Remote Sensing Campaign at the Roman Villa of Caddeddi on the Tellaro river (Noto, Italy)

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Abstract

The Villa of Caddeddi, in the territory of Noto (Siracusa) is located on the south bank of the Tellaro river, about 3km from its mouth. The site, interpreted as a rural luxury residence dated to the 4th-5th century CE, was first discovered in 1972 and intermittently investigated in the subsequent decades and mostly studied from the perspectives of the splendid mosaic floors there uncovered. The excavated structure accounts for just a portion of the complex, which is partially covered by an 18th-19th century farmhouse. After a long period of neglect, the villa, mainly known in literature for its exquisite mosaic floors, has been recently restored and opened to the public and become subject of new studies by the University of South Florida's Institute for Digital Exploration (IDEx) which between 2019 and 2022 conducted a remote sensing, using ground penetrating radar method, campaign in partnership with the Parco Archeologico e Paesaggistico di Siracusa, Eloro, Villa del Tellaro e Akrai and the Institute of Heritage Science - CNR. The integration between the digital exploration and ground penetrating radar allow new knowledge relating to the Roman villa.

Key Words: Roman Sicily, Ground Penetrating Radar, Remote Sensing, Roman Villa

1. Introduction

Perhaps the most well-known late Roman villa in southeastern Sicily, the Villa di Caddeddi is also known as the Villa del Tellaro. It was discovered in the early 1971 during renovations of the 18th and 19th century farmhouse that cover it. The Villa is located on a plateau in southeastern Sicily, looking over the Tellaro River valley, about 400m away on average as the crow flies. According to a traditional interpretation the villa is organized on two floors around a central peristyle that is surrounded by living quarters. The excavated structure accounts for just a portion of the complex, which is partially covered by an 18th-19th century farmhouse (Fig. 1). Only the north and south sides of the living quarters are preserved. It is best known for the upper rooms, which contain lavishly decorated floor mosaics that typical of the 4th century CE and are most comparable with those of the Villa del Casale at Piazza Armerina and villas in North Africa. The mosaics portray the redemption of the body of Hector, a hunting scene arranged around a seated female figure, perhaps the personification of Africa, and a Bacchic scene, all flanked to the south by a geometric mosaic in the corridor (Voza 2008, Wilson 2016, 2021). Systematic excavations began in 1972 with intermittent excavations through 2010 (Voza 1972-73, Guzzardi 2014, Accolla 2020). As a contemporary of the larger and more well-known Villa del Casale and Patti Marina (Sfameni 2016), it stands as one of the more important villas of Sicily more widely (Wilson 2018a). Archaeological explorations have shed light on the area’s reuse in Late Antiquity and the early Medieval period. A cemetery of Islamic rite was discovered to the southeast of the (Garipoli 2018). Byzantine and Arab period ceramics have recently been analyzed in a well from the site Rizza, 2016), though the context is unclear.

While large parts of the villa have already been excavated, publications on the ceramics and excavation notes are still pending after nearly 50 years. Due to the relative lack of information on the villa itself, however, it was decided to carry out a remote sensing campaign to breathe new interest in the analysis of the villa. Using innovative digitization methods and geophysical survey, a wealth of new data can be generated about the site without breaking any ground. This contribution then seeks to generate data and shed light on aspects of the villa that can be analyzed while its final publication is still pending. Therefore, in 2019, the University of South Florida, Institute for Digital Exploration – IDEx (www.usf.edu/idex), in partnership Parco Archeologico e Paesaggistico di Siracusa, Eloro, Villa del Tellaro e Akrai undertook a research project, to date still ongoing, that employed 3D digitization and geophysical prospecting to create an updated plan of the site and reassessing the traditionally suggested spatial layout and to investigate the subsoil for possible further archaeological remains. The present contribution focuses primarily on the results of the 2019, 2020 and 2020 fieldworks, with an emphasis on the geophysical studies.

Figure 1: The Roman Villa of Caddeddi, also known as Villa del Tellaro

2. Methods

Our interdisciplinary project has two main goals: to create an updated mapping of the archaeological area of the villa comparing the visible remains the geomorphology of the territory; to identify the possible presence of yet undiscovered parts of the villa, or the presence of structures that predate the villa in parts that have been excavated.

The first objective of updating the site map with a highly accurate digital 3D representation of the site was addressed in 2019 with a terrestrial laser scanning. Subsequently, the creation of mapping of the site in its wider environmental context was addressed using terrestrial and arial digital photogrammetry, executed in 2021. The second one the investigation of non-excavated areas of the site to establish the potential presence of further built archaeological features, was conducted in late 2020 via a Ground Penetrating Radar (GPR) survey by a partnering team of the Laboratory of Geophysics Applied to Archaeological and Monumental Heritage of the Institute of Heritage Science – CNR.

2.1 Terrestrial Laser Scanning

Two Faro Focus x330 terrestrial laser scanners were used over the course of three days in July 2019 in order to create a highly accurate, yet photorealistic representation of the site. Scanning began in the early morning to avoid harsh lighting conditions, but was not always avoidable, considering the summer conditions in Sicily. The scanning profiles were chosen with an eye for a mixture of quality data and time efficiency. The scanners were set to collect points at ¼ accuracy, x4 quality, and collecting photographs in order to generate RGB values for the point cloud. These settings amounted to roughly a 12-minute scan time giving a level of accuracy of +/- 6mm per 10m. The entirety of the villa was captured with a total of 102 scans between the two scanners. Particular attention was given to covering the interior of the protective structure to capture the preserved floor levels containing the mosaics (Figs. 2-3).

Figure 2. Terrestrial laserscanning at the Villa employing a Faro Focus x330.

Figure 3. Terrestrial laserscanning of the room of the Hunt mosaic

The 102 raw scans were then processed in Faro Scene (version 2019.1) back in the lab following the software’s automated processing workflow. Scans were automatically registered using default settings and then visually verified (Fig. 4). A Project Point Cloud (PPC) was generated and then manually checked for errors and extraneous data. Manually cleaning the point cloud was necessary due to the high number of artifacts from the scanning, most commonly moving persons, or irrelevant objects in the scans. The site was open to the public and operators could not always remove themselves from sight lines quickly enough, and the tripods from the scanner itself were frequently captured. Once the scan was cleaned (including objects that were captured outside of the site itself such as trees or cars) the PPC was updated, used to create orthophotos and site plans. The point cloud was then exported from Faro Scene as PTS files for archiving and analysis in other software (Figs. 5a, b).

