Perspectives: Remotely Sensing the Buried Past of Present Vegetation

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1. Introduction

This study is part of a research project (Landscape Archaeology on the Northern Frontier of the Roman Empire at Porolissum) that uses an interdisciplinary approach to explore the life and habits of the ancient inhabitants from the area of the Roman Empire LIMES situated on the present territory of Romania (Dacia Porolissensis). The comparative analysis of vegetation in different moments of time would allow the assembly of a more complete image of the Porolissum settlement since vegetation has directly influenced its organization and functioning.
Our goal is to map the distribution pattern of the current vertical structure of vegetation and to explore its correlation with the historical placement of structures within the Roman settlement. This would also make possible to detect traces of the ancient human impact from present vegetation structure and habitat quality. Since disturbance plays a fundamental role in determining the vertical structure of vegetation, knowledge of disturbance and land-use history and their legacies is vital for evaluating habitat resilience (Glenn et al. 1999, Foster 2003). This work is focused on contemporary landscape and forest habitat conditions derived from the analysis of certain LIDAR-derived data (Canopy Height Model-CHM) that is considered non-informational and “thrown away” by archaeologists, but often used in forestry for habitat structural features extraction, assessment and monitoring. Such information is important because characteristics associated with the 3D structure of forests are important factors that permit the estimation of habitat structure and quality. We explore if the buried Roman archeological remains modify the vertical structure of present forest growing above them. This approach goes beyond land cover and vegetation mapping to the next level of inferring habitats quality and conservation status from processing remote sensing and field data.

2. Study Area

The study area (Figure 1), covers 10 km² within the archaeological site from Moigrad-Porolissum (Sălaj County, Romania) - 47°11′49″N, 23°08′37″E, 504 m a.s.l., part of the Roman Empire Frontier fortification system (Figure 2), also called the Roman Empire LIMES. The remains of the LIMES today consist of vestiges of defense walls, ditches, forts, fortresses, watchtowers, civilian settlements and fortification structures that are hidden beneath forests. The climate is warm and temperate, the annual averages being a temperature of 9.2°C and 647 mm of precipitation.

