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A methodological approach to identify Roman roads using LiDAR sensing technology and aerial orthoimages. The case of *viae* XIX and XX (NW Iberia)

Samuel Nión-Álvarez

Department of History, University of Santiago de Compostela/Incipit, CSIC. Monte Gaiás s/n, Edificio Domingo Fontán, Block B4, First Floor, Door 123, 15702 Santiago de Compostela, A Coruña, Spain

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ABSTRACT

The following article proposes a methodology for the identification of Roman roads applied to the Northwest of the Iberian Peninsula, focused mainly on the *conventus lucensis*. Therefore, a methodology based on two aspects is presented: on the one hand, on the description of remote-sensing techniques, their relevance, and their validity; on the other hand, on the strategies that allow not only to identify historical roads, but also to differentiate and catalog them according to their structural characteristics. Finally, a brief context of the state of research on historical roads in the Northwest of the Peninsula is explained in order to apply the proposed methods in two cases of studies on the XIX and XX routes of the *Itinerarium Antonini* Augusti.

1. Introduction

The study of tracks, paths, and roads as a representative element of human mobility is a recurrent topic in archaeological and anthropological studies. Throughout the last decades, improvements on computational modeling and, in particular, GIS, have allowed for a remarkable progress in the study of mobility (Fonte et al., 2017; Nuninger et al., 2020; Wheatly et al., 2010). At the same time, the development of geospatial analysis thanks to the improvements of the accuracy of lidar-derived DTMs, photogrammetric reconstruction through UAV flights, and the progress in geophysical techniques has enabled a remarkable accuracy in recognizing, identifying, and interpreting archaeological sites.

Ancient roads have not been unaffected by this process (e.g. Herzog, 2017; Lasaponara et al., 2021; Vletter and Van Lanen, 2018), although most of the studies have been focused on the analysis of mobility through non-reconstructive techniques (Bevan, 2011; Llobera et al., 2011; Parcero-Oubiña et al., 2019; Polla and Verhagen, 2014). In the case of Roman roads, there are considerable differences between those regions with less rainfall and better-preserved roads (e.g., southern Iberia or southern Italy) and those where rainfall and vegetation had a much greater influence on soil erosion. The latter, which includes our study area, have created a breeding ground for the development of several remote-sensing techniques that aim to identify the original road configuration, as in *Britannia* (Gethin and Toller, 2014; Small, 2016), Flanders (Verbrugghe et al., 2017) or eastern France (Fruchard et al., 2010), with outstanding results.

In this work, different GIS-based remote-sensing techniques will be employed in order to characterize and define Roman roads. The proposed case study is focused on the western façade of the *conventus lucensis* (see Fig. 1), one of the administrative entities that divided the province of Gallaecia (NW Iberia). This area raises two major problems that may require such techniques: first, a scarce presence of representative elements of Romanization processes in the archaeological record; secondly, imprecise historical sources that hinder its location in the landscape.

2. Why NW Iberia?

Since the beginning of historical research in NW Iberia, works regarding the location of *viae* and *mansiones* have always attracted considerable attention (Arias Bonet, 1964; Caamaño Gesto, 1984; Caamaño Gesto and Naveiro López, 1992; Estefanía Álvarez, 1960; Rodríguez Colmenero and Álvarez Asorey, 2008; Rodríguez Colmenero et al., 2004; Vila Gómez, 2005). Most of them have been based on the analysis of classical sources, the primary resource available –mainly, the *Itinerarium Antonini Augusti*, the *Ravennatis Anonymi Cosmographia,* and the *Geographia* of Claudius Ptolemy– in combination with different archaeological findings (see Fig. 2).

Although in some cases these traditional strategies have been relatively successful, in other cases (such as the layout of the *conventus lucensis)* their results have not been able to transcend the realm of the

E-mail address: samuel.nion.alvarez@usc.es.

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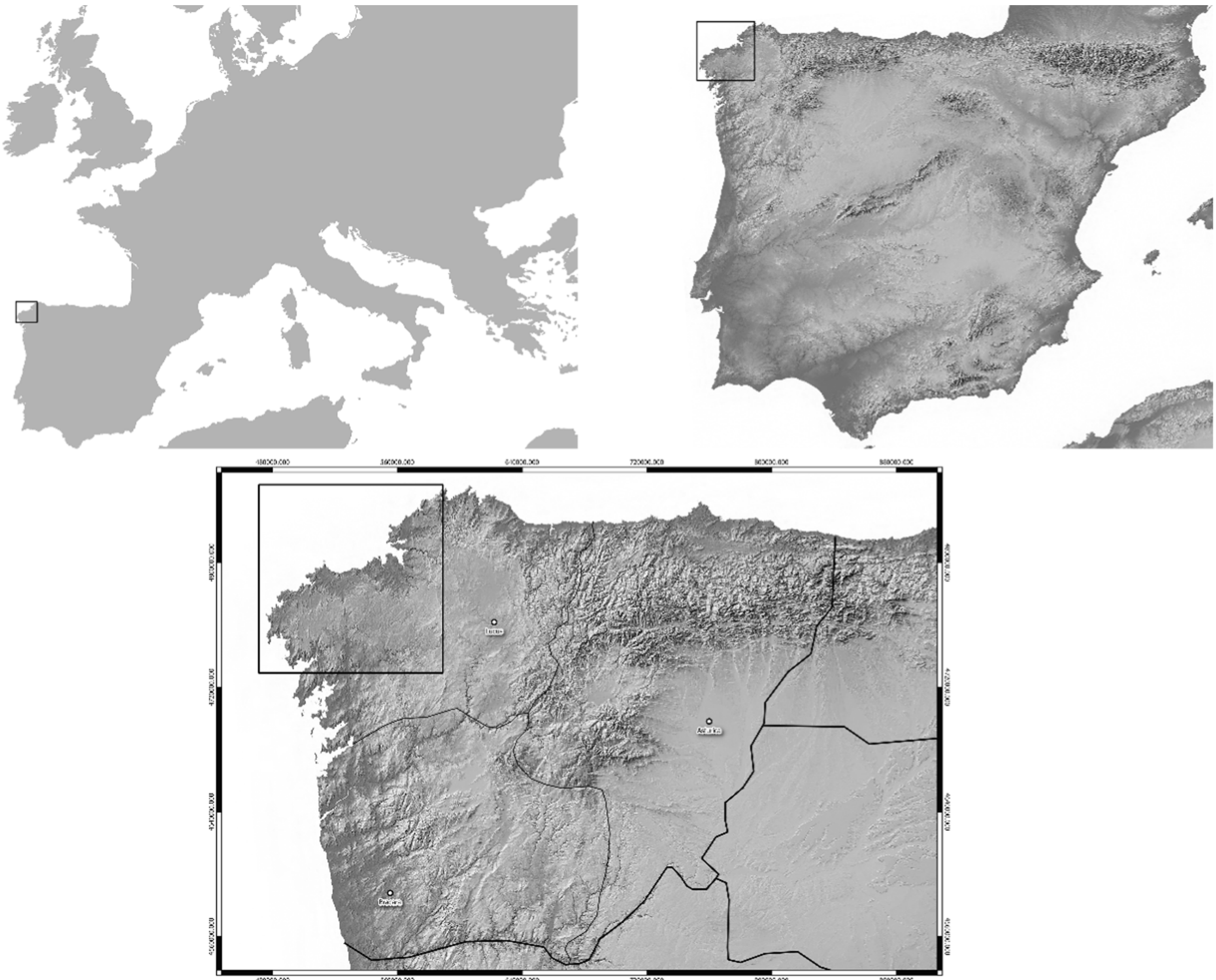

