
Up and Down the Hill: Hillforts and Dry Stonewall Enclosures on the Kvarner Islands
of Cres and Lošinj in Remote Sensing Data^{1,2}
*Gor in dol po hribu: gradišča in subozidne ograde na kvarnerskih otokih Cresu in Lošinju
v podatkih daljinskega zaznavanja*

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Abstract

The Cres–Lošinj archipelago is a region characterised by numerous topographically prominent settlements. In the past, systematic research on this subject has been limited, mainly due to the difficulty of accessing the area because of dense vegetation. This study aims to address this gap by providing an overview of 85 locations where hillfort settlements and other types of enclosures have been systematically examined. It is based on a systematic analysis of ALS data covering approximately 500 km² of the archipelago over several months.

The current state of knowledge offers little opportunity for traditional archaeological evaluation, which relies on the typological and chronological characteristics of ceramic materials or on formal analogies between settlement features. Therefore, the discussion in this study focuses primarily on the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. ALS interpretations of individual sites have been made available to experts to facilitate further discussion of the archipelago's dry-stone-walled landscapes in general and of hillforts in particular.

Keywords: ALS, Cres/Lošinj, hillforts, dry stonewalls, agro-pastoral remains

Izvlček

Cresko-lošinjški arhipelag je območje, značilno po številnih topografsko izrazitih naseljih. Doslej so bile sistematične raziskave tega območja omejene predvsem zaradi težkega dostopa, ki ga povzroča gosta vegetacija. Namen pričujoče raziskave je zapolniti to raziskovalno vrzel s pregledom 85 lokacij, kjer so bila sistematično preučena naselja na gradiščih in druge vrste naselbinskih ograj. Temelji na sistematični analizi ALS-podatkov, ki zajemajo približno 500 km² arhipelaga in pokrivajo večmesečno obdobje. Trenutno znanje ponuja malo možnosti za tradicionalno arheološko vrednotenje, ki temelji na tipoloških in kronoloških značilnostih keramičnih materialov ali na formalnih analogijah med naselbinskimi

1 Research data (appendix) will be published in the the repository of University of Primorska.

2 The editorial team used the AI tools DeepL, Grammarly, and Instatext to proofread the English text.

elementi. Zato se razprava osredotoča predvsem na potencial arheološkega daljinskega zaznavanja pri preučevanju topografsko izrazitih naselij v agropastoralnih kraških krajih. ALS-interpretacije posameznih najdišč so bile dane na voljo strokovnjakom, da bi olajšale nadaljnjo razpravo o suhozidnih krajih arhipelaga nasploh in o gradiščih posebej.

Ključne besede: ALS, Cres/Lošinj, gradišča, suhozidi, agropastoralni ostanki

Introduction

The Cres/Lošinj archipelago is home to the remains of numerous topographically prominent settlements, hillforts and different types of agro-pastoral enclosures. These are concealed not only by vegetation, but also by evidence of more recent human activity, such as agriculture and military installations. They have been the subject of limited research since their first mention in scientific publications over 100 years ago. This research has been primarily concerned with locating prehistoric dry stone fortification walls visible to the naked eye. Given the karst topography, dense ground vegetation and limited visibility of archaeological remains, not to mention the lack of technical resources available, researching hillforts was highly challenging. However, this situation has changed slightly because of advances in airborne laser scanning technology (ALS or LiDAR). It is currently the only successful method available for identifying the remains of dry stonewalls and fortifications in areas covered by dense vegetation. This is primarily because ALS is a remote sensing technique that is not subject to the same rigorous limitations as other prospection methods, enabling the exploration of areas that would otherwise be inaccessible. The limited use of ALS in recent years is due to the fact that, prior to 2024, such investigations in Croatia could only be carried out using project data (e.g. Tončinić et al. 2023; Popović et al. 2021; Doneus et al. 2015). However, this situation is set to change after 2024, as a complete ALS survey of Croatia has recently been made publicly available upon request. As part of the 'Multisensor Aerial Survey of the Republic of Croatia' project, a digital terrain model (DTM) with a grid width resolution of 1 m is provided. This nationwide data offers

a fresh perspective also on the islands of Cres-Lošinj archipelago.

This paper addresses the following research question: How might new technologies change our view, compared to previous studies, of hillforts on the islands of Cres and Lošinj? To answer this question, we systematically examined 500 km² of ALS-generated terrain models of the archipelago for traces of hillforts and subsequently compared our results with the current state of research. Due to the size of the study area, archaeological interpretation has focused on hillforts, with the mapping of prehistoric burial mounds being left aside.

Methodologically, this study is part of a consistent archaeological approach involving large-scale prospection for the study of the history of the archipelago. The current project, 'Osor beyond the myth', examines the role of Osor in maritime routes and Roman urban architecture within the city walls, as well as the city's landscape context and land use patterns. The use of large-scale prospection has therefore also benefited research into hillfort settlements.

Having introduced the case study area and the current state of research, we will present the methodology employed to identify and map relevant archaeological remains. The following discussion provides a comparison of the new results with those of earlier archaeological research. Finally, it examines the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. To this end, it is necessary to address the fact that the dry stonewall enclosures visible in the ALS data are not necessarily equivalent to the (prehistoric) hilltop settlements.

Case Study Area

The Cres-Lošinj archipelago comprises two large islands and several smaller inhabited and uninhabited islets (fig. 1). Together with the islands of Krk and Rab, they belong to the northernmost group of Croatian islands, situated in the Kvarner Bay. They are typical of the Dinaric karst landscape and are characterised by open pastures, slope terraces, sinkholes, karst valleys and agricultural plots surrounded by dry stone walls (Andlar et al. 2018). The karstic limestone, especially on Cres and Lošinj, is densely covered with typical Mediterranean vegetation, consisting mainly of dense, rigid, mostly evergreen shrubbery (*macchia*) – anthropogenic secondary vegetation (fig. 1).

Cres and Lošinj are two of the most mountainous islands in Croatia. While the southern

parts of both islands have mild relief and a rugged coastline, the western side of Lošinj below the 589-metre-high Osorščica mountain and the northern parts of Cres, with terrain heights of more than 500 metres above sea level, are extremely steep. The northwest-southeast orientation of the two main islands, together with the high terrain, acts as a divide for weather and winds. The east coasts of Cres and Lošinj are particularly exposed to stormy northeasterly winds (Croatian: *bura*), while the west coasts of the two islands are affected by strong southeasterly winds (Croatian: *jugo*).

The prehistoric hillfort settlements on Cres and Lošinj are part of the Bronze and Iron Age settlement pattern along the eastern Adriatic coast. Hellmuth Kramberger (2024) links Bronze Age hillforts in Istria to a turbulent pe-



Figure 1: Views of the Cres and Lošinj Archipelago: a) The Brdo site (54) Illustrates a Modern Development on a Presumed Prehistoric Site (elaborated by Filip Vukoja, 2019); b) Abandoned Agro-Pastoral Remains Surrounded by *Macchia* (elaborated by Michael Doneus, 2023); c) Aerial View on Osor and Densely Overgrown Part of Lošinj Island (elaborated by Michael Doneus, 2010)

riod in the 2nd millennium BC. During this time, climate fluctuations and natural disasters caused population shifts, resulting in new types of fortified settlements in protected locations. The widespread presence of prehistoric, fortified settlements on Cres-Lošinj archipelago was first noted at the beginning of the 20th century, when Marchesetti (1903) documented and listed more than 400 hillforts in Istria and the Kvarner Bay region. His work from 1924 is dedicated to the Kvarner Islands (Marchesetti 1924).

Since then, the state of preservation and visibility of dry stonewalls – which formed hillfort settlement features, topographically distinctive enclosures, or were used as a part of agro-pastoral activities – has changed in many locations. The large-scale abandonment of agro-pastoral use, especially after the Second World War, has led to complete coverage by scrub or bushland in many areas (figs. 1b, 1c). Some enclosures or presumed hillforts are not visible in the relief due to intensive agricultural terracing or military installations (e.g. Piccolo Calvario, Umpiljak and M. Telegrafo on the island of Lošinj).

