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LIDAR IN MEDITERRANEAN AGRICULTURAL LANDSCAPES - REASSESSING LAND USE IN THE MAUGUIO

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Abstract: The value of lidar data for the study of forested areas has been repeatedly demonstrated, recording large numbers of previously unknown sites and features where most survey methods are ineffective. However, the question of the value of lidar in cultivated areas already investigated through historical mapping and archaeological studies such as fieldwalking survey, aerial photographic survey and excavation remains open. This paper summarizes the results of recent research in the open and heavily cultivated Mauguio region of southern France and reflects on the challenges of integrating information from lidar survey into an existing body of knowledge on the development of an agricultural landscape.

Keywords: lidar, Mediterranean, agricultural landscapes, visualization

Introduction

This paper presents an assessment of the 'added value' of lidar data for the study of a Mediterranean landscape in the Mauguio area of the French Languedoc which has been intensively studied by archaeologists since the 1980s, primarily through the substantial fieldwalking surveys led by F. Favory and C. Raynaud (Favory, Girardot & Raynaud 1994). This area was further studied through a number of thematic projects at national and European level, enhancing the information about land use and settlement patterns in this area through regional and inter-regional comparanda.

In focusing on an agricultural Mediterranean landscape this paper highlights a regional divide in what might be termed the fundamental building blocks of knowledge about landscape history. Earthworks, ranging from ridge and furrow field systems to massive Bronze and Iron Age hillforts have long been essential to the character and archaeological description of landscapes throughout northern and central Europe. Landscape archaeology and the practice of survey in the Mediterranean, on the other hand, developed within a different research tradition - one heavily dependent on the ceramic and stone remains found through fieldwalking. Given a tradition of studying rural landscapes that does not take as much account of topography, what kind of role can lidar data play and how should its evidence be balanced with that from traditional data sources?

While many lidar surveys are commissioned, or existing data acquired, with the primary aim of identifying new sites (in the traditional sense of the term) or documenting existing ones, a lidar survey in 2007, covering a block of about 40 km², was undertaken with the specific aim of creating an accurate DTM to better understand changes in fluvial patterns, drainage systems and the evolution of the lagoon coastline. Following the completion of an initial palaeo-hydrological study, a second project was established to explore the relationship between archaeological features visible in the lidar, many of which were interpreted as related to agriculture or drainage, and land use patterns as understood from previous archaeological research. The relationship between areas characterized by extensive agrarian manuring spreads, indicative of intensive or long term agricultural use, and the visibility of features in the lidar data was of particular interest. Both projects focused on the agricultural landscape and the evolution of land use, rather than the settlement pattern (the usual focus of survey in Mediterranean archaeology) setting lidar up to play a complementary rather than augmentary role in landscape scale research in the region. In establishing the lidar survey as a source of complementary knowledge, technical challenges were posed by visual noise in the data caused by deep ploughmarks, and interpretive challenges arose from the process of integrating the detected features into existing datasets and assessing the value of such information in a well studied area.

Geographic Context

The Mauguio study area is located in the Languedoc region of southern France, part of a plain bordering the Mediterranean Sea. It is very flat, lying just a few meters above sea level, surrounding a coastal lagoon. This marshy area was heavily managed during the past and is currently occupied by scrubland, vineyards and agricultural land (Figure 1).

History of Research

Knowledge of local settlement history and land use is primarily based on the work of F. Favory and C. Raynaud (Favory, Girardot & Raynaud 1994) and the *Archaeomedes* Project undertaken in the 1990s (Van der Leeuw, Favory & Fiches 2003). The area was also studied through limited excavation, and satellite and aerial imagery were used to identify field systems and roads (Favory & Raynaud 1992). In the 2000s this region was studied by L. Nuninger & K. Oštir, using remote sensing data to detect palaeo-channels and develop a reconstructed palaeo-DTM (Nuninger & Oštir 2005).

The results of all these projects allow us to trace the general trends of long-term land use. While the earliest remains date from the Palaeolithic period, it is in the early Iron Age that settlement and activity along the banks of the coastal lagoon increases significantly. The Roman period saw further agricultural intensification on the plain, with the introduction of a cadastral land division system, an extensive settlement network and widespread drainage infrastructure installed. These developments totally changed the environmental dynamics of the area. The Roman drainage systems, roads and land divisions established the framework of the agricultural landscape for subsequent periods, and they remain apparent in the contemporary landscape.

DTM preparation in areas of intensive agriculture

The high resolution of the lidar DTM (0.5 m) is appropriate for the detection of micro-topographic features such as field boundaries, drainage ditches or ancient roads. However, this precision can be problematic in fields under cultivation because plough furrows, vineyards, and other artefacts of modern land use which are not easily separated from the 'interesting' ground surface (Figure 2) are also recorded in great detail. And where the agricultural noise is greatest in areas of heavy ploughing archaeological relief will be at its most subtle due to heavy erosion. Identifying subtle traces of past activity in the present-day agricultural landscape therefore required careful filtering and visualization to remove noise and improve visibility.

To facilitate the visual recognition of archaeological features in the plough zone, the removal of linear 'plough noise' using established image processing techniques was attempted. An initial effort (Nuninger et al., 2008: p. 36-39) demonstrated that Sobel edge detection, low-pass filters and directional filters, as implemented in Erdas Imagine, did not significantly improve the visibility of archaeological features.

However, an approach based on Fourier analysis was more successful in removing the traces of ploughing using operations (Figure 3). Two approaches were taken. The application of an 'Automatic Periodic Noise Removal' algorithm in Erdas Imagine, requiring a minimum of input from the user, was applied in the first instance. In cases where this did not improve the appearance of the image, manual editing in Fourier space to remove the periodic plough noise was performed. Removing the linear pattern created by the most recent phase of ploughing sometimes revealed evidence of earlier phases of cultivation and differences in land use in the form of changes in field size, row spacing and orientation of cultivation.

Visualisation in the ploughzone

The hillshading model applied always influences the visibility of features in a lidar DTM, and in heavily cultivated landscapes this effect is magnified by the shadows created by ploughmarks. Because fields may be ploughed in variety of directions, any directional hillshading model applied over a reasonably large area will cause serious shadowing effects in some fields where it is near-perpendicular to the direction of the ploughing. Consequently, while simple directional hillshades are often most effective, in this situation we tested two complex hillshading models: the Swiss Hillshade Model and the MDOW (Multi-Directional Oblique Weighting) Hillshade Model (**Erreur ! Source du renvoi introuvable.**).

The Swiss Hillshade Model is designed to, "*emphasize the major geographic features [and] minimize the minor features, smooth irregularities on the slopes, but maintain the rugged characteristics of ridge tops and canyon bottoms…You can then simulate an aerial perspective that makes the higher elevations lighter and the lower elevations darker*" (Barnes 2002). On first assessment, this model may not seem suitable for processing digital terrain models to detect archaeological entities, since it is supposed to highlight major geographic features, minimize the margins and smooth out slope irregularities. However, in an area dominated by ploughing it ameliorates the problems introduced by a directional hillshade. Further, by lightening shading on the highest altitudes, and darkening shading on lower elevations, absolute elevation differences are highlighted. In an area with a large elevation range such shading will not show up archaeological features, but it can be effective on very flat terrain where relief is very low (a few centimetres elevation change across a feature of several metres extent) and the total elevation variation is very small.

