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Spatial analysis and Lidar data for the extraction of archaeological features: the Etruscan site of San Giovenale, Blera (Lazio)

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***Abstract* –Over the past two decades, the use of LiDAR has found increasing popularity in archaeology due to its capability to "penetrate" the vegetation cover, thus providing information in areas were other technologies are ineffective and in places where field surveys are particularly difficult, such as areas with dense vegetation. Nevertheless, despite the recognized effectiveness of LiDAR, its capability for archaeological prospection could be strongly limited by very dense vegetation cover, and, in these cases, the data processing and analysis requires special attention. In this paper, to improve the identification of hidden archaeological features for the territory around the Etruscan site of San Giovenale, Blera (Lazio), spatial analysis was adopted to analyze the LiDAR –derived DEM.**

I. INTRODUCTION

The most recent airborne and satellite remote sensing technologies allow us to obtain more and more detailed and precise information even for the surfaces underlying the vegetation as in the case of acquisitions by LiDAR systems which enable us to obtain digital terrain models (DTM) and micro-topography /geomorphological details otherwise not obtainable with traditional survey methods. Actually, in areas characterized by a dense-vegetation cover LiDAR (Light Detection and Ranging) is the unique technology effective to map the terrain morphology and micro-topography, and in turn, to identify the presence of archaeological features hidden by the vegetation or terrain itself (see as examples [1], [2], [3]) and reconstruct the settlements of the past [4], [5]. However, the feature extraction is a quite complex task so that many techniques exist in literature and all the studies, (see, for example [3,5]) suggested a combination of diverse approaches. In this paper, to improve the identification of hidden archaeological features for the Etruscan site of San Giovenale, Blera (Lazio), the LiDAR –derived DEM was processed using the following three spatial analyses approches: 1) the hillshading combined with Principal Component Analysis, 2) the openness and 3) the sky-view factor.

II. METHODS

A. Hillshade

Hillshade is a method widely used in literature over LiDAR-derived data since '80s [6]. In this method a light source is fixed and shadows created by the terrain morphology are calculated [7]. It depends that hillshade strongly depends on the illumination direction, consequently there will be position of the light source that are able to enhance the researched features, others that hide them [8]. For this reason, in the last years in literature a combination of hillshade calculated from multiple directions [9] and Principal Component Analysis (PCA) [10] have been used..

B. Openess

Topographic openness is an angular measure, expresses in terms of nadir and zenith, connected to the concept of visibility of a territory [11]. In fact, according to the morphology in its surroundings, each pixel of the space has a minor of major visibility. In particular, positive openness expresses a dominance position of that pixel, while negative openness expresses and enclosure of it. Consequently, high positive openness values are particularly suitable to enhance convex forms, whereas low negative values highlight concave forms.

This method strongly depend on the number of sectors used for the calculation and from the search radius

C. Sky-view factor

The sky-view factor (svf) measures the visible sky from each pixel of the study area through a uniform illumination coming from a constant light source located over it [12]. It varies from 0, when the sky visibility is obscured, to 1, when the sky visibility is completely open [13].

As for the Openess algorithm, the svf depends from the number of directions considered in the calculation and from the radius.

III. THE CASE STUDY

A. The Etruscan Site of San Giovenale

In this paper , the area around the Estruscan site located over the Vignale plateau in San Giovenale (Blera) was surveyed and analysed (fig. 1). This area is particularly interesting from the archaeological point of view, because of its long human frequentation, with particular reference to the presence of the Etruscan civilization from the sixth century BC onwards [14], [15].

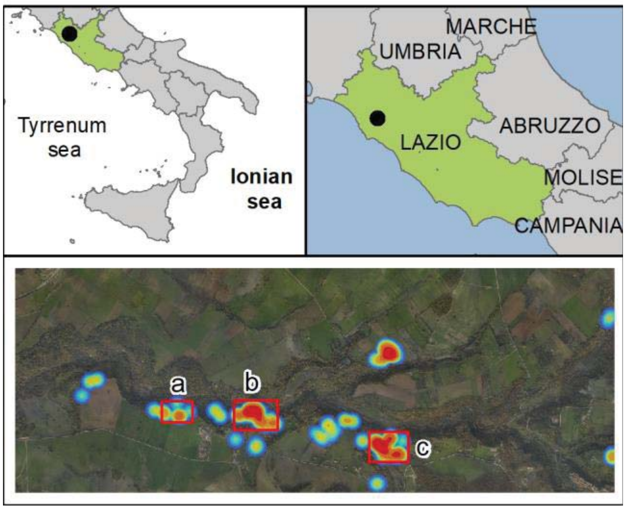

Fig. 1. Overlay between RGB image of the area surveyed by LiDAR and the KDE of the looting phenomenon. In red the subsets chosen to show the results.