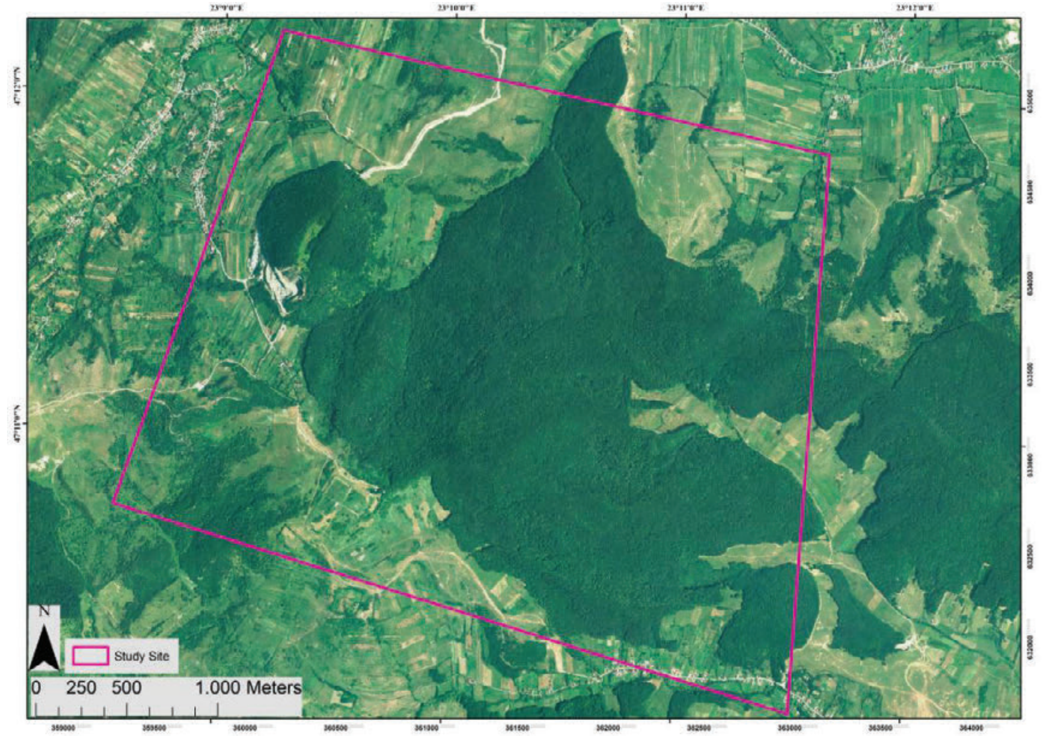

Figure 1: Aerial photography of the study area.

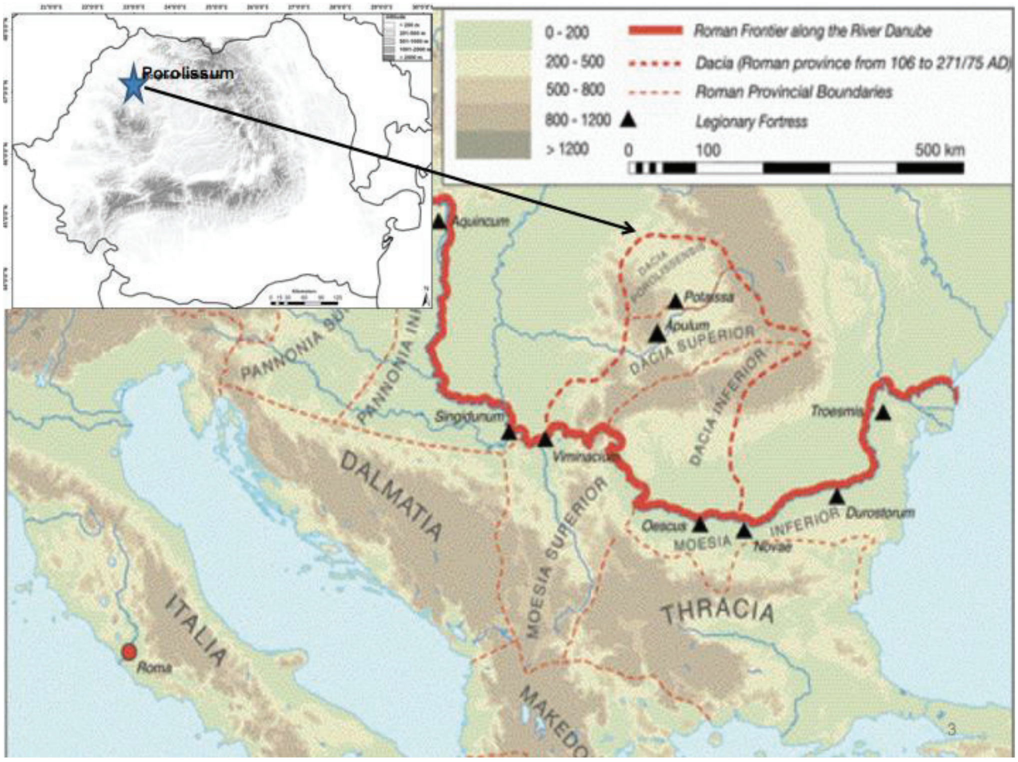

Figure 2: The Roman Empire LIMES (Breeze et al. 2009).

3. Materials and Methods

We used aerial photographs (pixel size: 0.5 m), taken in 2009, and field surveys of the surrounding vegetation (2012, 2013) based on an adapted version of the Braun-Blanquet method (1965) in order to generate the current vegetation map of the archaeological site. Recently, phytosociological methods have been used extensively for the purposes of plant community classification and vegetation mapping. A review of the relevé technique, its development and modification can be found in Kent (2012).