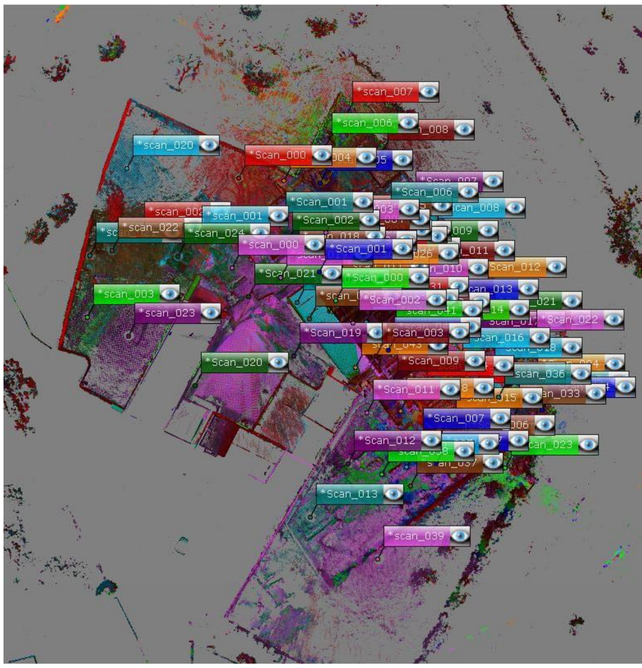
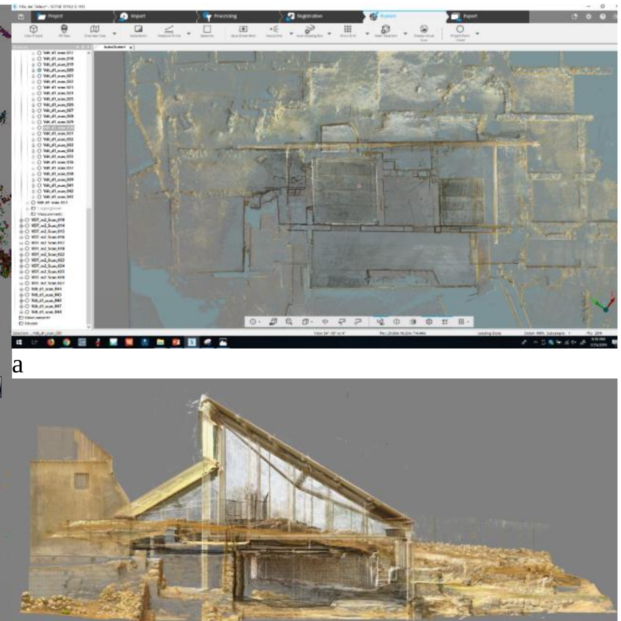


Figure 4. Registration of the entire site in Faro SCENE 2019.1.



a

b

Figure 5. a) 3D point cloud model processed with Faro Scene 2019.a; b) north-south section view of the point cloud model of the villa.

2.2 Photogrammetric survey

The photogrammetric survey was carried out both with aerial and terrestrial digital photogrammetry. The first was used to map the site in its wider context, while the second was to provide a photorealistic and highly accurate representation of the site.

Aerial photogrammetry was chosen for its balance between cost, efficiency, accuracy, and coverage, especially considering the large size of the archaeological area. A DJI Phantom 4 PRO V2.0 drone was used to collect two datasets (Fig. 6). The first was taken from a lower height (15m above ground), emphasizing details of the villa and its layout. Three hundred and fifty-six (356) images were taken during the first flight. The second dataset was collected at a higher altitude (75m above ground) to capture the relationship of the villa with the eponymous river; this dataset consisted of 406 photos, covering roughly 24 hectares the farmhouse and the Tellaro river further north. The flights were programmed to collect photogrammetric strips with a sidelap of 20% and total overlap of 60% (Pulighe 2009). The two datasets were imported into Agisoft Metashape (v. 1.8.0) to be processed. The software was used to align the photographs, generate point clouds, and then mesh and texture the models. Orthophotos were generated and georeferenced (Fig. 7). The orthophotos were then imported into QGIS software. The archaeological surveys were carried out in QGIS (Buscemi 2014). The 3D model produced by the 75m aerial photographs were used to generate a Digital Elevation Model (DEM) to accurately analyze the geomorphology of the area on which the villa complex is located (Filzwieser et al. 2021). In addition, we combined the existing cartography, vectorized for the occasion in the GIS environment, with the new map processed through the orthophoto, and with LIDAR data, obtained from the Regional Territorial Information System of the Sicilian Region. In this way we were able to create a map that contains the overall georeferenced map of the area, in which there are the archaeological remains that are still visible, and the archaeological evidence found during all the previous excavations of the villa.

Figure 6. Aerial digital photogrammetry survey via DJI Phantom 4 PRO V2.0 drone.

Figure 7. Ortophoto of the Villa complex at 80 meters of height.

A second campaign of terrestrial digital photogrammetry was carried out to create an even more detailed, from a photorealism point of view, 3D model with a focus on the mosaic rooms that were covered and impossible to view in aerial photogrammetry. Mapping the entire site of the villa del Tellaro with handheld photogrammetry was a challenging task and required careful planning study of the area to decide which was the most congenial action plan for the data collection needs, that is to have a final orthographic view of the environments as an accessory and comparative means to the data obtained from terrestrial scanning. The time of day was a relevant factor due to the changing direction and intensity of light, so the dataset was collected between 10.00 and 13.30 and 15.00 and 17.00. The dataset consisted of 4450 images taken by a Canon Eos 2000D DSLR camera. Photos were captured at roughly 1.7cm in height with a shooting angle between 35° to 80°. Where necessary a telescopic pole and Bluetooth remote were employed to avoid stepping on the mosaic floors when capturing their rooms (Figs. 8-9).

Figure 8. Terrestrial digital photogrammetry survey of the northern sector of the villa.

Figure 9. Terrestrial digital photogrammetry survey of the room of the Hunt mosaic

The dataset was imported into Agisoft Metashape Professional version 1.8.0 software for processing. Of the dataset, 4431 images were properly aligned with an overlay of> 9 images per single anchor point (Fig. 10) creating a sparse point cloud resulting in a total of 4,866,213 constraint points (Fig. 11). Subsequently, we moved on to the generation of the dense cloud, with a quality setting medium, as the high number of points already generated during the first was sufficient, resulting in dense point cloud of 295,142,892. After manually cleaning out the areas not relevant to the project to lighten the subsequent processing phases, we moved on to the generation of the 3D model. Here, too, the processing has been set to medium quality in order to lighten the processing time and the final weight of the produced file.

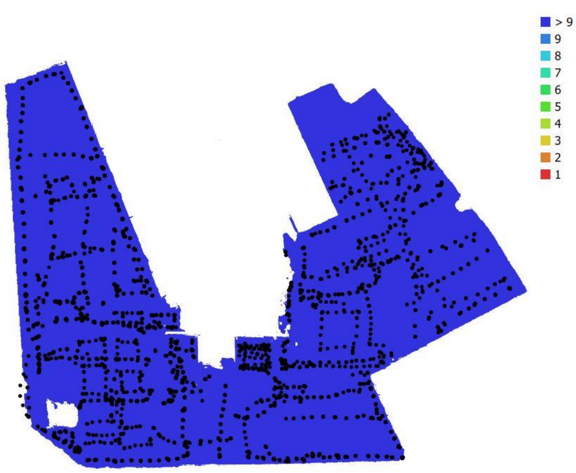


Figure 10. Camera position and level of overlap between images. Data generated from Agisoft Metashape 1.8.0 report.

