What you see is what you get: lidar applications in the northern Adriatic coastal regions

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Introduction

Airborne lidar has played a distinctive role in remote sensing case studies in the Mediterranean context for the last decade. The new possibilities offered by lidar methodology have made it a valuable tool in a number of Mediterranean countries, including Greece and Croatia. The coastal landscapes of both countries share similarities due to the influence of common factors like relief, climate, and vegetation. Furthermore, the numerous islands in both countries have played a significant role in long-distance maritime trade and communication throughout history. While the historical development of land use on the islands of the two countries may have differed, the lidar data indicate comparable remains of land use resulting from the Mediterranean agricultural practices of agro-pastoral societies. The challenges of preserving archaeological heritage in coastal areas are also similar. They can be attributed mainly to the effects of extensive (tourist) construction and development,[1] or to the impact of sea-level rise and the associated risks of flooding and erosion.[2] Given these similarities, it seems beneficial to present an overview of Croatian case studies in a volume dedicated to lidar studies in Greece, as airborne lidar represents an effective approach for the documentation and interpretation of the archaeological heritage in both countries.

The history of archaeological remote sensing in Croatian archaeology spans eight decades. It is closely associated with John Bradford, who served with the Royal Air Force Air Photography and Reconnaissance Unit in Puglia, Italy, and was the first to utilize vertical aerial photographs for archaeological research in the Mediterranean toward the end of the Second World War.[3] This allowed for the first time a panoramic view of the remains of Roman land surveying in the countries around the Mediterranean Sea, initiating a new phase of large-scale archaeological research. To this day, there is a close connection between aerial archaeology and Roman surveying research, not only in Croatia, but throughout Europe.

The introduction of lidar in Croatian archaeology, which occurred slightly over a decade ago, has precipitated a comparable revolution to that initiated by J. Bradford in the field of aerial archaeology. This was primarily due to the fact that lidar is not constrained by the same rigorous limitations as aerial photography, allowing for the exploration of areas that are inaccessible to all other survey methods. In particular, coastal regions with Mediterranean vegetation, such as maquis and evergreen, have benefitted from this development, as they have historically presented

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1 E.g. Tsilimigkas and Thanasis 2014.
2 Reimann *et al.* 2018; Zengin 2023.
3 Bradford 1957.

Journal of Greek Archaeology 10 (2025): 215–229

a challenging environment for archaeological research.[4] The potential applications are manifold, and the mapping of selected archaeological features represents one of them. Lidar in Croatian archaeology is employed for the mapping of new sites but is also effective in the discovery of linear features like the traces of Roman land surveying or military camps.[5] The restricted application of lidar methodology is attributable to the fact that, prior to 2024, such investigations were only feasible on the basis of project data. This is also reflected in the limited number of publications in comparison to neighboring regions in Slovenia and Italy.[6] This situation will change after 2024, as the recently publicly available total lidar survey of Croatia within the project 'Multisensor Aerial Survey of the Republic of Croatia' is available as a DTM at a resolution of 1m grid width, upon request.[7]

Lidar methodology also represents a robust three-dimensional tool that can yield particularly promising results in landscape-based archaeological research. Lidar data offer insights into the relationship between human settlement activities and the natural environment and can assist in understanding the ways in which natural relief has been used and modified to meet human needs.[8] Furthermore, there is the possibility of combining underwater and terrestrial research, which is particularly relevant in coastal areas due to rising sea levels.[9] Additionally, relative stratigraphic information from lidar data can provide insights into the temporal development and change of regional landscapes.[10]

From an interpretive standpoint, landscapes are manifestations of the actions and beliefs of bygone societies and individuals and have evolved over extended periods of time. Consequently, the cataloguing and topologizing of selected relics in the dataset and demarcating them as sites is insufficient to adequately address this issue. This approach places the interpretive focus on the sites themselves and the perspective of the archaeologist, rather than on that of the individuals who previously shaped the landscape. Furthermore, past human activities are not limited to archaeological sites. Therefore, the division into on- and off-site areas provides only practical support for archaeologists, as human activities can leave traces in the landscape in the absence of archaeological finds. This paper demonstrates how airborne lidar can overcome these limitations. The following section presents the case study areas in the northern Adriatic. Thereafter, an overview of a variety of lidar applications will be provided, accompanied by historical contexts mainly from the Roman period.

Study area

The Istrian peninsula and the Kvarner islands belong to the geographical area of the northern Adriatic (Figure 1). Istria is located between the Gulf of Trieste (Italy), Piran Bay (Slovenia) and the Kvarner Bay (Croatia). It is the largest Croatian peninsula, with a little indented coastline and a few islands, but with three large natural harbors (Pula, Medulin and Raša Bay). The region is a very fertile agricultural area, which nowadays profits greatly from the tourist industry.

South of Istria lies the Kvarner archipelago, the northernmost group of Croatian islands, which includes Krk, Cres, Lošinj and Rab, along with numerous smaller, often uninhabited islets. Krk and Cres are the largest Croatian islands and almost the same size, about 405 km^2. The Kvarner Bay and its islands represent a typical Dinaric Karst region.[11] Their karst cultural landscape is characterized

[4] For a current methodological review see Vinci *et al.* 2024.
[5] Tkalčec 2020; Vuković *et al.* 2024; Popović *et al.* 2021; Tončinić *et al.* 2023.
[6] E.g., Bernardini *et al.* 2013; Bernardini *et al.* 2020; Lozić and Štular 2025; Mlekuž Vrhovnik and Fabec 2024.
[7] Multisenzorsko zračno snimanje Republike Hrvatske, https://dgu.gov.hr/multisenzorsko-zracno-snimanje-republike-hrvatske/5700
[8] Doneus *et al.* 2020b.
[9] Doneus *et al.* 2013.
[10] Doneus *et al.* 2022a ; Doneus *et al.* 2022b.
[11] Fuerst-Bjeliš *et al.* 2024.