In contrast, the Multi-Directional Oblique Weighting (MDOW) Hillshade Model is theoretically an answer to the problem of, "*traditional computer-generated shaded-relief maps* [which] *emphasize structures that happen to be obliquely illuminated, but wash out structures that are illuminated along the structural grain. This* […] *technique, which emphasizes oblique illumination on all surfaces, provides more detail in areas of an image that would otherwise be illuminated by direct light or left in darkness by a single source illumination*." (Robert Mark, USGS, http://pubs.usgs.gov/of/1992/of92-422/of92-422.pdf) Testing this model revealed that rather than improve visibility in areas with multi-directional ploughing, noise associated with the plough lines in the image increased because more fields were affected by shading perpendicular to the direction of their ploughing.

While the Swiss Hillshades were judged to be useful, initial assessment did not indicate that any single visualization of the terrain consistently provided the best results. Following the practice of many projects a combined approach was taken, including using directional hillshades and other visualizations of the terrain in the course of interpretation. Successfully working with a variety of visualizations relies on experience interpreting topography and archaeological knowledge (see Halliday this volume) more than it depends on technical prowess or excessive computing power. Hillshades and other terrain models can be easily produced using batch scripts and storage space for the files is increasingly inexpensive and readily obtained. The challenge is in knowing which visualization is likely to be most useful for any area of landscape, in being able to look at a visualization and, based on its utility, select the next one to apply to the same area, avoiding having to systematically look through every rendering.

Integrating Lidar with existing Knowledge

After processing to remove noise and create good visualizations as described above, a large number of features associated with agriculture, drainage and land division were identified. An essential first step is discriminating between features that document past activity and those which are modern. Establishing chronology is always problematic when working with aerially acquired data. In this case, orthophotographic coverage (Figure 5) and the Napoleonic cadastre were used to assess relatively recent changes in the landscape and attempt to identify features associated with these changes before undertaking a comparison with data from fieldwalking survey. On the basis of this exercise 85 features were identified as being archaeological and previously undocumented. These were dominated by linear features such as field boundaries, drainage ditches and paths.

Comparison with the Napoleonic cadastre and orthophotographs

The Napoleonic cadastre was compiled for France and many other countries under the Napoleonic Empire during the course of the 19th century, continuing even after the end of the Empire. In this part of southern France these maps were made in 1811 (AD34, 3P3424) and for part of the study area the maps are available in digital form. These were georeferenced and all the field boundaries were digitized. Within the area covered by the digital maps, six of the 24 lidar features (25%) are depicted on the cadastral map, corresponding to established field boundaries. One of these is also visible on the orthophoto coverage (Figure 6).

Evidence for early field systems

Fieldwalking campaigns between 1986 and 1992 recorded both site (settlements) and off-site (manuring scatters) materials. In the eastern Languedoc almost 300 archaeological features were identified, the majority of which are characterized as settlements. The manuring scatters, while fewer in number, occupy a greater area and consequently play an important role in characterizing the land use history of the region. These scatters cover over 900 hectares and date from the Iron Age to the Modern Era (Figure 7).

In the study area defined by the lidar survey, two field systems dating from the Roman period were identified from aerial imagery, historic maps and excavations. These systems, known as *Sextantio-Ambrussum* and *Nîmes A*, strongly influenced the development of subsequent field systems. The earlier arrangement, *Sextantio-Ambrussum*, is oriented at 22°30'W while the *Nîmes A* is oriented at 30°30'W (Figure 8).

Global Orientation

Since the features detected from the lidar data were almost all linear features interpreted as field boundaries, their individual and global orientations were studied. The directional spectrum of the features identified in the lidar data was compared with those of the field systems shown on the 19th century cadastral map and the two Roman cadastres discussed above (Figure 9).

The directionality of these field systems was assessed by identifying the orientation of each linear feature in the field systems (i.e. individual field boundaries) and the results for each system were compared graphically (Figure 10). Based on the global similarities in orientation we conclude that many of the features identified in the lidar models are related to the Roman systems. For the lidar-derived features the most frequent orientation [66°;70°] matches that of the *Sextantio-Ambrussum* (67.5°) cadastre and the second most common orientation corresponds to the primary direction of the *Nîmes A* cadastre. While it appears that the majority of these features respect the orientations of the Roman cadastres, there are also important differences. For example, features oriented between 1° and 10° appear frequently in the lidar data, but not in the Napoleonic cadastre, the Roman cadastres or contemporary field systems.

Based on the graphical analysis, we have noted a global correlation between the Napoleonic cadastre and the models proposed for two Roman cadastres. Based on this similarity we suggest that elements of the system of land division established in the Roman period persisted into the 19th century, and its global orientation and structure continue to influence the current landscape. Alternatively, it can be proposed that the various landscape organizations are all influenced by the similar environmental and topographic factors, leading to broadly similar solutions for landscape organization.

Proximity to sites identified through fieldwalking

Following the assessment of the orientation of the field systems, the locations of individual features identified in the lidar were compared with data from fieldwalking. Here we assume that consistent spatial proximity, compared to a random distribution, may suggest a link between the presence of features in the lidar data and sites found through field walking. That is not to say that individual features identified in the lidar should be specifically associated with nearby remains from field walking, but that the overlap between the overall patterns from the two data sources allows us to identify more and less active areas of the landscape.

Thirty sets of random points with the same count as the lidar-derived feature set were generated within the spatial extent of the lidar coverage and features identified in the lidar data were assigned centroids. The minimum distance between each centroid and the closest point indicating a feature identified through field walking was calculated (Figure 11). The analysis was then repeated measuring the minimum distance between each point feature identified through field walking and the nearest point in each random set.

The results of this analysis show a difference between the mean minimum distances observed for features seen in the lidar and those for random point sets. The smaller average minimum distance for the lidar features indicates a potential link between the location of these features and field walking sites. Based on this analysis it was suggested that concentrations of features from the two datasets, representing increased activity in the landscape, should be expected to appear together.

Areas with evidence of long term agricultural activity

To further investigate long term land use dynamics a second analysis was conducted comparing the average durability of agrarian occupation, based on evidence from manuring scatters (as defined by the *Archaedyn* project, Poirier & Tolle 2008) and the density of lidar features (Figures 12 and 13).

Based on a global comparison there is no demonstrable correlation between the average durability of agricultural activity as represented by manuring scatters and the density of lidar features detected (Figure 13). However, further analysis based on refined chronologies of both the lidar features and manuring areas, or analysis based on another metric for concentrations of lidar features, may provide different results.

Conclusions and future directions

The project described here sought to improve knowledge of past agricultural and land management systems in the contemporary agricultural landscape of the Mauguio, combining lidar data, aerial photographs, field walking data and historic maps. Based on the history of research in the Mauguio area, and no doubt influenced by the general habits of researchers who work on Mediterranean landscapes, the approach taken here was one of making the lidar data 'fit' with existing evidence from field walking and historical map sources on which rural Mediterranean studies often depend, (and noting where it differed. The testing of 'fit' between lidar and other data sources was carried out primarily through formal and graphical spatial analysis. This approach, while contributing some new knowledge in this case, presents two notable problems.