Archaeological research into hillforts has focused so far on unsystematic surveys and small-scale excavations (Marchesetti 1924; Mirosavljević 1955; 1956; 1959; 1960; 1974). A detailed summary of this research can be found in publications of Blečić Kavur (2014, 25–41; 2015, 25–38). Works summarising the distribution of hillforts across the entire Cres-Lošinj archipelago essentially reported the same information without verifying their distribution in the field (e.g. Ćus-Rukonić et al. 2013; Ćus-Rukonić 1982, 9–13; 2005). The difficult terrain combined with dense vegetation probably also played a role here. Stražičić's work (1981, 106–13) provided a good overview for the time, offering his thoughts on the functions of hillforts. Recent research is still limited to unsystematic surveys, either carried out for professional interest (Branković and Benven 2024) or in response to large-scale construction projects (Fidon and Eko invest 2021). The dating of the paleosol with pottery fragments next to the hillfort above Vrana lake (Hrib (34))

to 1900 cal BC (Ilijanić et al. 2024) is a rare example of geological research that archaeology can profit from.

Another approach to studying hillforts is the use of GIS analysis. Čučković (2017) argues for a link between seafaring and the Bronze Age settlements on the island of Lošinj due to the numerous hillforts, which, in his opinion, are unlikely to have been built for agricultural purposes due to the limited amount of available agricultural land. A comparison with Istria could suggest that most of the hillforts are likely to date in the Bronze Age (Čučković 2017, 532).

Overall, research into prehistoric hillforts within the Cres-Lošinj archipelago is insufficient. While some studies have been conducted on other islands in the Kvarner Basin (e.g. Konestra and Nowacki 2020), a general comparison with prehistoric karst research on the nearby mainland illustrates the advances that have been made in the study of prehistoric settlements and landscapes in general (e.g. Bernardini et al. 2013; Vinci and Bernardini 2017; Bernardini et al. 2020; Lozić and Štular 2024; Mlekuž Vrhovnik and Fabec 2024).

Methodological Approach

In a region where no new systematic research on hillfort settlements has been conducted for decades, the first step is to compile basic documentation. This was achieved through a systematic interpretation of ALS data. Operated from an aircraft, this remote sensing technique can cover large areas in a relatively short time, providing dense 3D point clouds that represent the terrain of the scanned area, as well as all vegetation and objects located thereon (Vinci et al. 2024). Based on a classification of the individual points, digital terrain models (DTM) and digital feature models (DFM) can be derived through appropriate selection (Pingel et al. 2015; Štular et al. 2021), especially in the latter case revealing the terrain and all modern and archaeological structures that are still visible in relief.

The nationwide ALS-derived digital terrain model (DTM) for Croatia, mentioned above,

came in the form of an ASCII grid with a raster size of 1 m and was visualised using the Relief Visualisation Toolbox (RVT) (Kokalj et al. 2020; Kokalj and Somrak 2019). The ‘archaeological combined cVAT’ visualisation technique was used, blending hillshading from three directions with slope, positive openness and sky-view factor.

In order to interpret and enhance this ALS-based terrain model, we drew on two complementary data streams. Firstly, the published records of known hillforts and fortified settlements across the archipelago were georeferenced to create a point layer containing basic chronological and research history metadata. Secondly, we conducted a systematic screening of the RVT-enhanced DTM itself, mapping the topographic signatures of preserved remains and identifying enclosed sites that had not previously been documented. Together, these steps form the basis of the archaeological interpretation.

The data was collected and managed in a spatial database using the desktop GIS-software QGIS (ver. 3.40.5) in the form of a GeoPackage. The geometries were organised within a relational database scheme, with an entry in the point layer for each site entity (n=85), as well as related line features for the archaeological interpretation of visible structures. Additionally, a polygon representing the maximum extent was generated to provide general information on the size of the structures. To ensure clear identification, the site names are based on the Croatian base map (HOK), although many of the hills have different local names to those used on official maps.

Additional parameters were recorded as attributes for each entity, based on the established scheme of the ‘Atlas of Hillforts of Britain and Ireland’ (Lock and Ralston 2022). The Atlas of Hillforts applied three main inclusion criteria: (1) a locally dominant topographic position, (2) enclosing works that were sufficiently substantial (e.g. multivallate ramparts or ditches with a width of at least ~4 m), and (3) a minimum internal area (commonly set at around 0.2 ha). This criteria were simplified and adapted for the use

in the northern Adriatic. We treated enclosed sites as a morphological continuum, incorporating enclosures of every size and type where an exclusive modern agricultural or pastoral use could be ruled out based on their form and/or relative stratigraphy. The degree of certainty was categorised as one of three levels, based on the literature and the visible structures in the digital terrain model (DTM). The topographic position was categorised into different classes: knoll/hill-ock, hilltop, hillslope, plateau/cliff-edge, ridge and inland promontory. A short qualitative description categorises the sites into three size classes and describes any fortification features.

Some hillforts, mainly on the island of Lošinj, have been surveyed in recent years (Branković and Benvin 2024). Several sites, particularly those near Osor, were surveyed also during the autumn and winter of 2024/25.

Results

A total of 85 locations were systematically reviewed. Detailed terrain models revealed 35 locations where simple dry stone wall enclosures or settlement fortifications had already been identified as archaeological sites. As expected, the terrain models provided a clearer picture of the shape, structure and complexity of these remains. However, no visible archaeological traces were evident in the ALS data at the other 22 presumed sites. Furthermore, 28 new locations of enclosures and settlements were added to the catalogue.

The results are summarised in table 1. The table compiles ALS results and publications by Marchesetti (1924), Mirosavljević (1955; 1956; 1959; 1960; 1974), Stražičić (1981), Miletić (2002), Šiljeg (2006), Starac (2011), Čučković (2017), Ilijanić et al. (2024) and Branković and Benvin (2024). For ease of reading, tab. 1 primarily cites works by Stražičić and Čučković. The second publication contains detailed references, which do not need to be repeated here (Čučković 2017, 21).

In table 1 slightly stricter criteria were used for the interpretation of the dry-stone wall remains



Figure 2: An Overview of the Mapped Hillfort Settlements and Enclosures Classified by Source (background data: DTM HR; elaborated by Martin Fera, 2025)

(settlement, enclosure) than in previous studies. The result is illustrated in fig. 2. The locations/sites were grouped into three categories: sites documented only in regional publications; sites mapped only using high-resolution ALS data; and sites reported in literature with visible dry stonewall remains in the remote sensing data. Sites that did not meet the criteria of at least two of these categories (e.g. ALS structures and datable finds from trial excavations/unsystematic surveys) were marked with a question mark. This applies to the majority of the hilltop settlements recorded by Marchesetti (1924). In elevated areas with no clear defensive structures other than simple enclosures, the distinction between agro-pastoral use and archaeologically defined fortified settlements was not always clear. Therefore, simple enclosures for which no data-

ble finds were available were generally designated as 'enclosures'. However, where the features in the ALS data were extremely distinct and/or datable finds mentioned in the literature, the enclosures were defined as fortified settlements. The term 'settlement' is used in the broadest sense to refer to human habitation in permanent dry stone walled structures, without discussing the function of the individual locations. For this discussion, we believe that systematic research including meaningful dating is needed, as it can be assumed that the same hills could have fulfilled different functions over time. Therefore, the list of 85 locations is not equivalent to the same number of (prehistoric) hillforts; it merely comprises locations where hillfort settlements and other types of enclosure were systematically reviewed.

There is an obvious discrepancy between the locations of the hillfort settlements mentioned in the literature and those revealed by the analysis of ALS data, as only 35 have visible structures in the DTM; for the remaining 22 locations, this was not the case. Of the sites mentioned in the literature, only 50% showed clear fortification structures in the DTM.

