URBANIZATION IN IBERIA AND MEDITERRANEAN GAUL IN THE FIRST MILLENNIUM BC

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T.R.A.M.A 7
TREBALLS D'ARQUEOLOGIA
DE LA MEDITERRÀNIA ANTIGA

Institut Català d'Arqueologia Clàssica

Tarragona 2019

ICREA: Institució Catalana de Recerca i Estudis Avançats
ICAC: Institut Català d'Arqueologia Clàssica
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Edició de les actes de la sessió «Urbanization in Iberia and Mediterranean Gaul in the first millennium BC», dins el congrés internacional 24th Annual Meeting of the European Association of Archaeology, que va tenir lloc a Barcelona el dia 6 de setembre de 2018, amb la participació del projecte «Caracterización de los asentamientos urbanos en la costa de la Iberia septentrional (siglos VI-III a. C.):» (HAR2015-67946-C2-1-P i HAR2015-67946-C2-2-P).

Aquesta obra ha estat possible gràcies al projecte de recerca «Caracterización de los asentamientos urbanos en la costa de Iberia septentrional (siglos VI-III a. C.): teledetección, documentación y restitución de estructuras constructivas» (I+D HAR2015-67946-C2-2-P); 1 de gener de 2016 a 31 de desembre de 2019.

Aquesta obra ha passat revisió d'experts. / This is a peer-reviewed publication.

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Primera edició: desembre de 2019
Coordinació editorial: Publicacions de l'ICAC
Correcció: Ramon Vidal Muntané, B2B Translation, Paul Turner
Imatge de la coberta: Vista aèria del sector III de l'acròpolis de l'enclavament arqueològic de l'antiga Anserona (Llenguadoc, França). © Rémy Marion / Pôles d'images / Centre des monuments nationaux
Disseny de la col·lecció i de la coberta: Indústries Gràfiques Gabriel Gibert
Maquetació i impressió: Indústries Gràfiques Gabriel Gibert

Dipòsit Legal: T 328-2020
ISBN: 978-84-949747-4-8

VIII • USING LIDAR TO DETECT ARCHITECTURAL FEATURES IN URBAN SITES ON THE COAST OF NORTHERN IBERIA (6th - 3rd CENTURIES BC). PRELIMINARY RESULTS[1]

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Abstract

We present here the first results of an ongoing research project aimed at improving our knowledge of the urban settlements of the north-eastern Iberian Peninsula during the Iron Age. In the 4th-3rd centuries BC, and probably as early as the 6th-5th centuries BC, we detect a strongly hierarchical settlement pattern in this area. It was composed of settlement types that were differentiated by their size and function. The urban sites at the top of the hierarchy are the least known, as their excavation and study present several difficulties, such as the large areas they cover (around 10 hectares) and the fact that most of them lie under dense forest cover that obscures the archaeological remains. This last factor makes it difficult to apply certain non-invasive methods, including geophysical prospection. They are, however, suitable for study by remote sensing techniques. In this paper we discuss the efficiency of those techniques, more specifically the use of lidar data as a method of detecting architectural features in these settlements.

Keywords: remote sensing, lidar, Iron Age, Iberian Peninsula, urbanism

Resum

Presentem els primers resultats d'una investigació en curs que pretén millorar el coneixement dels assentaments urbans a l'edat de ferro del nord-est de la península Ibèrica. Almenys per als segles IV-III aC, i probablement ja des dels segles VI-V aC, s'ha detectat un patró d'assentament fortament jerarquitzat en aquesta àrea, integrat per diferents tipus de nuclis segons la seva grandària i funció. Els jaciments urbans, al capdamunt de la jerarquia, són precisament els menys coneguts, ja que la seva excavació i estudi presenten diverses dificultats, incloent-hi les grans superfícies que cobreixen (al voltant de 10 ha) i el fet que la majoria d'ells es troben sota una densa capa forestal que oculta les restes arqueològiques. Aquest últim factor fa que sigui difícil aplicar certs mètodes no invasius, com ara la prospecció geofísica. En canvi, són susceptibles de ser estudiats a través de tècniques de teledetecció. En aquest article analitzem l'eficàcia d'aquestes tècniques, més concretament l'ús de les dades lidar, com a mètode per detectar estructures arquitectòniques en aquests assentaments.

Paraules clau: teledetecció, lidar, edat del ferro, península Ibèrica, urbanisme

1. This research has been funded by the Spanish Ministry of Economy and Competitiveness (Project HAR2015-67946-C2-2-P).

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1. Introduction

The study of the Iron Age settlements in the north-eastern Iberian Peninsula (present-day Catalonia) has achieved important results during the last four decades. As discussed elsewhere (see Sanmartí *et al*. in this volume), Iberian communities were organized into different political entities, each with its own territory. In what is now Catalonia, at least in the coastal areas, each territory contained settlements of different categories and with diverse functions. There were various sizes of towns, villages, fortified sites and rural settlements. They were organized under a hierarchical pattern and a proto-state structure with the main towns acting as the capitals of each territory. This organization is attested at least by the Middle Iberian period (4th-3rd century BC) (Asensio *et al*. 1998; Sanmartí 2002 and 2004; Sanmartí 2014, 462) and probably began during the 6th-5th centuries BC (Sanmartí *et al*. 2006, 153).

Urban sites were at the top of the settlement hierarchy. We can distinguish between first-order towns, which could be as large as 10 ha or even more, and second-order towns of between 2 and 4 ha. They were typically located on hilltops and their urban area may also have extended over one or more of the hillsides, sometimes following a terraced pattern. They were usually protected by defensive walls, towers and moats (Sanmartí and Santacana 1994; Asensio *et al*. 1998).