First, through spatial analyses concentrations of undated features identified in the lidar data were (loosely) related to concentrations of dated archaeological or historical features. This kind of proximity based analysis is inherently problematic. It is well known that individual features that appear together are not necessarily related, and it may be that even general trends in concentrations of features should not be correlated. Even where spatial analysis legitimately suggests how features identified through lidar survey might fit with patterns identified from historical maps and field walking data, it is usually suggested that further study in the field is needed to understand the character, function and chronology of the lidar features. While recognizing the problems involved in interpreting lidar data partly on the basis of spatial analyses, precluding spatial analysis entirely does not seem the way forward, as doing so would seriously limit the possibilities for formally integrating evidence from lidar surveys with other datasets and the creation of new knowledge.

Equally problematic is the implicit treatment of evidence from the lidar survey as secondary to field walking and historic mapping data, and the underlying expectation that it will augment, rather than contradict, existing datasets. In wooded areas where little previous archaeological research has been undertaken, evidence from field walking, historic maps and lidar may easily find themselves on equal footing as new knowledge is developed. Landscapes with long research histories start us off with a certain set of prejudices and ideas. By sheer quantity field walking data dominates the available information for the Mauguio study area, and as it has been the subject of extended study across several projects it is unsurprising that as interpreters we are more confident in our assessment of this material. But does this mean that we should necessarily be surprised if the evidence derived from the lidar survey points to different, or just partially divergent, conclusions than those drawn by previous studies? Clearly not, and the need to be willing to revise our interpretations over time is well argued by Rog Palmer (this volume). At the same time, it is important to consider whether it is our original interpretation or our understanding of the new evidence that should be questioned. The challenge of integrating new evidence and reassessing our confidence in different data sources occurs whenever an area or subject is restudied because new information has come to light. Meeting this challenge is essential if we wish to use lidar data to study multifaceted topics like long term land use and if we plan to include lidar in ongoing research on the rural Mediterranean, where multiple sources of information and complex histories of research abound.

Bibliography

Barnes, D 2002, "Using ArcMap to Enhance Topographic Presentation." *Cartographic Perspectives*, vol. 42, pp. 5-11.

Favory, F & Raynaud, C 1992, "La production du paysage en Langudoc oriental dans l'Antiquité et au Moyen Age : Etude de Mauguio (Hérault)." *Mappemonde*, no. 1, pp. 12-16.

Favory, F, Girardot, J & Raynaud, C 1994, "L'habitat gallo-romain autour de l'étang de l'Or (Hérault). Hiérarchie, dynamique et réseaux du 2è s. av. au 5è s. ap. J.-C.," in *Mélanges Pierre Lévêque 8*, Paris, pp. 123-215.

Nuninger, L & Oštir, K 2005, "Contribution à la modélisation des paléo-reliefs de la plaine littorale de l'Etang de Mauguio (Languedoc, France) : premières approches par télédétection," in J Berger, F Bertoncello, F Braemer, G Davtian, & M Gazenbeek, *Temps et espaces de l'homme en société, analyses et modèles spatiaux en archéologie, actes des rencontres 21-23 octobre 2004*, APDCA, Antibes, pp. 123-134.

Ouriachi, M J 2009, *Habitat, terroirs et territoire en Languedoc oriental durant l'Antiquité : approche spatio-temporelle d'un système de peuplement*, PhD thesis, University of Franche-Comté, available at: http://tel.archives-ouvertes.fr/tel-00429724/fr/

Poirier, N & Tolle, F 2008, "Measurements of Diachronic Stability of Agrarian Exploitation," in A Posluschny, L Karsten, & I Herzog, *Layers of Perception. Proceedings of the 35th Computer Applications and Quantitative Methods in Archaeology Conference, Berlin, Germany, April 2-6, 2007 (Kolloquien zur Vor- und Frühgeschichte, vol. 10)*, Habelt, Bonn.

Poirier, N, Opitz, R, Nuninger, L & Oštir, K 2010, "The ModAgSpace Project: Lidar Data and Landscape Archaeology in Southern France," in *Proceedings of CAA 2010, Granada*,

Sittler, B 2004, "Revealing historical landscapes by using airborne laser scanning. A 3-D model of ridge and furrow in forests near Rastatt (Germany)." *International Archives of Photogrammetry (ISPRS)*, vol. 26, pp. 258-261.

Van der Leeuw, S, Favory, F & Fiches, J 2003, *Archéologie et systèmes socio-environnementaux. Etudes multiscalaires sur la vallée du Rhône dans le programme ARCHAEOMEDES*, CNRS, Paris.