There are various reasons for this outcome. Firstly, it is challenging to identify the actual location, layout and purpose of enclosed settlements without systematic use of prospection methods and excavations. Secondly, the presumed hillforts could be hidden beneath the modern settlements, as in the case of Beli (9). Thirdly, some of the settlements referred to by Marchesetti (1924) are now partially or wholly occupied by military installations (see, for instance, the levelled plateau on M. Telegrafo (76)) or obscured by subsequent land use (for instance 11, 15, 19, 54, 58, 73 or 80). Other presumed hillforts, such as Jablanac on the island of Cres – where, according to Ćus-Rukonić et al. (2013, 11), a 'signaling and monitoring station' is expected to be situated – were not included in the list at all due to a lack of supporting evidence.

In terms of geographical distribution, more than half of the presumed hillfort and enclosure

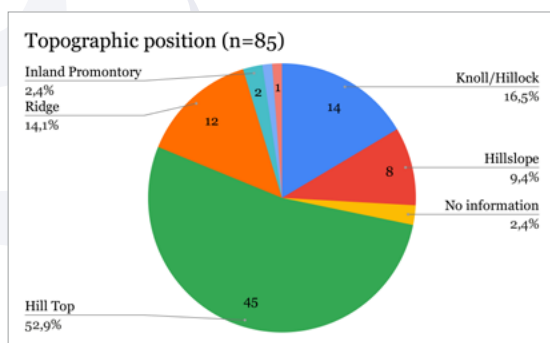


Figure 3: Pie Chart Listing the Actual Topographic Position of the Documented Sites (elaborated by Martin Fera, 2025)

sites (46 out of 85) are located on the island of Cres. Another 28 sites are found on the island of Lošinj, and a further 12 are located on smaller islands. A clear concentration can be seen on Cres in the topographically higher regions in the north, as well as around Lake Vrana. In con-

trast, the southern half of Cres, including Punta Križa, has a sparse distribution. The highest density of sites is found on the narrow, rugged island of Lošinj.

The classification of the topographical location paints a diverse picture: only slightly more than half are designated as hilltop locations (fig. 3). The rest are located on small hills, mountain ridges, plateau edges or steep slopes. The extent, construction and complexity of the ramparts, and the structure and use of the enclosed areas, also vary considerably. Documented interior or surrounding features are generally limited to central mounds, built (platform) or agricultural terraces or, in a few cases, ecclesiastical ruins dating from after the prehistoric occupation or modern settlement use (fig. 1a)

Most enclosures are relatively small (up to 5 ha) to medium (5 to 15 ha) in size defined by one or more low ramparts, banks, or dry-stone

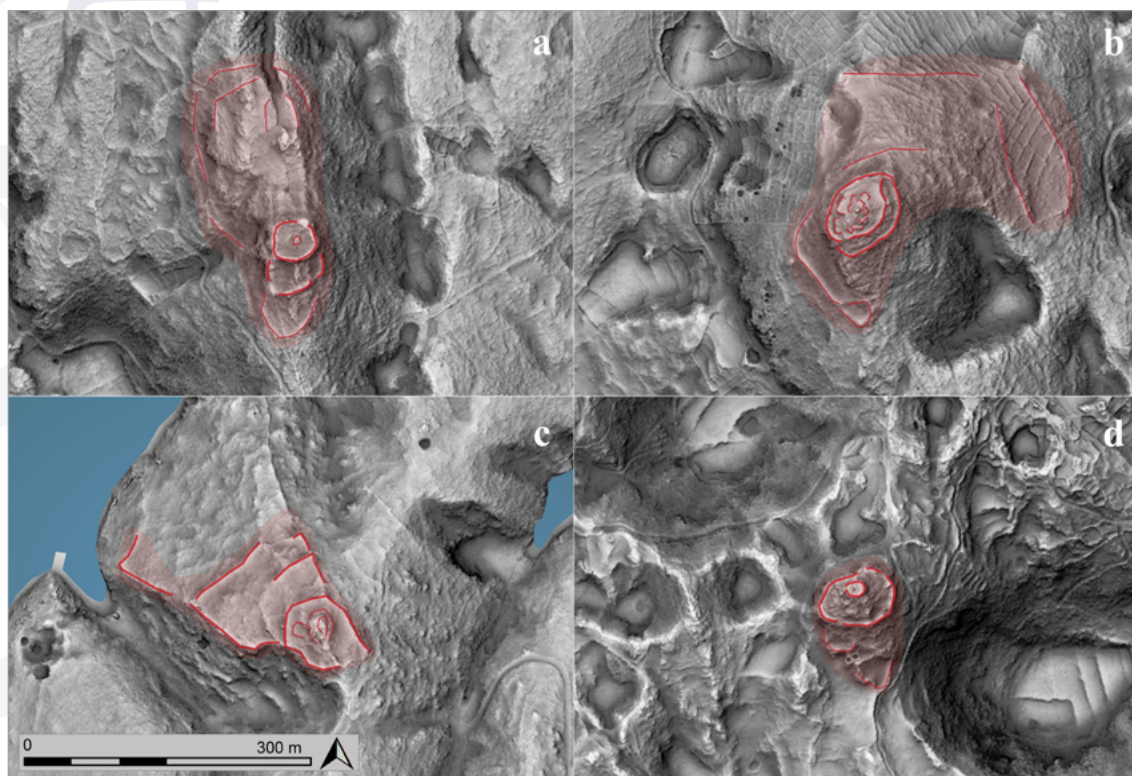


Figure 4: Multi-Zonally Organised Prehistoric Fortifications: a) Pukonjina (21), b) Pelginja (20), c) Gradac (57) and d) Vazminec (4) (background data: DTM HR; elaborated by Martin Fera, 2025)

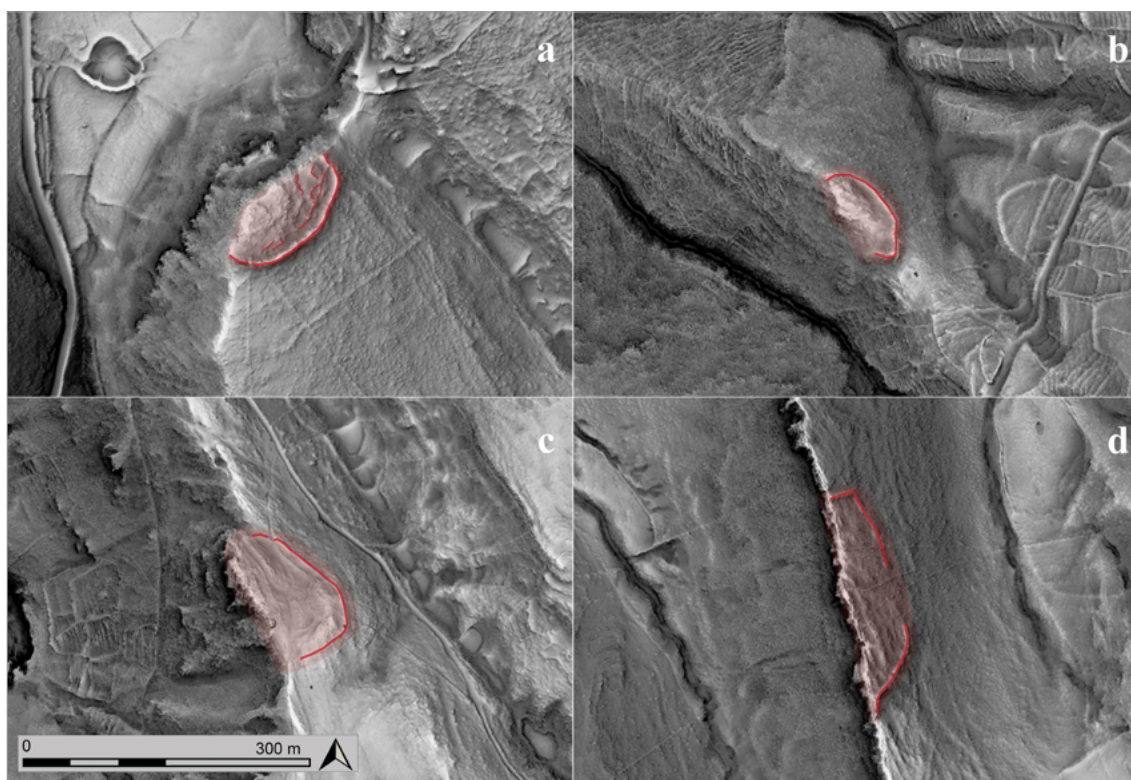


Figure 5: Plateau / Cliff-Edge or Ridge: a) Mravinci (16); b) Draga Buč (22); c) Brajdice (25); d) Hrib (34) (background data: DTM HR; elaborated by Martin Fera, 2025)

walls. Extensive, multi-zonally organised pre-historic fortifications can be recognised in some cases, some of them including elevated round structures or mounds (fig. 4). Other hillforts are situated on plateaus bordering the cliff edge, sur-

rounded by a single enclosure (fig. 5). Of all these examples (16, 22, 25, 29 and 34), only the preliminary dating of the paleosoil containing pottery fragments next to the hillfort Hrib (34) to 1900