Figure 1. Region of the North Adriatic Sea with the locations of the case study areas (©SRTM).

by a variety of geomorphological elements (Figure 2). These include open pastures and hillside terraces, as well as sinkholes, karst valleys and agricultural plots enclosed by dry-stone walls.[12] The landscape is further marked by the presence of numerous archaeological remains.

The historical developments of Istria and the Kvarner Islands are similar, though not identical. The presence of hilltop settlements from the Bronze and Iron Ages is a common and widespread phenomenon, despite the existence of regional differences in the material culture associated with these settlements.[13] From the 3rd century BC onward, Roman interest in the area became evident, ultimately leading to the formation of the provinces of Histria and Illyricum/Dalmatia.[14] The origins of both Istrian colonies, Pola (today's Pula) and Parentium (today's Poreč) (Figure 1), as well as of other coastal towns, are thought to date back to the later reign of Augustus Caesar.[15] The foundations are accompanied by a transformation of the rural area through Roman land division (*centuriatio* with square basic units of 710 x 710 m)[16] and the gradual foundation of more than 200 rural settlements.[17] In addition, two dozen luxurious estates line the western coast of Istria and serve as witnesses to Roman art and architecture.[18] At the same time, they reflect the two centuries of Istrian economic prosperity from the Augustan period onwards.

In contrast, the Kvarner islands feature only sporadically in these historical processes, with fewer mentions in written or epigraphic sources than Istria, for instance. Moreover, the current state of research in comparison to Istria is still inadequate, despite some recent systematic field research and publications.[19] At the same time, the Kvarner islands are rich in both terrestrial and

[12] Andlar *et al.* 2018.
[13] Buršić-Matijašić 2007; Blečič Kavur 2014a.
[14] Matijašić 2009.
[15] Matijašić 2018.
[16] Bulić, 2012; Popović *et al.* 2021.
[17] Matijašić 1998.
[18] Bowden 2018.
[19] Blečić Kavur 2014b; Čučković 2017; Welc *et al.* 2019; Bully and Čaušević-Bully 2024.

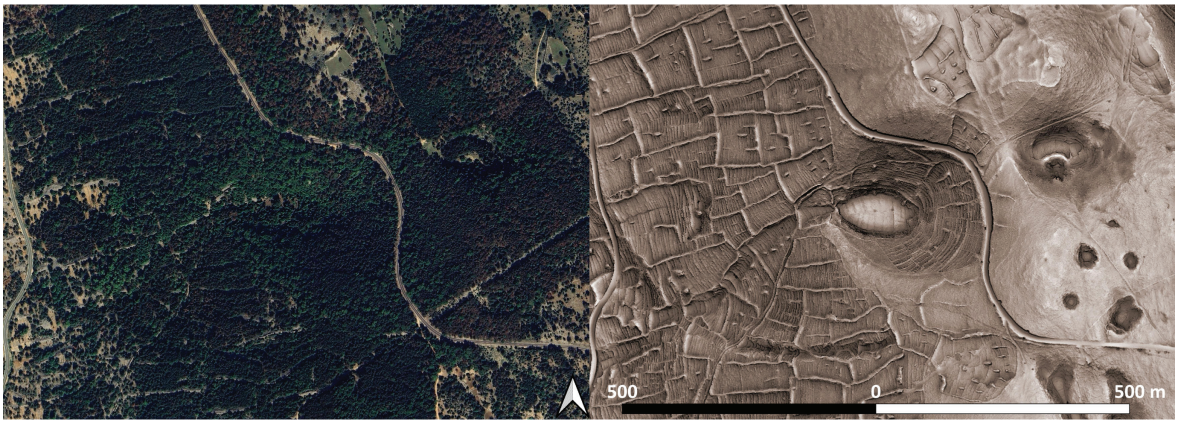

Figure 2. Left: Aerial photograph of a typical setting on the island of Cres with dense maquis. Right: Digital terrain model derived from airborne lidar data revealing a former agricultural landscape with terraces and karst features (dolines) (©Croatian State Geodetic Administration [SGA]).

underwater sites and are home to numerous prehistoric hilltop settlements.[20] For many decades, archaeological research was constrained by the fact that the Kvarner islands, in particular Cres and Lošinj, are covered with dense vegetation and represent the most mountainous islands in Croatia. This presented significant challenges for archaeological fieldwork and could only be overcome as lidar technology emerged. The region was therefore selected as a case study area to address this challenge a little over 10 years ago. In the context of a strategic project, we focused on the applicability of lidar in Mediterranean environments with the goal of developing an integrative approach for terrestrial and underwater archaeology. The application of both airborne laser scanning and airborne laser bathymetry have proven to be successful.[21]

Methods and data

The digital feature models[22] presented here are based on three aerial surveys conducted in 2012, 2018 and 2023 as part of archaeological projects on the Cres/Lošinj archipelago and Istria. The parameters are listed in Figure 3. While all of the datasets were georeferenced, including a strip adjustment by the data providers,[23] the classification and subsequent ground point filtering and interpolation of the remaining point clouds to digital terrain and digital feature models was done under archaeological criteria.[24] The resulting models were created using the Relief Visualization Toolbox (RVT).[25]

Results

Lost temporal scale: visibility and stratigraphy

Archaeological research directs our attention to the tangible remnants of the past. However, due to the influence of our expectations, this is seldom an objective and impartial process, but rather one that is driven by the search for evidence of generally valid historical processes. The mapping of individual, selected relics in relief also results in two-dimensional distribution maps. These are among the earliest archaeological tools and provide support in the development of archaeological hypotheses. However, such maps only reflect the current state of research and must be constantly

[20] E.g. Mirosavljević 1974; Ćus-Rukonić 1982; Vrsalović 2011; Faber 2000.
[21] Doneus *et al.* 2013; Doneus *et al.* 2017.
[22] Pingel *et al.* 2015; Lozić and Štular 2021.
[23] Doneus and Briese 2011.
[24] For a more detailed summary of the parameters and, in particular, the classification steps for creating a digital terrain model or a digital feature model, see Doneus 2020a; Doneus *et al.* 2022b.
[25] Zakšek *et al.* 2011; Kokalj and Somrak 2019.