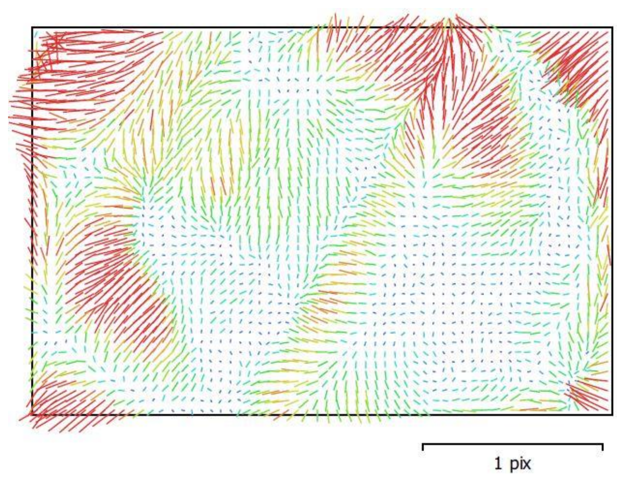


Figure 11. Residual Image for Canon EOS 2000D (18mm). The colored vectors show the average reprojection error of the pixels in the corresponding cells, calculated on all images. Data taken from Agisoft Metashape 1.8.0 report.

A mesh model was generated with 66,426,886 faces, and then decimated in Metashape to 5,000,000 faces and 2,509,056 vertices, which had no impact on the visual quality of the model (Fig. 12). A texture of 8,192x8,192 pixels was generated which presents a good level of detail at the orthophoto level and in the elevation of the structures, with a high level of scalability of the model, which shows the first signs of image blur at approximately <1m above the ground.

Figure 12. Visual comparison between the original model's mesh (Sx) and the mesh of the decimated model (Dx). As can be seen from the comparison of the two models, the difference is practically undetectable to the human eye..

2.3 GPR Survey

The GPR survey carried out in 2020 divided the site into five Areas (Fig. 13). The prospection was performed with a Hi Mod model GPR instrument made by IDS. The choice of the antenna frequency was linked to the specific geographical context of the survey (Conyers, 2004; Conyers, 2006; Conyers, 2012; Leucci, 2019).

Figure 13. Areas of the site identified for GPR survey.

In this case the 200-600 MHz dual band antenna, using the time window equal to 80 ns (nanoseconds) for the 600MHz antenna and 160 ns for the 200 MHz antenna (Figs. 14-15). The proposed configuration represents a standard and was optimized through trials in the field (Leucci, 2019). The geophysical investigations were carried out within five areas according to a 0.25 m pitch grid with 512 samples / track; the other acquisition parameters were optimized on site and kept constant for all the profiles of each survey.

Figure 14. GPR survey in Area 1.

Figure 15. GPR survey in Area 2.

The datawere subsequently processed using standard two-dimensional processing techniques by means of the GPR-Slice Version 7.0 software (Goodman, 2013). The processing flow-chart consists of the following steps: (i) header editing for inserting the geometrical information; (ii) frequency filtering; (iii) manual gain, to adjust the acquisition gain function and enhance the visibility of deeper anomalies; (iv) customized background removal to attenuate the horizontal banding in the deeper part of the sections (ringing), performed by subtracting in different time ranges a 'local' average noise trace estimated from suitably selected time–distance windows with low signal content (this local subtraction procedure was necessary to avoid artefacts created by the classic subtraction of a 'global' average trace estimated from the entire section, due to the presence of zones with a very strong signal); estimation of the average electromagnetic wave velocity by hyperbola fitting; (vi) Kirchhoff migration, using a constant average velocity value of 0.1 m/ ns.
The migrated data were subsequently merged together into three-dimensional volumes and visualized in various ways in order to enhance the spatial correlations of anomalies of interest.
A way of obtaining visually useful maps for understanding the plan distribution of reflection amplitudes within specific time intervals is the creation of horizontal time slices. These are maps on which the reflection amplitudes have been projected at a specified time (or depth), with a selected time interval (Conyers, 2006). In a graphic method developed by Goodman et al. (2006), termed 'overlay analysis', the strongest and weakest reflectors at the depth of each slice are assigned specific colours. This technique allows the linkage of structures buried at different depths. This represents an improvement in imaging because subtle features that are indistinguishable on radargrams can be seen and interpreted in a more easyily. In the present work the time-slice technique has been used to display the amplitude variations within consecutive time windows of width Δt=5 ns.
Moreover the highest amplitudes were rendered into an isosurface (Conyers, 2004, 2012; Conyers et al., 2013; Leucci, 2019). Three-dimensional amplitude isosurface rendering displays amplitudes of equal value
in the GPR study volume. Shading is usually used to illuminate these surfaces, giving the appearance of real archaeological structures. In this case the threshold calibration is a very delicate task in order to obtain useful results.

The results were then merged drone photographic survey of the investigated areas. The measurement of anomalies' exact extension was used to realize of a sort of virtual excavation by inserting the anomalies inside the investigated areas into a digital 3-dimensional space to facilitate the interpretation of the geophysical anomalies in relationship to existing structures.

3. Results

3.1 Results of the 3D Mapping Campaign

The TLS survey and photogrammetric models generated during the 2019 and 2020 field seasons resulted in multiple highly accurate digital surrogates of the site (Rabinowitz 2015). The PPC of the villa (Fig. 16) was used to generate an overview in Faro SCENE, which resulted in a highly accurate site map that is more comprehensive and accurate than that which existed previously from the excavations in the 20^{th} century. The site updated site plan was superimposed over the previous site plan to show the errors in the previous site plan (Fig. 17).

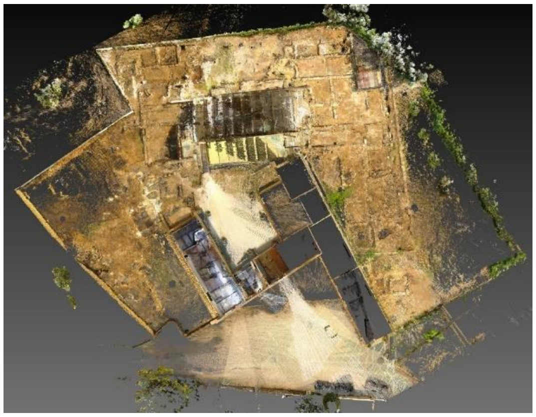


Figure 16. Project Point Cloud of the entire site after processing.

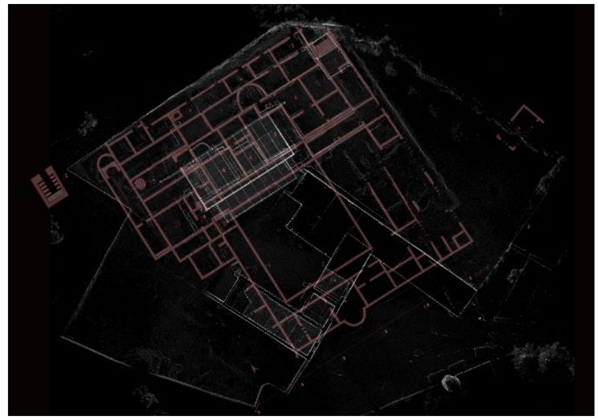


Figure 1. Overlay of the PPC and hand drawn plan.