In spite of their importance and interest, these large sites are the least known settlement type. Recent fieldwork has mainly focused on smaller sites and, except for the case of Ullastret (see Codina, Plana and Prado in this volume), none of the urban sites has been extensively excavated. This is because their excavation and study present several challenges: they cover large areas (about 10 ha) and most have overlapping occupations from the Roman, medieval and modern periods. As for the possibilities of non-destructive survey methods, most of these sites lie under a dense Mediterranean forest cover consisting of evergreens (mostly pine) and dense bushes that obscure the archaeological remains and hinder attempts to carry out geophysical surveys.

Given the characteristics of Iberian towns, remote sensing (RS) techniques appear to be suitable for their study, as they allow large areas of land to be analysed. Among the different RS possibilities, we decided to carry out a study using lidar (Light Detection and Ranging) data. The object of this was two-fold: firstly, to gain information about the main building features and urban planning of these settlements, and secondly to test the suitability of the methodology. In this paper we present the first results of the study.

2. Methodology

The methodology for the study of the selected settlements was, as stated above, the use of remote sensing techniques, more specifically lidar data. This method is based on the emission of laser light and the measurement of the reflected pulses to generate a point cloud representing the earth's surface (DSM, Digital Surface Model). The model includes every feature of the relief, including the vegetation. We can then select the elements of the topography, filtering out the vegetation cover, and obtain a high resolution DTM (Digital Terrain Model). This allows small reliefs created by anthropic action to be highlighted through specific filters, the use of GIS and specific software.

Lidar technology has been used in archaeology since the beginning of the century (Bewley and Raczkowski 2002). It has been applied to various types of archaeological site presenting very different challenges. It has been used to study archaeological sites in forest areas, such as the First Iron Age settlement of Purbach in Austria (Doneus *et al*. 2008) and the prehistoric settlement of Welshbury Hill in Gloucestershire, England (Devereux *et al*. 2005). It has also been applied to landscape studies in Germany, specifically at Rastatt (Sittler 2004), and the Mayan site of Caracol in Belize (Chase *et al.* 2011). This technology has also proved to be efficient at sites not obscured by vegetation, for example, the high-resolution DTMs that highlight archaeological microtopography, such as in the area around Stonehenge, England (Bewley, Crutchley and Shell 2005). Lidar-derived DTMs are today commonly used as a data source for the automated detection of cultural heritage elements (Davis, Lipo and Sanger 2019; Schneider *et al.* 2015; Trier, Zortea and Tonning 2015).

On the Iberian Peninsula, lidar technology came later to archaeological studies. It is worth highlighting the research carried out to locate the Roman military camps in the north-west (Menéndez *et al*. 2017; Fonte and Costa-García 2017), as well as the modern-era fortifications on the Miño River in Galicia and Portugal (Blanco-Rotea *et al*. 2016). It has also been used in more specific cases, such as the First Iron Age settlement of Irueña in Fuenteguinaldo, Salamanca province (Berrocal-Rangel *et al.* 2017), or to describe hydraulic engineering techniques in Roman mining works in north-western Spain (Fernández-Lozano, Gutiérrez-Alonso and Fernández-Morán 2015).

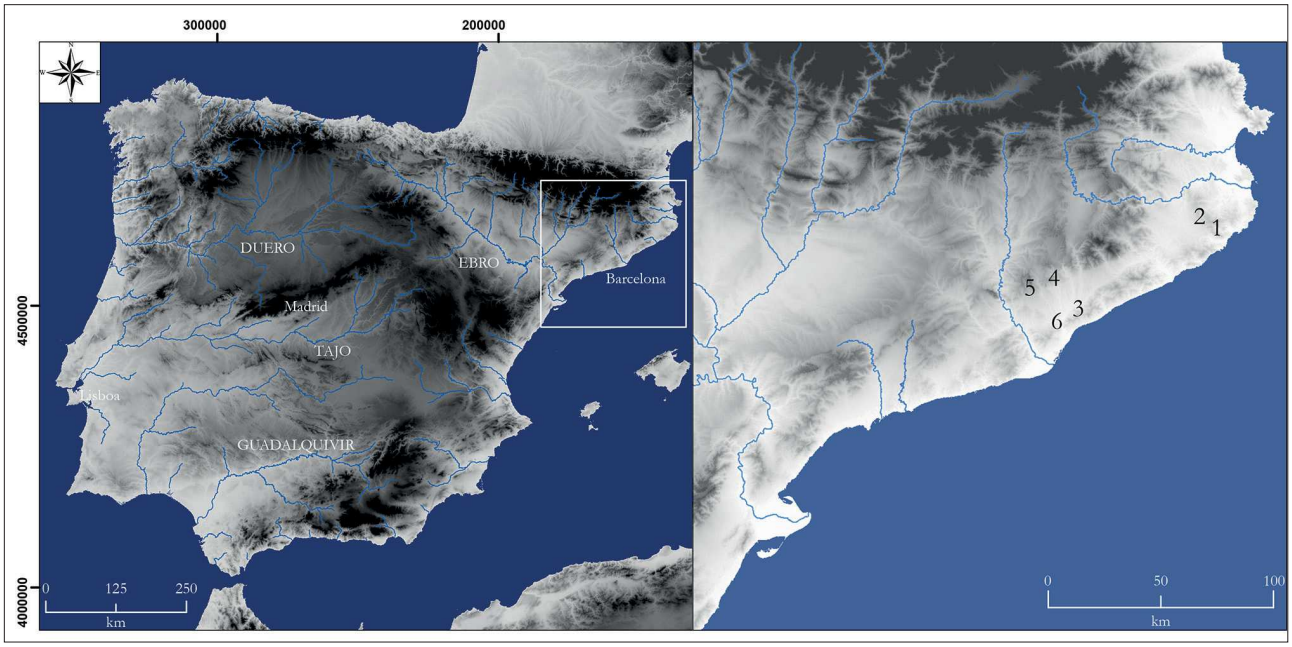

FIGURE 1. Study area within the Iberian Peninsula and the locations of the studied sites: 1) Castell Barri (Calonge, Girona); 2) Puig d'en Rovira (La Creueta de Quart, Girona); 3) Burriac (Cabrera de Mar, Barcelona); 4) Puig Castell (Cànoves i Samalús, Barcelona); 5) La Torre Roja (Caldes de Montbui, Barcelona); 6) Sant Miquel (Montornès/Vallromanes, Barcelona). Map background: DTM SRTM 90 m (CGIAR-CSI).