LiDAR data were collected in March 2013 (leaf-off season) using a D-EBMW/C207 helicopter equipped with Riegl's LMS-Q560 laser scanner, flying at an altitude of 600 m. The raw LiDAR data were used to create very accurate digital terrain models (DTM) and digital surface models (DSM). The set of XYZ files was converted to ASCII raster file, then to ESRI GRID, using XYZ2GRID 2.1 (Huang 2003). Subsequently, the CHM (computed as a difference between DSM and DTM) was visualized and analyzed with the FUSION software (McGaughey 2014).

4. Initial Results

The data from the vegetation field survey were mapped in ArcGIS 10 (ESRI 2011). According to the phytosociological relevés the forests belong to plant community *Lathyro hallersteinii-Carpinetum*, the shrubs to *Sambucetum ebuli* and *Pruno spinosae-Crataegetum*, and the pastures to *Festuco rubrae-Agrostietum capillaris*, *Trifolio repentis-Lolietum*, *Poo-Trisetetum flavescentis* (Figure 3). There is also an area covered by a successional stage dominated by oak (*Quercus cerris*), resembling the ancient forest type from Roman times (Şuteu et al. 1978).

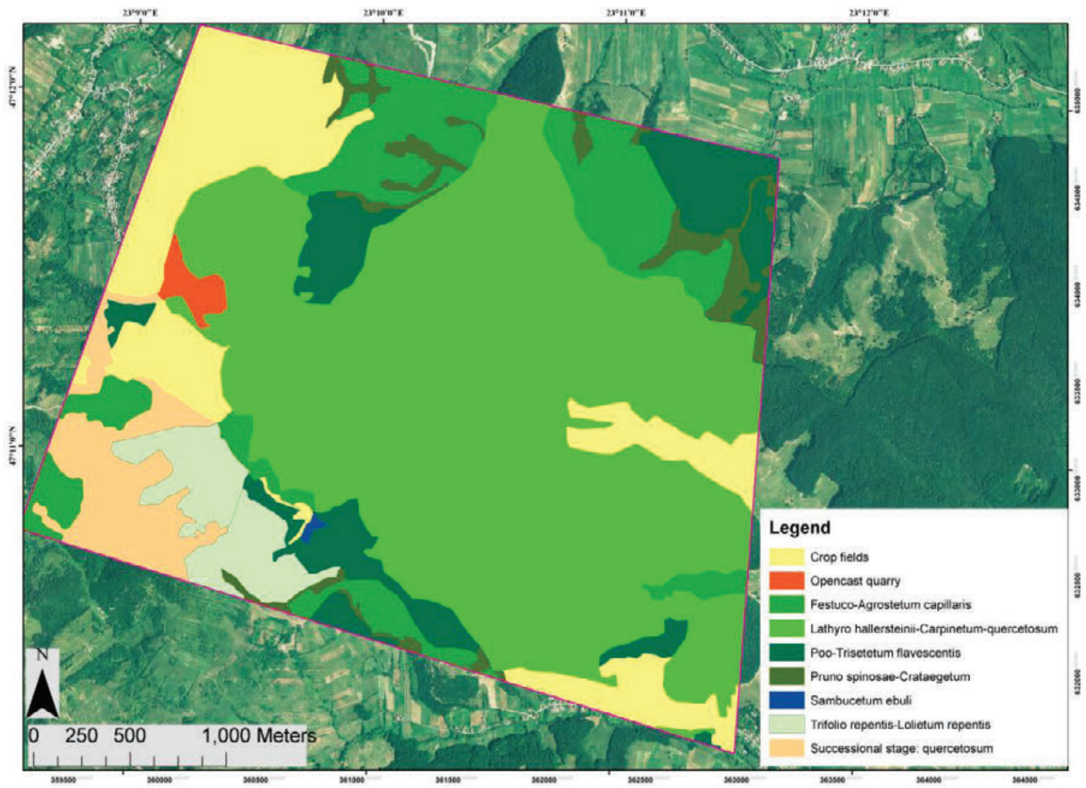

Figure 3: The current vegetation map at plant community level.