Two types of archaeological features are present in this area, having different geometrical characteristics: the first one is holes due to clandestine excavations (or looting phenomenon), concave elements with circular shape and a diameter up to 5m; the second one is linear features probably sign of buried structures. Fig. 1 shows Kernel Density Estimation [16] applied over holes mapped by hands after a visual interpretation of Lidar derived models (LDMs) as explained in the next section, in order to emphasize areas more affected by this phenomenon and to choose subset areas to show in the results expounded in section IV.

B. LiDAR data preprocessing

The first elaboration step consisted in the pre-processing of LiDar data to obtain the LDMs of the terrain.
The noisy points (isolated points) and outliers (low points, that is lower outliers, and air points, that is higher outlier) where removed. In this way the Digital Surface Model (DSM) of the terrain was calculated. After the filtering, the DSM was classified (for the classification method see [17]) in order to derive the Digital Elevation Model (DEM) of the terrain (fig. 2).

C. Spatial analysis application

The methods explained in section II were applied. Specifically, for each method, the parameters described below were selected.
For what concerns the hillshade from multiple directions, a number of 16 sectors was chosen, while the first three components coming from the PCA are the most representative of hillshading.
For what concerns the openness and the different search radia, varying from 5 to 30m were iteratively introduced in order to find the one that best improves the enhancement of archaeological features.

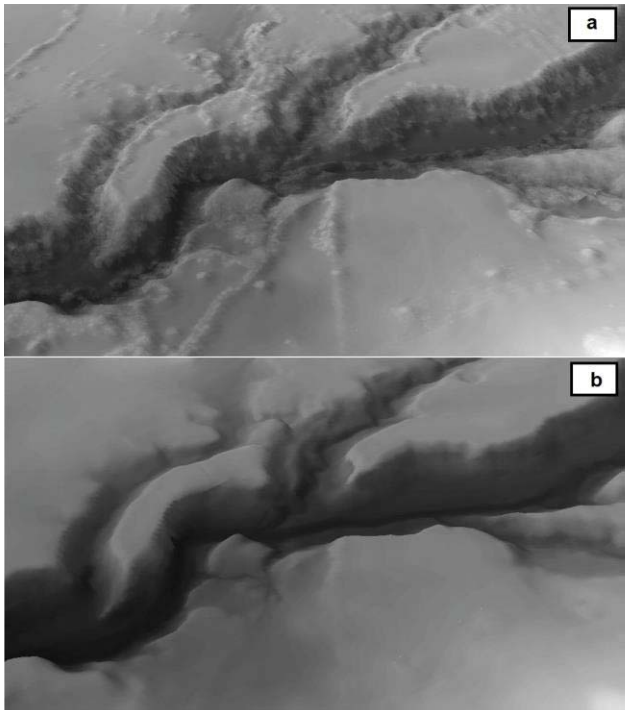

Fig. 2. Subset of the LiDAR derived DSM and DEM.

IV. RESULTS

The use of the spatial analysis enabled the enhancement of many features in all the methods herein adopted. However, as expected, a positive openness with a 20m radius was particularly useful to enhance linear features (fig. 3), while a negative openness with a 5m radius better enhances the looting phenomenon (fig. 3-4-5). Instead for the sky- view factor, a radius choice of 5m highlights better both pits and linear features (fig. 3-4-5).

V. FINAL DISCUSSION

In this study, the Etruscan site around the Vignale plateau in San Giovenale (Blera) was selected for our investigations, because of its great archaeological interest and also because affected by clandestine excavations, as, unfortunately, other Etruscan sites. For the aims of our investigations, to monitor the looting phenomenon and improve our knowledge about hidden archaeological elements, a detailed LiDAR survey was carried on.