Fig. 1. Location of the study area.

hypothetical due to the absence of precise sources that allow for the mapping of *mansiones*. In the case of Via XX, for example, there is no agreement regarding the location of any *mansio*, only 5 milestones have been found, and there is a reduced presence of population centers of significant size as well as of evidence of an "effective implementation" of the usual urban planning of the High Roman Empire (Nión-Álvarez, 2021: 657-658). This problem, though not exclusive to this area, collides with the abundant primary sources available for most of the Peninsula (Moreno Gallo, 2006).

In recent years, traditional research has given way to new approaches focused on geospatial analysis to study road networks (see Fig. 3), the constructive logics of the road layout, and the relation with the landscape (Fonte et al., 2017; Güimil-Fariña and Parcero-Oubiña, 2015; Parcero-Oubiña et al., 2019). Nevertheless, these works have been focused on the roads of the *conventus bracarensis* (*viae* XVII and XVIII) since the amount of information available is considerable. Unlike those, the routes of the *conventus lucensis* (XIX and XX) present a limited amount of archaeological data that do not allow us to ask "Why are the roads there?" (Güimil-Fariña and Parcero-Oubiña, 2015: 35), because we need to discover where they are first.

Due to the striking absence of archaeological and epigraphic information and to the impossibility of carrying on research from other approaches, new strategies for the modelling and interpretation of roman roads should be proposed. The application of remote-sensing methodologies not only offers the possibility of identifying different sections of the road network according to morphological characteristics, but also a set of strategies and techniques that can solve similar issues in other regions of the Roman Empire. In the Iberian Peninsula, this work follows a general line of research that has recently started to rely on these techniques to find evidence of Roman engineering in mining exploitations (Fernández-Lozano et al., 2015; Fonte et al., 2021) or the military and defensive structures (Costa-García et al., 2019; Morillo Cerdán et al., 2020). By complementing these procedures with methodologies that identify traces of Roman roads in the landscape –especially in those areas where their study is still a dialectical exercise– a wider representation of the Roman occupation and conquest of the territory will be presented.

3. Materials and methods

The aim of this paper is to develop an approach to identify and analyze Roman roads through GIS-based spatial analysis and remote sensing. In this case, the goals are modest: we do not intend to identify a complete road or to draw up new methodologies, but to identify some tools to recognize certain features that define a Roman road and to apply them in a study area where they have not yet been analyzed through remote-sensing techniques.