Title	DFG Project 'Harbours and Landing Places on the Balkan Coasts of Byzantine Empire (4th to 12th Centuries).	EU Project 'Archaeological Park Vižula'	FWF Project 'Osor beyond the myth'
Purpose	Combined land and underwater survey	Combined land and underwater survey	Combined land and underwater survey
Date	March 2012	March 2018	March 2023
Operator	Airborne Technologies	Kabelik GmbH	Kabelik GmbH
Instrument	Full waveform (with online waveform processing)	Full waveform (with online waveform processing)	Full waveform (with online waveform processing)
Scanner type	RIEGL VQ-820-G	RIEGL VQ-820-G	RIEGL VQ-820-G & Q-680-i
Pulse repetition rate	200 kHz	284 kHz	266 kHz
Wavelength	532nm	532nm	532nm & 1550nm
Scanning angle	60°	42°	60°
Additional sensors	IGI Digicam H-39	IGI Digicam H-39	IGI Digicam H-39
Altitude above ground	450m	400m	400-650m
Flight strip overlap	70%	70%	50%
Footprint diameter	45cm	40cm	40-65cm
Average laser pulse density per m^2	16	15	28
Average ground points per m^2	5.1-5.5	11	6
Strip Adjustment	YES, using OPALS	YES, using OPALS	YES, using OPALS
Ground-point filtering	SCOP++	SCOP++	OPALS (Ver. 2.5.0) TerrainFilter

Figure 3. Parameters of airborne lidar acquisition campaigns.

reviewed in the light of methodological developments. This is also the case with Roman land surveying on the Croatian coast, where the use of lidar methodology has provided new results.

The initial insights into Roman surveying (*centuriatio*/centuriation) were obtained as early as the nineteenth century. However, it was only through the application of aerial archaeology that a comprehensive examination of the topic was feasible.[26] In the subsequent decades, the archaeological remains of Roman land surveying were primarily sought in the vicinity of the larger coastal towns (*coloniae*) through mapping of dry-stone walls visible in the aerial photographs or indicated on maps.[27] With digital data and GIS software, previously limited access to photographic and cartographic materials has significantly improved. At the same time, the research focus remained unchanged on the mainland and in proximity to former Roman colonies, due to the prevailing view that Roman surveying was expressed in a singular form: as *centuriatio* in the vicinity of a *colonia*. In contrast to the mainland, only minor Roman towns (*municipia*) are known to have existed on the Croatian islands. The presumed survey relics on the islands[28] were therefore considered to be part of the territories of the major cities on the mainland.

The fact that this historical interpretation is primarily linked to a specific type of landscape and the methodological limitations of aerial archaeology were not addressed in previous archaeological

[26] Suić 1955; Bradford 1957.
[27] Suić 1955; Bulić 2012.
[28] E.g. Gamulin 2011; Kadi 2019.

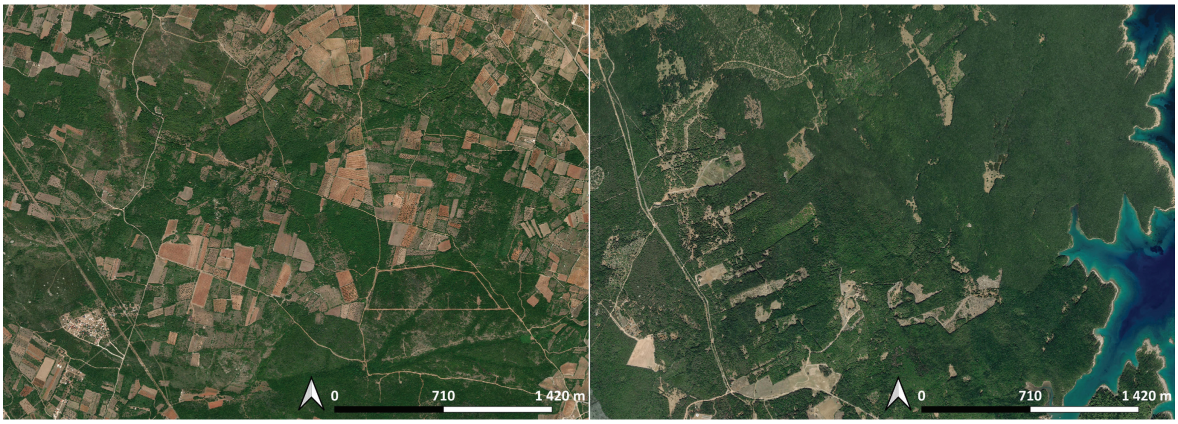

Figure 4. Left: Agricultural land use east of Pula, with visible Roman *centuriae*, which are partly integrated into the modern transport network. Right: Southern part of the island of Cres (Punta Križa) with limited agricultural land between the evergreen vegetation, which completely conceals relics of Roman surveying (©Microsoft® Bing™ Maps).

research. The regions in question have been cultivated more or less continuously since Roman times. It is therefore not surprising that these are the surrounding areas of coastal towns, most of which developed from the Roman *coloniae* and remain populated today. In such areas, the Roman dry-stone walls, which served as boundaries in the context of land surveying, were integrated into the more recent agricultural utilization. This not only ensured their preservation but also provided good visibility in aerial photographs by clearing the vegetation.

