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REMOTE SENSING AND LiDAR APPLICATIONS IN THE ALLUVIAL GEOARCHAEOLOGY OF NE ITALY

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ABSTRACT: Ninfo A. *et al., Remote sensing and LiDAR applications in the alluvial geoarchaeology of NE Italy.* (IT ISSN 0394-3356, 2011)
LiDAR technology, beside aerial photography and Near Infrared images, taken during summer, were used to investigate a large portion of the Venetian-Friulian Plain. These researches allowed to discover a number of new archaeological traces and to map some sites with a submetric definition.

RIASSUNTO: Ninfo A. *et al*., *Utilizzo di telerilevamento e LiDAR nella geoarcheologia alluvionale dell'Italia nord-orientale*. (IT ISSN 0394-3356, 2011)
La tecnologia LiDAR, la fotografia aerea obliqua e le immagini estive riprese nella banda dell'infrarosso sono state utilizzate nell'analisi di un'estesa porzione della bassa pianura veneto-friulana permettendo di documentare tracce archeologiche. Le ricerche hanno portato all'individuazione di numerosi nuovi siti e della ricostruzione con un dettaglio submetrico di antiche aree urbane.

Key words: Oblique aerial images, cropmarks, NIR, DEM, Holocene, Venetian-Friulian Plain.

Parole chiave: Olocene, Pianura Veneto-Friuliana, microrilievo, foto aeree oblique, cropmarks, soilmarks

In Italy until 2000 aerial images could be acquired only under the permission of Aeronautica Militare; also for this law restriction, previous researches dealing with geomorphology and archaeology used almost only zenithal photos at scale 1:5000-1:60.000. These were realized by national and regional administrations mainly for the construction of topographic maps. Nevertheless, the use of remote sensing for archaeological survey had already brought to important results in the Venetian-Friulian Plain, as for example the discoveries related with the city of Cittanova-Heraclia (TOZZI & HARARI, 1984).
In the last years specific projects considered large portions of NE Italy and they validated indications obtained from remote sensing and digital terrain model (DEM) with field surveys. The investigations were carried out in the framework ofthe Project "Via Annia", funded by Veneto Region, Padua Municipality and A.R.C.U.S. S.p.A. (MOZZI & NINFO, 2009) and the Project "Padova underground: goearchaeology at the roots of the city", sponsored by Cariparo Fundation (MOZZI *et al*., 2010a) and "Non-invasive investigations for the assessment and evaluation of the archaeological and paleoenvironmental resourses of Altinum" funded by Veneto Region.
Between 2007 and 2010 ~30,000 oblique aerial images were acquired during 100 hours of dedicated low altitude flights, covering large portions of the plain from Rovigo to Aquileia. Data were stored in a GIS database through GPS positioning. Analyses of these images supported a huge amount of new data that were compared with information obtained through an almost complete review of the available aerial and satellite images, with a special focus on high-resolution platforms (i.e. Quickbird).
Since the 80', topographic microrelief has been widely used in NE Italy to recognize and characterize the landforms of alluvial plain; detailed DEM were obtained by interpolation of selected elevation spots of the 1:10,000 maps chosen as representative of the natural surface. In the last years the spreading of LiDAR (Light Detection And Ranging) technology allow to survey large areas with a density generally of 1-10 point/m^2 and ~5-20 cm of vertical accuracy. At the moment LiDAR data are available only for some parts of the plain, but

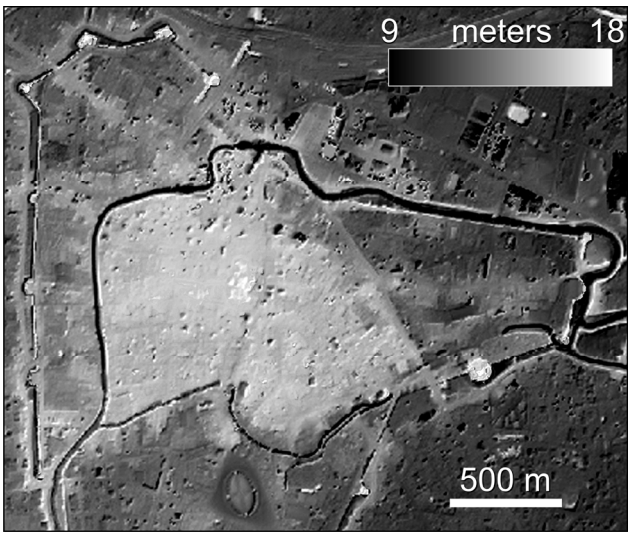

Fig. 1, LiDAR-deriver DEM of the centre of Padua.
DEM ottenuto da LiDAR del centro di Padova.

