scale.
It is possible for the person interpreting the information to check how far it extends over large areas, thus to receive multiple confirmation of the significance attributed to the signs singled out and to correlate the deduced natural phenomena of these with both past and present anthropic signs.
All this makes it possible to look at the relationship between humanity and the territory in a regional perspective.
Both the recognition and interpretation of signs are markedly facilitated by the possibility of using multispectrum images each one of which is known to be directed towards identifying specific territorial parameters.
Research for archaeological purposes generally favours the green spectrum band (Landsat TM/Bd 2 and Spot/Bd 1) and the near infrared band (Landsat TM/Bd 4 and Spot Bd/ 3), because they show up anything present in the subsoil best, even the weak signs of which there is no discernable trace on the surface.
The elements that are derived from analyses of the above mentioned spectrum bands can then be compared and supplemented with each other, thus offering mutual confirmation and adding to the

final picture of information about the territory.
The periodic, multitemporal nature of the way in which the available images are acquired is a great help in the process of interpretation because it allows not only for repeated checks to be made on the information, but also permits even the faintest signs that emerge from the subsoil to be studied under optimum conditions, with particular reference to the presence of ancient human remains.
The signs interpreted can be found on the territory through geo-referenced images. With the Spot satellite in particular, which has photogrammetrical characteristics, one can obtain restitution up to a scale of 1:50,000 of the configuration of the information acquired on the topographic grid. This permits a sufficiently exact verification of, and check on, all the patterns on the ground which can be traced back to the configurations acquired.
Figure 1 is offered as an example of the interpretation given to one part of a Landsat TM/Bd 4 image. This image refers to the territory around ancient Selinunte, one of the most famous Greek cities in Western Sicily (VII - III BC). For the first time, traces of two superimposed systems have been discerned, one (unbroken line) from the Greek period (2nd half of the VI century BC,) (Gullini, G. 1985), the other (broken line) from after the Romanisation of Sicily (III - II BC). These are the initial references for identifying a model of territorial use unknown before.

Analysis of aerial photographs

In this case one uses stereoscopic aerial photographs that are already held in archives and other shots taken at different heights and in different periods.
This is the best known phase and that which is most used by persons involved in these studies, especially by archeologists. Nevertheless, today, interest is declining in this as opposed to other systems of remote sensing, because the images are usually only obtained

