Remotely Sensing the Ancient Interactions between Humans and the Environment during the Roman Period at Porolissum

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Introduction

This paper summarizes results from a landscape archaeology research project that explores the ways in which ancient Romans from the territory of Dacia Porolissensis (Romania) used and modified the environment around them. Based on LiDAR-derived data (Light Detection and Ranging) for accurate archaeological, geomorphological and vegetation feature detection, the most probable effects of past human land-use on the present landscape values are assessed. Knowledge of human disturbance periods, land-use history and their corresponding legacies is vital for evaluating habitat resilience and predicting future ecosystem services (Glenn et al. 1999; Foster 2003; Ritter 2011).

Materials and methods

The study area covers 10 km^2 and encompasses the archaeological site from Moigrad-Porolissum (Sălaj County, Romania), which is part of the Roman Empire Frontier fortification system, also called the *Roman Empire Limes* (Figure 1a). LiDAR data were collected in March 2013 during the leaf-off season using a helicopter equipped with Riegl's LMS-Q560 laser scanner, flying at an altitude of 600 m. The raw LiDAR data were employed to create the very accurate and high resolution (0.5 m) Digital Terrain Model (DTM) and Digital Surface Model (DSM). Subsequently, the DTM was visualized by generating different topographical and geomorphological models. The Canopy Height Model (CHM), which revealed the 3D vegetation structure, was computed as a difference between the DSM and DTM. These LiDAR-derived models enabled the detection of both ancient human influences and their results in the present landscape characteristics.

Results and discussion

The visualization techniques of the LiDAR-derived DTM (Figure 1b and 1c) allowed the accurate mapping of previously unknown underground archaeological remains (Opreanu et al. 2014; Roman et al. 2016a manuscript) situated in forested steep terrain (Figure 2). These ancient structures, placed strategically within the landscape, are the vestiges of defense walls, ditches, forts, fortresses, watchtowers and tumuli. In addition, the present road network, water courses, some ancient roads, small anthropogenic depressions and caves (e.g. Figure 1d) were detected using these LiDAR derived-data (Roman et al. 2015; Roman et al. 2016b manuscript).

The analysis of 3D forest structure (CHM) revealed substantial differences in tree height between the trees growing upon underground ancient structures and the surrounding canopy (Roman et al. 2014). Currently, the forest vegetation is dominated by beech, hornbeam and oak species, (Roman et al. 2014), being considered similar to that found in this region during the Roman period (Nyárády et al. 1966; Raţiu 1966; Grindean et al. 2014).

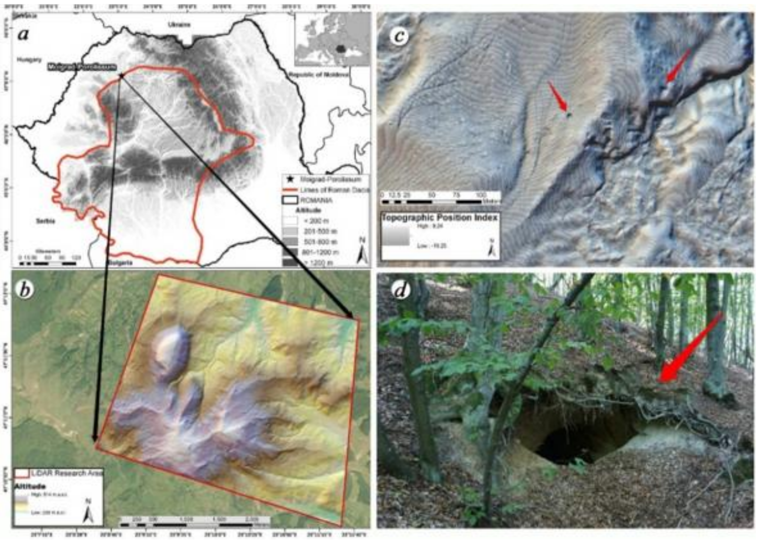

Fig. 1 (a) The frontiers of the ancient Roman Dacia and the study site; (b) The LiDAR-research area and derived terrain models: Hill-shade model displayed with a 60 % transparency on the DTM; (c) The topographical position index with the detected small anthropogenic depressions and caves (red arrows); (d) In-situ validation of a small depression – cave opening (red arrow).

The above mentioned interdisciplinary results support the understanding of ancient human activities and their impact on the environment during the Roman period at Porolissum (106-276 AD). We have identified the main interacting factors that shaped the natural landscape into a cultural one with many embedded legacies. The most important one is land cover, which was considerably different at that time. In contrast to the present forest dominance, it appears that in the areas of the Roman Empire Frontiers, like Porolissum, there was a deforested landscape with intense military and most probable agricultural activities. The defense walls and ditches, watchtowers, forts and fortifications, were built strategically on the local relief and formed an intricate system that had the role of early warning against barbarian attacks. Besides being mandatory for defensive purposes (visibility for communication between the watchtowers), the open landscape hypothesis is also supported by paleo-environmental studies and palynological analysis that indicate large-scale deforestation within this area (Rosch & Fischer 2000; Tanţău et al. 2003; Tanţău et al. 2006; Feurdean 2010; Tanţău et al. 2014). Oak, beech, and hornbeam show a decrease in the pollen spectra during a time span overlapping the Roman period (Grindean et al. 2014). Moreover, historical data sources also mention that deforestation around the military encampment was a basic strategic measure in the Roman provinces (Chew 2008; Ritter 2011). The buried remains of these ancient structures have caused anomalies in the soil matrix that translate nowadays into human generated tree height patterns (Figure 3a and 3b). These, along with the Roman earthworks (more than 7 km of turf defensive mounds build on the ridges) remain visible throughout the millennia.