However, the Croatian coast, including its many inhabited islands, has a very complex history of conflicts, famines and epidemics, which led sometimes to the abandonment of agriculture due to the low population density. The maquis, the vegetation so typical of many islands today, is a secondary type of vegetation and a consequence of this process. In these areas, the dry-stone walls, as relics of past land use, have not been preserved to the same extent as around the coastal towns and are therefore not visible in aerial photographs or mapped in cartographic materials (Figure 4).

Dry-stone walls are also an integral component of the traditional cultural landscape on the Kvarner islands[29] and the technique is likely to have originated in the prehistory.[30] While parts of Krk and Rab are now devoid of vegetation and most relics of the past land use, the islands of Cres and Lošinj are predominantly covered with dense, low-to-ground evergreen vegetation or woods in the northern part of Cres. Lidar-based digital feature models can be employed here for a diachronic archaeological interpretation of the dry-stone wall landscapes.

A systematic and large-scale interpretation of a portion of the lidar data was recently conducted for Punta Križa, the southernmost point of the island of Cres (Figure 1).[31] Accordingly, a relative chronological sequence of agricultural relics (dry-stone walls, terraces) was delineated south of the Roman city of Osor. The oldest stratigraphic units were identified as the remnants of collapsed dry-stone walls, which run parallel to each other at a distance of approximately 710 meters (Figure 5). The relics lacked datable material, similar to the Roman boundary lines (*limites*) of a *centuriatio* on the mainland.[32] A chronology for one of these features was obtained therefore through the use of OSL-PD profiling and dating, providing an approximate date of AD 200 ± 100.[33] To obtain a more comprehensive data set, the other major islands in the Kvarner archipelago (Krk, Lošinj, and Rab) were subsequently examined for potential land surveying remnants within the lidar data.

[29] E.g. Kremenić *et al.* 2021.
[30] Faber 2018.
[31] Doneus *et al.* 2022.
[32] Popović *et al.* 2021.
[33] For the optically stimulated luminescence profiling and dating method see Srivastava *et al.* 2023.

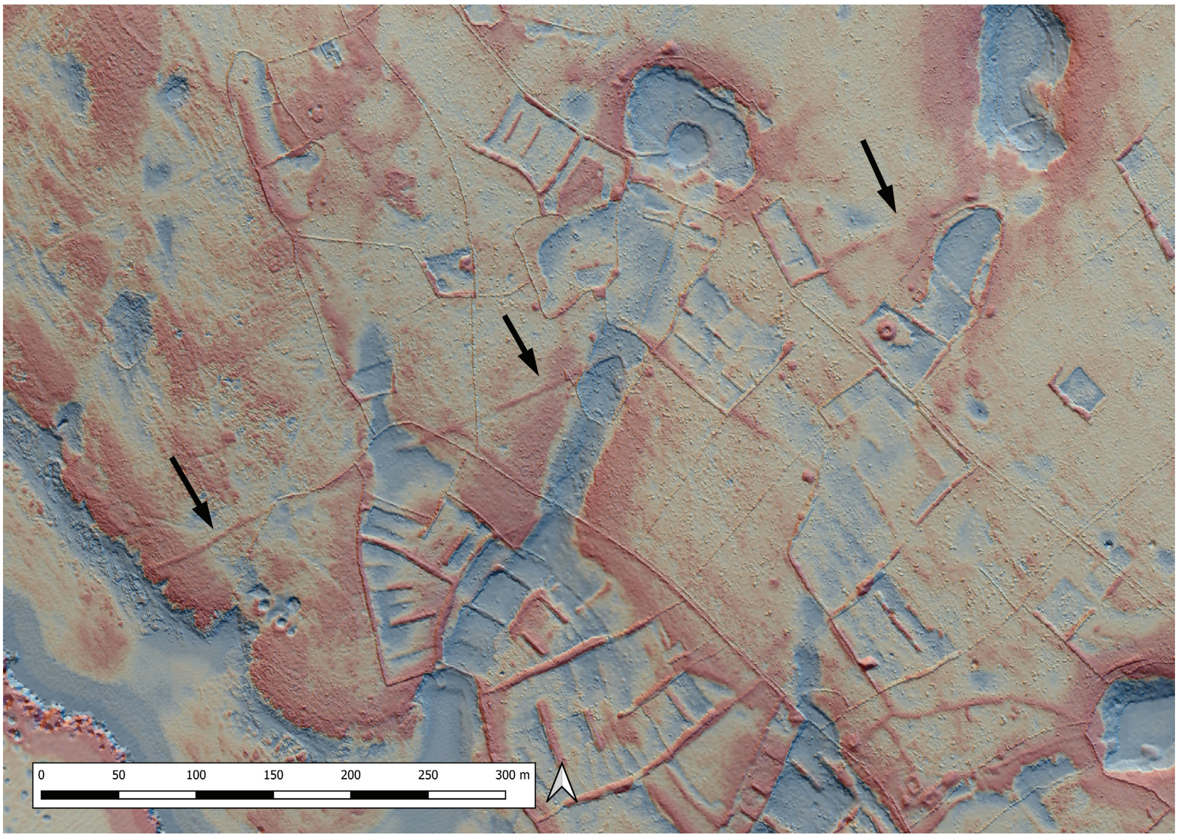

Figure 5. Local relief model (r=50) with the range of 0.3 to -0.3m and indicated Roman dry-stone boundary wall (©Doneus *et al.* 2022).