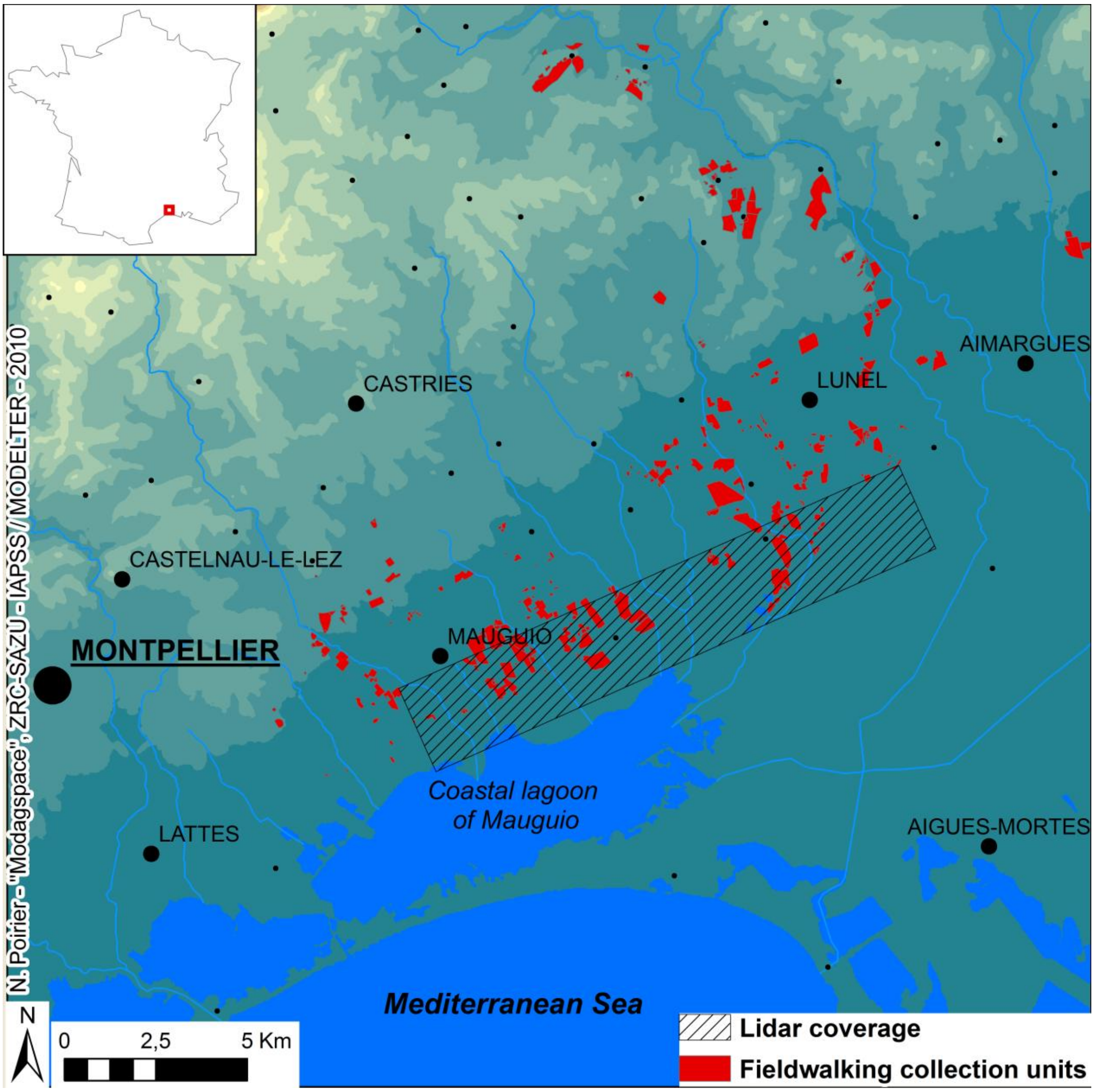

Figure 1 : Location of the study area

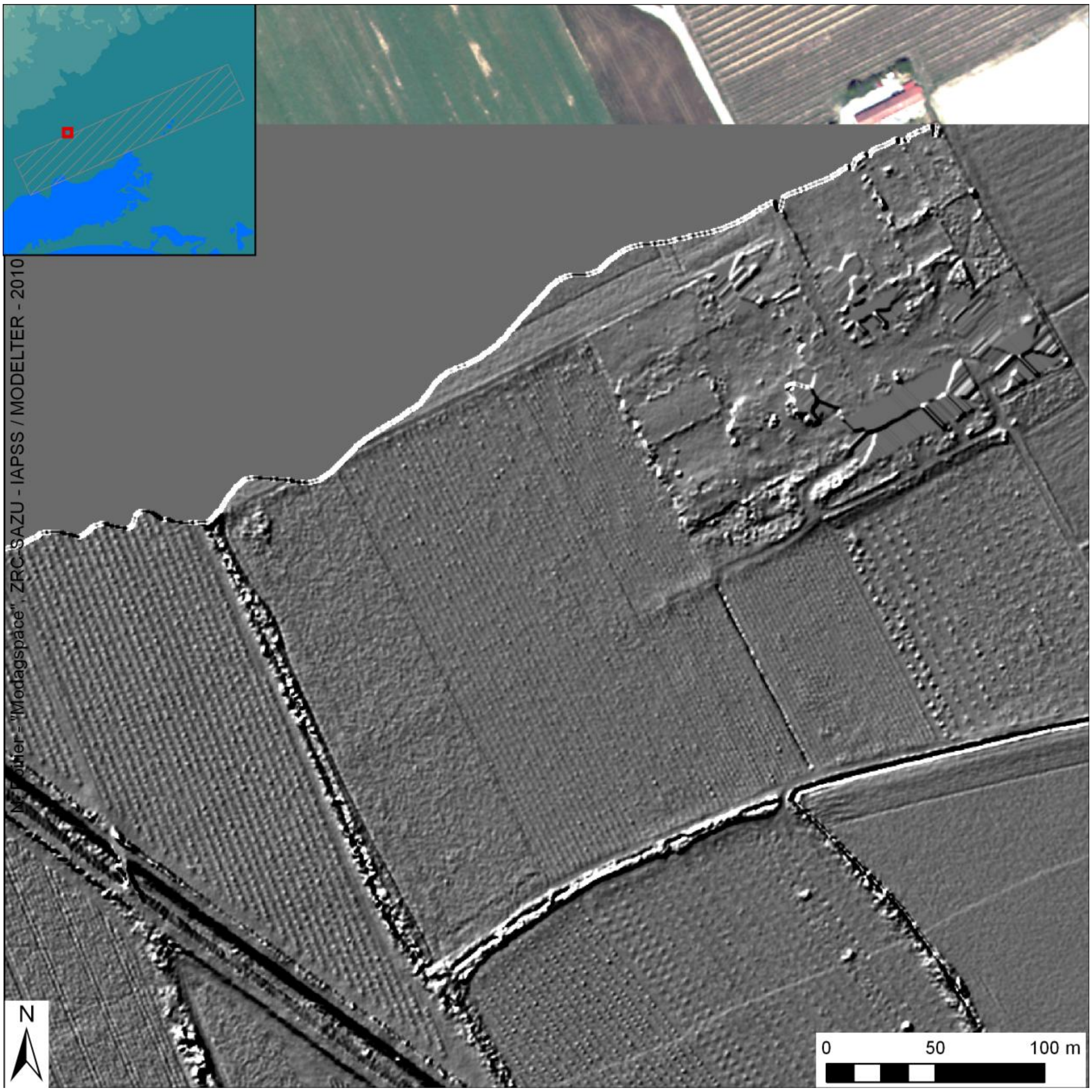

Figure 2 : Detection of micro-relief

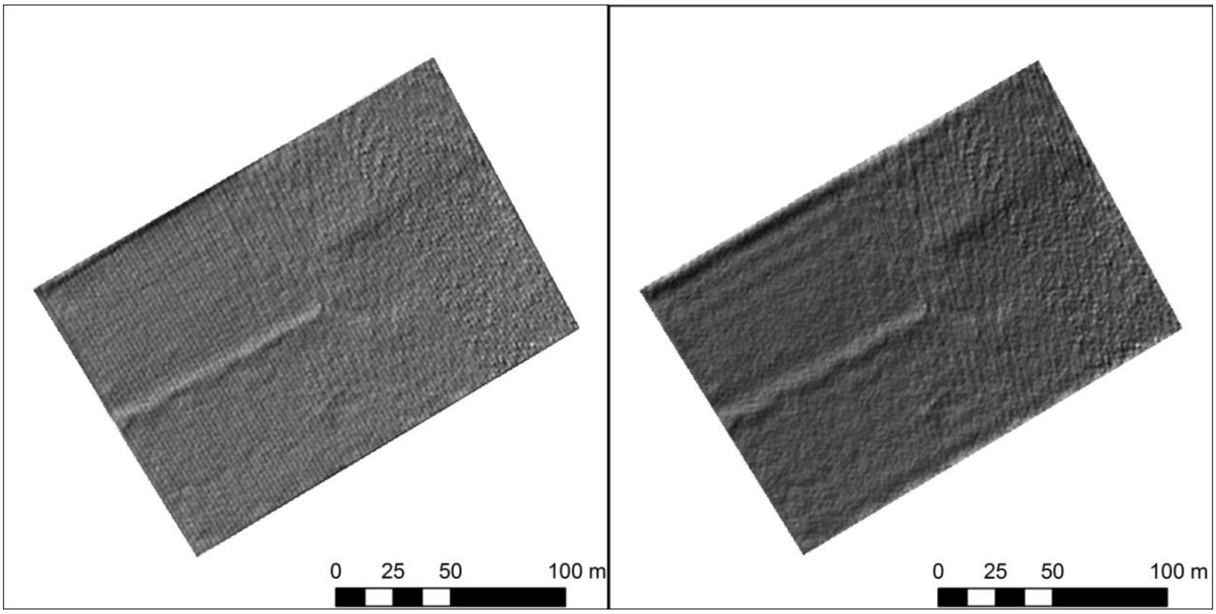

Figure 3 : Testing the Automatic Periodic Noise Removal - an earlier pattern of cultivation is revealed (right)