Data regarding the historical landscapes are important since ancient forests are often used as a baseline for ecological restoration (Honnay et al. 2002). Nevertheless, their primary character is uncertain because the limited historical records available do not allow tracing a site's history for hundreds or thousands of years (Peterken 1996). LiDAR techniques can help landscape archeology go beyond this time barrier. Within the Porolissum site, the geomorphological and archaeological evidence combined with the vegetation data suggest a deforestation land-use phase. There are just a few other ancient forest studies in France and Belgium that demonstrated the persistence of Roman land-use effects on both soil and vegetation characteristics for more than two millennia (Dupouey et al. 2002; Vanwalleghem et al. 2004).

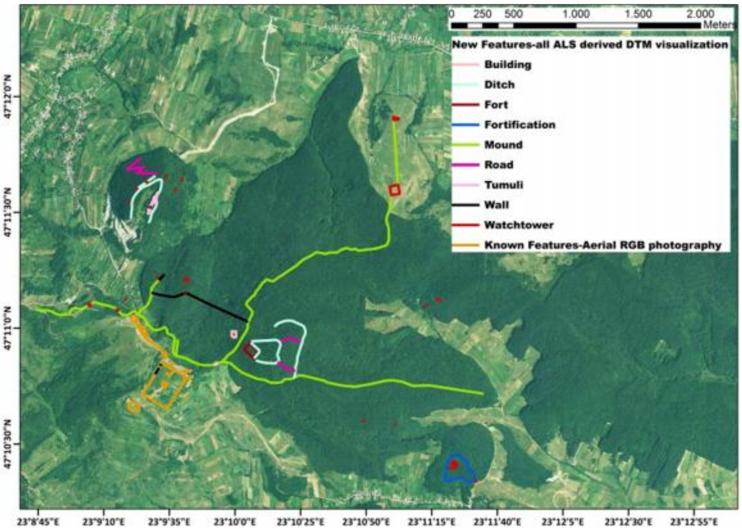

Fig. 2 The present forested cultural landscape with ancient underground defensive structures at Porolissum.

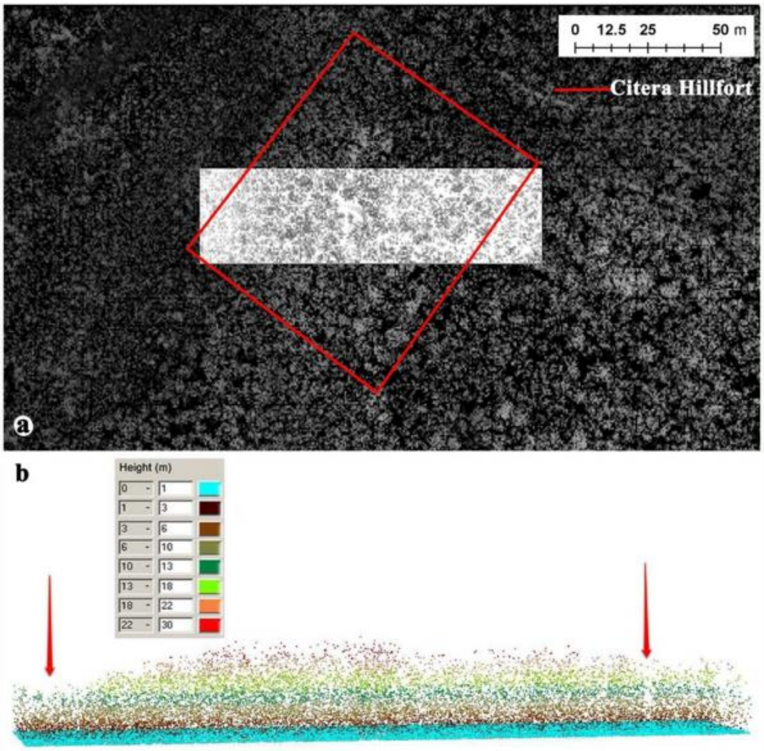

Fig. 3 (a) The DSM and the underground Citera Hill Fort remains (red lines) with a selection from the LiDAR-data point cloud (white rectangle); (b) Cross-section of the LiDAR point cloud displaying the 3D forest structure and tree height pattern (red arrows-low tree height above the ancient underground walls).

Conclusions

Vegetation analysis and mapping together with active and passive remote sensing provide a base for combining the knowledge of plant ecologists and archaeologists in order to achieve a thorough landscape analysis and understand the interacting processes that influence habitat quality. Since such buried legacies of ancient settlements, although widespread, are easily overlooked mainly in forest habitats, they are of particular interest to conservationists and land managers as well as to scientists. These results emphasize the long term, irreversible effects of ancient human impact on the landscape, which is often cultural beneath its natural appearance. The detected trends should also raise awareness among scientists (e.g. biologists, soil scientists, geomorphologists) that research in historical sites requires a particular perspective. There are cases when habitats like ancient forests are not actually primary. In such circumstances, the seemingly intrinsic variations in vegetation, soil or relief are in fact the result of ancient human impacts on the environment. Consequently, the historical perspective and the awareness of land-use legacies may be facilitated by the remote sensing techniques, specifically when inferring the natural or cultural state of a landscape.

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