From LIDAR data we obtained very accurate (0.5 m ground resolution) DSM and DTM (Figure 4) that were used to extract key forest habitat characteristics such as tree heights and their spatial distribution.

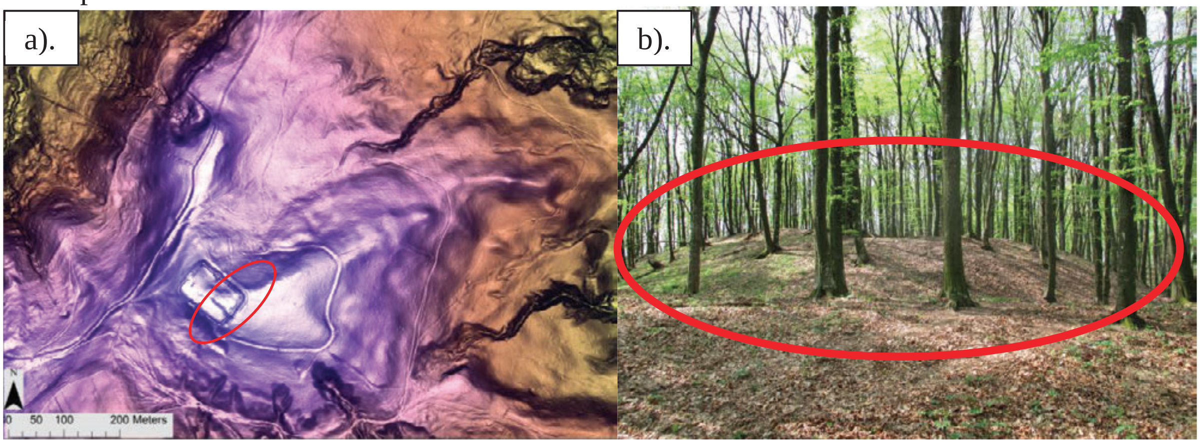

Figure 4: a). Aspect from the DTM revealing the archaeological remains, part of the Roman defensive system, confirming the deforestation of the area. b). The red oval indicates the area of the former Roman Fort, covered today by trees that display height patterns.

The tree height distribution (Figure 5) was visualized and analyzed with Fusion/LDV (McGaughey 2014). Obvious differences in tree height were noticed between the trees growing on the ancient structures and the surrounding canopy. This pattern needs to be confirmed through specific analyses after calibration of LIDAR–derived heights with control ground measurements.

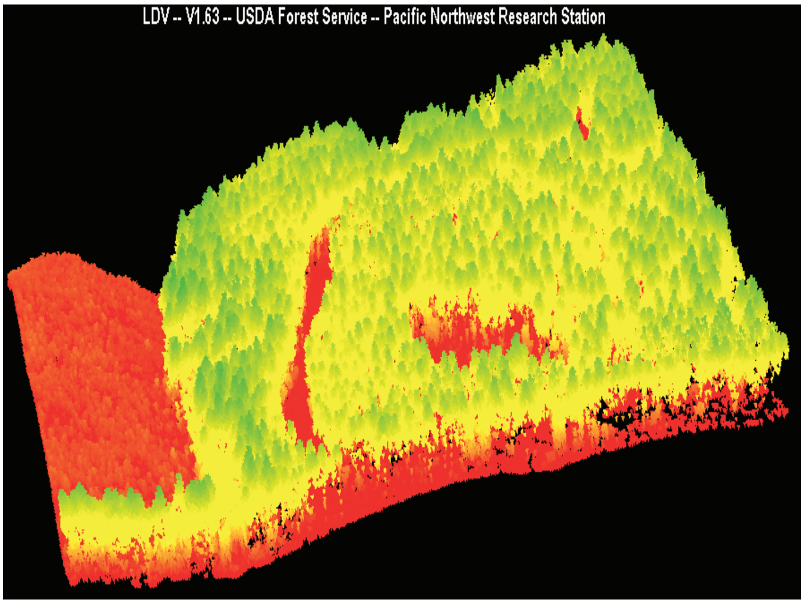

Figure 5: Visualizing the tree height patterns.