among them some important ancient cities as Padua, Altinum and Aquileia were surveyed.
The researches were compared with field surveys which collected information about geomorphology, stratigraphy, chronology of the archaeological features identified with remote sensing (e.g. cropmarks, soilmarks and other elements related with ancient human activity and settlements of the past).
In Padua and in Altinumthe LiDAR allowed to recognize the existence of a topographic anomalies coinciding with the ancient core of the city; Padua has been settled since Protohistory and the vertical succession of stacked living floors brought to the formation of an anthropic mound with an area of about 1.5 km^2. This artificial hill is nicely evidenced by LiDAR-derived DEM and has a maximum thickness of 6.5 m (FERRARESE *et al*., 2007; MOZZI *et al.,* 2010b; in press). In Fig. 1 the topography was filtered from the present buildings, thus the present ground surface is represented. Stratigraphic investigations allowed to calculate the volumes built during the different cultural phases from 1200 BC to Middle Age, and to demonstrate that the mound mainly consists of Iron Age and Medieval layering.
A similar setting was detected near Altinum, the Roman city which was abandoned between V-VII century AD leading its people to settle permanently in the Venice lagoon. The LiDAR survey highlights the existence of an archaeological mound with an elevation of about 3-4 m over the adjacent lagoon environment (MOZZI *et al*., 2010c).
Altinum is the only large Roman city in Northern Italy and one of the few in Europe that has not been buried by medieval and modern cities. This setting allows spatial investigation through remote sensing (NINFO *et al*., 2009). Figure 2 is a zenithal image taken at the end of July 2007 by Realvista - Telespazio S.p.A., during severe drought, which caused water stress of the maize and soy crops. The image consists of a digital photos with pancromatic and Near Infrared radiation (NIR), which is highly sensitive to vegetation health, highlighting the archaeological features. In Fig. 2 the lighter crop marks show the subsurface presence of stones, bricks, or compacted soil; the dark ones correspond to depressed features like pits, spoliation hollows, canals, and paleo-channels filled with silty-clay sediments. The images reveal ancient urban fabric and waterways, the city walls and gates, the street network, dwellings with their internal divisions, and monumental buildings (e.g., theatre, odeon, amphitheatre, forum with emporia, and basilica). The geo-archaeological aerial survey along *via Annia* path (about 200 km) has been carried out over the whole year, collecting images in