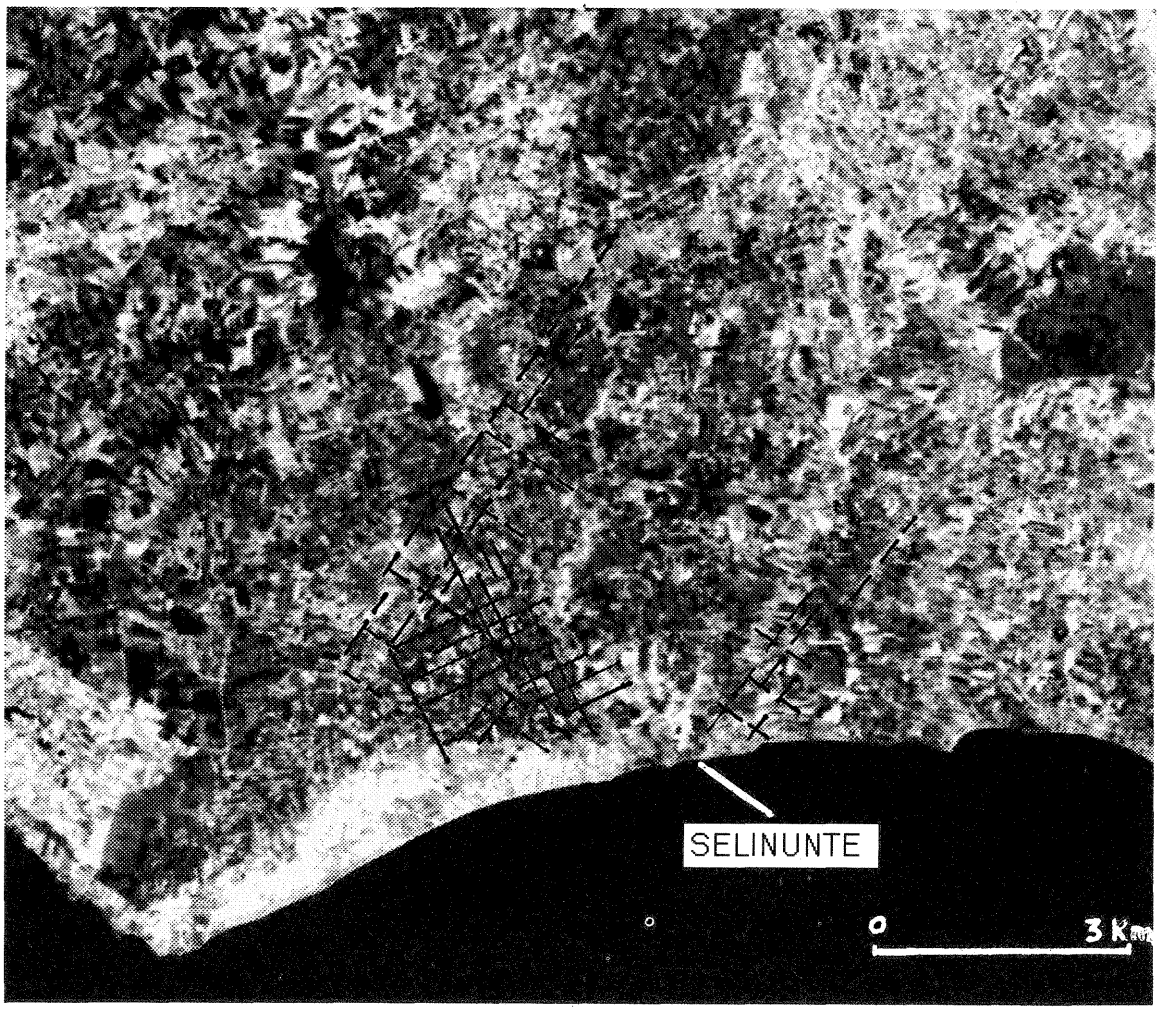

Fig. 1 - From a Satellite Landsat 5TM Bd 4, archaeological interpretation of the territory around the ancient city of Selinunte (VII - III BC) Western Sicily.

in the panchromatic visible spectrum which limits both the quality and the quantity of the information obtained.
On the other hand, this type of analysis is also in crisis because of the spread of the most recent structural infrastructural and agricultural interventions.
However, even if the geometrical resolution of aerial photographs were sufficient for the requirements of interpretation, it should still be borne in mind that there is no existing archive of images for reference which is organised according to criteria of standardisation of the characteristics of either acquirement, or scale, or criteria of a systematic nature.
Furthermore, technological advances in the system of acquiring images with satellites, as well as providing multispectrum images, have also made it possible to arrive at interpretations the same as, or almost equal to, those of aerial photographs.
Therefore, the tendency to bypass the use of aerial photographs and to substitute them with more targeted photographs, taken at low altitudes, would seem to be justified. This leaves aerial photographs the function of being an archive of information which refers to a reality that is decidedly in the past.
Figure 2 offers an example of the interpretation of an aerial photograph taken over an area of the territory around Selinunte, the same as that previously analysed, and about which the satellite images raised some questions (see Fig. 1).
The signs that can be seen are more detailed, but are confined to some sections of the territory only in respect of those identified by the satellite. In any case they do not help to clarify the geometrical meaning of the elements being interpreted any better, and do not permit the coherence of synthesis obtained by the satellite image.