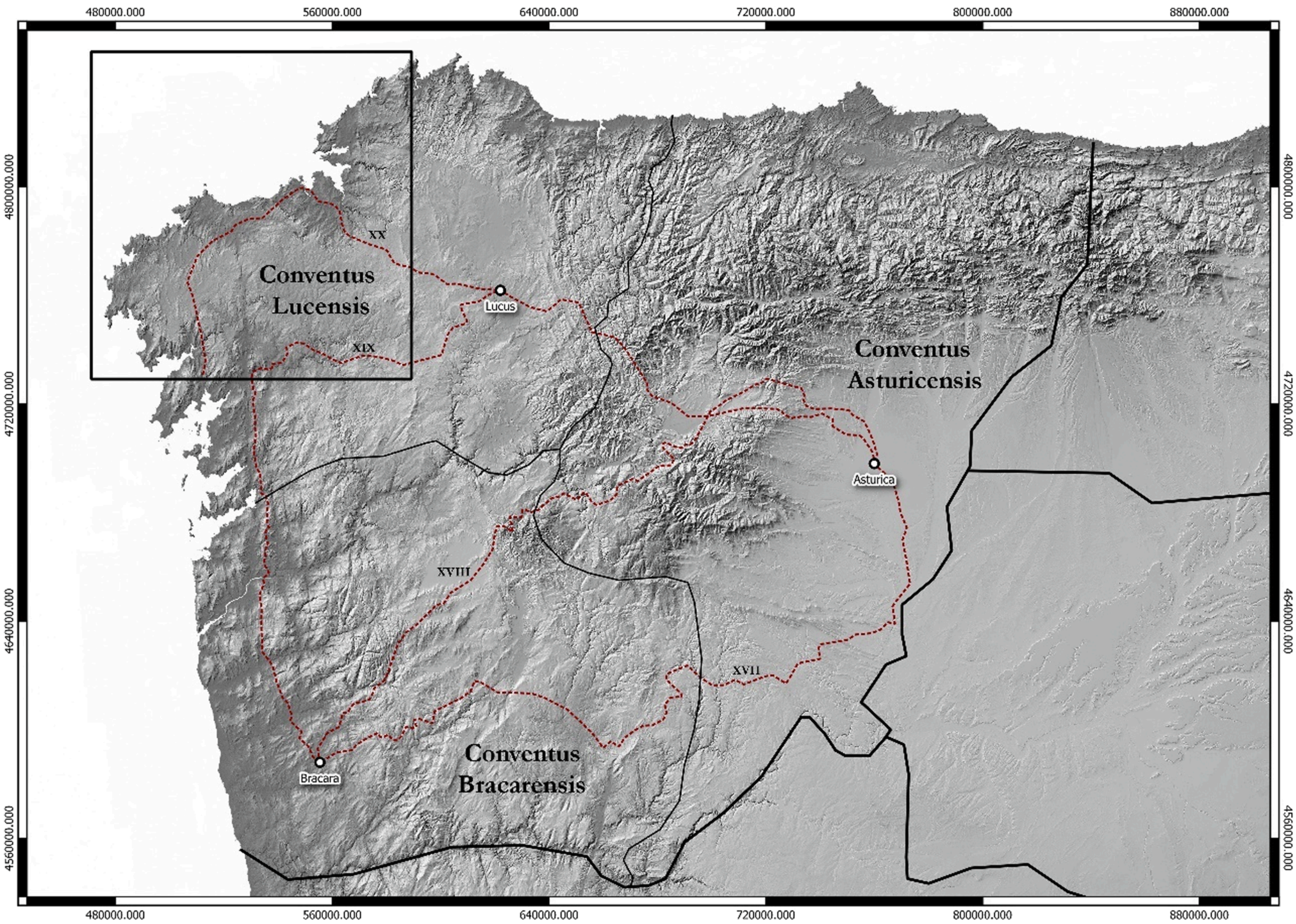

Fig. 2. First Roman roads of the Roman province of Gallaecia (according to Rodriguez Colmenero *et al.*, 2004).

3.1. Selection of areas with a high archaeological potential

Considering the limitations of the record previously exposed, it is necessary to propose a localization criterion to select areas with a greater archaeological potential. Simple criteria, based on the limited archaeological evidence, have been defined and different "nodes" have been established according to their certainty of and influence on the road layout (see Figs. 4 and 5). The basis for the choice of the "nodes" is strictly archaeological: a greater "weight" is assigned to elements such as milestones or major settlements, while secondary importance is given to less representative evidence of a Roman general itinerary. An example could be the altars dedicated to the *lari viali*, very frequent in NW Iberia and usually linked to the main Roman roads (Rodríguez Colmenero et al., 2004), but which can be related to any type of track (Nión-Álvarez, 2021: 687), especially with crossroads (Abascal Palazón, 2019: 268).

Although it has not been applied in this case because most of the routes are unidentified, a potential tool is offered by the buffers of influence attending to orography (Verbrugghe et al., 2017). Taking into account that the main function of a road is to link two places (Fonte et al., 2017: 164), both of them unknown in this case, our assumptions may obstruct any identification attempt. These tools, however, can be rather useful if the volume of information increases.

3.2. Methodology of analysis

The proposed methodology is based on the processing of LiDAR-based DTMs and aerial photography. LiDAR data have been obtained from the Spanish Geographic Institute (IGN),[1] while aerial photographs come from the Spanish Orthophotography Program (PNOA) and from the WMS services provided by the Spanish Infrastructure of Spatial Data (IDEE).[2] The point cloud provided by the LiDAR of the IGN has a density of 1 point per m^2 at most, with a general spatial resolution of 1 m. For the visualization of the models, different techniques have been used to highlight small-scale anomalies, as well as irregularities that facilitate the identification of linear structures, according to the requirements of the subject of study.

- Sky-View Factor: SVF shows the portion of visible celestial hemisphere limited by relief through diffuse light instead of direct illumination (Zakšek et al., 2011: 399). For the study of archaeological remains, although not always effective in flat areas, it offers remarkable results in identifying longitudinal anomalies at medium scale, especially if a low pixel radius and a vertical exaggeration of over 2 is applied (Zakšek et al., 2011: 412).
- (Simple) Local Relief Models: LRM or SLRM, unlike other visualization techniques, are based on the extraction and representation of small-scale topography (Hesse, 2010: 70-71). Thus, they avoid visual interpretations based on shaded relief images with different

[1] Available at https://centrodedescargas.cnig.es/CentroDescargas/catalogo.do#.

[2] Available as a WMS at https://www.ign.es/wms/pnoa-historico.