For this research we selected six settlements in which only limited fieldwork has been carried out to date (Fig. 1). They all lie under dense forest cover (Fig. 2). Our research was carried out in two phases and the results were of differing quality. Firstly, we worked with the available resolution data from the Catalan Cartographic and Geographic Institute (ICGC) lidar data, with a medium resolution of 2p/m^2 (unclassified). We obtained satisfactory results for only two sites: Puig Castell (Cànoves i Samalús) and Burriac (Cabrera de Mar). In order to increase the number of settlements with positive results, we attempted a second research phase with the acquisition of higher resolution lidar data through a new survey (5 unclassified points per m^2), also from the ICGC, but carried out specifically for the project. Our hypothesis was that a greater number of points per m^2 would allow some of these to penetrate the vegetation cover and facilitate more ground returns, giving us more information about the weakest topographic anomalies that could be signs of smaller archaeological structures.

The results obtained in the first phase were not uniform, as the density of the vegetation cover did not allow enough ground returns to filter it out and generate a DTM with sufficient resolution. Likewise, at some sites the points classification provided by the ICGC may have led to errors, such as identifying possible topographical anomalies in the understory as low vegetation. In these cases, where the LAS files are used to isolate ground returns and produce DTMs, those topographic anomalies that may indicate the presence of archaeological structures in the subsoil are not visible.

We processed the lidar files using QGIS 2.12.0-Lyon and LAStools. More specifically, we worked with the module lasground tool, which allows you to extract and work only with the points corresponding to the terrain. These data were later refined and, after examining several possibilities, we observed that the best results were obtained by establishing "nature" as the type of land and "fine" as the pre-processing. The resulting .las file, which only corresponded to the points classified as "ground", was transformed into a DTM using the lasAdem tool. A hillshade was later applied to the resulting DTM, allowing initial verification of the quality of the DTM and a first review of the presence or absence of topographical anomalies that could be interpreted as archaeological.

3. Case studies: location and previous research

The six settlements of our sample are located in the northern and central coastal regions of Catalonia and correspond to the ancient Iberian territories of the Indiketes (in the northern area, organised around the town of Ullastret) and the Laeetani (in the central area, organised around Burriac). Burriac is a first-order settlement, while

the other five correspond to smaller urban settlements, considered as second-order towns.

From north to south, the site of Castell Barri (Calonge, Baix Empordà, Girona) is located on a hill at 297 m a.s.l., very near the sea and in a densely built-up area (Fig. 2.1). Very little is known about it. In the mid-20th century, Miquel Oliva (1947) visited it and described the remains of the western and north-western stretches of a defensive wall 1.80-1.90 m wide that would have delimited the town, although he did not record any visible architectural remains inside the wall. No plan or photographs of the architectural features accompanied this description. Oliva also collected some archaeological surface finds that suggest a possible dating of between the 4th and the 3rd centuries BC (Oliva 1947, 291). The site has not been excavated, except for a small area in the 1990s (Caravaca *et al.* 1996). More recently, Aurora Martin described it as a lookout point to monitor the surrounding territory (Martin 2005, 333). We interpret it as a probable secondary town of the Indiketan polity.

We selected a second settlement in the same area, Puig d'en Rovira (La Creueta de Quart, Girona) (Fig. 2.2). Located on a wooded hill at 150 m a.s.l., it is about 30 kilometres from the coast, near the modern city of Girona and therefore in a densely built-up area. Part of the site was destroyed by a modern quarry. The settlement was occupied at least from the late 4th century BC (Martin 2005, 328). Excavations carried out in the 1940s revealed part of the defensive wall, the remains of habitation walls, some of them superimposed and corresponding to different phases, and abundant archaeological finds (Riuró 1943, 119). All these data suggest that this settlement would have been either a small town or a third-order settlement.

The other four sites in our sample are in the Laeetanian area. Among them, Burriac (Cabrera de Mar, Maresme, Barcelona) is a first-order settlement, probably the capital of the Laeetani (Fig. 2.3). It is located on the southern slope of a hill on the Catalan coast at a maximum height of some 400 m a.s.l. It has been proposed that the occupied area covered approximately 10 ha (Zamora 2007, 325), whereas the remaining habitation sites in this region do not exceed 4 ha. The archaeological excavations at the site were carried out mainly between the 1930s and 1980s (Barberà and Pascual 1979-1980; Benito *et al*. 1982-1983 and 1985; Garcia and Zamora 1994; 1986; Ribas 1931, 1952 and 1964; Ribas and Lladó 1977-1978). However, only a small part of the fortified enclosure is known and there is practically no information regarding the internal urban layout. We only know of the existence of several rows of houses organised on terraces at different levels, following a well-known pattern of urbanism in the Iberian culture. A larger construction attached to the eastern wall was initially interpreted as a public building (Barberà and Pascual 1979-1980, 212-222), although more recently as part of a large dwelling (Zamora 2007). The fieldwork allowed the site to be dated to between the 6th and the 1st centuries BC. The centrality of this town is also confirmed by the existence in its surroundings of three funerary areas dating from the 3rd century BC: Turó dels dos Pins, Can Rodon and Can Ros (Zamora 2007). This is significant given that the few necropolises documented in the study area are always associated with the first-order towns (see Sanmartí *et al*. in this volume). Finally, groups of rural buildings and silos are located in the town's peri-urban area (Zamora 2012), an aspect also characteristic of the main settlements.