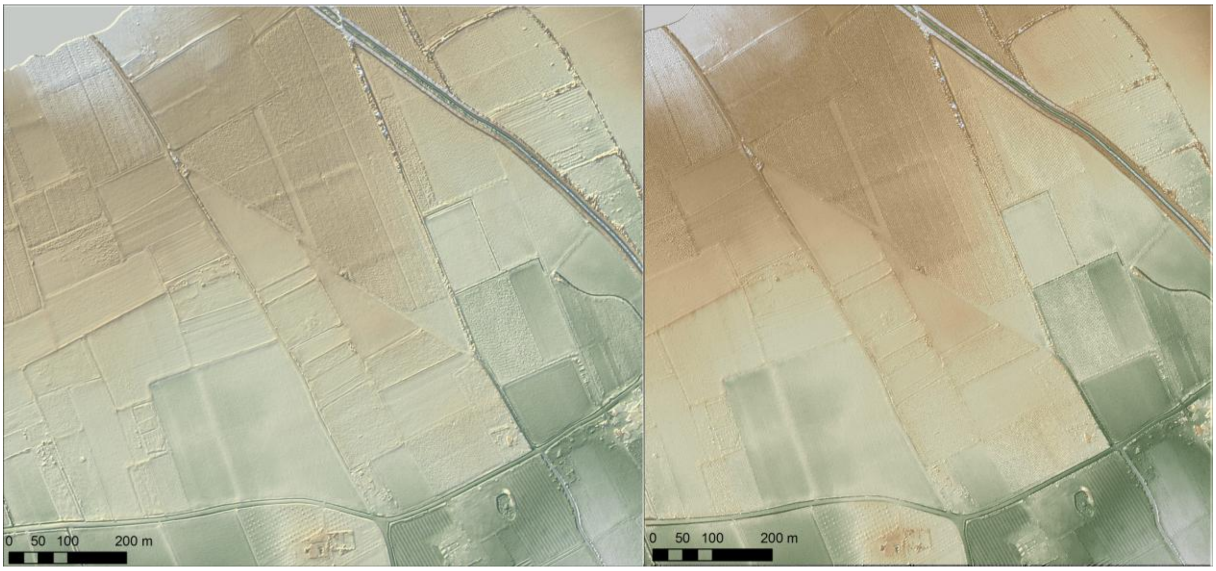

Figure 4 : Testing two hillshading methods: Swiss Hillshade Model (left) and MDOW (right)