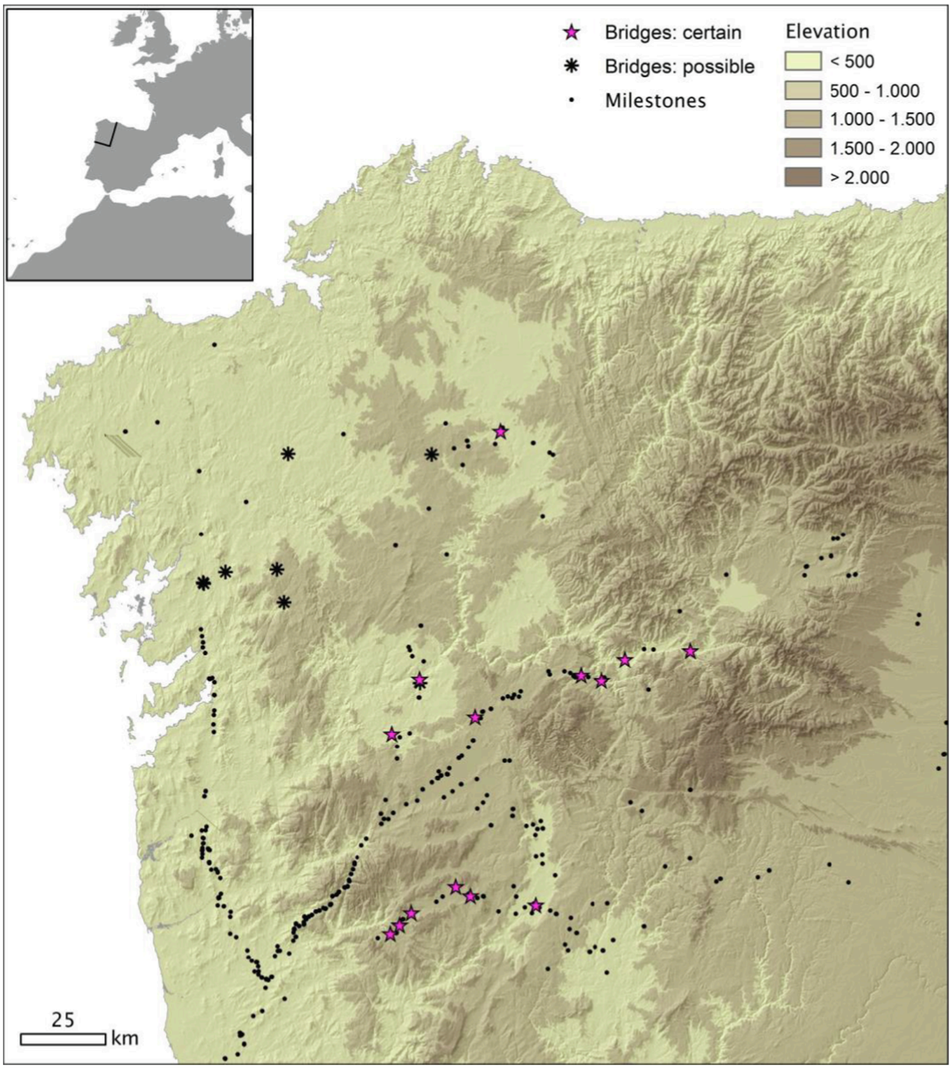

Fig. 3. "Dots" of a non-reconstructive analysis of NW Iberian Roman roads (Güimil-Fariña and Parcero-Oubiña, 2015: 34). The scarcity of archaeological evidence of *viae* XIX and XX can be observed.

HIGH RELIABILITY	Milestone (original location), evidence of road network (roadways, buildings, ramps…)
MEDIUM RELIABILITY	Large population centers (larger than 5 ha), milestones (out of context)
LOW REALIABILITY	Another road epigraphy (*lari viali*), smaller population centers, large burial places, possible evidence of road network

Fig. 4. Markers of Roman roads presence according to their potential reliability.

illumination angles, which shows linear anomalies that would be invisible if aligned with the light (Hesse, 2010: 71). In this representation, a local scale of elevation values is set (Zakšek et al., 2013) to eliminate large-scale morphological elements and make small-scale components visible (Nión-Álvarez et al., 2018: 49; Thompson, 2020: 2). Their value to identify low topographic features makes them an essential visualization technique to identify small-scale archaeological evidence that has left its mark on the landscape (Hesse, 2010: 69). They are, therefore, especially useful for the analysis of historical roads. Moreover, their particular effectiveness in flat or low-slope areas (Polla and Verhagen, 2014) offers a remarkable potential for the analysis of Roman roads, given their greater presence in such landscapes.

– Openness: openness is an angular measure of the relation between surface relief and horizontal distance that quantifies the degree of unobstructedness of a location (Yokohama et al., 2002). Considering that it is not subject to any directional bias, it does not contain horizontal displacement (Doneus, 2013: 6428), which makes openness an excellent tool for unveiling archaeological evidence, especially subtle long linear structures (Vletter, 2015: 36; Zakšek et al., 2011: 404). However, in models that are built on low-density point clouds or too noisy, certain display errors may eventually appear.

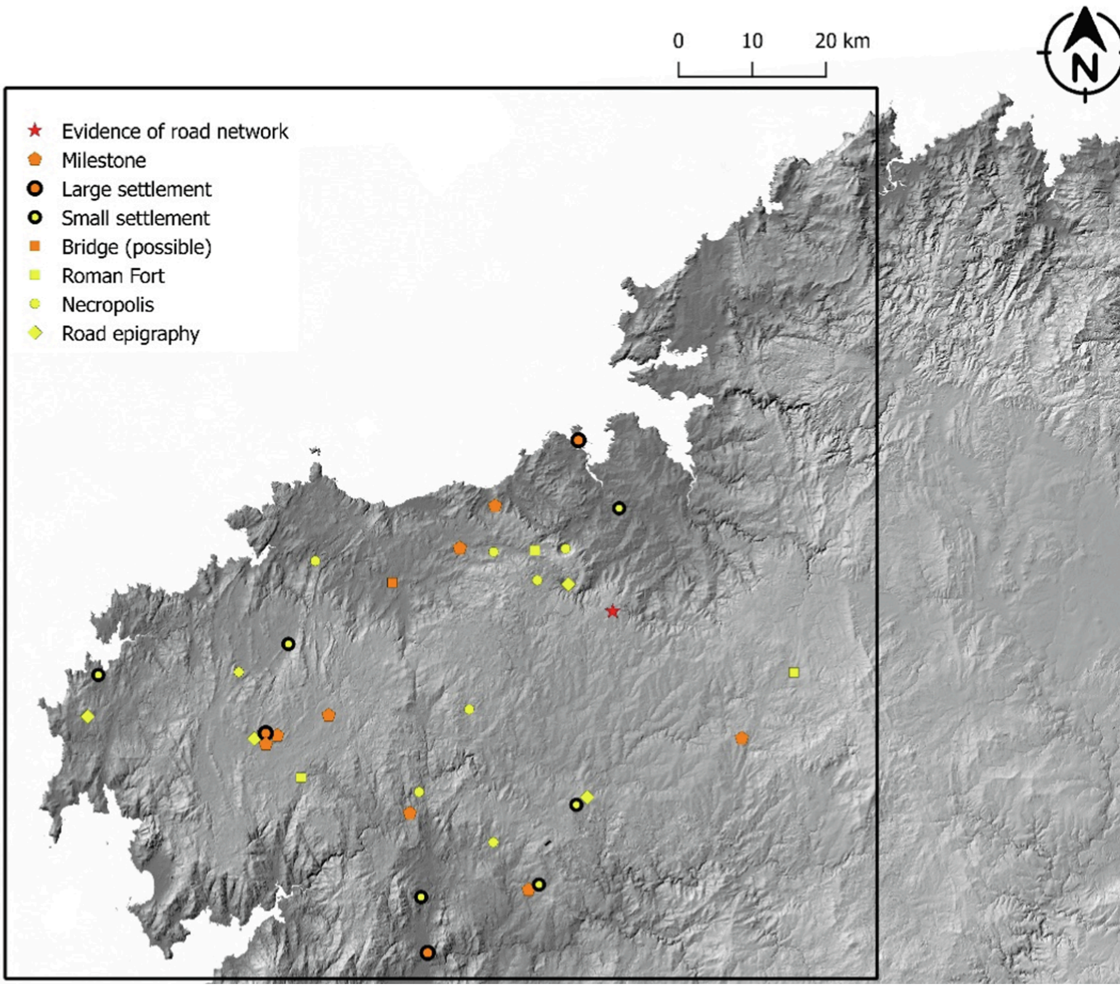

Fig. 5. Location of archaeological markers related to the case study: low reliability (in yellow), medium reliability (in orange), and high reliability (in red).