The results revealed that only two of the four major Kvarner islands had been surveyed.[34] A single surveying system was identified on the island of Cres, while two were discovered on the island of Krk. Two of the three measuring systems are likely to be evidence of the Flavian land reform, which was initiated in the 1st century AD and carried out in the course of the 2nd century AD, in the form of a strip survey (*scamnatio*). The third measuring system, which in its regular execution is strongly reminiscent of a *centuriatio*, is possibly somewhat older. The *terminus post quem* is the granting of municipal rights to the towns of the Kvarner islands, which took place from Augustus at the earliest.[35] All in all, the results can be considered to represent the first verified Roman survey of the municipal territories on the Croatian islands.

Lost topographical context: coastal sites

Croatian coastal areas have been affected by a sea level rise estimated at 1 to 1.5 meters for the northern Adriatic over the last 2000 years.[36] For archaeological research, this situation has several consequences. The course of the coastline and the small-scale relief above and below the water have changed due to sea-level rise, erosion and sedimentation. As a result, the spatial context of each port city is being permanently lost, making it difficult to understand the remains of buildings or marine infrastructure. At the same time, partly submerged archaeological sites pose a methodological problem, as they are set both in terrestrial and underwater environments. This fact is often reflected in archaeological fieldwork, as different methods and specialists are needed to combine research on land, in shallow water and underwater.

[34] Doneus *et al.* 2024.
[35] Margetić 1979.
[36] Faivre *et al.* 2010.

The incorporation of bathymetric lidar into the research strategy for coastal and submerged sites is one way to address these issues.[37] Green laser scanners can be operated on land and over vegetated areas and allows at the same time the documentation of intertidal and very shallow water zones. The approximate penetration depth of 10 meters is sufficient for the interpretation of coastal settlements, as it provides detailed underwater terrain models, thus enabling the identification of potential archaeological structures.[38]

The small Iron Age and Roman port city of Osor on the island of Cres (Figure 1) provides an illustrative case study of the necessity for a research strategy that can effectively integrate landscape and marine aspects. Osor is situated on a circular land-bridge between the islands of Cres and Lošinj, which are separated by a 10m wide Osor Channel.[39] The archipelago, like other islands in the Kvarner Bay and a significant portion of the Croatian coastline, is subject to the influence of stormy winds, with recorded gusts reaching up to 180 km/h. The region is subject to microtidal conditions, with an average amplitude of approximately 30 cm.[40] However, the confluence of low atmospheric pressure, storm winds, spring tides, and seiche phenomena can elevate sea levels to a maximum of 1.6m above mean sea level.[41] This illustrates the need for safe ports along the route between Istria and Dalmatia, and Osor was potentially one of them. The city appears to have attained regional significance during the Iron Age, with the Osor Channel, believed to have been operational since at least the Roman era.[42] In this context, the question arises as to whether the thesis put forward is correct and whether shipping in Roman times already had similar difficulties to those in the Middle Ages or in modern times due to the shallow water around Osor. The shallow depth south of Osor is primarily attributed to sedimentation processes.[43] Given the 1-1.5m lower sea level during the Roman era, it may suggest navigational challenges for larger Roman cargo vessels.[44] In the context of the ongoing investigations, these questions are being examined through a combination of lidar, marine geophysics, and geoarchaeological investigations. As the bathymetric lidar records data only up to a depth of approximately 10 meters, it was fused with the multibeam sonar data to create a seamless relief extending from the shoreline to a depth of approximately 50 meters below the seafloor (Figure 6).[45] In a subsequent phase, the present-day underwater relief will be linked to the analyses of marine cores. By correlating all cores and utilizing C14 dating, it will be possible to discuss relative sea level change, palaeo-coast lines and the potential date for the opening of the Osor Channel. The dating of these events paves the way for a more comprehensive understanding of the city's role on the long-distance maritime routes between Italy and Greece. A historical reconstruction is based on the actual landscape context of the city, which allows for a more accurate representation of the city's past.

The interconnection between land and sea is a significant factor not only in the investigation of port towns but also in the study of the so-called *villae maritimae*: large, luxurious country residences that emerged during the 2nd century BC on the Campanian coast and slightly later on the west side of Istrian peninsula.[46] While there are slight variations in the layout of each *villa maritima*, they are unified by a common location on the coastline and the integration of the surrounding topography into the villa's design. In some cases, his has led to the modification of entire coastal areas to align with the desired architectural layout. The best example here is the *villa maritima* in Verige Bay on the island of Veliki Brijun (Figure 1). The architectural remains cover the entire bay and most

[37] For bathymetric lidar applications in submerged landscape research see Davis *et al.* 2024.
[38] Doneus *et al.* 2013; Doneus *et al.* 2015.
[39] Doneus *et al.* 2017.
[40] Benac *et al.* 2008.
[41] Furlani *et al.* 2011.
[42] Faber 1982.
[43] Brunović *et al.* 2019.
[44] Boetto 2010.
[45] This research, which will be detailed in a forthcoming paper, is being conducted in collaboration with the Croatian Geological Survey, which provided the multibeam sonar data.
[46] Bowden 2018.