The overview map, coupled with the resulting photogrammetric surveys of the surrounding area, were used to generate CAD maps that incorporated other excavations near the villa itself (Fig. 18). The point cloud and maps generated from the 2019 campaign were also used to inform the 2020 GPR survey, cutting down on time needed to plan the survey in the field. The handheld photogrammetric campaign also generated a photorealistic representation of the site that can be used in parallel with the PPC generated in SCENE.

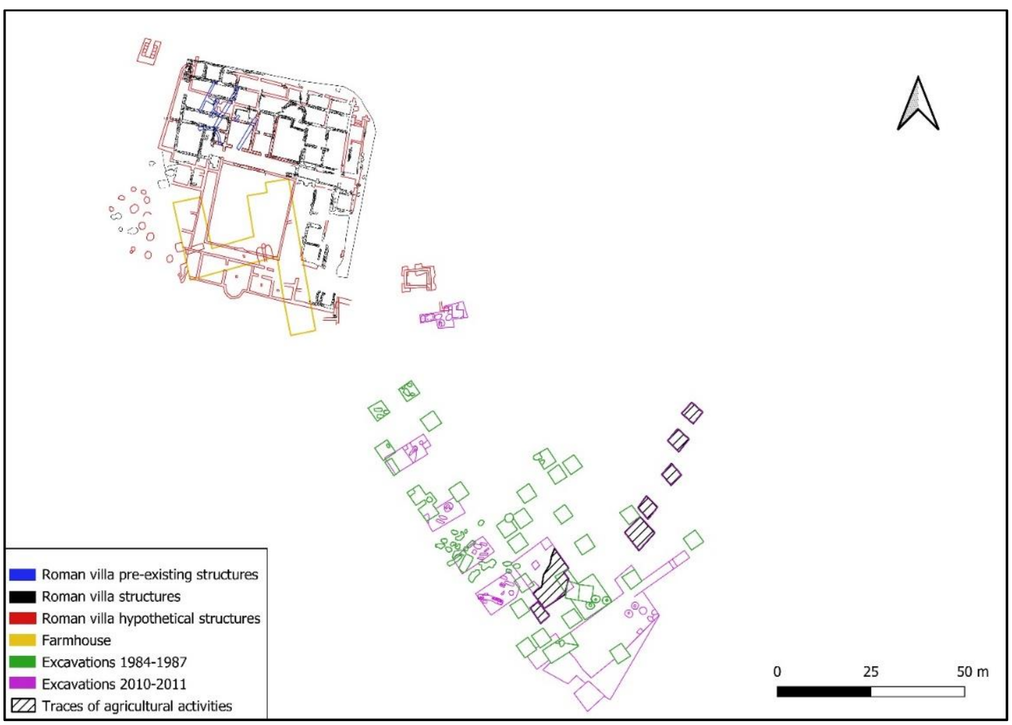


Figure 2. Archaeological map of the villa and its immediate environs in 1:1,000 scale.

While the results of the TLS scanning of 2019 and handheld photogrammetry of 2020 provided information about the site, the aerial photogrammetric survey provided results relating to the wider context of the villa in the landscape. In addition to the abovementioned archaeological map which takes into account other archaeological investigations, the aerial photogrammetric survey mapped the relationship of the villa del Tellaro with its eponymous river. The DEMs generated in QGIS show the gentle slope of the landscape between the villa and the river (Fig. 19). In another, there is a clear distinction between its built upper floor and the ground level below it (Fig. 20).

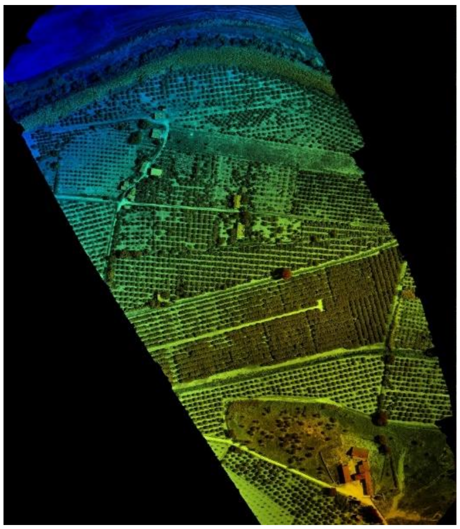


Figure 19. Digital Elevation Model of the Villa and its environs (DEM) up to the Tellaro river.

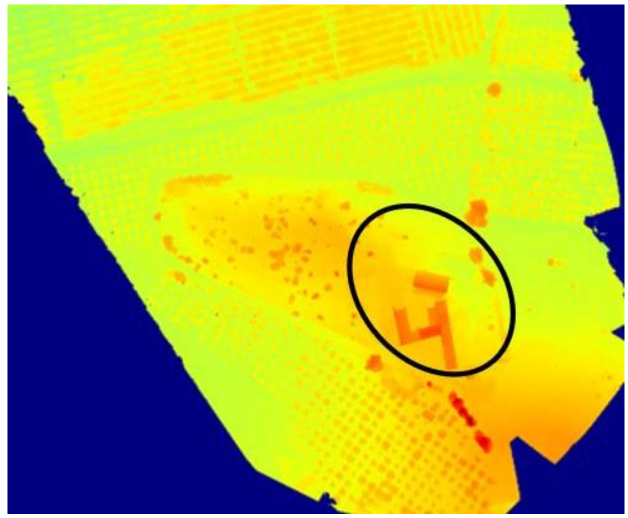


Figure 3. Detail of the sudden change of altitude in the DEM.

3.2 Results of the Geophysical Survey

The results of the GPR survey were of high quality thanks to a series of measures adopted in the acquisition phase, and anomalies related to possible archaeological built features were identified in every area. All of the areas demonstrated good penetration of the electromagnetic signal, reaching a time depth equal to 70 ns for the 600MHz antenna, corresponding to a depth of approximately 3.5 m, considering an average speed of propagation of electromagnetic waves in the subsoil is equal to about 0.1 m / ns. In all of the areas, the data acquired by the 200MHz antenna confirmed the results obtained by the 600MHz antenna and did not detect any further anomalies at a further depth.

Area 1 was divided into two subareas, 1A and 1B (Fig. 21). The survey in Area 1A yielded identified the extent of probable structures of archaeological interest (Figs. 22, 23). Area 1B also showed amplitude slices relating to the 600MHz antenna detected the extent of the probable structures of archaeological interest (interpreted as walls) at depths varying on average from 0.4 m to 1.5 m. (Fig. 24) which are further visible in the amplitude iso-surfaces (Fig. 25).