A second site in this territory is Puig Castell (Cànoves i Samalús, Vallès Oriental, Barcelona) (Fig. 2.4). It is located in the Catalan Pre-Coastal Mountains, approximately 30 km from the coast and built on a hilltop at 631 m a.s.l. Discovered by Josep Estrada in the nineteen-fifties (Estrada 1955; Estrada and Villaronga 1967), it was studied by Arnau Garcia Molsosa (2015) for his PhD. It is in fact the best-known settlement in our selection, thanks to excavations carried out in recent years by Marc Guàrdia. These have brought to light a large part of the rampart, a structure two metres in width built in the 4th century BC, as well as part of the towers in the same defensive system. The archaeological site is located in the Montseny Natural Park where deforestation is not permitted, making open-area excavations very complicated (Fig. 3). As in other cases, practically no fieldwork has been undertaken in the interior of the town, and its urban layout is therefore barely known. It covers an area of approximately 4 ha and would have been an important town in the Laeetani territory (Garcia Molsosa 2015; Guàrdia 2015 and 2016).

Still in this area, Torre Roja (Caldes de Montbui, Vallès Oriental, Barcelona) is also located in the Catalan Pre-Coastal Mountains and is built on an upper slope 375-400 m a.s.l. (Fig. 2.5). The site was occupied from the late 6th century to the mediaeval era. Recent excavations have revealed a habitation area dated to the Iberian period (5th-4th to 1st centuries BC), with several buildings initially laid out in regular rows and separated by a central street, as well as later modifications that transformed the urban layout into a more complex system. The defensive wall has also been partially identified (Fortó and Maese 2009-2010).

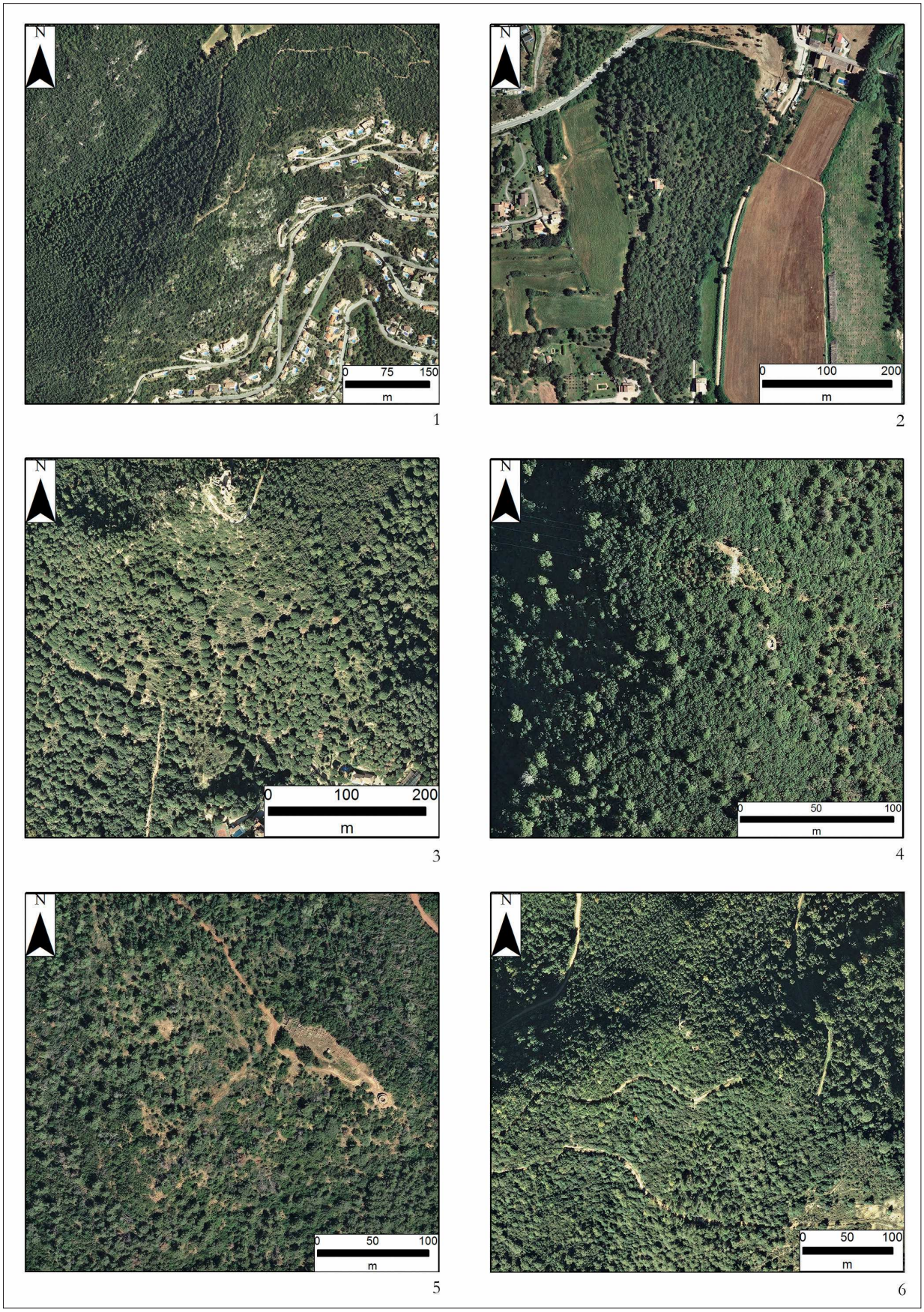

FIGURE 2. An aerial perspective that allows us to appreciate that the analysed sites are covered by the forest. 1) Castell Barri (Calonge, Girona); 2) Puig d'en Rovira (La Creueta de Quart, Girona); 3) Burriac (Cabrera de Mar, Barcelona); 4) Puig Castell (Cànoves i Samalús, Barcelona); 5) La Torre Roja (Caldes de Montbui, Barcelona); 6) Sant Miquel (Montornès/Vallromanes, Barcelona). Map background: Orthophotomap 1:2.500 ICGC.