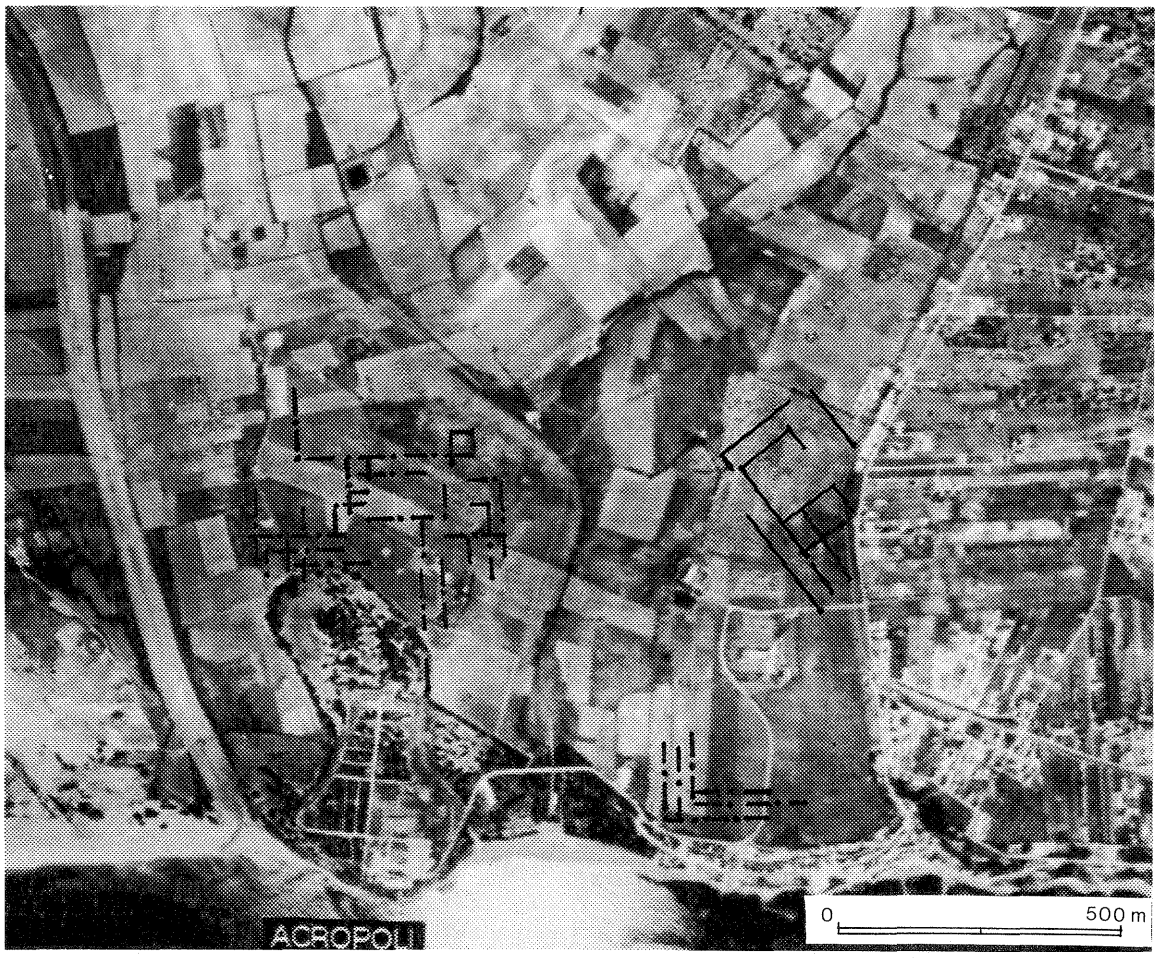

Fig. 2 - From an aerial photograph taken in 1975 visible spectrum original scale about 1:17,000 Archaeological interpretation of the area around the Acropolis of Selinunte.