Area 2 was subdivided into three subsectors (Fig. 26). The amplitude slices of the 600MHz antenna detected probable extensions of walls related to the villa between depths of 0.7 and 2.2m in Area 2A (Fig. 27). The slices relating to depths of 0.7 to 0.9m in particular indicate the likely presence of a pavement with potential walls beneath them, which can be confirmed from the 2D radar sections (Fig. 28). In area 2B, the amplitude slices relating to the 600MHz antenna identify the extent of the probable structures of archaeological interest at depths varying on average from 0.5 m to 0.9 m (Fig. 29). The amplitude iso-surface better show the probably structures of interest (Fig. 30). In Area 2C, the amplitude slices relating to the 600MHz antenna show the extent of the probable structures of archaeological interest indicated with black dotted lines. The depths vary from 0.4 m to 1.2 m (Fig. 31). The iso surfaces of electromagnetic wave amplitude better highlight the probable structures of interest (Fig. 32).

Figure 21. Subdivision of Area 1 into two parts, 1A and 1B.

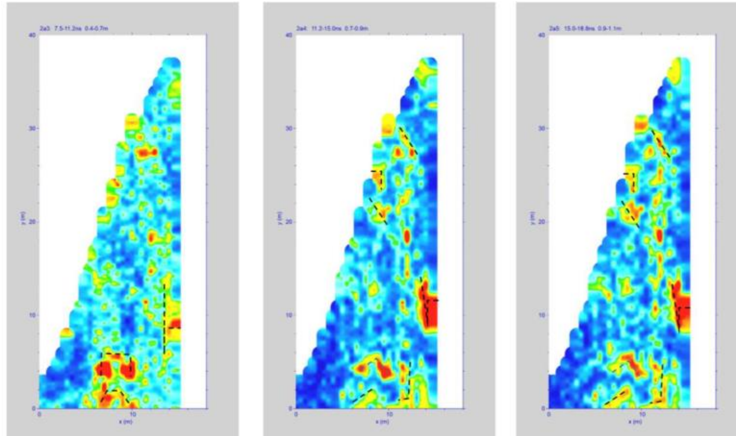


Figure 22. Area 1A time slices. The black dotted lines indicate probable built features.

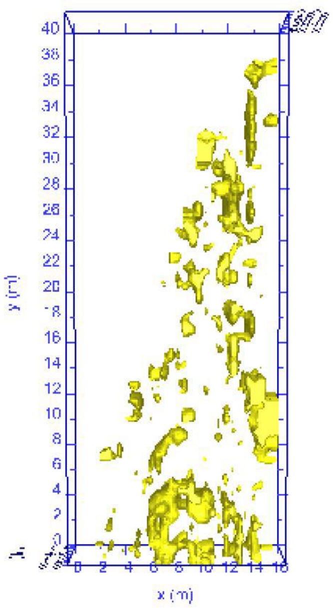


Figure 23. Iso-surface amplitude of Area 1A.

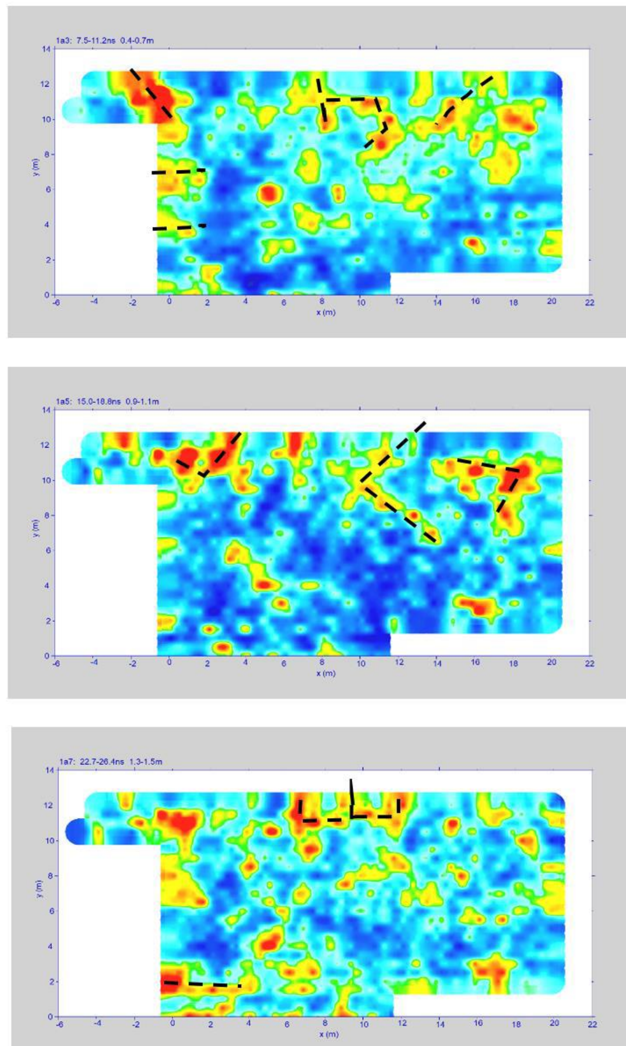


Figure 24. Time slices of Area 1B, black dotted lines indicate probable built features

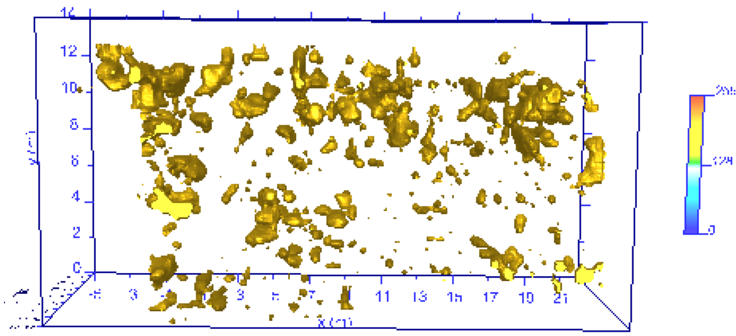


Figure. 25. Iso-surface amplitude of Area 1B.

Figure 26. Area 2 subdivided into three areas, Area 2C, Area 2B and Area 2A.

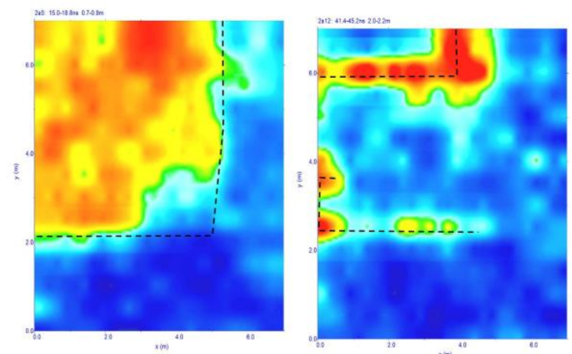


Figure 27. Area 2A time slices. Black dotted lines indicate presence of built features. To the left, possible pavement or destruction layer, to the right, walls below.