Finally, it is necessary to consider the combination of LiDAR-based DTM visualizations with those from UAV photogrammetry (Kršák et al., 2016). In this case, the possibility has been discarded due to the legal obstacles of the use of UAVs in areas near airports (which cover almost the entire study area) as well as to the dense vegetation of the area that limits its application most of the year; both issues hinder a fast processing that, on the other hand, LiDAR-based models did allow for.

Aerial photography is still in full force even in the era of LiDAR and photogrammetric reconstruction (Agapiou et al., 2016; Keay et al., 2014; Verbrugghe et al., 2017). In the case of the Iberian Peninsula, we have a wide range of orthophotographs from 1945 to the present day; however, the application of aerial photography in the identification of archaeological remains has not been particularly common (Parcero-Oubiña, 2016: 12-14). In the northwest, the use of these methods has faced important limiting factors, such as the continuous irrigation of the soil throughout the year, the dynamics of agricultural production, and the fragmentation of parcels (Parcero-Oubiña, 2021: 19); still, weather conditions in certain years may be more suitable (Parcero-Oubiña, 2021: 28). In this work, aerial photography has been a complementary technique to verify some interpretations, as well as to discard if the identified sections were built in modern times (see Fig. 6).

3.3. Characteristics of the Roman road network in the landscape

The study of archaeological evidence through DTM, beyond its obvious advantages, entails some issues that must be addressed. Elements such as the background, experience, or interests of the researcher directly influence what is observed and how (Nuninger et al., 2020: 66), which should be considered in this sort of analysis. In the case of pathways and roads, one of the main problems is their chronological and cultural identification, a common problem in LiDAR-based analyses that, in this case, is heightened due to their wide morphological diversity (Nuninger et al., 2020: 67) that impedes drawing comparisons and conclusions at a chronological and cultural level (Ainsworth et al., 2013). Any attempt at identifying a cultural phenomenon must recognize these methodological and epistemological uncertainties, as well as the need to establish mechanisms to identify and reduce them.

In this case, the great Roman roads, fortunately, have very specific technical and morphological characteristics (with small regional variations or adaptations to the topography of the place: Talbert, 2000) derived from well-defined constructive and technical guidelines. In addition, the considerable monumentality of these works, under certain circumstances, permits its preservation and fossilization in the landscape. Both questions justify the analysis of a homogeneous volume of information that can be defined, detected, interpreted, and classified. To this end, these are some of the most significant characteristics for identification through a DTM-based analysis and aerial photography:

- Topographical features: as a main rule, major roman roads preferably cross flat areas due to the characteristics of Roman road engineering. If possible, the chosen areas would have certain potential for visual control, ideally plateaus. These general characteristics, although representative, may experience morphological variations depending on the orography, the environment, and the geographical

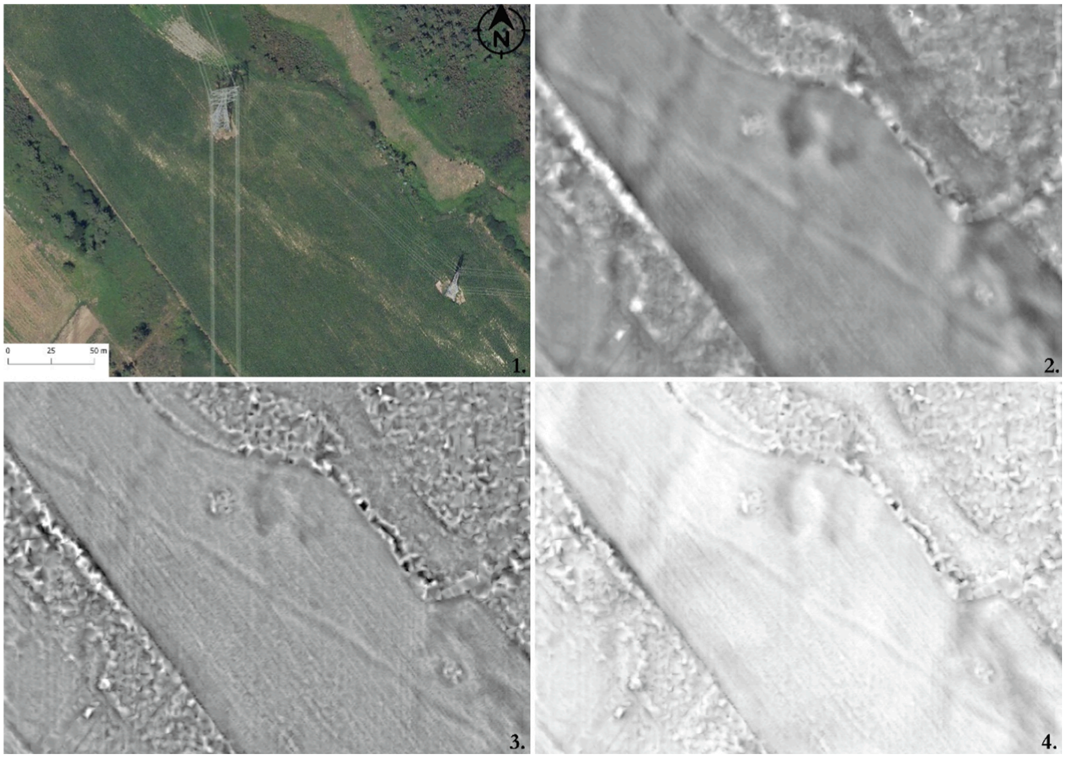

Fig. 6. Roman road in As Travesas: PNOA 2010 (1), SLRM (2), openness (3), and SVF (4).

or geological conditions. It is necessary to bear in mind that roads follow particular territorial, economic, and socio-political decisions, and the choice of certain transit areas responds to a necessity that cannot always be explained by construction techniques or geographical conditions: these roads, perhaps for the first time in history, presented the functional logic of truly high-capacity roads, whose function was to establish small, medium, and large-scale connections.