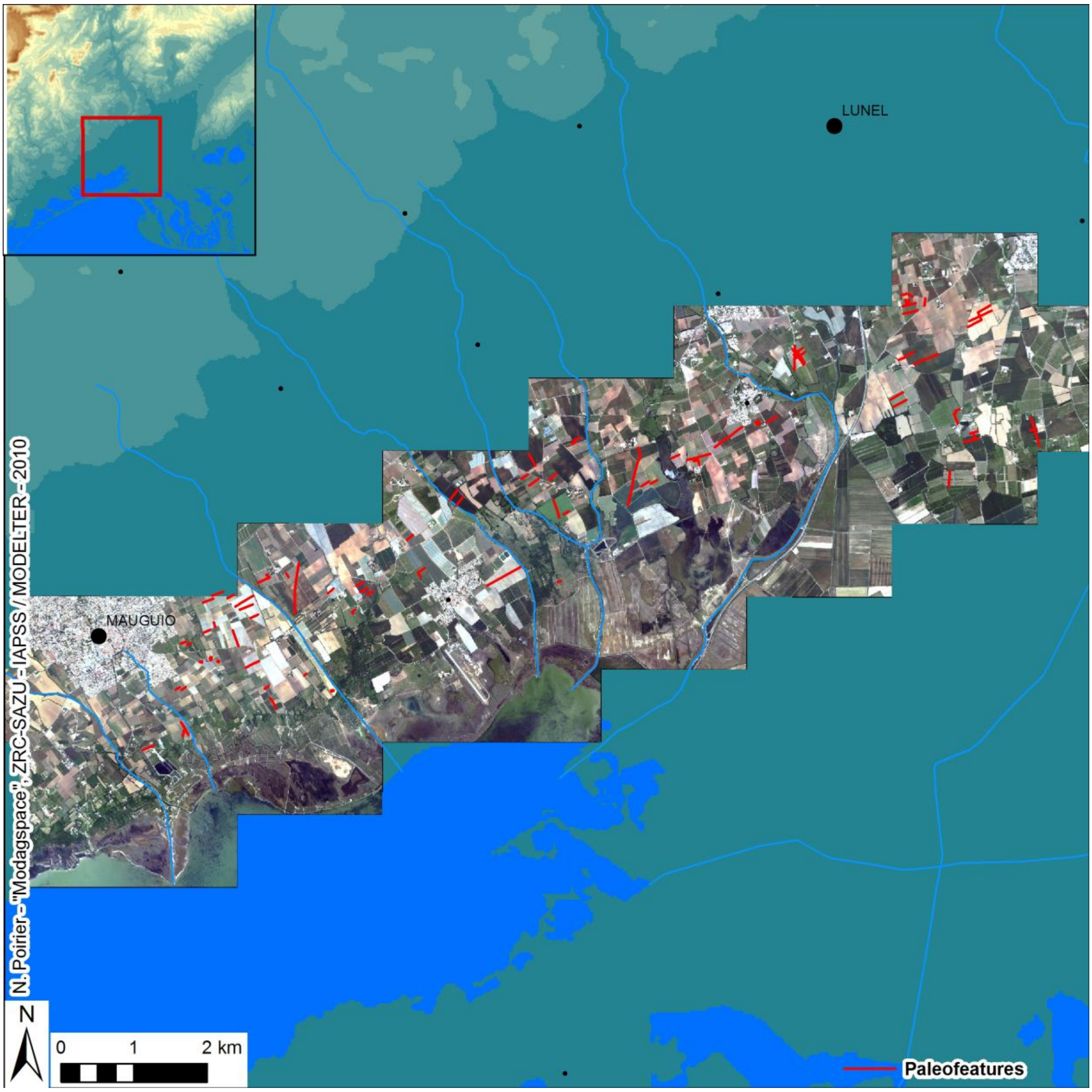

Figure 5 : Palaeo-features detected and orthophoto coverage

Figure 6 : Palaeo-features detected overlain on the Napoleonic cadastre

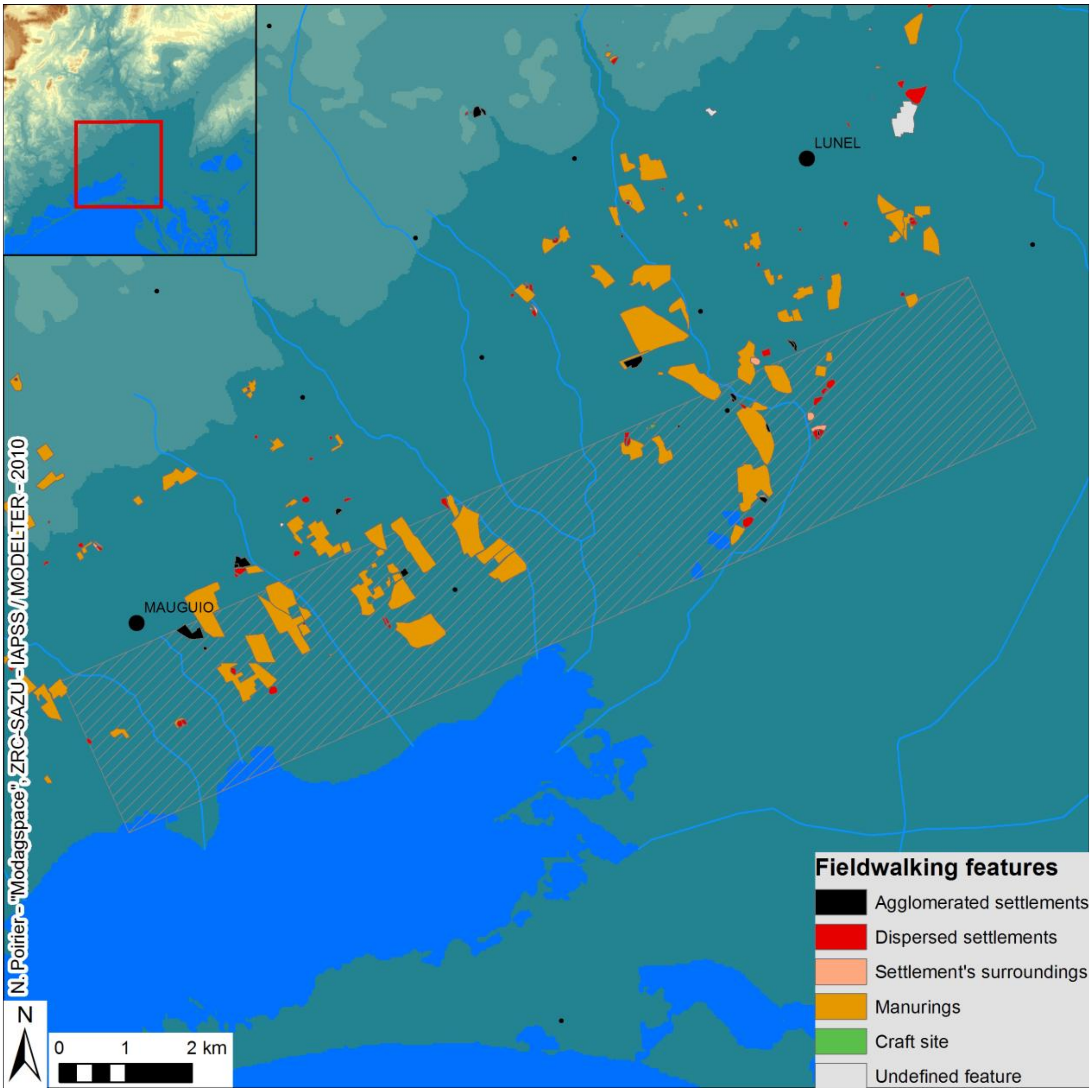

Figure 7 : Fieldwalking data

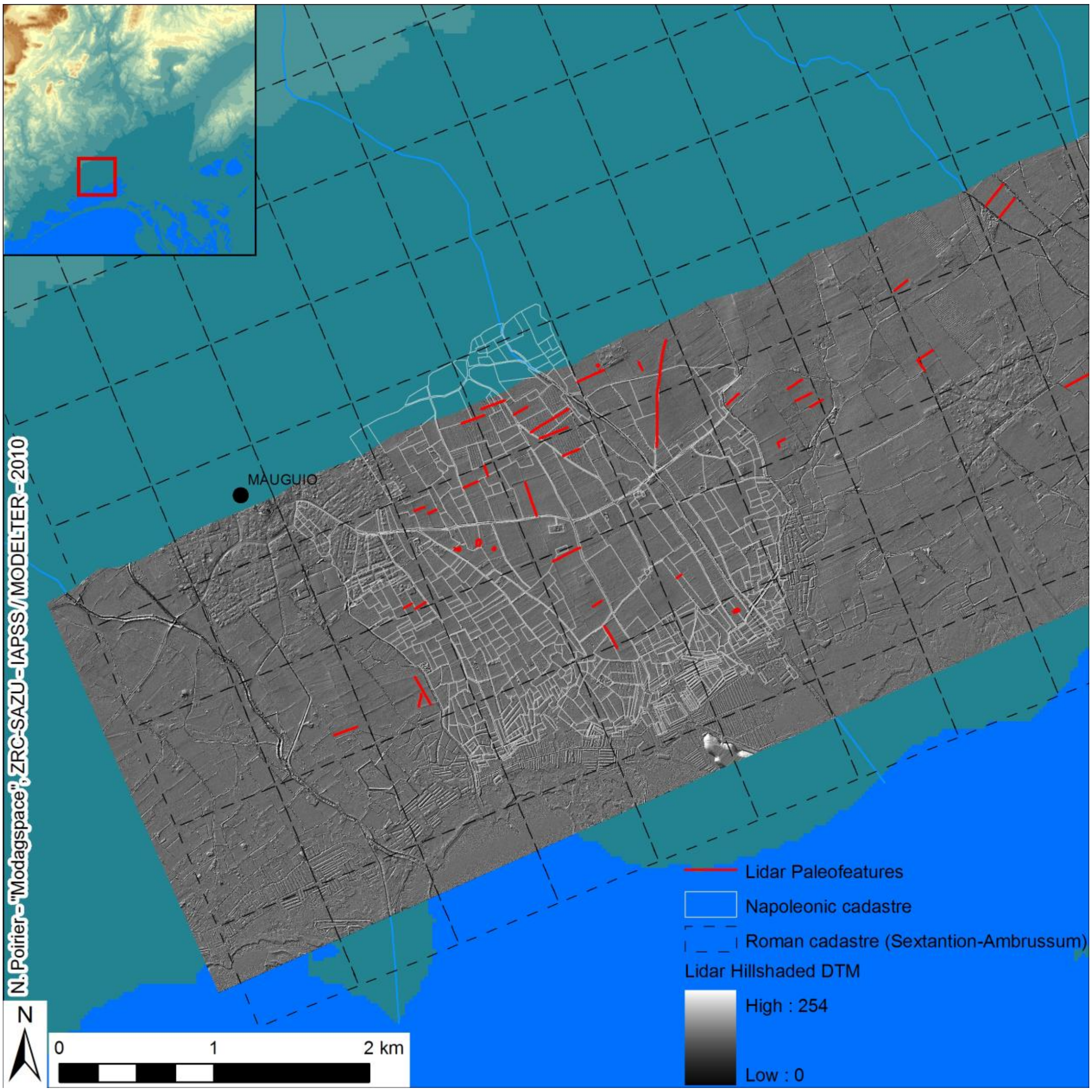

Figure 8 : Roman cadastre, Napoleonic cadastre and palaeo-features