The Lidar- LDMs, processed using three spatial analysis techniques: 1) the hillshading combined with Principal Component Analysis, 2) the openness and 3) the sky-view factor, enabled us to enhance and capture many features related both to the presence of archaeological remains and traces of the looting.

Further improvements can be achieved in the future by a refinement of the segmentation techniques which can also facilitate the implementation of an approach less qualitative and more quantitative.

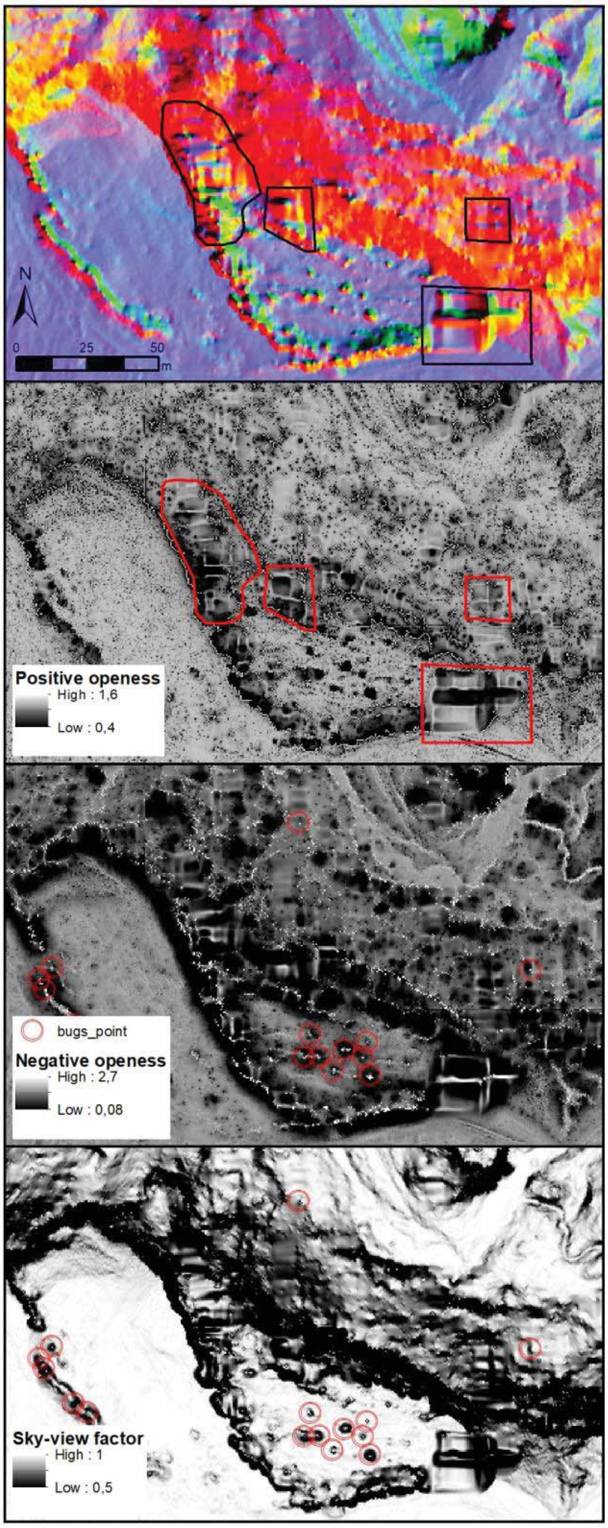

Fig. 3. Subset A. From top to bottom: PCA composition in false color of hillshades; positive openness, negative openness and sky-view factor indexes. In black (over the PCA) and in red (over the other layer) some looted points and some linear features are highlighted.