Although this fact emphasizes the Roman preference for flat areas, it also meant that, eventually, areas of steep and mountainous orography had to be crossed, which caused the fossilization of potentially identifiable features in the landscape. In some exceptions, especially in areas with humidity problems, flat areas could be avoided in favor of slightly high locations. In any case, and according to our knowledge of Roman road engineering, large roads are not usually built in areas with a slope over 8 % (Alvarado Blanco et al., 2000), reaching, in exceptional cases, 10 % (Quilici, 2008: 562), but never exceeding it. In those cases where overcoming steep slopes was required, huge earthworks were carried out, large retaining walls were built, or zigzag paths were designed (Moreno Gallo, 2006: 47-49), which are potentially identifiable in the landscape. In the case of slopes, considering the upper limits, predictive models that exclude areas with steeper slopes from potential circulation zones can be proposed.

- Rectilinear layout: perhaps the most recognizable visual characteristic of a Roman road is its linear design. There are no large roads with sharp curves or abrupt turns; even in areas with a complex orography, straightness prevails, making curves with subtle changes of orientation. In the cases in which orography allows it, roads can maintain a strictly straight route for more than 90 km, as the Appian Way between Rome and *Tarracina* (Quilici, 2008: 555) or the Aurelian Way between *Forum Aurelii* and *Centum Cellae* (Moreno Gallo, 2006: 49).
- Technical and constructive characteristics: the features of Roman roads, despite territorial variations due to topographic, climatic, political, or social criteria (Chevalier, 1997: 107-118) provide a homogeneous set of data that differentiates them from other roads. A particularly useful feature for their identification is their width. Those roads wide enough to allow for the circulation of a vehicle were called *viae* (Laurence, 1999: 58), at least 8 feet (2.4 m) –12 feet (3.6 m) wide if they were public. If they were not as wide but sufficient for the transit of pack animals (at least 4 feet, 1.2 m) and adequate for transport, they were called *acti* (Laurence, 1999: 59). More humble pathways were considered *itinera* or *semitae*. As a general rule, large-scale *viae* were usually around 14 feet (4.1 m) wide (Quilici, 2008: 563), although those of large capacity (for regular traffic of vehicles) were usually around 20 or 22 feet (between 6 and 6.5 m: Quilici, 2008: 566). In flat or hilly areas, roads were built on embankments, which guaranteed good preservation and drainage and minimized the impact of water (Moreno Gallo, 2006: 70). This feature, together with the homogeneous measures previously exposed, enables their identification in the landscape through geospatial analysis.
- Abandonment or continuity? Though it may seem obvious that these roads were employed over the centuries, the absence of a powerful political entity comparable to the Roman Empire, with the capacity to maintain and administer these roads, complicated their continuity in some cases. Many Roman roads were “fossilized” and remained in use for centuries (Moreno Gallo, 2010), but only in those places with a suitable socio-political context and/or climate. In areas where rainfall or vegetation are particularly outstanding, the conservation of these roads becomes very complicated if there is not a political organization capable of guaranteeing their conservation. In fact, in some regions, roads have not survived but routes have, giving birth to numerous parallel roads to ancient Roman roads no longer in use, such as in Great Britain (Small, 2016), the French Alps (Fruchard et al., 2010) and, as we will see, NW Iberia.

The above-mentioned issues regarding rainfall and vegetation, as has already been explained, hinder the conservation of Roman roads (no case is known in the whole region), as it happened in other regions of the

Fig. 7. Mapping the differences between paths: mule-tracks (1), modern roads (2), and roman roads (3).

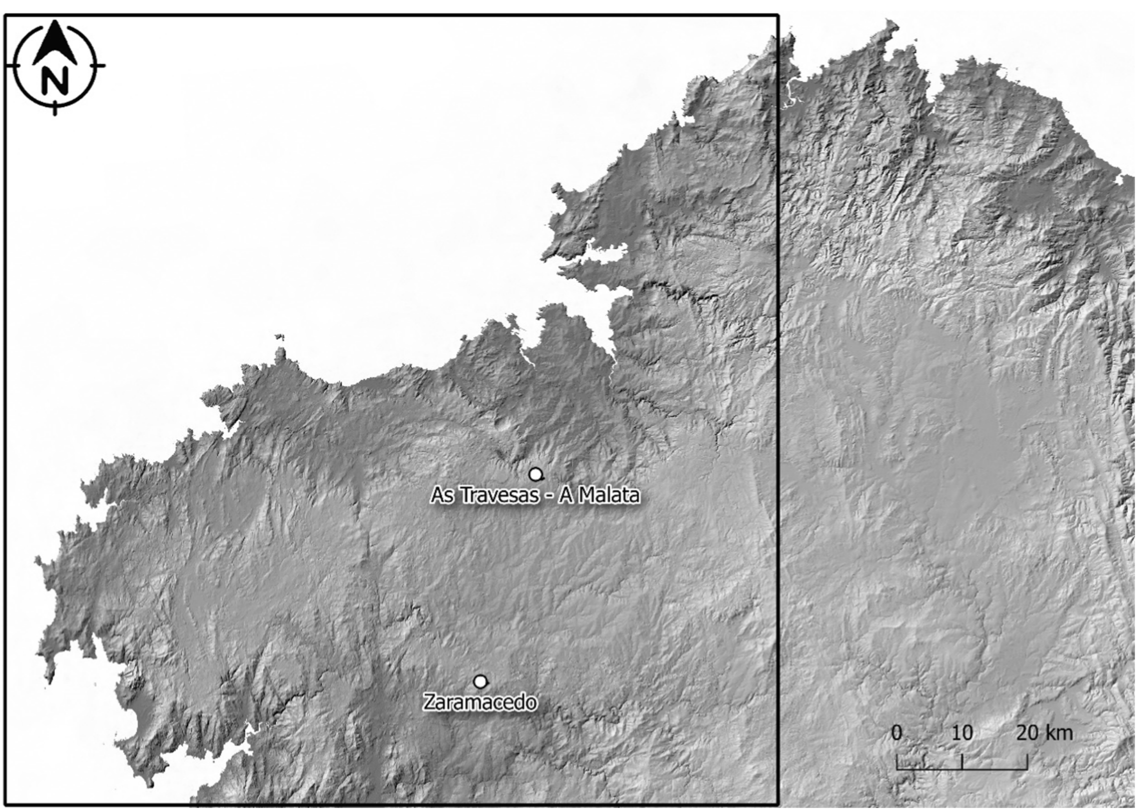

Fig. 8. Location of the case studies.