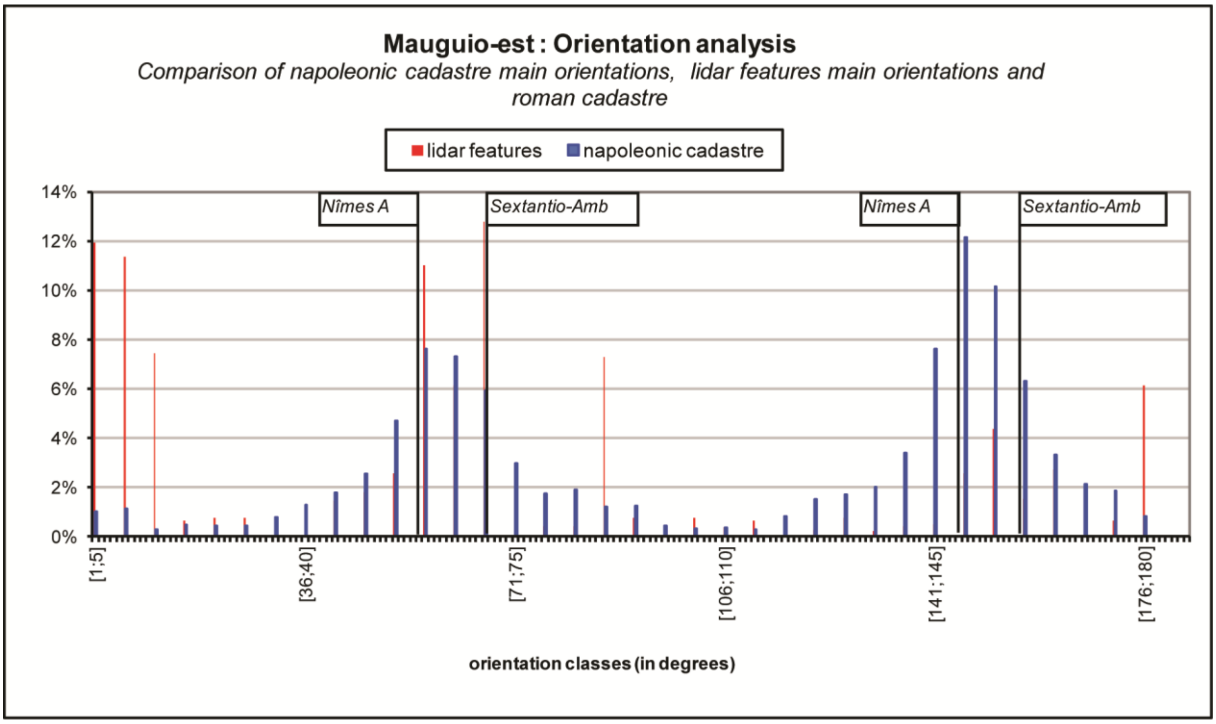

Figure 9 : Comparing the orientation of the Roman cadastres, Napoleonic cadastre and features identified through the lidar survey

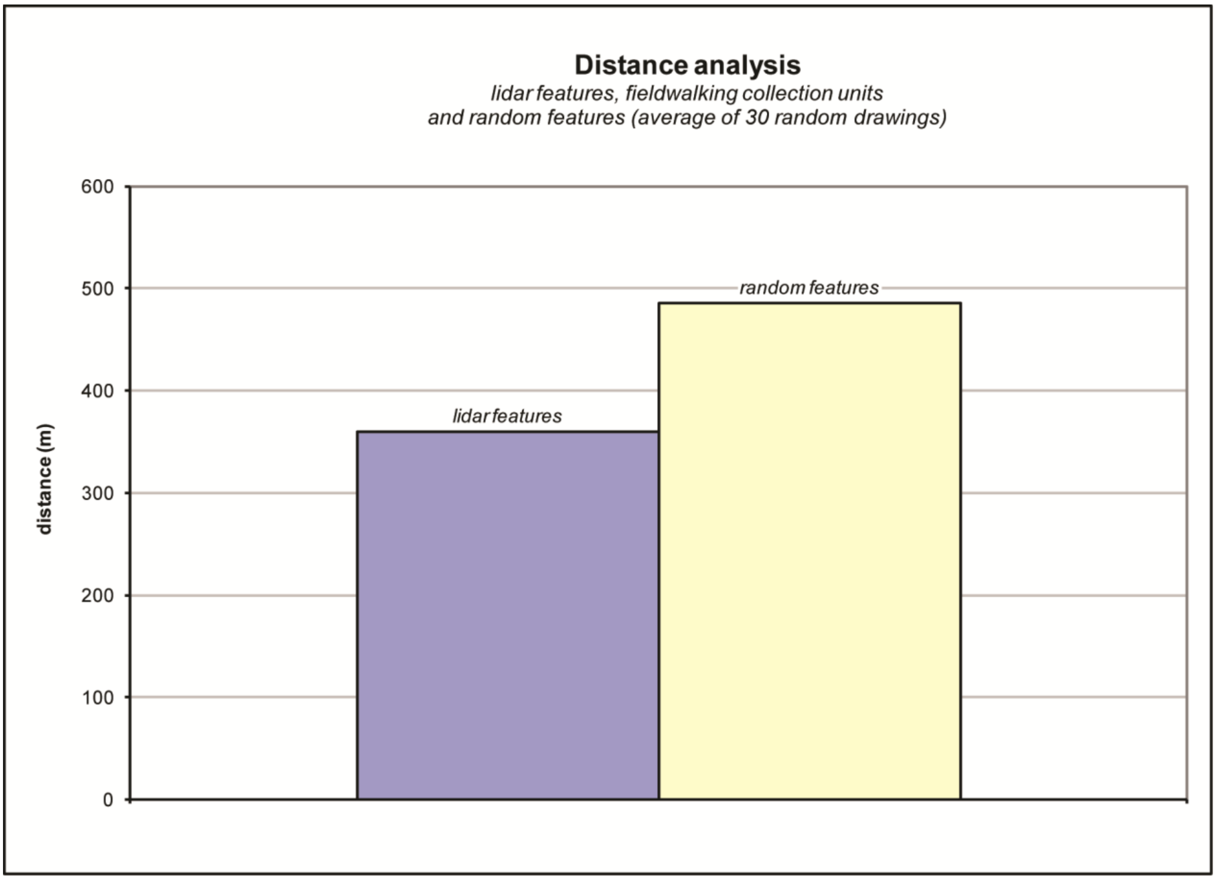

Figure 10 : Distance analysis between lidar features, fieldwalking features and random points.