Analysis of low-altitude images: archeoelectronic survey

This is the final phase of the analytical approach of remote sensing, an approach which was devised and perfected by a research team the Authors belong to (BAGGIO P., SIGALOTTI G.B., 1991).
It is designed to be able to take up, on a larger scale and with better resolution, the problem of the analysis and the restitution of areas that are considered to be the most important for the reconstruction, and in depth study, of the settlement model.
The acquired images are 1:1000 scaled for visible, photographic infrared (PIR) and thermal infrared (TIR) spectral bands. These frames are carried out from digital processing of images, stored on line in a mass memory of personal computer or, off line, through analog to digital conversion of recordings on a cassette or a videotaperecorder (VTR). These images are taken from a platform made using an Ultralight Motorized aircraft (ULM), flying at 200 metres above the ground, which is able to fly at stalling speed (about 50 km/h equal to 15 metres/sec) and is thus suitable for low altitude photography. Unlike images taken by a satellite, the low altitude width spectrum and geometric resolutions have all proved to be excellent because there is no interference from interposed atmospheric strata. The width resolution at 128 levels permits the individual discernment of even the slightest differences in the electromagnetic signal in the different bands. These are particularly useful to the researcher for finding even the very weak signs which correspond to buried archaeological structures. The geometrical resolution is supported by halfmetric Rollei 6006 cameras as its photogrammetric PC processing resolves better 10 centimetres at a scale 1:1000. The geometrical skeleton of the analyzed territory resulting from the photogrammetric process represents a base grid for the referenced location of archaeological objects which are often remote sensing using a system of sensors able to show up anomalies but do not give a precise definition of the geometrical outlines of the remains. The expert may often interpret some basic partial signs wich have no precise pattern but which are enough to identify buried structures. Using a stereoscope he or she can, with sufficient precision, outline and measure polar coordinates of an anthropic linear integrating them with information obtained from the model in use. In this way, an electronic archeological survey of a generic area can be carried out without there being any physical contact with the area.
Such a survey offers a rapid and useful synthesis as a support and guide for subsequent direct surveys by archeologists. The archeologist can then also work in smaller areas thus reducing the costs and the times of archaeological research.
A Global Positioning System (GPS) stores the three baricentral coordinates of each photo syncronized by the camera trigger. The GPS allows to keep the constant route during the flight assuring lateral overlay between adjacent strips. Furthermore an electronic control sets and keeps cardinal orientation of every photo when programmed routes change whitin the same area and/or it also prevents the platform from deviation during remote sensing.
Digital processing of the prememorized images allows for the generation, at desisered scale, of images cover the area under survey any superimposition. The expert can interpret archaeological signs from the jigsaw puzzle constructed from the total of all sections which relae to each area, with reference to the photogrammetric grid. Filters are available for each section of image. These are designed to isolate out the useful information better, to eliminate electronic interference and, above all, to remove that part of the information which is of no use and which often represents a barrier to interpretation. Obviously the researcher must intervene in the elaboration of the information and interact with the computer.
It is in this phase that the elements of information are extracted in order to implement or optimalise the settlement model as a feedback even while, at the same time, the model itself is being used in order to integrate the nonrecoverable information. It is not possible to simulate any entirely automatic interpretation on the computer because of the fragmentary nature and the uncertainty of the information relevant to archaeology which can be found in the territory.
Interactive elaboration is based on the enhancement, by means of a multispectrum comparison of the images available, of information which has been selected by the researcher on the basis of its anthropic symptomatology. This enhancement constitutes the first, fundamental check on the information deduced from a direct observation, both stereoscopic and monoscopic, of the image. At this point the interpreted configuration can be restored to the topographic network in order to permit further checks on the ground.
Figure 3 shows the interpretation of an image taken at low altitude in the visible spectrum, but compared with an analogous scene taken in the IRT. This relates to a very restricted area of the territory of Selinunte just to the North of Temple G on the Eastern Hill.
The ground is under cultivation, olive groves, and has been unevenly developed with uncultivated areas too. Above all in relation to the latter, interpretation has shown up systems of reticular