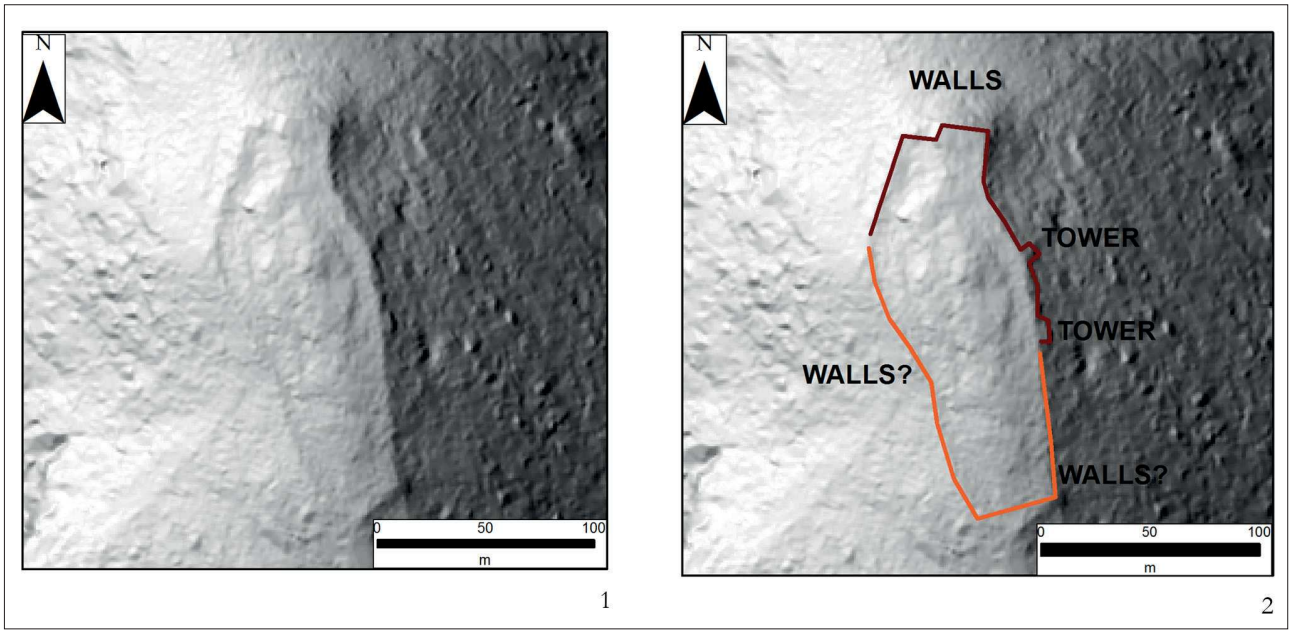

FIGURE 3. Puig Castell: The DTM shows the entire fortified enclosure of the site (wall and several towers). Map background: Orthophotomap/LIDAR ICGC.

However, the available information is insufficient to define the total area of the settlement.

The last site is Sant Miquel (Vallromanes/Montornès, Vallès Oriental, Barcelona) (Fig. 2.6). Located on an inland hill at 410 m a.s.l. in the Catalan Coastal Range, this Iberian settlement occupied the top and two slopes of the hill. Limited fieldwork was carried out in the late 1960s when the remains of the rear wall and domestic buildings were discovered, as well as finds from the 3rd century BC (Barberà and Pascual 1969-1970), although little is known about the urban planning of the settlement. Although no later excavations have been undertaken, a recent review of the archaeological finds allows us to date the occupation period of the settlement from at least the second half of the 5th century to the end of the 3rd century or the beginning of the 2nd century BC (Asensio and Guitart 2010, 70). An updated topography of the settlement has allowed an area of between 1.5 and 2.5 ha to be proposed (Asensio and Guitart 2010, 63). It probably corresponds to a second order town.

4. Results and discussion

The best results were obtained at Puig Castell (Cànoves i Samalús), where almost the whole fortified enclosure was detected, as well as some of the defensive towers. Its general outline coincides with that obtained from the excavations (Guàrdia 2015, 54, Fig. 2). However, we did not identify any topographical anomalies inside the ramparts (Fig. 4). At Burriac (Cabrera de Mar), the analysis revealed two anomalies to the east and west of the site that could correspond to two stretches of the wall. No anomalies were observed inside the site's enclosure and there is no trace of the southern stretch of the fortification (Fig. 5).

FIGURE 4. Detail of the rampart of Puig Castell), after Guàrdia 2015, 55, fig. 4.