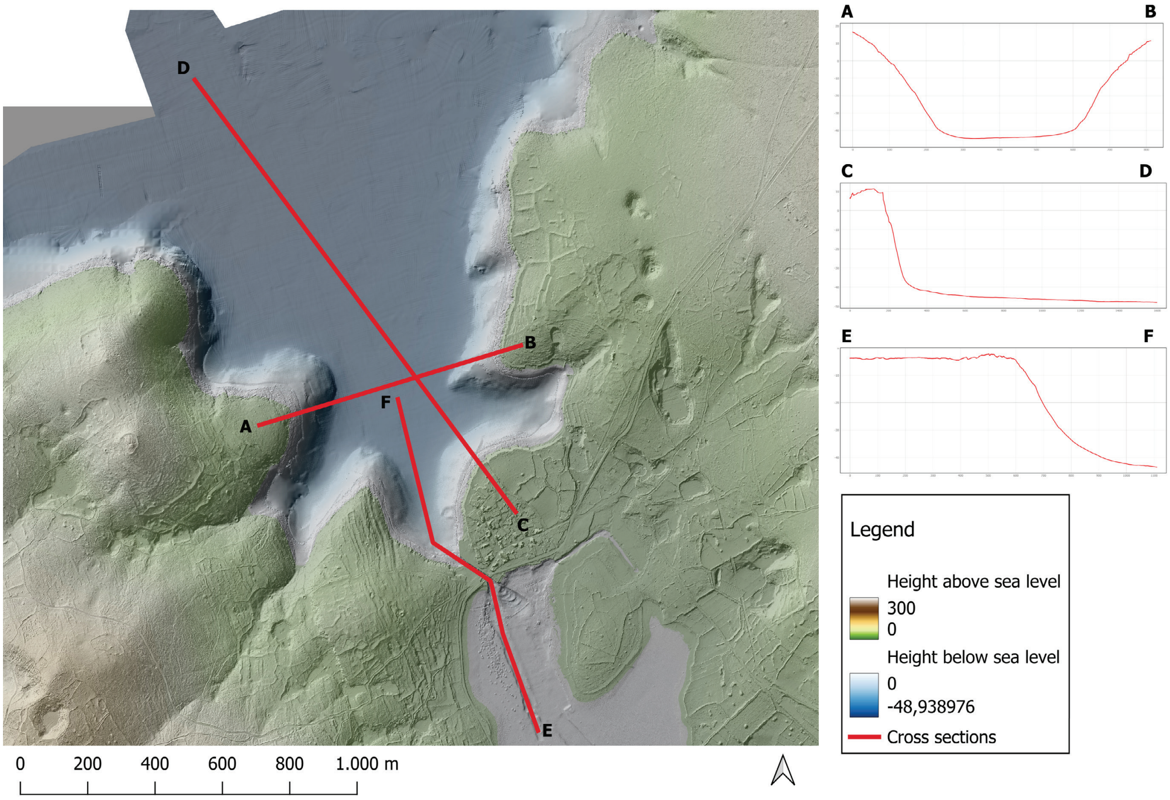

Figure 6. Combination of terrain models from bathymetric lidar and multibeam sonar data delivers a seamless terrain model of the topography onshore and offshore and allows different profiles, which clearly show the underwater topography and the steep drop from Osor towards Istria (©Project 'Osor beyond the myth').

were excavated at the beginning of the 20th century.[47] According to Begović Dvoržak,[48] a simple late Republican *villa rustica* lies at the origin of the property and the development into a highly luxurious estate is completed by the beginning of the 2nd century AD. The coastline has been adapted to the needs and aesthetic preferences of the residents and includes a pier on both sides of the bay, as private access from the sea is a common feature of all *villae maritimae* in Istria (Figure 7).

The submerged nature of these architectural relics, combined with the generally large scale of *villae maritimae*, makes it difficult to document them comprehensively through excavation alone. However, a combination of prospection methods with terrestrial and underwater excavation results can provide detailed insights into any Roman villa, regardless of its size. This was also the case with the so-called *villa maritima* of Vižula, located in Medulin Bay, on the southern tip of Istria (Figure 1). An evaluation of the entire area of about 24 hectares, including submerged features, has shown that instead of a single luxurious residence, several contemporary complexes of standardized size were lined up along the coast (Figure 8).[49] In order to better display the villa architecture, the western side of today's peninsula was terraced in Roman times. At the same time, the eastern side of Vižula was left unbuilt, possibly for agricultural use by the small *villa rustica*, which is located about 300 m away from the other architectural remains. The combined interpretation of the excavation and prospection results has thus provided not only a detailed picture of the Roman architecture at Vižula, but also the first indications of the Roman land use.

[47] Gnirs 1915.
[48] Begović Dvoržak 1990.
[49] Doneus *et al.* 2020b.