Peninsula. In fact, the absence of examples could pose some interpretative problems in order to differentiate Roman roads from other kind of routes such as medieval roads. However, the differences are remarkable: medieval roads of NW Iberia tend to be located in interfluvial regions and the surroundings of valleys, are more prone to cross steeper areas and, furthermore, tend to avoid the paving of road networks (Nárdiz Ortiz, 1991: 38-39).

Moreover, the absence of a road system prior to the arrival of the Romans should also be noted. Although several natural transit routes (Criado Boado and Villoch Vázquez, 1998) and paved roads for internal circulation systems in large fortified settlements (Nión-Álvarez, 2021: 440) are known, there are no architectural road systems between settlements that have left a physical trace in the landscape. Their existence has been identified through the combination of mobility analysis with other elements related to human transit (Fábrega Álvarez, 2011). In short, the characteristics mentioned above not only define a Roman

Fig. 9. SLRM visualization of the identified road section (1), aerial photography detail 2010 (2), 2007 (3), SLRM detail (4).

road, but also establish criteria to differentiate them from other routes (see Fig. 7).

4. An approach from NW Iberia: The (probable) case of *Viae* XIX and XX

The following section presents a first approach to two case studies (see Fig. 8), following the local and geospatial criteria previously proposed for their detection, identification, and chronocultural ascription. The goal is to evaluate the potential of the proposed methodology to identify the characteristics of Roman roads. These two study areas have been chosen because they offer promising data previously reviewed in the field.

It should be noted, however, that there are some obstacles to reliably linking the identified elements to the routes of the *viae* XIX and XX. Given the lack of associated epigraphic evidence, this method proposes the identification of two sections of *viae* according to their morphological, technical, and archaeological characteristics; however, it is not possible to confirm their relations with a specific road layout. Regarding the problems inherent to classical sources, even a large volume of information as the *Itinerarium Antonini,* they were collected by people who did not know the specific characteristics of the routes, possibly at times when many of them had already been abandoned (Vila Gómez, 2005: 28), maybe with typographical errors (Pérez Losada, 2002: 300) or even mistranslations and misunderstandings (Roldán Hervás, 1966). It cannot be ruled out either that important routes have been lost or that they lack

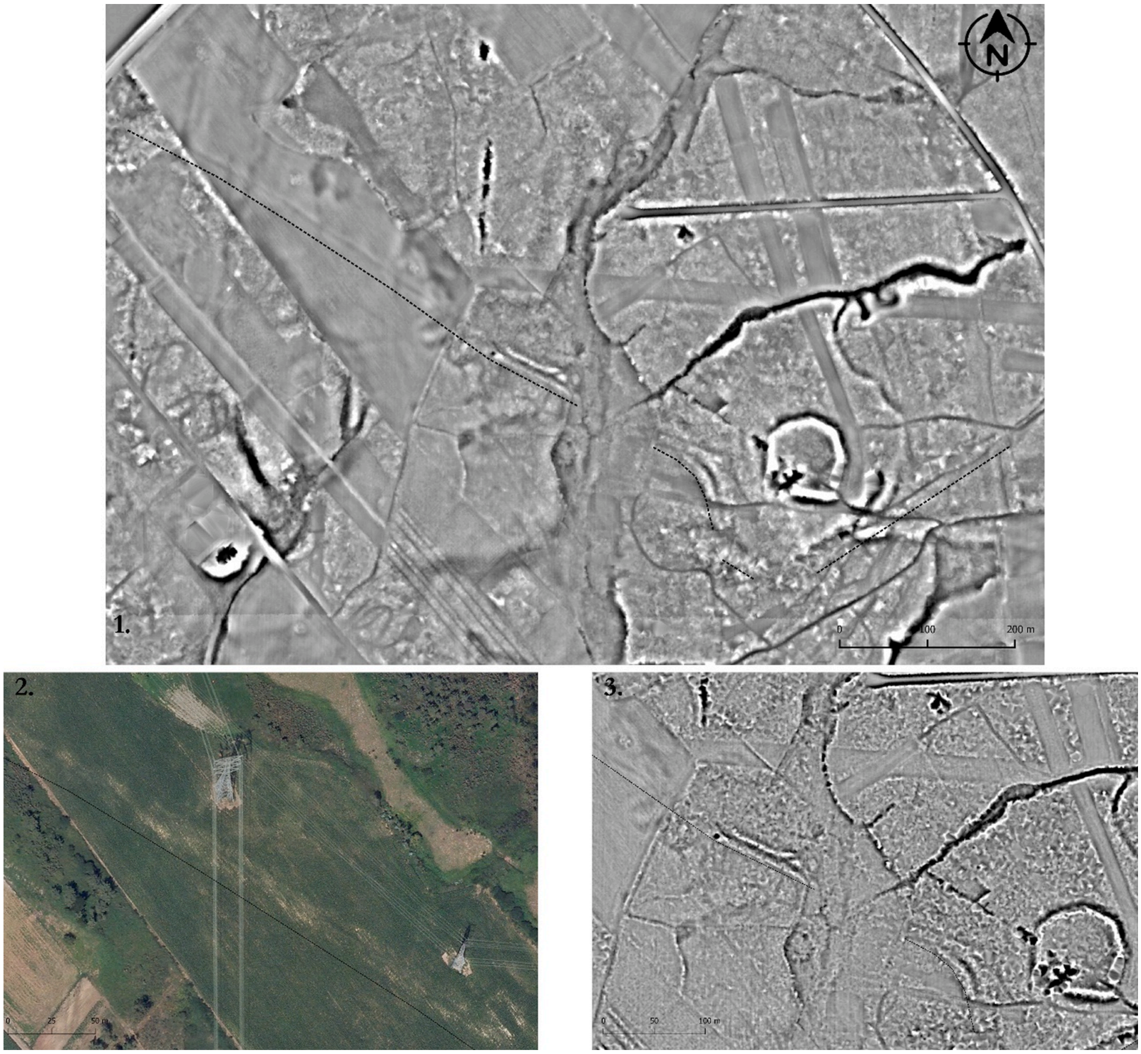

Fig. 10. SLRM visualization of the identified road section (1), aerial photography detail (2), and openness in detail around Castro da Alcaiana (3).

a name or references (Ruiz Acevedo, 1998: 26), which would explain that some major roads archaeologically identified were not included in classical sources. These questions should be considered not only in this study, but also in any study on Roman roads.