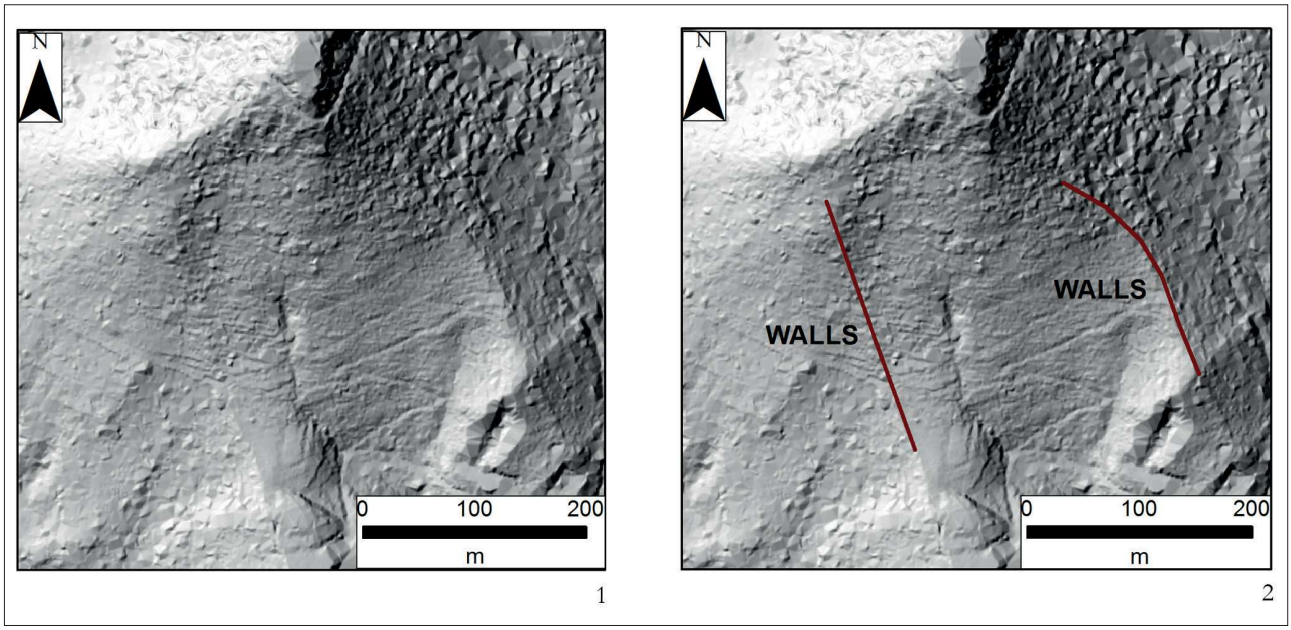

FIGURE 5. Burriac: The DTM allows us to appreciate the eastern and western stretches of the wall. Map background: Orthophotomap/LIDAR ICGC.

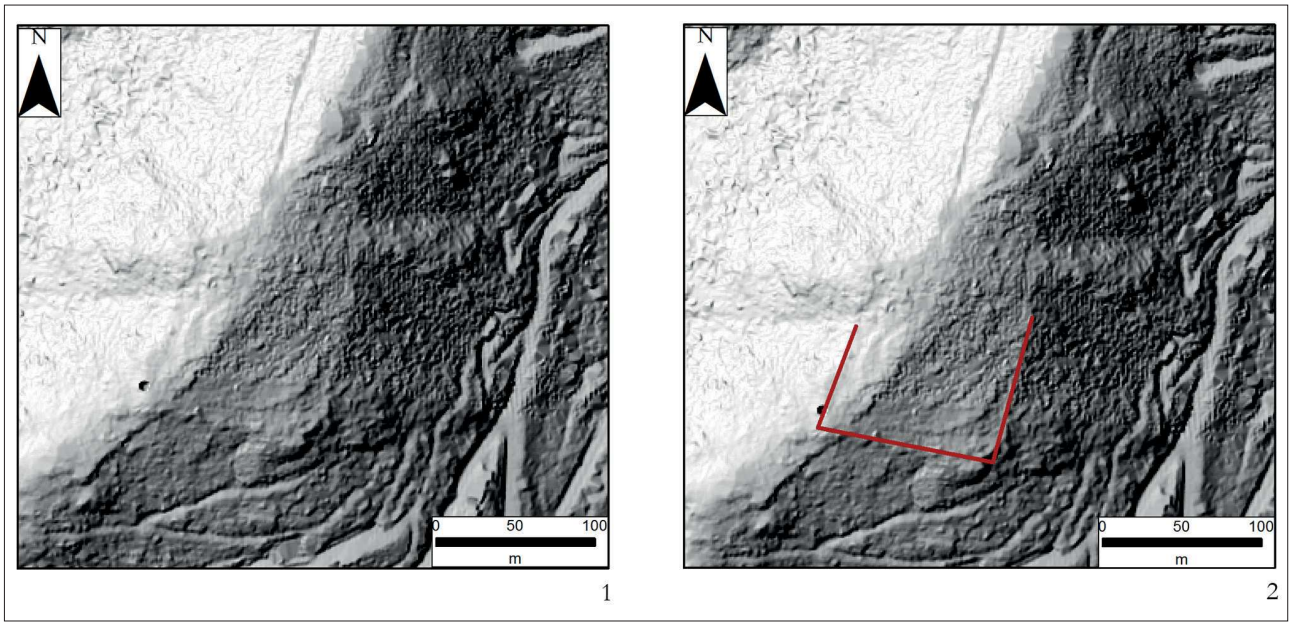

FIGURE 6. Castellbarri: The analysis allows us to locate a part of the hypothetical fortified enclosure, specifically part of the eastern, southern and western stretches of the wall. Map background: Orthophotomap/LIDAR ICGC.

During the second phase, the most satisfactory results continued to be from Burriac and Puig Castell. The analysis of the rest of the sites gave minor results, with the exception of Torre Roja (Fig. 8), where the rampart surrounding the settlement perimeter was also detected.

In the case of Castell Barri (Calonge), a possible anomaly was detected on the upper part of the southern hill slope; this could correspond to part of the eastern, southern and western stretches of the town wall, with a total length of 283 m. They define a partial area of 1 ha, although the settlement probably extended northwards and thus undoubtedly occupied a larger area (Fig. 6).

In the analysis of Puig d'en Rovira (La Creueta, Quart), it can be clearly observed that the hill has been considerably affected by a modern quarry and has marked terracing on the eastern slope. On the northern slope, however, there are anomalies that could be of an archaeological nature, corresponding more precisely to a possible 126-metre stretch of wall that follows the relief of the hill (Fig. 7).