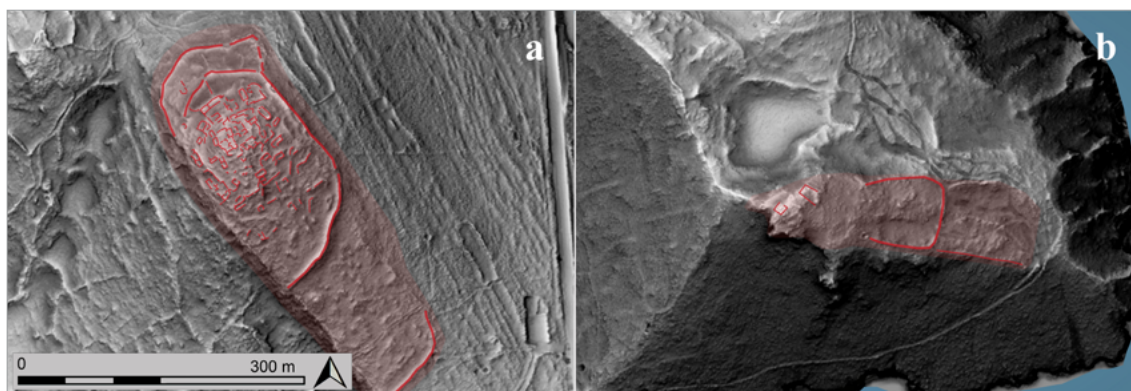


Figure 6: Large, Oval Hilltop Settlements with Partially Preserved Building Structures in the Central Area: a) Sv. Lovre (47); b) Petričina (2) (background data: DTM HR; elaborated by Martin Fera, 2025)

cal BC provides a chronological reference (Ilijanić et al. 2024).

Three hillforts (Petričina (2), Porozina (3) and Sv. Lovre (47) (similar to Kuši (40)) (fig. 6) have entirely different layouts to those described above. They are similar in size, being two to three times larger than other hilltop settlements and have a uniform shape. This is defined by two enclosures, one of which encloses the central settlement area and the other the entire site. A prime example is the hillfort of Sv. Lovre (47), which is over 400 metres long and has three separate terraces. In the central part, numerous dry stone dwellings are still preserved. Unfortunately, past surveys have only revealed a few pieces of prehistoric pottery (Branković and Benvin 2024, 92). On its northern side, the settlement is overlaid by several mortared dwellings, including a church dedicated to Sv. Lovre and a possible her-

mitage, which Jurković (2008, 19) counts to the 11th and 12th centuries.

Discussion

Integrating large-scale ALS surveys into the study of hillforts has generated a substantial amount of data. A detailed discussion of each site would therefore exceed the scope of this publication. However, in order to verify the results presented here and stimulate further research in the region, a basic interpretation of each documented hillfort and/or enclosure is provided in the Appendix.

The discussion offers a brief evaluation of the new results and compares them with those of previous studies. It also considers the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. To this end, it is

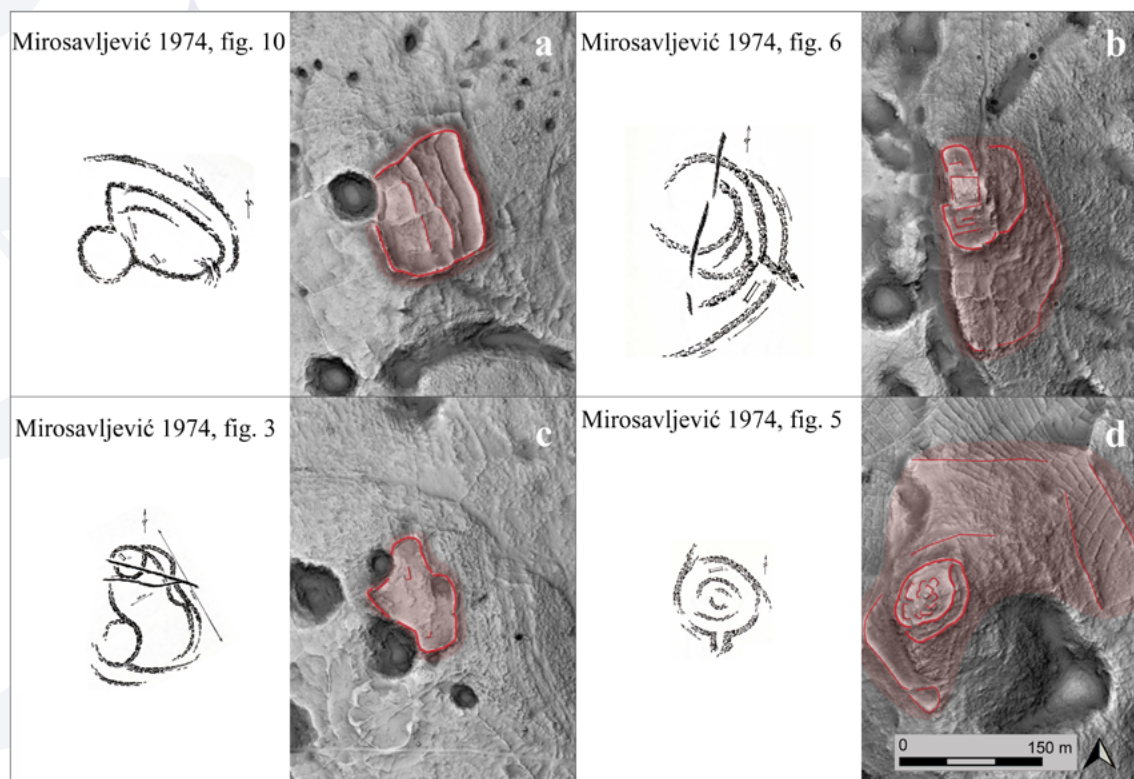


Figure 7: A Comparison of the Ground Plans (in Approximate Scale) From Miroslavljević's Work (1974) With Those Obtained Through the Analysis of ALS data: a) Vela straža (48); b) Skulka (26); c) Jelovica (32) and d) Pelginja (20) (background data: DTM HR; elaborated by Martin Fera, 2025)

necessary to address the fact that the dry stone-wall enclosures visible in the ALS data are not necessarily equivalent to the (prehistoric) hillfort settlements.

The Hillforts of the Cres-Lošinj Archipelago

The standard practice of documenting visible ramparts, which has been employed since the earliest studies of fortified hilltop settlements (e.g. Marchesetti 1924), must nowadays be modified and extended. This is most easily demonstrated by comparing the hillfort plans in Mirosavljević's publication (1974) with the results of this study (fig. 7). Given the difficult ground conditions and technical resources available in the late 1960s, it is evident that his documentation of the settlement features was – from today's perspective – only partially successful. The settlement of Vela Straža (48) located on the Punta Križa Peninsula, for example, appears completely different in the ALS data than on well-known maps (Fig. 7a). The settlement's unusual shape may have been caused by the area's agricultural use, meaning the original layout is no longer visible. Further minor errors in the original plan are also visible, such as the dry stonewall surrounding the sinkhole, which was mistakenly attributed to the hillfort at the time. Similar results are revealed by the other comparisons shown in fig. 7.