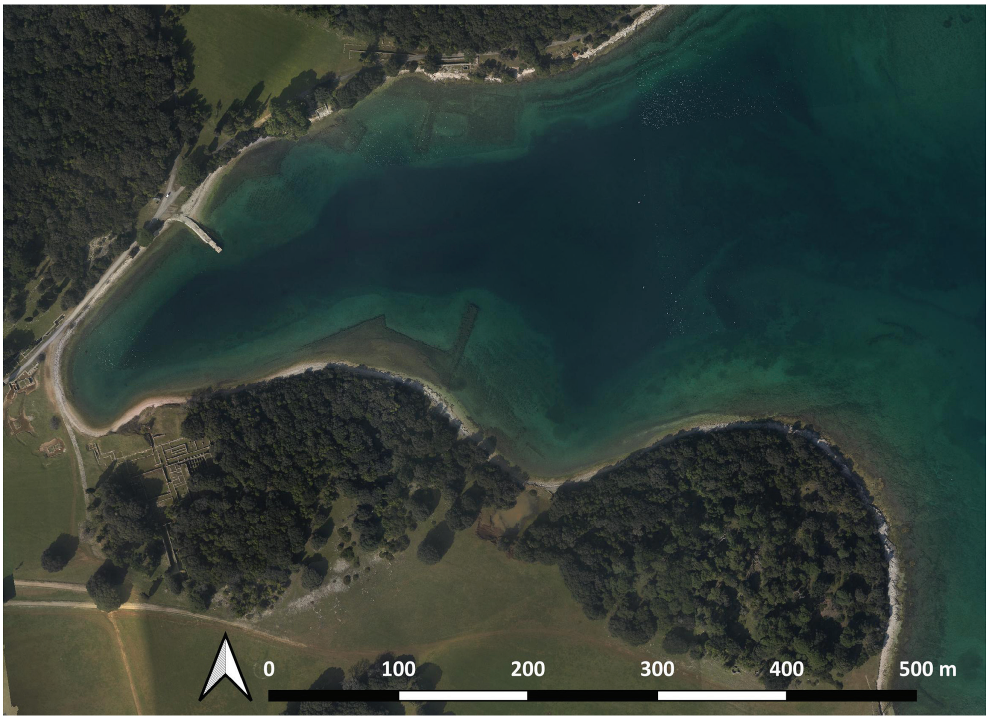

Figure 7. Aerial view of the bay of Verige on the island of Veli Brijun. The Roman villa extends along the entire bay and includes not only various buildings, but also a stone-built shoreline, which is now submerged (©Project 'Archaeological Park Vižula').

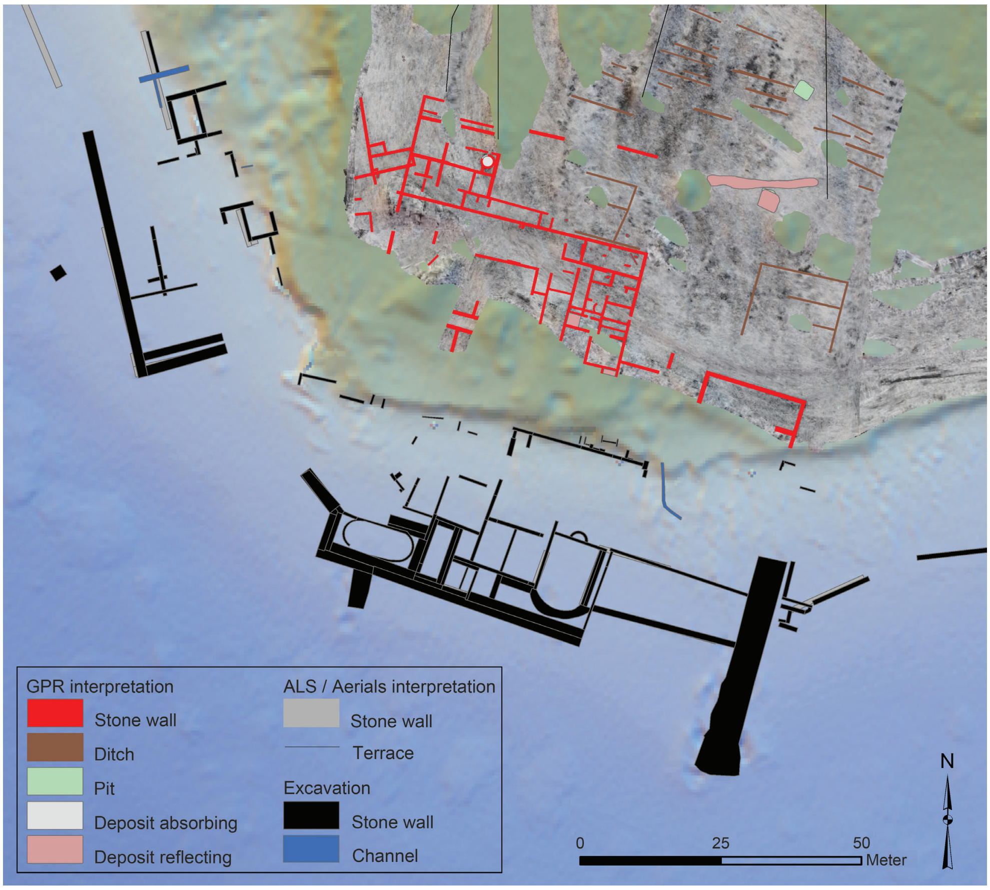

Figure 8. Part of the Roman architecture on the Vižula peninsula. An integrative interpretation of the results of the excavations, where geophysical and lidar surveys reveal a partially submerged *villa maritima* and, to the north, a small *villa rustica* (©Doneus *et al.* 2020b).