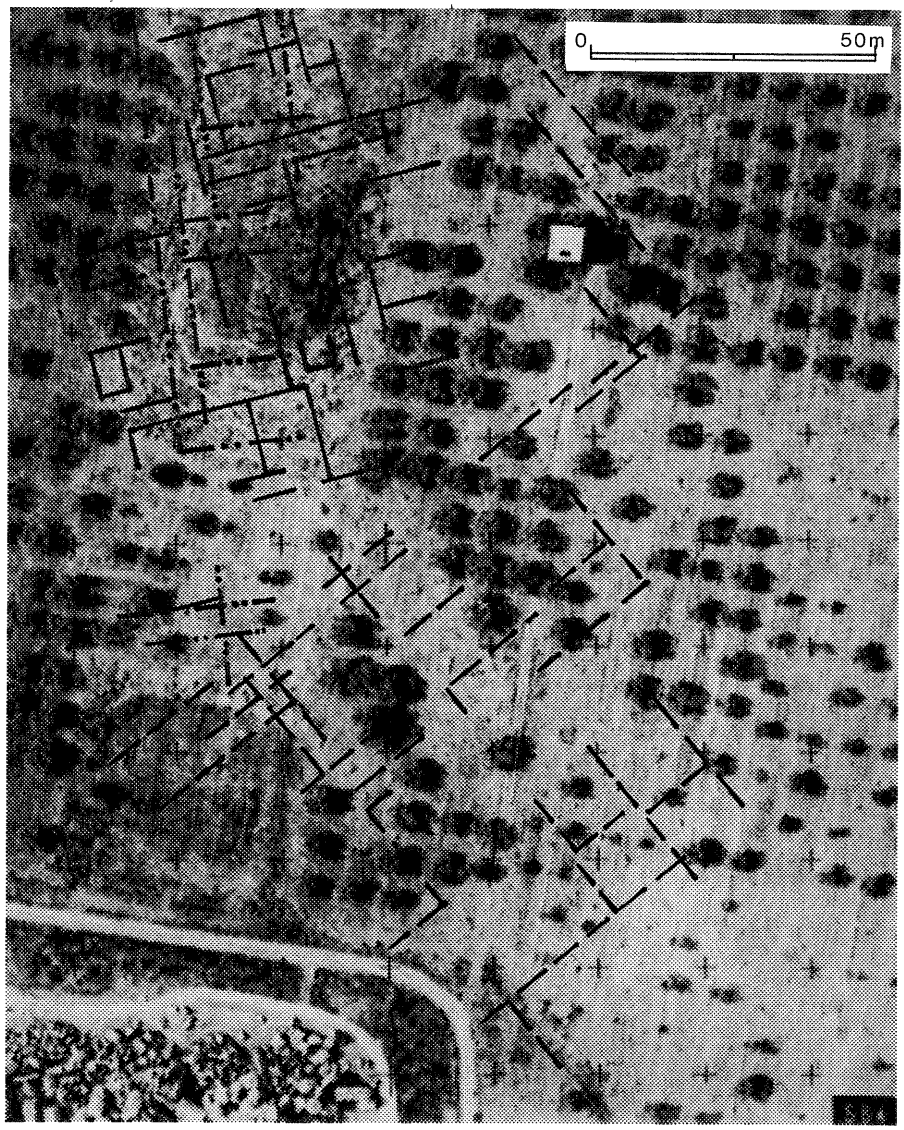

Fig.3 - From a low altitude aerial photograph taken in 1991 original scale 1:1,000. Archaeological interpretation of the area around Selinunte, to the North of Temple "G" (partially visible, bottom left) on the Eastern Hills.

lines which, in two cases, closely follow the orientation of settlements discerned during previous remote sensing analysis.
The three systems that have been identified, probably from the protohistoric, Greek and Roman periods, are defined, with geometric precision on the graph scale shown in Fig. 3. There the outline, the continuity and the density of the signs permit these conformations to be studied in relation to settlement models within a chronologically differentiated picture.
Furthermore, they make it possible to choose the area which would be best suited to carry out the checks within which stratification sequences are verified and, hence, to define the period of the remains themselves.

Lastly, geophysical prospectings (above all magnetic, electric and radar) which should be carried out in the area indicated by the information, constitute an efficient check on the ground.

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