Evaluating the 500 km² area provided new insights into the distribution, shape and location of the hillforts. However, the dating of the individual sites still requires further research. Questions of prehistoric material culture on the archipelago have been addressed in detail mainly in context of research of Osor (Blečić Kavur 2014; 2015; Blečić Kavur and Kavur 2024, 2025). After Čučković (2017, 532) the presence of prehistoric pottery fragments on hillforts mostly indicates a Bronze Age settlement horizon. However, this assessment must be confirmed by future research, given that systematic research on Bronze and Iron Age pottery is still lacking. In this context the question arises not only as to the location of Iron Age settlements, but also as to the

extent to which sites – now referred to as prehistoric hillfort settlements – contain settlement traces from more recent historical periods. As all research builds upon the work of Marchesetti (1924), his views are widely accepted, particularly in compilations on the research history into the archipelago (e.g. Čus-Rukonić 1982; Čus-Rukonić et al. 2013). As he was primarily interested in prehistoric hillforts, he included all topographically prominent enclosures in his list, creating the impression that these were entirely prehistoric or Bronze Age settlements. At the same time Marchesetti noted later finds on the hillforts although without the distinction between Roman and Late Antique times. Consequently, descriptions of Roman or Late Antique settlement patterns in the archipelago (e.g. Čus-Rukonić 1982) are of little help in reconstructing settlement processes after the Iron Age. Archaeological material from the Roman or Late Antiquity period has been noted so far at only few sites (15, 57, 60–62). This figure will probably increase after further research on the archipelago. For the Late Antique hillfort of Beli (9), see the contribution on Roman urbanisation in this volume.

Hillforts in the Area of Osor

Systematic research is also required into the hillfort settlements in the area around Osor. As the only known example of a lowland prehistoric settlement to date, Osor is strategically located on a circular land bridge between the islands of Cres and Lošinj. On its western edge the city is bordered by a narrow channel that also separates the islands of Cres and Lošinj. Current geoarchaeological research on the Osor Channel indicates the transport of sediments by currents between Cres and Lošinj as early as 5621–5313 cal BP (3672–3364 cal BC) (see Miko et al. 2025 – in this volume). This indicates that the narrow strip of land between Cres and Lošinj had already been submerged by the Bronze Age, leading to the separation of both islands by the sea. This change in the landscape and the creation of the new maritime route may be related to prehis-

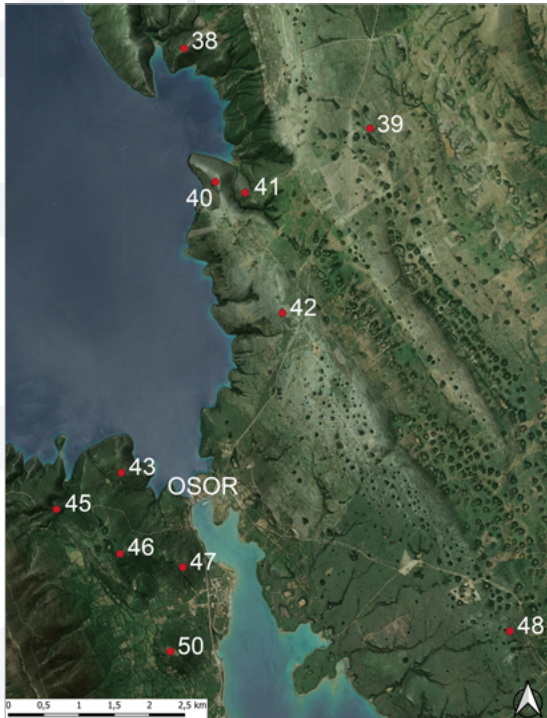


Figure 8: Gračišće Ustrine (38), Sv. Mihovil (39), Kuši (40), Ognjarice (41), Peščenji (42), Bog (43), Kalčić (45), Bijela glava (46), Sv. Lovre (47), Vela Straža (48) and Halmac (50) (background data: [Credit Nimbo by KERMAP]. Contains modified Copernicus Sentinel data 2023; elaborated by Martin Fera, 2025)

toric trade in and around Osor. Grave and settlement finds from the Bronze Age (Blečić Kavur 2014; 2015; Blečić Kavur and Kavur 2013; 2025) demonstrate the area's earliest archaeological traces, prior to the establishment of the Iron Age and Roman town. The richest archaeological finds from this period come from the city's necropolis and valuable insights into the inhabitants of Osor (Mihovilić 2013; Blečić Kavur 2015; 2021; 2025 – in this volume; Blečić Kavur and Kavur 2013; 2024). After Blečić Kavur and Kavur (2025) the material culture confirms the role of Osor as an economic centre of the Kvarner region and the wider northern Adriatic during the last two millennia of the prehistoric era.

The presumed concentration of hillforts near Osor was considered an indication of Osor's

leading role in the Iron Age (e.g. Stražičić 1995, 76; Ćus-Rukonić et al. 2013, 11). This reasoning is easy to understand. In two-dimensional maps, which have been used for archaeological overviews for over a century (fig. 8), Osor appears to be surrounded by hilltop settlements (Stražičić 1981, fig. 29; 1995, fig. 2). However, to better understand the apparently high number of hillforts around Osor, it is necessary to view them not as dots on a map, but to compare their location with the prevailing relief. The dense distribution of hillforts is not limited to the north-eastern tip of Lošinj Island but extends across the entire island (fig. 2). This is due to the numerous locations suitable for topographically prominent settlements arising from the rugged terrain and the mountain ridge running parallel to the coastline.

Given that none of the eleven hilltop settlements near Osor have been systematically investigated, there is scope for a great deal of speculation, which cannot replace systematic archaeological research on the subject. The available sources currently suggest that prehistoric pottery fragments were found at most of the eleven hilltop settlements (38, 39, 40, 42, 43 and 50) (Miroslavljević 1974; Starac 2011). However, this is not sufficient to determine which hillforts were inhabited during which time periods, whether there was a clear process of settlement and abandonment or how the topographically prominent locations were used at other times. No trace of the hillfort of Konopičje, which is mentioned by Ćus-Rukonić et al. (2013, 11), has been found in the ALS data. The location has been defined as a burial site in a recent publication (Blečić Kavur and Kavur 2024, 26–8).

From Hillforts to Landscapes

Geographically, the archipelago belongs to the typical Dinaric karst landscape (Fuerst-Bjeliš et al. 2024). This is characterised by dry stone walls that serve various settlement and agro-pastoral purposes, such as enclosing slope terraces, sinkholes, and agricultural land (Kremenčić et al. 2021; Andlar et al. 2018). To adequately ad-