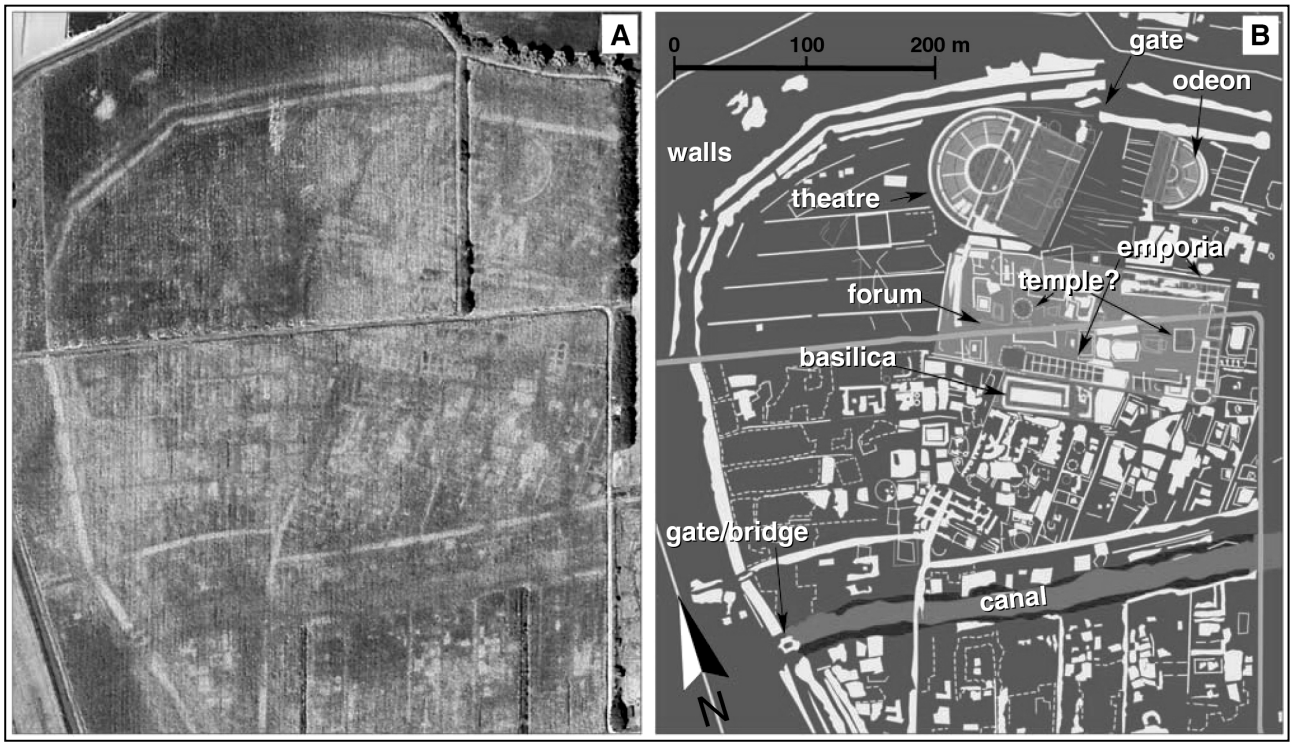

Fig. 2, Digital enhanced false-color composite image (NIR, red and green spectral bands) of the center of the Roman city of Altinum (Telespazio S.p.A., Rome, Italy), with maize and soy cropmarks; B) interpretation of A)(NINFO et al., 2009)
Immagine digitale a falsi colori enfatizzata (combinazione delle bande spettrali NIR, rossa e verde) del centro della città romana di Altinum (Telespazio S.p.A., Roma Italia) con cropmarks su mais e soia; B) interpretazione di A) (NINFO et al., 2009).

the different seasons with variable conditions of land use, soil moisture and vegetation growth. These different parameters strongly affect the visibility of the archaeological and palaeohydrographical features. Before this extensive survey, among geomorphologists and archaeologists the common idea was that winter zenithal photos were the most suitable images for detecting traces of the ancient landscapes; the new data collected within these projects evidence that the best moment of acquisition to maximize the cropmarks and soilmarks response is at the end of periods of drought along the growing period of vegetation. Another new concept is that oblique images on cropmarks have a particularly efficacy in detecting complex traces of little dimensions (e.g. ditches, necropolis, dwelling patterns) up to a centimetric detail. The possibility of flight with little aircrafts allows to collect images in very specific time windows, taking benefits from different light conditions and variable effects of shadow, that sometimes could enhance crops differential growth.

To be noted that in the processing of the oblique images a long time is need to rectify them. Moreover every oblique images could be corrected and georeferenced only for limited portion of it and a large number of them is needed to cover large extent.

Also the recent advances involving the sensors of aerial and satellite support new capability in cropmarks detection, specially with the wider use of hyperspectral sensors and the introduction of pancromatic scanners with an elevated geometric resolution (pixel of 1.0-0.4 m).

The integration between high-precision DEM and aerial images with a high resolution and, possibly, with pancromatic and NIR bands allowed to collect a number of new data in a wide area of NE Italy. The positive results achieved in the Venetian-Friulian Plain suggest to apply this methodology in other similar areas, as for example the distal and coastal sector of Po Plain, between Lombardy, Emilia Romagna and Veneto regions. LiDAR-derived DEM are currentlyavailable only for some limited zones, but in the next years they will cover the whole national territory, as planned by Environmental Ministry.

The examples presented in this paper focus on geoarcheology but, considering the aforementioned methods in a floodplain environment, many geomorphological and depositional aspects could be investigated with a high-resolution perspective. In this case the satellite images are important to support correlation of traces belonging to the same features, as for example different scroll-bar sequences formed by the same paleochannel.

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