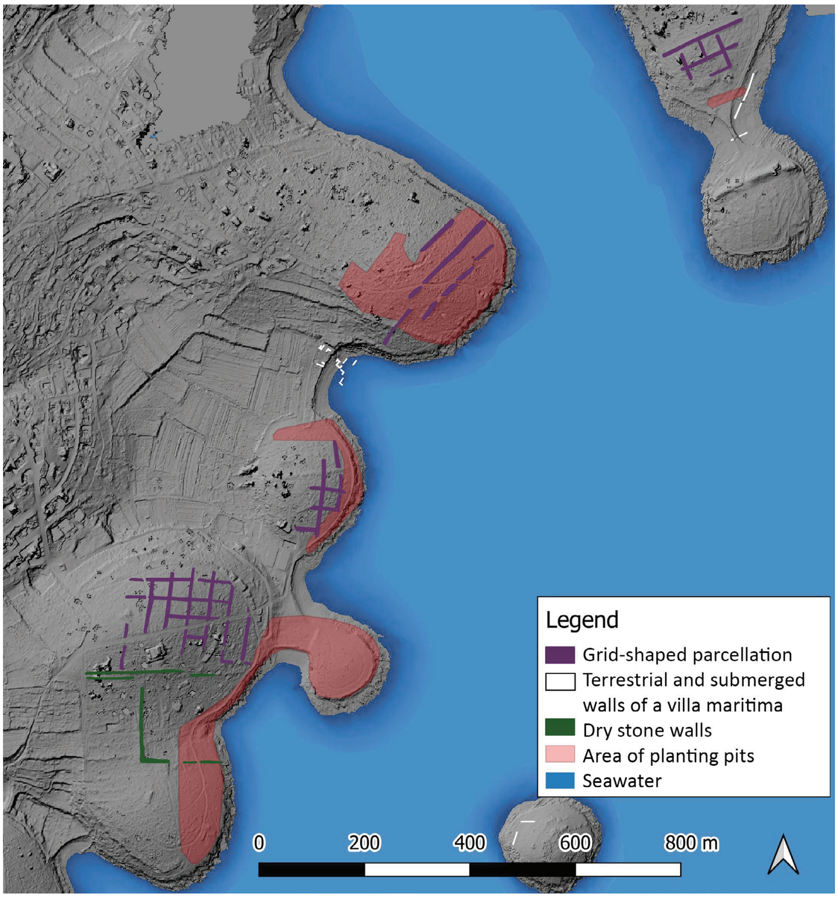

Figure 9. Premantura Peninsula, Medulin Bay, with remains of Roman agriculture (©Doneus and Doneus 2024).

Lost agricultural landscapes: land and politics

The 2018 lidar survey of the Medulin Bay focused on the Roman architecture of Vižula and its landscape context, but the interpretation of the 24 km^2 survey also revealed a large number of other archaeological features.[50] The lidar methodology has the potential to identify parts of the settlement infrastructure, such as agricultural, industrial or other economically used areas, which are rarely discovered in archaeological excavations. Often these relics do not contain finds and are not classified as archaeological sites, as in the case of the Roman land survey.[51] The same is true for the remains of the agricultural landscapes.

The aerial photographs taken at the same time as the lidar survey identified numerous pits, recognizable as vegetation marks or eroded pits in the vegetation-free strip along the seacoast.[52] They had already been published in 2012,[53] but only the new aerial photographs of better quality showed that we were dealing with a large-scale phenomenon. Altogether, it seems that pits of the same size and distance from each other were systematically laid out over an area of at least 13 hectares. At the same time, the lidar-based terrain model revealed another group of land use relics that were not visible in the aerial photographs: shallow linear banks in a grid pattern. The banks form a regular grid of square cells 35-39m wide and most likely represent heavily levelled remnants of dry-stone walls. Both groups show a spatial relationship, a common orientation, and the same units of measurement (Figure 9). Similar results from the area of the *villa maritima* in Verige Bay and numerous parallels

[50] Doneus and Doneus 2025.
[51] Popović *et al.* 2021
[52] Doneus and Doneus 2024.
[53] Matijašić 2012.

found in Roman agricultural practices around the Mediterranean allow a Roman dating and an interpretation as planting pits of nurseries or orchards and protective walls for agriculture.

These agricultural remains are a particularly visible testimony of Roman politics, as they are linked to the phenomena of the *villae maritimae*. Their emergence during the 1st century BC is likely to be in close connection with political and economic decisions. A. Starac[54] sees in the change of the border of Histria and the closer ties with the Italian peninsula practical economic advantages, which primarily benefited the narrow elite circle surrounding Emperor Augustus. Consequently, the considerable investment by Roman senatorial families in the newly established province of Histria[55] coincided with the emergence of novel economic sectors driven by profit, which, as evidenced by observations in Medulin Bay, likely encompassed large-scale agriculture.

Conclusion

The experience of the last 10 years on the Croatian coast demonstrates that lidar can yield results of comparable quality to those obtained on the European mainland. This suggests that a similar research design may be a viable option for other Mediterranean countries like Greece. In this context, it seems important to consider lidar as an important component of archaeological prospection. Every prospection method is constrained by its inherent limitations, and optimal results are therefore only achievable through the integration of multiple prospection methods. While lidar is a highly effective tool, it is merely one among several others.

Archaeological prospection is most effective when applied to large-scale, landscape-based research. The sheer quantity of information that lidar data provide is here both a problem and a solution. The capacity to document extensive areas does not necessarily enhance our expertise in archaeology, given the often limited time available for data interpretation. The mapping and typologizing of signatures derived from lidar data is only a first step in the effort to study the archaeological remains, as prospection methods can challenge the traditional boundaries between on-site and off-site archaeology, between site and landscape, and between past and present.

The landscape-based interpretation of lidar data can reveal complex interrelationships between human settlements and land use practices over time. We should use this opportunity to define new and challenging research questions, as in the case of Roman land surveying. While the founding of the Roman cities and the subsequent land division was undoubtedly an important political change, it is only through the decoding of the spatial context with the previous Iron Age land use that we can transform the simple Roman surveying lines into living witnesses of history.

In this regard, it is evident that agrarian relics, frequently identified in the lidar data and closely associated with the abandonment of agricultural activities, deserve particular attention. The process of the decline of agriculture is accompanied by the tragic fate of countless generations, regardless of whether the Iron Age population lost their land due to imperial land claims or the modern population was forced to emigrate due to war or famine. It is therefore essential to recognise that the past can only be properly honoured if it is seen and remembered in its entirety.

Acknowledgements

The presented paper is part of a research project 'Osor beyond the myth' funded by the Austrian Science Fund (FWF): Grant-DOI: 10.55776/I6039.

[54] Starac 1999: 58.
[55] Tassaux 2005.

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