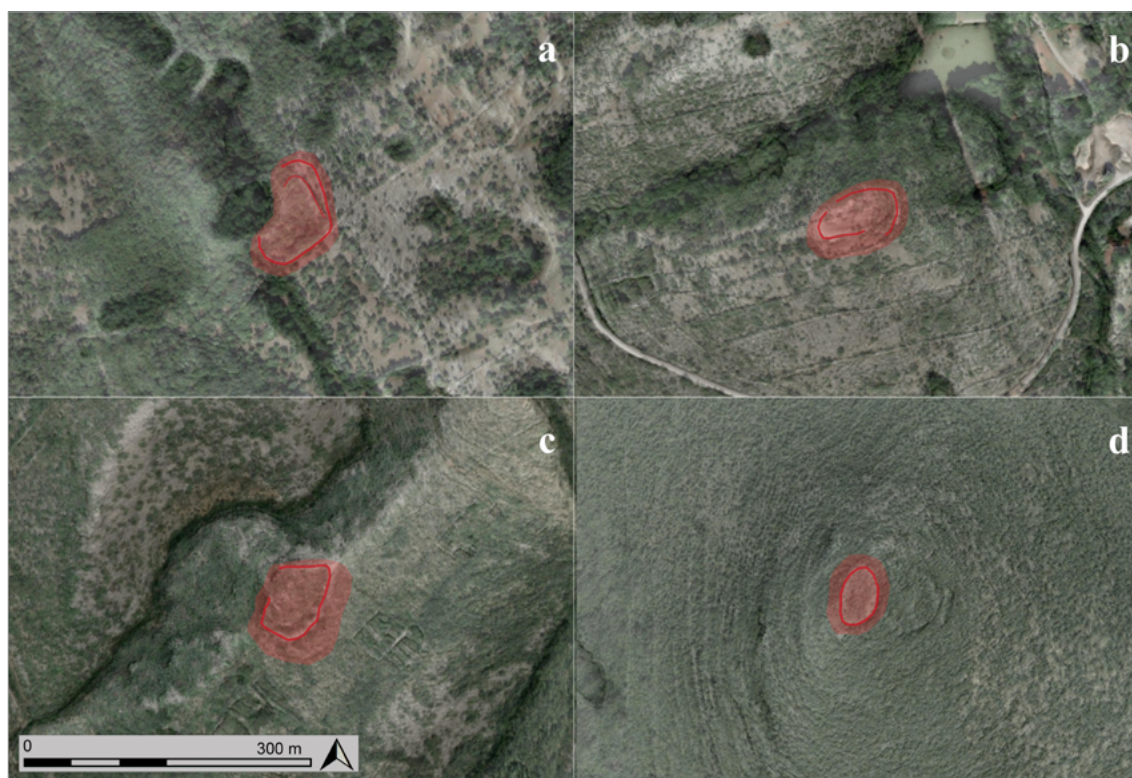


Fig. 9: Examples of Different Enclosures: Novograjca (5), Telcar (10), Banestrovica (31) and Malondarski (49) (background data: DTM HR, Bing Satellite Imagery © Microsoft, elaborated by Martin Fera, 2025)

dress the specific archaeological remains amidst this complexity, archaeological methods capable of handling extensive and complex data sets are required. This primarily involves landscape archaeology, which covers a wide range of topics (e.g. Doneus and Doneus Forthcoming). A key aspect of landscape archaeology is providing a comprehensive, diachronic, large-scale description of the location, extent, character, and chronological sequence of material remains. Archaeological prospection is the first step in this process, as it establishes the spatial context of archaeological finds, features and sites. In this sense, the purpose of remote sensing methods, or archaeological prospection in general, is not to identify specific archaeological remains. Its strength lies in its ability to comprehensively document all visible remains, regardless of their age or the research topic, since the relevance of

the remains can only be determined through subsequent data interpretation.

The same applies to research into hillfort settlements, which can be considered part of the archipelago's dry stone wall heritage. Archaeological interpretation of ALS data alone, or in combination with unsystematic surveys, does not always allow distinction to be made between hillforts and enclosures of different origins (see also Mlekuž Vrhovnik and Fabec 2024, 89) (fig. 9). They are located in different positions and heights, vary in size and shape, and may have been altered by different uses to become what we see today in the data (e.g. fig 7a).

A closely related field to archaeological prospection is the study of prehistoric landscapes. Large-scale data interpretation provides an opportunity to shift the focus from individual prehistoric enclosures and fortifications to the surrounding landscape (e.g. Cowley et al. 2019).

The karst landscapes surrounding the eastern Adriatic coast have been repeatedly in the focus of archaeological remote sensing, providing archaeological research also with insights into prehistoric agro-pastoral landscape features (Vinci and Bernardini 2017; Bernardini et al. 2020; Lozić and Štular 2024; Mlekuž Vrhovnik and Fabec 2024). In addition, the figs. 4 and 7 demonstrate that the karst landscape of the Cres-Lošinj archipelago has preserved more than just fortifications of prehistoric hillforts. They show multi-fortified settlements and highlight the need for large-scale interpretation to document not only nearby burial mounds, but also nearby the remains of prehistoric land use.

It is challenging to identify prehistoric land use based on dry stonewall systems, particularly in complex karst landscapes, as these systems are subject to change and are often exposed to decay, rebuilding and reshaping. Nevertheless, the remains of dry-stone walled landscapes can provide chronological and typological indicators similar to finds and excavation features. Airborne laser scanning provides the necessary methodological toolkit for obtaining the relative stratigraphic sequence of dry stonewalls directly from the ALS data. Mapping and interpretation of a small area on the Punta Križa Peninsula, extending from Osor to the southern end of the island of Cres, has highlighted the advantages of diachronic interpretative mapping (Doneus et

al. 2022). The area in question has a very dynamic landscape of dry-stone walls and contains at least five phases of agricultural use, reflecting the complexity of the island's economy in past centuries. The oldest stratigraphic feature is a bank belonging to a Roman land survey, dating to 200 + 100 AD (Doneus et al. 2024).

Absolute dating of the dry stonewalls, which were used as boundary markers in Roman land surveying, was carried out using optically stimulated luminescence profiling and dating (OSL-PD). The method measures the last time buried deposits were exposed to light (Kinnaird et al. 2025). In the first stage, the luminescence properties of the sediment in the core are evaluated using portable OSL equipment (Munyikwa et al. 2020). A relative luminescence stratigraphy is then constructed and used to identify down-core positions for dating purposes. This stratigraphy is subsequently employed to determine the most promising locations within the core for dating. The OSL dating method is highly versatile and has been successfully employed in various research projects, including those investigating Mediterranean terraces (Kinnaird et al. 2017; 2025; Srivastava et al. 2023; Turner et al. 2021), prehistoric field patterns (Vervust et al. 2020), individual sites (Kinnaird et al. 2019), and the reconstruction of coastal landscapes (for Osor see the geoarchaeology article in this volume). The successful application of the OSL-PD

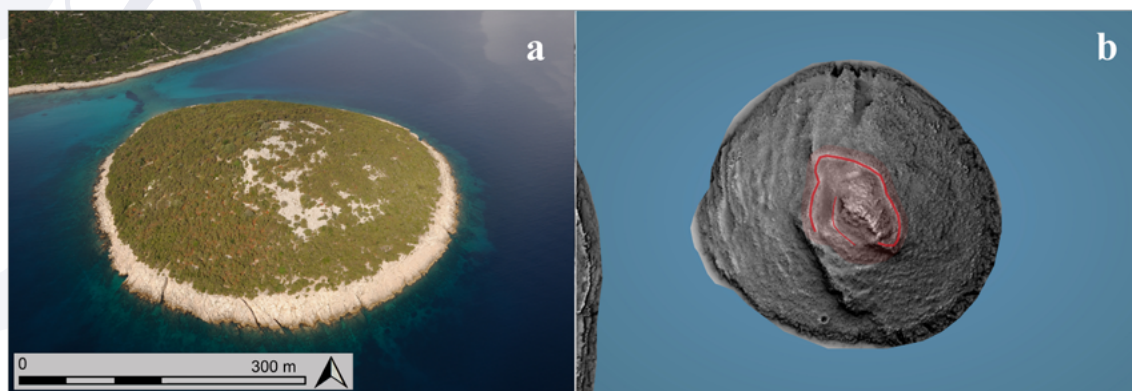


Figure 10: Site and Island of Veli Osir (65): a) Aerial Photograph; b) ALS-Based Data Interpretation (aerial photograph by Michael Doneus, 2012; background data DTM HR, elaborated by Martin Fera, 2025)

method in the karst landscape of Cres-Lošinj makes it possible to combine ALS data to create relative stratigraphic sequences and use the OSL-PD method to date (prehistoric) hillforts and/or past land use on the archipelago.