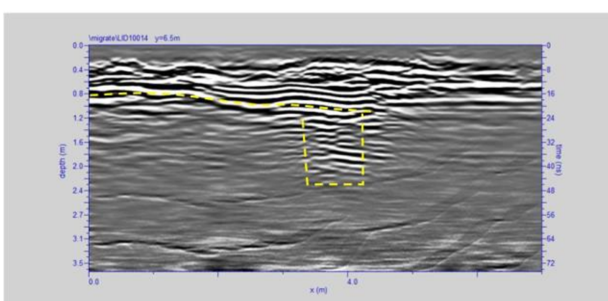


Figure 28. Area 2A, elaborated radar section. Yellow dotted lines indicate anomalies that are likely built features. Likely a wall beneath a pavement of destruction layer.

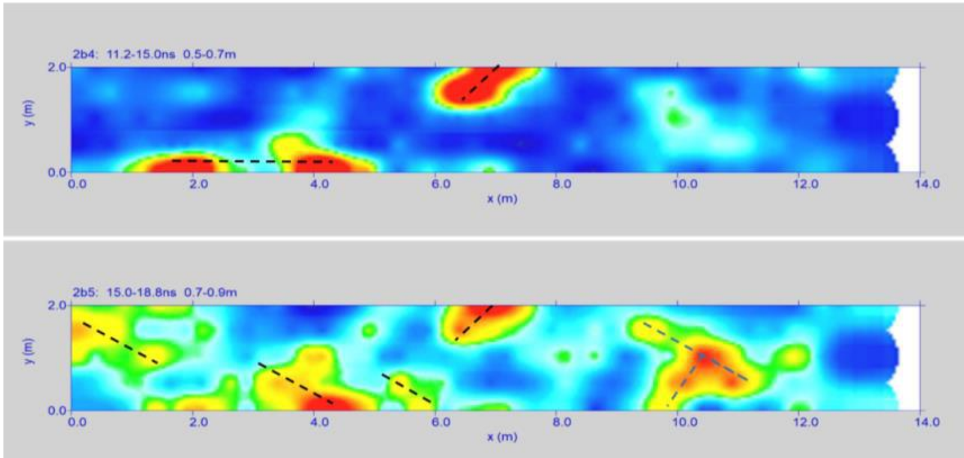


Figure 29. Area 2B time slices. Black dotted lines indicate the likely presence of built features.

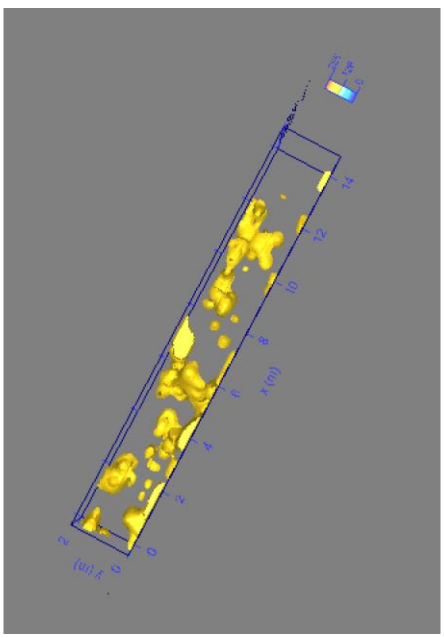


Figure 30. Iso-surface amplitude of Area 2B.

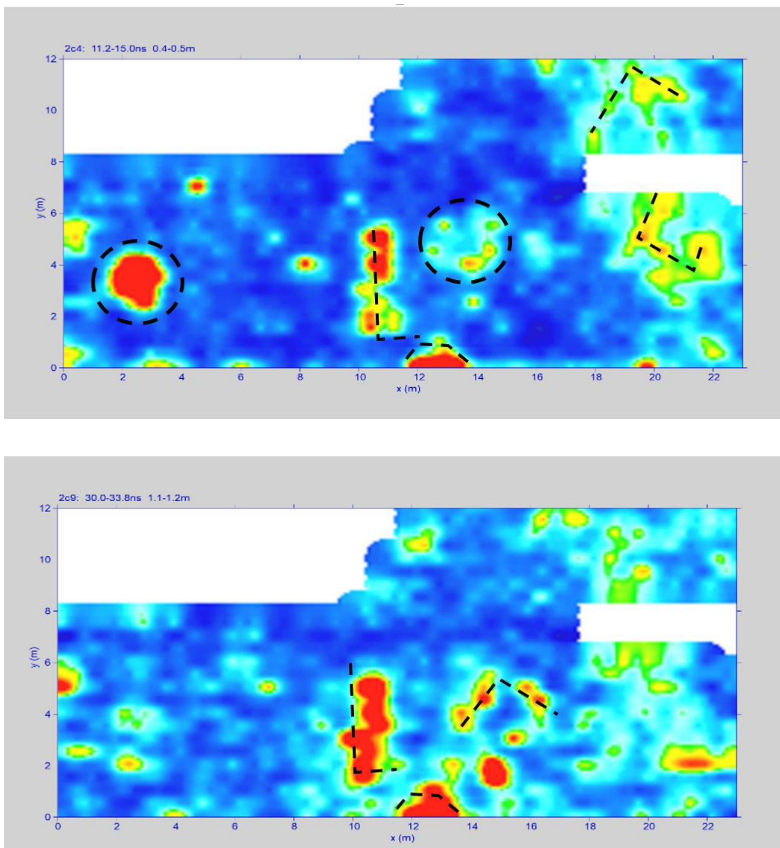


Figure 31. Area 2C time slices. Black dotted lines indicate probably built features. Circular features in particular could indicate kilns.

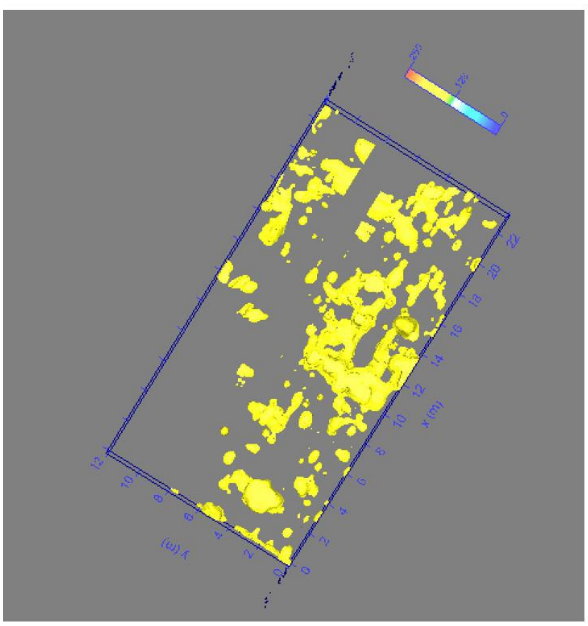


Figure 32. Iso-surface amplitude of Area 2C..

In Area 3 (Fig. 33), the amplitude slices relating to the 600MHz antenna demonstrate the extent of the probable structures of archaeological interest at depths between 0.0 m to 1.6 m (Fig. 34). The iso surfaces of the electromagnetic wave amplitude better highlight the probable structures of interest (Fig. 35). The smaller Area 4 (Fig. 36) show the possible extent of the built features archaeological interest at depths average from 0.3 m to 2.4 m. (Fig. 37).