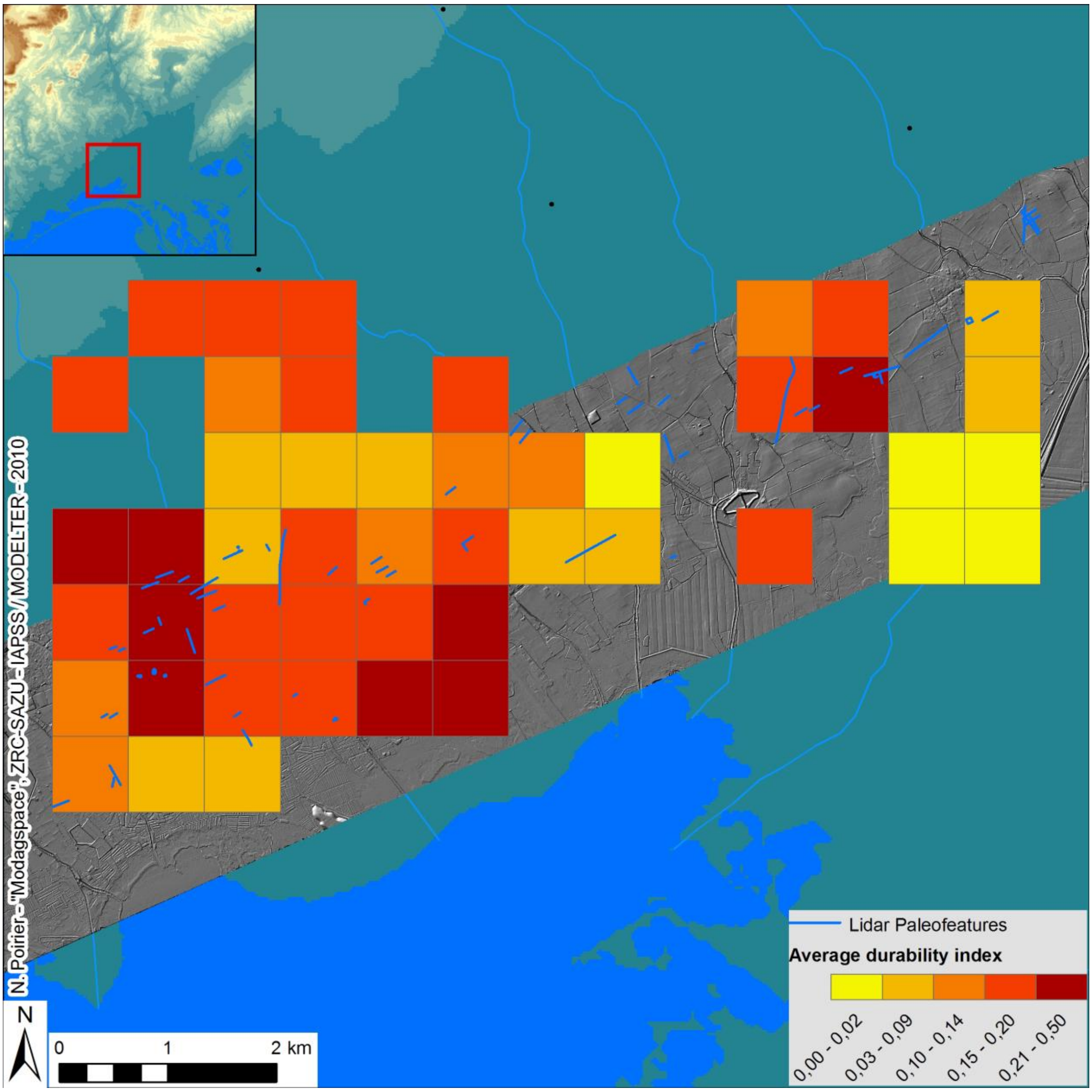

Figure 11 : Analysis of the durability index and density of lidar features

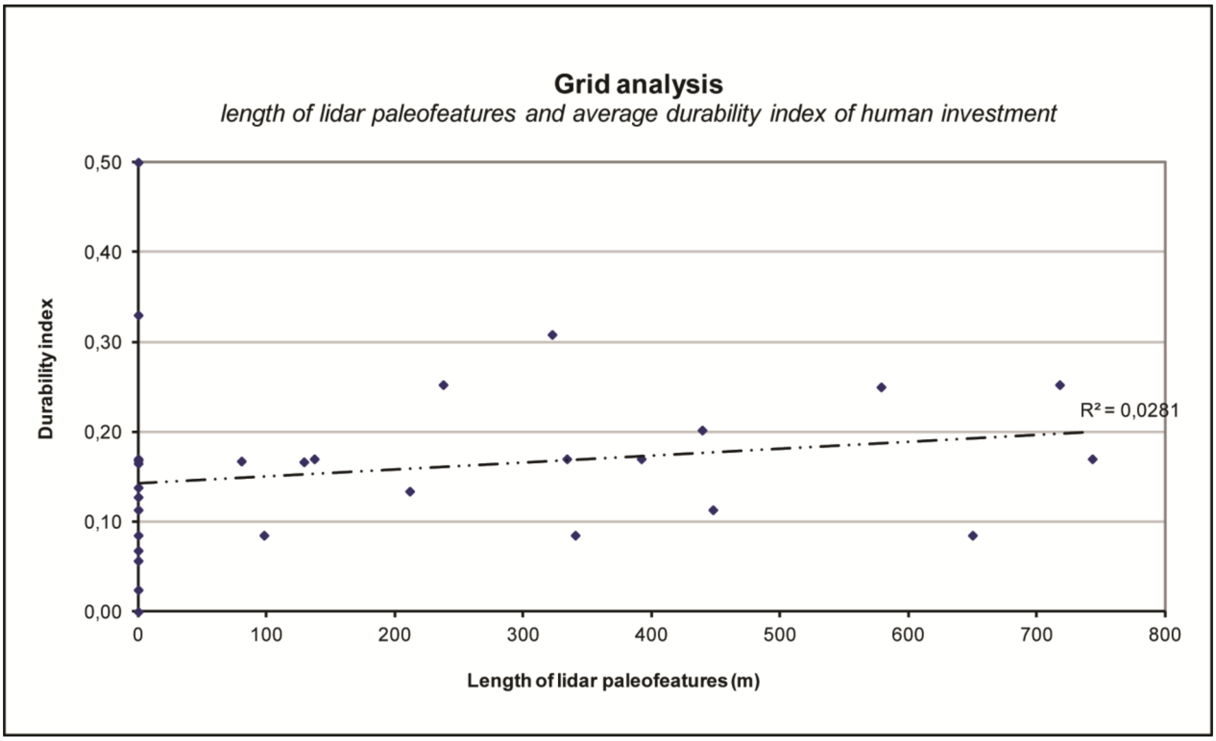

Figure 12 : Dispersion graph showing durability index values and lidar features density