Another potential use of the OSL-PD method is to date terrestrial and marine sediments. The potential hillfort on the small island of Veli Osir (65) appears to be a suitable candidate for this method (fig. 10). Due to its current location, it is hardly recognisable as an elevated settlement as the island has low relief (53 m). Nevertheless, the surrounding area and the seabed are worth exploring. Given the continuous rise in the sea level, reconstructed to approximately -3 metres for around 4600 BC (Brunović et al. 2019) and based on the current maximum water depth of 5 metres between the islands of Lošinj and Veli Osir it can be assumed that the visible elevation in aerial photograph on fig. 11a represents the remains of a submerged prehistoric path to the settlement. Although submerged prehistoric sites have played a minor role in Adriatic Sea research (for Punta Križa see Parica 2023, 124–7), sites like Veli Osir, provided that surface finds confirm its use in prehistoric times, offer the opportunity to break new ground in the study of prehistoric settlements.

Conclusion

A systematic investigation of detailed terrain models confirmed 35 locations where simple dry stonewall enclosures or settlement fortifications

had previously been recognised as archaeological sites. No visible archaeological traces were evident in the ALS data at the other 22 presumed sites. However, 28 new locations of enclosures and settlements were added to the catalogue.

Although high-resolution ALS-derived digital terrain models markedly improve our capacity to detect anthropogenic landforms beneath dense vegetation, the threshold of feature recognition remains constrained: subtle morphological anomalies may be filtered out or masked by processing algorithms, and their archaeological significance cannot be addressed reliably without systematic ground assessment. Furthermore, the interpretation process has shown that in some cases, the distinction between simple pastoral or agricultural enclosures and those with a fortified character is difficult to make based solely on ALS data. In addition, well-known hillforts exhibit a variety of overlapping functions throughout their lifespan. Combining modern remote sensing with older field research gives the project breadth but also highlights discrepancies that can only be resolved through large-scale systematic research.

One key point that could significantly advance future research is that investigating ALS-based terrain models shifts the focus from sites to landscapes. Combined with appropriate dating methods, such as OSL-PD method, this allows the archaeology of the landscapes around and between hillforts to be investigated, leading to new research questions and perspectives.

Table 1: List of Documented Hillforts and Enclosures. The 'Source' Column Refers to the Background Information for Single Locations: a) DTM HR, b) Stražičić 1981, c) Čučković 2017, d) Ilijanić et al. 2024, e) Miletić 2002, f) Starac 2011, g) Šiljeg 2006.

Nr.	Name	Interpretation	Archaeological finds	EUTM ₃₃ N	NUTM ₃₃ N	Source
1	Gornja Glava	Settlement (?)	?	446668	4948886	a, b
2	Petričina	Settlement (?)	?	450311	4948256	a, b
3	Porozina	Settlement (?)	?	444845	4948065	a
4	Važminec	Settlement (?)	?	448149	4947161	a
5	Novograjca	Enclosure	?	446081	4946972	a

Nr.	Name	Interpretation	Archaeological finds	EUTM ₃₃ N	NUTM ₃₃ N	Source
6	Palvana	Enclosure	?	447793	4946873	a
7	Višnjin	Enclosure	?	444733	4946041	a
8	Halm	Settlement	Prehistory	445053	4944772	a, c
9	Beli	Settlement	Prehistory (?), Late Antique (?) - modern times	449276	4944745	b
10	Telcar	Enclosure	?	444822	4944377	a
11	Kalci	Settlement (?)	?	448632	4944084	a
12	Sis	Settlement (?)	?	449197	4943643	a, c
13	Velo Gračišće	No structures		451021	4943112	b
14	Zakenj	Settlement (?)	?	450599	4942941	a
15	Sv. Bartolomej	Settlement	Prehistory/Roman/Late Antiquity/Early Middle Ages	454483	4942419	a, c
16	Mravinci	Settlement (?)	?	457396	4941994	a
17	Melzicar	Settlement (?)	?	456060	4940397	a
18	Sv. Marija	Settlement (?)	?	446372	4938399	a
19	Draga	Settlement (?)	?	455161	4937776	a
20	Pelginja	Settlement	Prehistory	454690	4937702	a, c
21	Pukonjina	Settlement	?	455194	4937677	a, c
22	Draga Buč	Settlement (?)	?	452835	4937502	a
23	Trnket	Settlement (?)	?	453422	4936418	a
24	Vrh sela	Enclosure (?)	?	447748	4935523	b
25	Brajdice	Settlement (?)	?	447457	4934794	a
26	Skulka	Siedlung	Prehistory	454034	4934260	a, c
27	Krasa	Settlement (?)	?	454772	4933298	a, c
28	Helm	Settlement (?)	?	448212	4932101	c
29	Heljčić	Settlement (?)	?	449645	4931888	a
30	Punta Zaglavac	Settlement (?)	?	452076	4931022	a
31	Banestrovica	Enclosure	?	448743	4930772	a
32	Jelovica	Settlement	Prehistory	456346	4930401	a, c
33	Dolec	Enclosure	?	452206	4930380	a
34	Hrib	Settlement	Prehistory	453000	4930156	a, d
35	Sv. Kristofor	Settlement	Prehistory	450143	4930002	a, c
36	Orlec	Enclosure	?	450285	4929920	a
37	Gračišće, Belej	Settlement (?)	?	453629	4929199	a, b
38	Gračišće, Ustrine	Settlement	Prehistory	451687	4928795	a, b
39	Sv. Mihovil	Settlement	Prehistory	454322	4928749	a, g
40	Kuši	Settlement	Prehistory (?)	452128	4927132	a, g
41	Ognjarice	Settlement (?)	?	452551	4926962	a

Nr.	Name	Interpretation	Archaeological finds	EUTM ₃₃ N	NUTM ₃₃ N	Source
42	Peščenji	Settlement (?)	Prehistory	453081	4 922643	a, b
43	Bog/Straže	Settlement	Prehistory	450793	4 922523	a, c
44	Osorščica	Enclosure	?	449044	4 922142	a
45	Kalčić	Enclosure	?	449876	4 948886	a
46	Bijela glava	Settlement (?)	?	450776	4 948256	a, c
47	Sv. Lovre	Settlement (?)	Prehistory (?)	451666	4 948065	a, c
48	Vela straža, Cres	Settlement	Prehistory	456302	4 947161	a, c
49	Malondarski	Enclosure	?	442578	4 946972	a, c
50	Halmac	Settlement	Prehistory	451493	4 946873	a, c
51	Pogled	Settlement (?)	?	449695	4 946041	c
52	Laće	Settlement (?)	?	450509	4 944772	c
53	Maslovník	Settlement	Prehistory	457640	4 944745	a, c
54	Brdo	Settlement (?)	?	451538	4 944377	a, c
55	Vela straža, Unije	Enclosure	?	440954	4 944084	a
56	Maračol	Settlement (?)	?	441516	4 943643	a
57	Gradac	Settlement	Prehistory/Roman/Late Antique	460999	4 943112	a, b
58	Jakov	Enclosure	?	452025	4 942941	a
59	Sičin	Settlement	Prehistory	441158	4 942419	a, c
60	Sv. Damjan	Settlement	Roman/Late Antique	463204	4 941994	f
61	Turan	Settlement	Prehistory/Roman/Late Antique (?)	442181	4 940397	a, c
62	Polanža	Settlement	Prehistory, Roman/Late Antique	452622	4 938399	a, c
63	Čunski	Settlement	Prehistory	453259	4 937776	a, c
64	Grušina	Settlement (?)	?	451694	4 937702	c
65	Veli Osir	Settlement (?)	?	453945	4 937677	a, c
66	Vela straža, Vele Srakane	Settlement	?	444381	4 937502	c
67	Stan	Settlement (?)	?	451793	4 936418	a, c
68	Krbošćak	Settlement (?)	?	454759	4 935523	a, c
69	Koludarc	Settlement (?)	Prehistory (?)	455037	4 933298	a, c
70	Vela straža, Lošinj	Settlement (?)	?	456318	4 932101	c
71	Malin	Enclosure	?	457730	4 931888	a
72	Kaštel	Settlement (?)	?	458255	4 931022	c
73	Vršak	No structures		458571	4 930772	c
74	Piccolo Calvario	Settlement (?)	?	457424	4 930380	c
75	Umpiljak	Settlement (?)	?	459160	4 930156	c
76	M. Telegrafo	Settlement (?)	?	457371	4 930002	c
77	Stražica	Settlement (?)	?	460534	4 929920	c