Figure 33. Aerial photo with indication of the limits of Area 3.

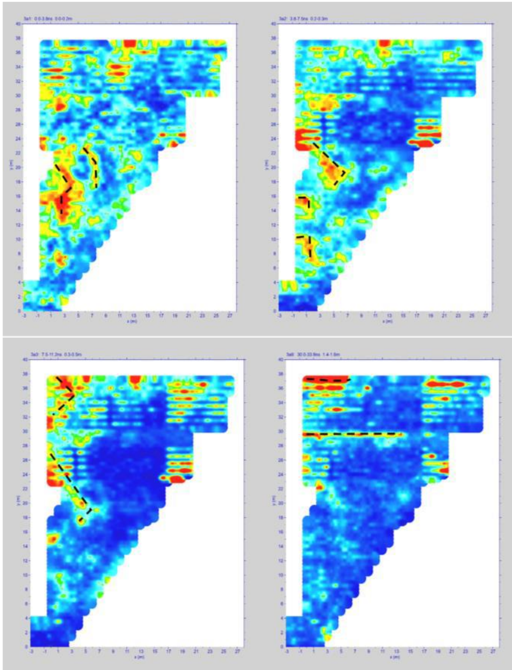


Figure 34. Area 3 time slices. Black dotted lines indicate likely built features.

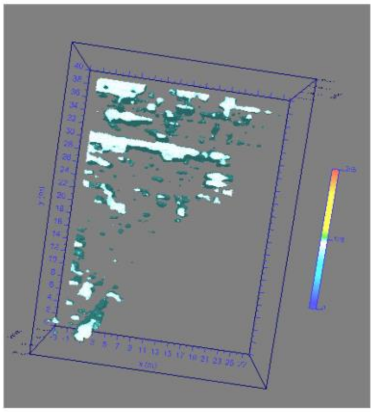


Figure 35. Iso-surface amplitude of Area 3.

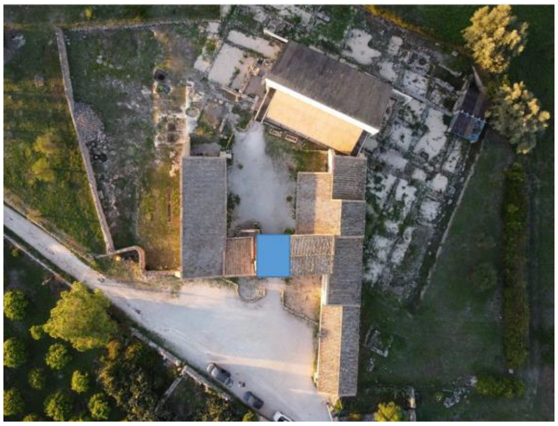


Figure 36. Aerial photograph with indication of Area 4.

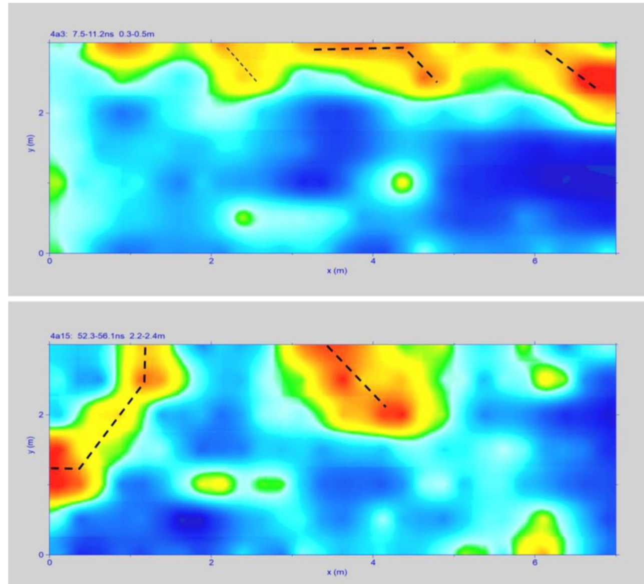


Figure 37. Area 4 time slices. Black dotted lines indicate the presence of probable built features.

In the Area 5 (Fig. 38) the amplitude slices relating to the 600MHz antenna (Fig. 39) show the extent of the probable structures of archaeological interest. The depths of the anomalies vary from 0.1 m to 0.7 m with a particularly interesting anomaly in a dotted black line. The high amplitude anomaly inside a dotted circle could be due to the presence of an old tank. This is evident in a 2D radar section (Fig. 40). The isosurface (Fig. 41) show the distribution 3D of the anomalies in the Area 5.

Finally, all the areas were incorporated together into the drone photogrammetric survey (Fig. 42), creating a sort of virtual excavation of the anomalies detected below the surface of the soil.

Figure 38. Aerial photograph of the villa with Area 5 delimited in blue.

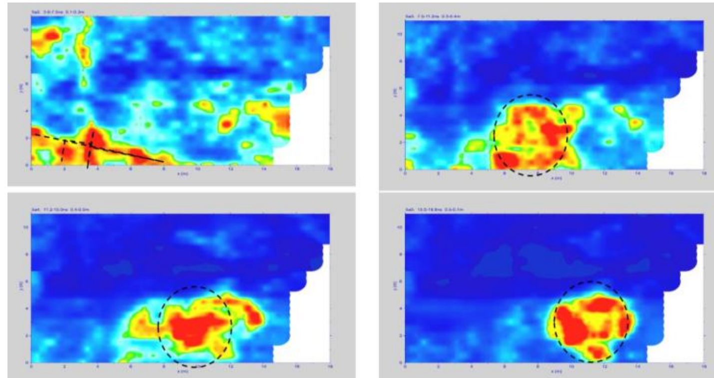


Figure 39 Area 5 time slices. The black dotted lines indicate probable built features.

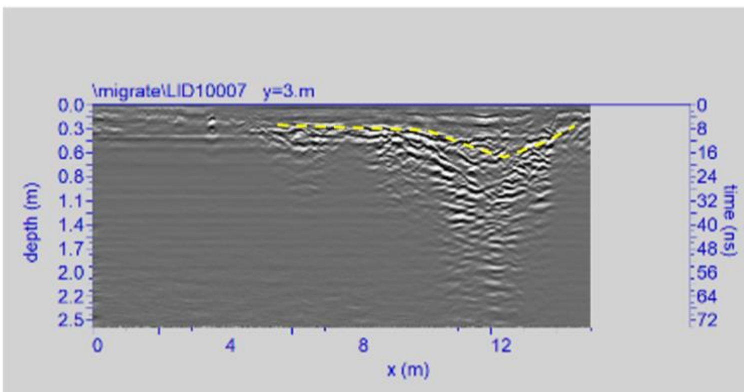


Figure 40. Area 5, processed radar section.