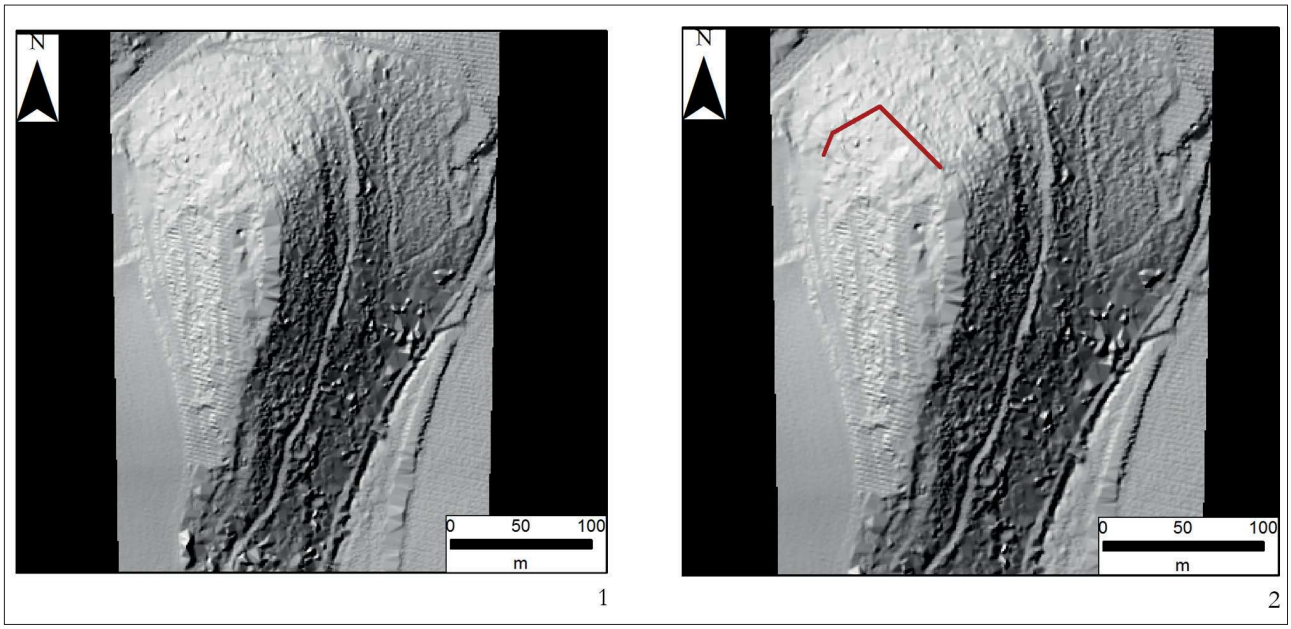

FIGURE 7. La Creueta: Observation of DTM allows to follow part of the possible layout of the wall to the north of the hill. Map background: Orthophotomap/LIDAR ICGC.

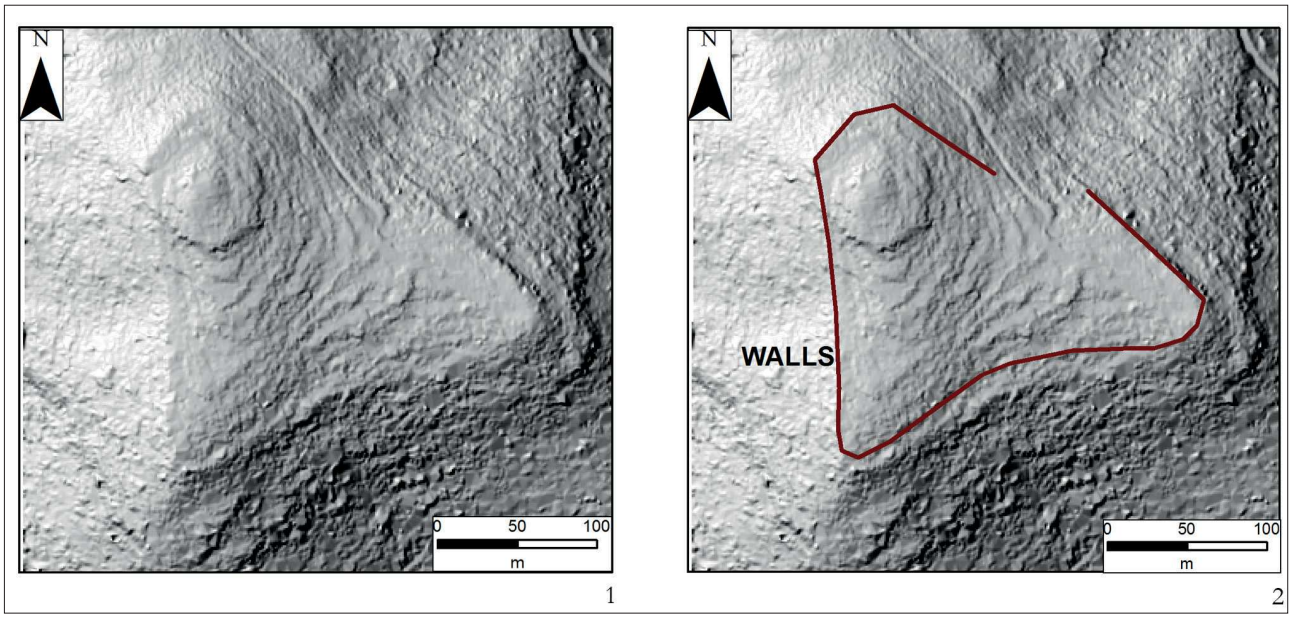

FIGURE 8. Torre Roja: The LIDAR data processing allows us to locate almost all the probable layout of the wall. Map background: Orthophotomap/LIDAR ICGC.

In the case of Torre Roja (Caldes de Montbui, Barcelona), most of the perimeter wall of the settlement appears to be defined. On the upper part of the hill, as well as on its south-eastern slope, several topographic anomalies are detected that appear to mark the northern, southern and eastern stretches of the wall; they have a total length of 676 m, giving a possible size for the settlement of around 3 ha (Fig. 8).

Finally, the study of Sant Miquel (Montornès/Vallromanes) presents greater difficulty. The dense vegetation cover on the eastern, northern and western slopes makes it difficult to record the points corresponding to the understory. Nevertheless, two possible anomalies can be identified on the southern slope of the hill, probably corresponding to stretches of the defensive wall of 120 m and 70 m respectively. However, there is also a mediaeval fortification on this site (known as Sant Miquel castle) and it cannot be ruled out that the elements identified are related to this later construction (Fig. 9).