5. Discussions and Conclusions

The forest habitats from this area are dominated by oak species, beech and hornbeam (Figure 3), being similar to the ones that were found here during the Roman period (Nyárády et al. 1966, Rațiu 1966, Grindean et al. 2014). However, our LIDAR based research indicate that within this particular area of the Limes, there was extensive deforestation during the Roman period, required for strategic reasons (communication and early warning against barbarian attacks). Moreover, deforestation in the Roman has been a common practice for economic purposes (wood exploitation and clearings for agriculture). Therefore, in the 2nd century AD, within the Limes area at Porolissum, there was an open landscape with intense human military activity and defensive structures distributed over cca. 40 km², in contrast to the present forest habitat dominance. The buried remains of these structures have generated anomalies in the soil matrix that translate into human generated vegetation patterns that remain visible through the millennia. While these vegetation marks are well documented in grasslands and crop fields, we have detected them in the Canopy Height Model derived from LIDAR data, that, to our knowledge, has never been approached before.

Within this interdisciplinary study, phytosociological analysis and mapping together with active and passive remote sensing provides a base for combining the knowledge of plant ecologists, archaeologists and foresters in order to achieve a thorough analysis of the landscape and understand the interacting processes that influence habitat quality. Since such buried legacies from ancient settlements, although widespread, are easily overlooked especially in forest habitats, they are of particular interest to conservationists and land managers as well as to scientists. Consequently, we conclude that the historical perspective and the awareness of land-use legacies may be approached using the perspectives that remote sensing offers especially when inferring drivers that influence habitat quality.

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References

Braun-Blanquet J, 1965, *Plant Sociology. The study of plant communities*. Hafner, London, UK.

Breeze DJ, Jilek S and Thiel A, 2009, Frontiers of the Roman Empire. The Danube Limes-A roman river frontier. Univesity Warsaw, Poland.

ESRI, 2011, ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Foster D, Swanson F, Aber J, Burke I, Brokaw N, Tilman D, and Knapp A, 2003, The importance of land-use legacies to ecology and conservation. *BioScience*, 53 (1), 77-88.

Glenn M, Wilson P, Foster D, and Allen A, 1999, Vegetation patterns in heterogeneous landscapes: The importance of history and environment. *Journal of Vegetation Science*, 10, 903-920.

Grindean R, Tanţău I, Fărcaş S, Panait A, 2014, Mid- to late-Holocene vegetation shifts in the NW Transylvanian lowlands (Romania). *Studia UBB Geologia*, in press.

Huang ML, 2003, XYZ2GRID2.1-Batch User's Guide, National Cheng Kung University, Tainan, Taiwan.

Kent M, 2012, *Vegetation description and data analysis: a practical approach*. John Wiley & Sons Ltd.

McGaughey R, 2014, FUSION/LDV: software for lidar data analysis and visualization. Version 3.14. Seattle, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Nyárády A, Lupşa V, Boşcaiu N, 1966, Studiul geobotanic şi palinologic al mlaştinii de la izvorul râului Crişul Repede. *Studii şi Cercetări Biologice Seria Botanică*, 18 (4), 331-339.

Rațiu F, 1966, Istoricul vegetației, în Flora şi vegetația rezervației naturale „Defileul Crişului Repede". *Contribuții Botanice*, 155-161.

Şuteu Ş, Teodoreanu E and Diaconeasa B, 1978, Prezentul şi trecutul vegetației palustre din tăurile de la Hereclean (jud.Sălaj). *Contribuții Botanice*, 265-268.