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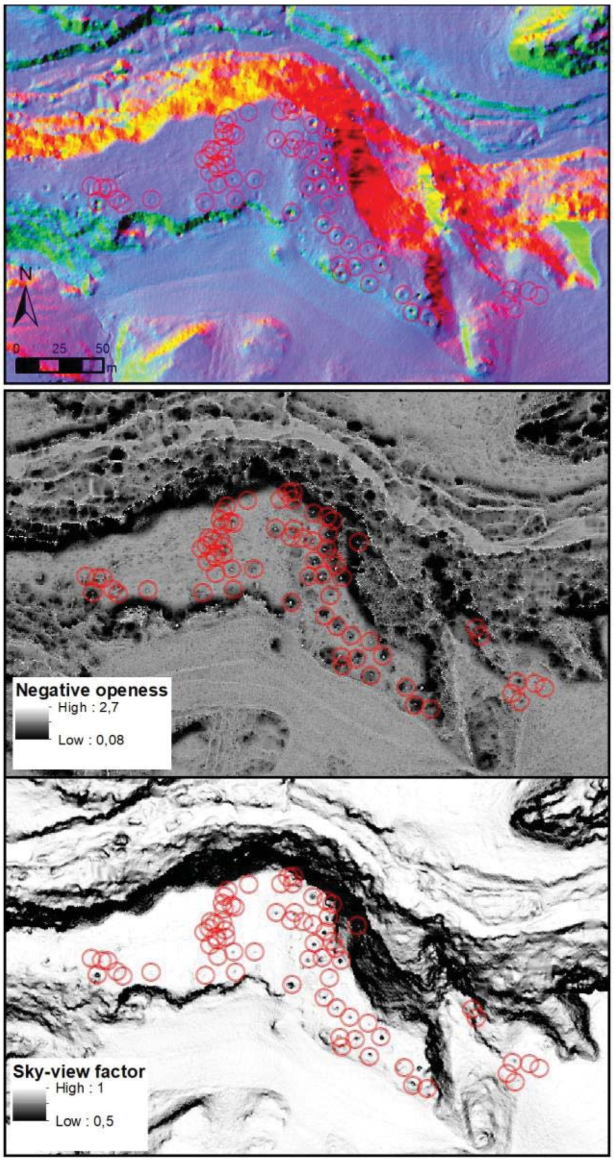

Fig. 4. Subset B. From top to bottom: PCA composition in false color of hill shades; negative openness and sky-view factor indexes. In red) some looted points are highlighted.

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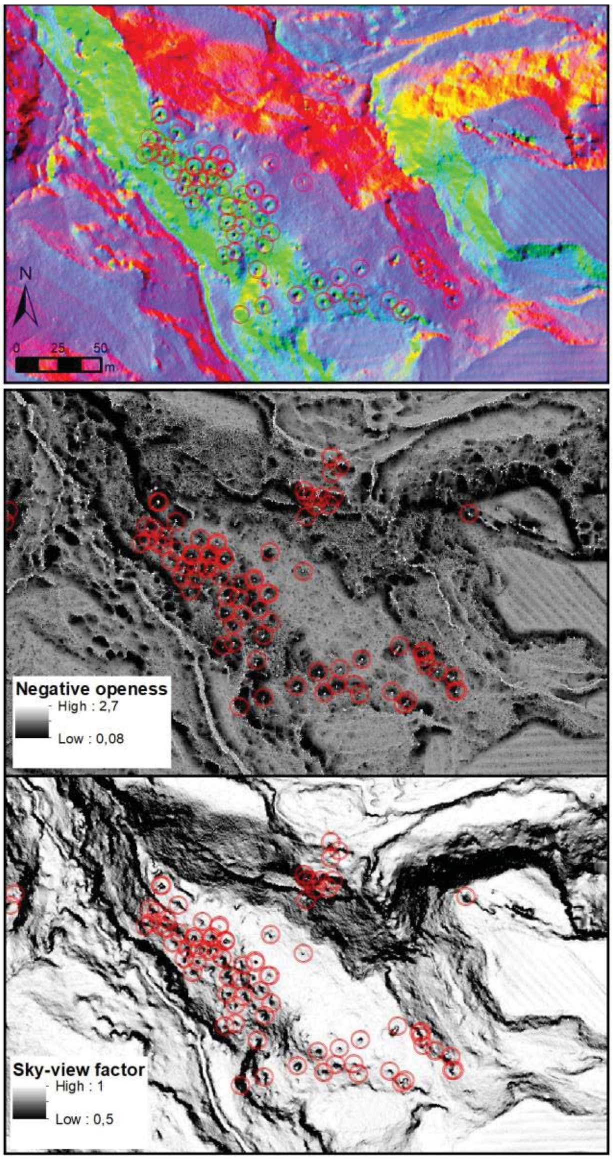

Fig. 5. Subset D. From top to bottom: PCA composition in false color of hill shades; negative openness and sky-view factor indexes.