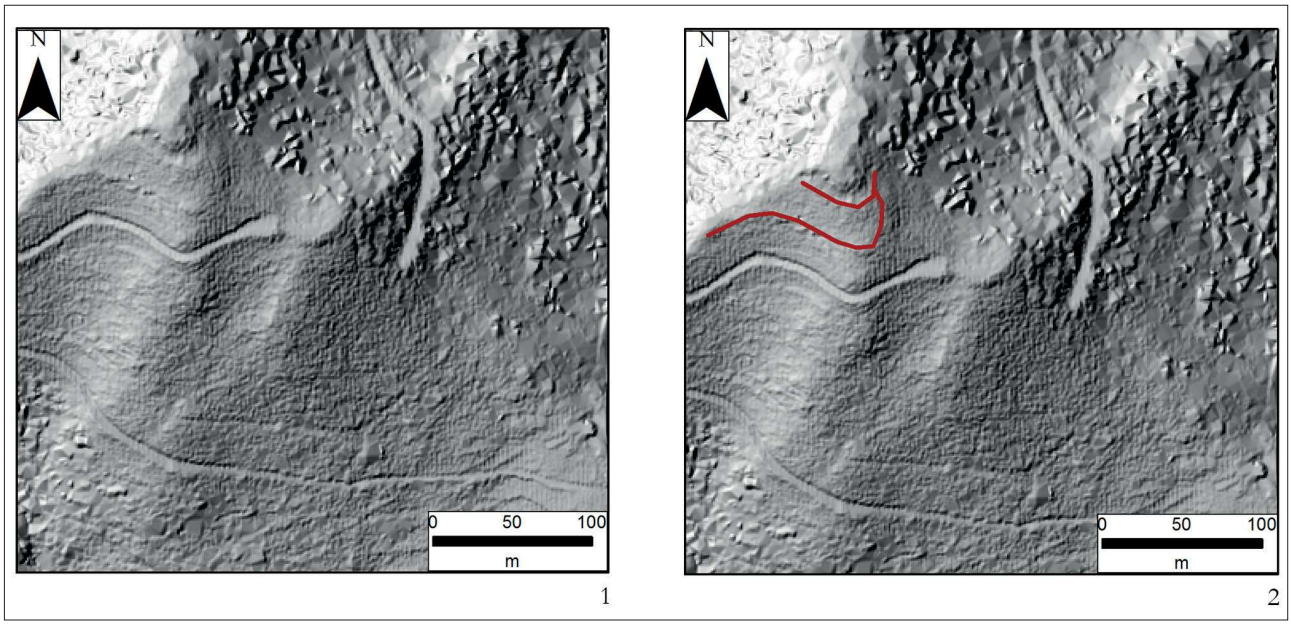

FIGURE 9. Sant Miquel de Vallromanes: Two topographical anomalies can be identified just south of the hilltop, although they could also be related to the medieval fortification. Map background: Orthophotomap/ LIDAR ICGC.

By and large, the structures detected through lidar coincide with those identified by archaeological excavations, where they have been carried out. The latter are sometimes still visible on site, although in the case of earlier excavations (Sant Miquel de Vallromanes, Puig d'en Rovira or Burriac) they are not discernible due to the vegetation.

5. Conclusions and perspectives

Preliminary results show that this technology is useful for the study of large areas with dense vegetation, at least for the identification of large defensive structures such as towers, walls and moats. This is a major step forward if we take into account that for most of the cases under study we do not even know the extent of the sites. The perimeter walls detected in our survey surrounded settlements with areas of between 2 and 4 hectares, a figure that corresponds to the proposed size of second-order sites. An exception would be Burriac, the only first-order nucleus in the sample, which is much larger, probably reaching around 10 ha. To date, however, this method has not allowed us to clearly identify smaller structures, such as house walls.

With the preliminary results of the second phase we have been able to confirm that a higher resolution of points per m^2 allows us to obtain incipient results at sites that had not previously revealed possible archaeological structures. Despite this, it has not been possible to improve the results already obtained for Burriac and Puig Castell. It is entirely possible that the habitation structures within the perimeter wall do not present any topographic imprint on the surface. This will be tested during a third phase of the project by means of a high resolution topographic survey using a differential GNSS system.

In some cases, it becomes apparent that the points density is not high enough to provide the ground returns necessary to produce a high-resolution DTM, given the dense tree vegetation and the undergrowth (Sant Miquel). This is particularly problematic as evergreen vegetation maintains a similar leaf density thorough the year and ground visibility conditions do not improve at any specific time. A second challenge is the steep slope across which part of these sites is built. Slopes are a challenge as they increase the illuminated ground area but not the point density, which can result in a substantial reduction in ground return density. The slopes in the area also tend to concentrate forest and shrub vegetation, which results in a further decrease in ground returns per area. Lastly, hillshading, the visualisation method currently employed, tends to produce unsatisfactory results. Our research is now entering its final phase and the aim is to achieve the highest possible quality DTMs in order to extract as much information as possible from these settlements and to define to what extent there may be other types of impediment that do not allow us to obtain more results.

6. Future work

The ICGC recently released a second version of the Catalan lidar point cloud. After initial testing, it became apparent that new version presents a similar point density to the first, although with a different distribution. This opens up new avenues for increasing the ground returns at the different sites. In the coming months we aim to correlate the two versions of the ICGC's cloud point data with that acquired specially for the project. This will involve the use of automatic cloud point correlation algorithms. Once all ground heights from the three cloud points have been perfectly correlated, they will be classified using algorithms that can better discriminate ground returns on slopes. The classified ground returns will be used to generate a DTM through interpolation procedures. Lastly, the surface will be subjected to microtopographic analysis using a Multi-Scale Relief Model (MSRM). This method of identifying microtopographic imprints on the terrain produces superior results to previous methods such as hillshading (Orengo and Petrie 2018), but it has yet to be tested in complex topographic settings. This will be an excellent opportunity to do so.

7. References

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