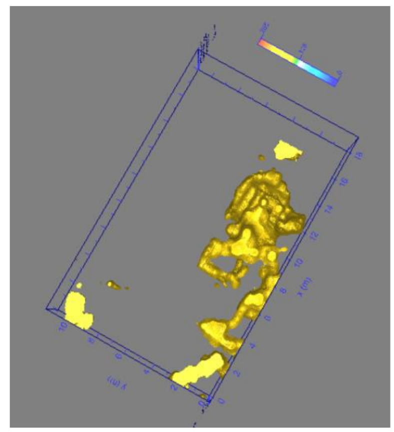


Figure 41 Iso-surface amplitude of Area 5.

Figure 42. Superimposition of iso-surface amplitudes of all areas onto aerial photograph, creating a 3D representation of the anomalies detected in context.

4. Discussion

4.1 3D Mapping Campaign

The generated PPC and site maps from the TLS scanner and photogrammetric campaigns can now be used to as surrogates for the site *in absentia*, plan future investigations, and create new visualizations of the site, whether those be plans, section views, or other spatial configurations used in spatial analysis. While the site is clearly two stories when viewed in person or discussed in the literature, no previous visualizations, apart from a few photographs, exist that would allow a researcher to explore this fact further. On paper, height variations between the lower level of the villa and those areas where mosaics have been found on a potential upper level are not clear. The hypothesis from researchers is that the upper level was traditionally used for the *dominus* and their family while the lower levels were likely for storage and servant or slave quarters (Voza 2008; Wilson 2016; 2018a). Using the VR tool in Faro SCENE or using the 3D data in other VR visualization solutions, this placement of levels and scale of the walls can help to better understand this hypothesis and potential layout of the villa in terms of height.

The addition of a map generated or extracted from the TLS data demonstrates a positive leap in understanding the site's layout. It is worth noting that Faro Scene has an onboard VR viewing tool, so that the point cloud of the villa can be used to explore the villa. This was an especially useful feature, as the fieldwork preceded the Covid-19 pandemic, which made returning to the site, impossible. The ability to create a VR experience from the data has been especially important since the disruption that the pandemic caused to travel, tourism, and the resulting effects on cultural heritage infrastructure. Many scholars have pointed out that the technology exists to allow visitors to visit their museums (or sites, as the case with the Villa of Caddeddi) (Iguman 2020). From a research perspective, the viewing of the point cloud in VR functionality and in 2D allowed for a very up close and personal experience with the mosaic floors and measurements that would be difficult to do in person as visitors to the site can only view the mosaics from a metal walkway that sits several meters from the floors.

Furthermore, the use of the drone allowed a rapid acquisition of data, which were subsequently used for the realization of predictive analyzes, maps and three-dimensional models (Minucci 2018, pp. 91-92), with particular attention to the study of the relationship between the geographical positioning of the Roman villa and the geomorphology of the territory (Minucci 2018). While the villa existed on two levels, there is now quantifiable data that points to the sudden and significant change in altitude between the preserved levels of the villa, located between the current courtyard of the villa and the adjacent area to the north, where it quickly passes from 15m to 11-12m. This sudden change in altitude is not recorded in the other 24 hectares filmed by the drone flight, reinforcing the hypothesis of the existence of a second floor of the villa. The DEM shows that the villa was purposefully built on the highest part of the plateau, about 15 meters above sea level, while the sector immediately to the north and east of it is located on average 3 meters lower. Villas are typically strategically located for both productive and luxurious purposes (Métraux 2018), and no doubt the owner of the villa saw opportunity in the viability of the river nearby, which has its mouth at the port city of Heloros, and the luxury in the views over the gently sloping valley. The data collected and processed for this survey can serve as the seed for investigations on the viability of the area or to perform viewshed analysis from the villa.

Finally, the 3D models generated during this campaign have a lot of applications for public outreach. The final product of the handheld photogrammetry a superior visual impact clearly to other survey techniques and it follows that the finished product could be exploitable for visualizations or to create assets that can be used in virtual environments, including those of gaming (Zięba 2016) or 3D printing. A photorealistic 3D representation of the site, therefore, is no less important for its potential reuse for public consumption.

4.2 Archaeological Interpretation of the GPR Survey

The 3D visualization of results facilitated the interpretation of the anomalies. Area 1A presents evidence of masses of that could be interpreted as walls. Several of these are in line with the villa, and others are set at odd angles. Area 1B also shows potential for walls, though some are at odd angles when compared with the villa.

The western part of the villa was never excavated to the same extent as the northern and easters sectors. This made the GPR carried out in Area 2 particularly exciting. Area 2 was subdivided into three areas to avoid archaeological features and other stone deposits. Area 2A, immediately to the west of one of the farmhouse walls, yielded a mass of an anomaly on the at a depth of 0.7-0.9m continuing downwards until they solidify into features that may be interpreted as walls at a depth of 2.0-2.2m. Area 2B also shows the probability of walls parallel or slightly angled from the villa. Area 2C, to the NW of the other two areas, is located next to two hypothesized kilns (Wilson 2016). Area 2C Particularly interesting are the circular anomalies that could indicate the presence of kilns. Kilns have been particularly important to the study of Late Roman Sicily recently, since stamped tiles have been shown to be able to identify the owner of a villa (Wilson 2014a, 2014b, 2018b, Wilson and Ramsay 2017).

The 0.0-0.2m slices in Area 3, the modern gravel entryway/parking are of the villa showed evidence of probable evidence of excavation activity. Area 5 dashed black circle could be due to the presence of a cistern which, as shown by the 2D radar section could have collapsed. This is another potentially exciting feature, as if it were an ancient cistern, it likely would contain dateable material once it had been abandoned. One of the few analyses of the villa to date has been from a dump of ceramics in an abandoned well (Rizza, 2016).

5. Conclusions

The aim of this remote sensing campaign was to change the status quo of the state of knowledge of the important Roman Villa di Caddeddi. Despite decades of relative abandonment in the academic literature apart from the art historical treatment of its mosaics, it remains an important site. The generation of new site plans, archaeological maps, 3D models of the site and its surrounding landscape, and data concerning anomalies in the subsoil provide the groundwork for further investigations of the villa. Thanks to the TLS and photogrammetric campaign, the site can be viewed in 3D from any internet-connected computer. The highly accurate point clouds allow scholars to interrogate intra-site questions with plans, sections, and other spatial information. These data are also primed to be viewed in stereoscopic 3D. The aerial data, georeferenced and incorporated into a GIS, open the villa to interrogations on a landscape level. The geophysical investigations conducted have also provided important results for future archaeological investigations. The distinct lack of detected anomalies below 2m anywhere in the surveyed areas shows the limits of the possibility of certain preexisting structures. Either preexisting structures were incorporated into the villa itself, were completely removed by the construction or the villa, or were simply absent in this part of the landscape. The identification of possible kiln sites, which have become an important theme in other investigations of Late Roman and Late Antique villas in Sicily, provide a hope that there are still stratified deposits under the excavated areas in Area 2, possibly containing stamped tiles that have provided so much data at other sites, such as the Roman villa of Gerace. Area 5 was found to likely contain a cistern, which, provided it is indeed ancient, would likely be the source of more important stratified deposits relating to the villa.

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