Nr.	Name	Interpretation	Archaeological finds	EUTM ₃₃ N	NUTM ₃₃ N	Source
78	Garbe	Settlement (?)	?	444472	4929199	c
79	Sv. Ivan	Settlement (?)	?	460034	4928795	c
80	Bulbin	Settlement	Prehistory	461780	4928749	a, c
81	Mulmon	Settlement	Prehistory	462909	4927132	c
82	Pogled	Settlement (?)	?	461564	4926962	c
83	Križine	Settlement (?)	Prehistory (?)	463367	4922643	c
84	Mala straža, Ilovik	Settlement (?)	?	464841	4922523	a
85	Velika straža, Ilovik	No structures		465581	4922142	c

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Summary

The landscape of the Cres–Lošinj archipelago is characterised by the remains of numerous topographically prominent settlements, hillforts, and various types of agro-pastoral enclosures. Both vegetation and more recent human activity contribute to the concealment of these sites. Since their first mention in scientific publications over a century ago, research has been limited, primarily focusing on locating prehistoric dry-stone fortification walls. The karst topography, dense ground vegetation, and limited visibility of archaeological remains have made the study of hillforts particularly challenging. This situation has changed with advances in airborne laser scanning (ALS or LiDAR) technology. A comprehensive ALS survey of Croatia has recently been made publicly available, offering a new perspective on the islands of the Cres–Lošinj archipelago.

This study addresses how archaeological remote sensing can alter our understanding of hillforts on Cres and Lošinj. We approached this by systematically examining ALS-derived terrain models covering 500 km² of the archipelago for traces of hillforts and comparing the results with the current state of research.

In total, 85 locations were systematically reviewed. Detailed terrain models confirmed 35 locations where simple dry-stone enclosures or settlement fortifications had previously been identified as archaeological sites. As expected, the terrain models provided a clearer picture of the shape, structure, and complexity of these remains. No visible archaeological traces were apparent in the ALS data at the other 22 presumed sites. Addition-

ally, 28 new locations of enclosures and settlements were added to the catalogue. There is a clear discrepancy between the locations of hillfort settlements reported in the literature and those revealed by ALS analysis; only 50% of the literature sites exhibited clear fortification structures in the DTM.

While high-resolution ALS-derived digital terrain models have substantially improved our ability to detect anthropogenic landforms, research into prehistoric material culture remains fragmented. An exception is the ongoing research at Osor, but it remains insufficient for establishing a relative chronological framework for hillforts across the entire archipelago. Consequently, there is little scope for the traditional archaeological evaluation of newly documented hillforts and enclosures based on the typological or chronological characteristics of ceramic materials or on formal analogies between settlement features.

Accordingly, the discussion focuses primarily on the potential of archaeological remote sensing for studying topographically prominent settlements in agro-pastoral karst landscapes. It highlights that the dry-stone enclosures visible in the ALS data do not necessarily correspond to (prehistoric) hillfort settlements. At the same time, ALS allows for a shift in focus from individual enclosures to prehistoric landscapes, which can include extensive, multi-zonally organised fortifications across the Cres–Lošinj archipelago.

The bird's-eye perspective also facilitates the planning of targeted field research. However, this does not eliminate the need for challenging on-site investigations. As large-scale excavations have become rare and many dry-stone walls yield no finds, the OSL-PD method offers an alternative, providing absolute chronological data where other evidence is lacking. The complexity of the archipelago's agro-pastoral karst landscape, including (prehistoric) hillforts and enclosures, may be seen as a challenge but also represents a compelling archaeological opportunity. Accordingly, archaeological interpretations of all catalogue sites are provided as part of this publication to support further discussion of the archipelago's dry-stone-walled landscapes in general, and of hillforts in particular.

Povzetek

Krajino arhipelaga Cres–Lošinj zaznamujejo ostanki številnih topografsko izrazitih naselij, gradišč in različnih vrst agropastoralnih ograj. Gostota vegetacije in kasnejše človekove dejavnosti prispevajo k prikritju teh najdišč. Od njihove prve omembe v znanstvenih publikacijah pred več kot sto leti so bile raziskave omejene predvsem na lociranje prazgodovinskih suhozidnih obrambnih zidov. Kraška topografija, gosta rastlinje in omejena vidljivost arheoloških ostankov so predstavljali velik izziv pri preučevanju gradišč. Ta situacija se je spremenila z napredkom tehnologije daljinskega zaznavanja z letalskim laserskim skeniranjem (ALS ali LiDAR). Nedavno je postala javno dostopna celovita ALS-preglednica za Hrvaško, ki ponuja povsem nov pogled na otoke arhipelaga Cres–Lošinj.

Prispevek obravnava vprašanje, kako lahko arheološko daljinsko zaznavanje spremeni naše dojetanje gradišč na otokih Cres in Lošinj. To smo raziskali s sistematičnim pregledom 500 km² terena arhipelaga na osnovi ALS-modelov za sledi gradin in kasnejšo primerjavo rezultatov z obstoječim stanjem raziskav.

Sistematično je bilo pregledanih skupno 85 lokacij. Podrobni terenski modeli so potrdili 35 lokacij, kjer so bile že identificirane preproste suhozidne ograje ali naselbinske utrdbe kot arheološka najdišča. Kot pričakovano so modeli terena omogočili jasnejšo predstavo o obliki, strukturi in kompleksnosti teh ostankov. Na preostalih 22 predvidenih lokacijah v ALS-podatkih niso bili zaznani arheološki sledovi. Poleg tega je bilo v katalog dodanih 28 novih lokacij ograj in naselij. Obstaja očitna razlika med lokacijami gradišč, omenjenimi v literaturi, in tistimi, ki jih razkrivajo ALS-podatki; le 50 % lokacij v literaturi je v DTM pokazalo jasne obrambne strukture.

Čprav digitalni terenski modeli visoke ločljivosti, pridobljeni z ALS, bistveno izboljšujejo zaznavanje antropogenih oblik v pokrajini, raziskave prazgodovinske materialne kulture ostajajo fragmentirane. Izjema je tekoče raziskovanje v Osorju, vendar to še vedno ni dovolj za vzpostavitev relativne kronološke sheme gradin po celotnem arhipelagu. Posledično je malo prostora za tradicio-

nalno arheološko ovrednotenje novoodkritih gradišč in ograd na osnovi tipoloških ali kronoloških značilnosti keramičnih materialov ali formalnih analogij naselbinskih elementov.

Zato se razprava osredotoča predvsem na potencial arheološkega daljinskega zaznavanja pri preučevanju topografsko izrazitih naselij v agropastoralnih kraških krajih. Pri tem je treba upoštevati, da suhozidne ograje, vidne v ALS-podatkih, ne predstavljajo nujno (prazgodovinskih) gradišč. Hkrati ALS omogoča premik fokusa z individualnih ograd na prazgodovinske krajine, ki lahko vključujejo obsežne, večsistemsko organizirane obrambne strukture po celotnem arhipelagu Cres–Lošinj.

Pogled iz zraka olajša in poenostavi načrtovanje ciljanih raziskav v prihodnosti, vendar ne nadomešča zahtevnega terenskega dela. Ker so obsežna izkopavanja redka in številni suhozidi ne dajejo najdb, je metoda OSL-PD alternativa, ki lahko v takih primerih zagotovi absolutno kronološko določitev. Kompleksnost agropastoralne kraške krajine arhipelaga, vključno s (prazgodovinskimi) gradišči in ograjami, je lahko izziv, hkrati pa predstavlja zanimivo arheološko priložnost za nadaljnje raziskovanje. Zato so v pričujočo objavo vključene arheološke interpretacije vseh lokacij iz kataloga, da bi torej olajšale nadaljnjo razpravo o suhozidnih krajih arhipelaga nasploh in o gradiščih posebej.