However, some points suggest that both case studies are related to the road routes included in the *Itinerarium Antonini.* In the study area, the reduced presence of public works, settlements, or constructions carried out by the Roman Empire is noteworthy (at least, in comparison with most of the Iberian Peninsula). The Atlantic façade of the *conventus lucensis* is a peripheral region, with exceptional economic interest at some points (Nión-Álvarez, 2021: 675-680), but reduced territorial importance, political influence, or demographic weight. Hence, it would be unusual to build a dense road network in an area where there are few relevant points to connect. In addition, the examples analyzed geographically match most of the outlines proposed for the *viae* XIX and XX. Moreover, their morphological features reflect real high-capacity *viae,* which, given the unlikelihood of a high-density road layout in a peripheral area, suggests that the case studies analyzed correspond to the roads mentioned in the *Itinerarium Antonini.*

4.1. Zaramacedo (Santiago de Compostela, Galicia). Via XIX.

This section is placed in a 375-metre-high flat area following the natural communication route between Alto de Castelo and Coto de Neiro. In this area, the remains of a 2.1 km long track have been identified, with a SW-NE orientation. Its layout has a rectilinear plan delimited by two embankments on both sides. Its current state of preservation is poor at some points due to agricultural and reforestation works, which have destroyed some parts of the road. Despite its state of preservation, it is possible to differentiate the embankment from the circulation area at certain spots and to document a track width of between 6 and 6.2 m (see Fig. 9), exactly the usual width of high-capacity *viae.* It is also significant that no medieval, modern, or contemporary road infrastructure seems to have been built in this location, according to the aerial photography. Any relations with pathways of the *Camiño de Santiago* can also be discarded: their historical route (in relation to the French Way) runs 1.5 km in a northerly direction, showing differences in their morphological and constructive features.

This enclave, from the general perspective of the layout, is consistent with the proposed route for the Via XIX (Rodríguez Colmenero et al., 2004). However, the significant distance (7 km) to the urban center of Santiago de Compostela, whose origins have usually been linked to the construction of this road and the *mansio* of *Asseconia* (López Alsina, 1986; Pérez Losada, 2002: 318; Suárez Otero and Caamaño Gesto, 2003: 35-37) is noteworthy. The location and orientation of the identified section suggests that, instead of approaching the urban environment, the road would run parallel to it at a certain distance, a finding that will be contrasted and reviewed in further research.

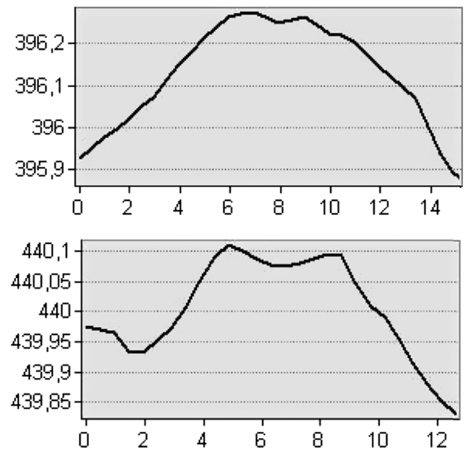

Fig. 11. Topographic profiles of Zaramacedo (above) and As Travesas-A Malata (below).

4.2. As Travesas-A Malata (Carral-Abegondo, Galicia)

This section is located on a 425-metre high plateau in a natural passage with a remarkable visibility over the region of As Mariñas. In this area, a 1.2 km long section has been identified, divided into several segments due to significant alterations caused by agricultural works and industrial and forestry exploitations on the landscape. In its initial section, in fact, the route is completely lost due to the construction of a power substation, as well as in its final section due to the presence of several livestock farms.

According to its characteristics, it is defined as NW-SE oriented at the beginning, turning to a S direction 700 m from its starting point and turning again after 150 m in a SW-NE direction, possibly to avoid the hillfort known as Castro da Alcaiana. At a morphological level, the road is defined by two embankments that set a rectilinear path, with two turns with very open angles. Its state of conservation makes it difficult to propose measurements, although, in the better-preserved areas, it seems to have a width of 5.1–5.4 m approximately. In any case, it seems to be slightly narrower than the previous one, although also corresponding to the standard measurement for large Roman roads.

In this case, data from an archaeological intervention carried out in 2011 confirm some of the proposed features. In this excavation, a 5.18 m wide (18 feet approximately) road section with drainage structures in the contour (1.18 wide, equivalent to 4 feet) was identified (see Figs. 10 and 11), which is a confirmed characteristics of its Roman origins (Fernández Malde and Castro Vilariño, 2013: 67) and indicates a high-capacity *viae*. Likewise, its differences with other modern and/or traditional roads, as well as with the English Way of the *Camiño de Santiago* (which run parallel or close to this road: Fernández Malde and Castro Vilariño, 2013: 66-68), were also highlighted. Its location is consistent with the proposed route for Via XX (Caamaño Gesto and Naveiro López, 1992), although considerable uncertainties exist in its definition. Future studies will be necessary to investigate the location of other sections.

5. Conclusions

The current progress of geospatial analysis techniques has allowed to explore new possibilities in the study of roads and mobility, following its remarkable development in archaeological research. In this work, an approach for detecting and identifying Roman roads through the application of remote-sensing techniques has been proposed within the framework of a spatial study at small and medium scale. Two case studies have been analysed in with significant problems for the study of mobility in Roman times, which has permitted the assessment of the application of these techniques.

Therefore, this work intends to be a support tool for researchers, either to obtain data in other historical investigations or to be applied in other regions with similar characteristics. In both cases, this research may be helpful for updating or revising the available data and, therefore, opening new lines of historical and archaeological research.

CRediT authorship contribution statement

Samuel Nión-Álvarez: Conceptualization, Data curation, Methodology, Formal analysis, Investigation, Resources, Visualization, Software.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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