Low-cost GPS/GNSS Real Time Kinematic receiver to build a cartographic grid on the ground for an archaeological survey at Piscina Torta (Italy)

Alessandri, Luca; Baiocchi, Valerio; Monti, F.; Cusimano, Luca ; Fiorillo, Angelica; Gianni, Virginia; Rossi, Caterina; Attema, Peter; Rolfo, Mario Federico

Published in:
ACTA IMEKO

Publication date:
2023

ACTA IMEKO
ISSN: 2221-870X
December 2023, Volume 12, Number 4, 1 - 6

Low-cost GPS/GNSS Real Time Kinematic receiver to build a cartographic grid on the ground for an archaeological survey at Piscina Torta (Italy)

Luca Alessandri[1,2], Valerio Baiocchi[3], Felicia Monti[3], Luca Cusimano[4], Angelica Fiorillo[4], Virginia Gianni[4], Caterina Rossi[4], Peter A. J. Attema[1], Mario Federico Rolfo[4]

[1] *University of Groningen, GIA, Poststraat 6, 9712 ER, Groningen, Netherlands*
[2] *Sapienza University of Rome, Department of Science of Antiquities, P.le Aldo Moro, 5 00161, Rome ,Italy*
[3] *Sapienza University of Rome, Department of Civil, Constructional and Environmental Engineeering (DICEA), Via Eudossiana, 18, 00184, Rome, Italy*
[4] *University of Tor Vergata, Department of History, Culture and Society, Via Columbia 1, 00133, Roma, Italy*

ABSTRACT
The collection of samples and finds for archaeological surveys is traditionally based on the establishment of grids that allow the area under study to be discretized into generally square cells in order to allow a statistical assessment of the highest or lowest concentration of finds. Currently, such grids are implemented in a local coordinate system established by means of total stations or tape measures. We validated the capabilities of a low-cost GPS/GNSS Real Time Kinematic (RTK) receiver to build a grid during the intensive archaeological survey of the Piscina Torta site (Italy), in the framework of the Salt and Power project of the University of Groningen. We also tested not using a local grid but a cartographic grid (WGS84 UTM zone 33 N) and naming the single cells with the coordinates of one of its vertices. This approach is greatly facilitated by the recent availability of inexpensive RTK receivers with few centimetres accuracy, very small in size and weight and with hardware protected enough to be used in the field. This would facilitate the use and exchange of the data (e.g. about the materials collected in the cell) among the scientific community and can be thought of as a proposal for standardization.

Section: RESEARCH PAPER

Keywords: Piscina Torta; Ostia; Iron Age; GNSS; GPS; Rome

Citation: Thomas Bruns, Dirk Röske, Paul P. L. Regtien, Francisco Alegria , Template for an Acta IMEKO paper, Acta IMEKO, vol. A, no. B, article C, Month Year, identifier: IMEKO-ACTA-A (Year)-B-C

Section Editor: Section Editor

Received January 1, 2021; **In final form** January 31, 2021; **Published** March 2021

Funding: The work was supported by The Netherlands Organization for Scientific Research (NWO Free Competition grant 406.20.HW.013).

Corresponding author: Luca Alessandri, e-mail: luca.alessandri@uniroma1.it

1. INTRODUCTION

The site of Piscina Torta under study is in central Italy, very close to the shore of the Tyrrhenian Sea in the territory of the municipality of the city of Rome, south-east of Ostia. Here, in 1984, G. Pisani Sartorio and S. Quilici Gigli [1] found a huge amount of Iron Age potsherds scattered on a surface of about 14 ha, inside the Natural Park of the Pineta di Castel Fusano (Figure 1 and Figure 2). The potsherds, which can be dated to the VII and VI centuries BCE, all belonged to reddish jars and dolia (large storage containers). These types of vessels are usually associated with some specialised activities like fish processing (sauce, conservation) and/or salt production, possibly by means of the briquetage technique. The latter is a widespread technique all over Europe [2]-[4] and consists in boiling brine in a ceramic container (the reddish jars) until the salt (NaCl) precipitates due to evaporation. To extract the salt cake, it is necessary to break the vessel: this would explain the huge amount of potsherds in those specialised sites [5]-[7].

Before the archaeological excavation, we decided to perform a series of non-invasive surveys: magnetometry, laser scanning LiDAR, and surface potsherd collection [8]. When dealing with sites of considerable extent, the implementation of comprehensive non-invasive surveys serves the purpose of

Figure 1. The site of Piscina Torta and the new joined GNSS network of Abruzzo and Lazio Regions (From Regione Abruzzo, modified).

mapping anomalies, whether they manifest magnetometrically, altimetrically, or in terms of surface ceramic density. Once these anomalies are categorized, a select number of controlled excavation tests are conducted to aid in their interpretation. This methodology allows for a holistic characterization of the site, including its settlement patterns and structures. The purpose of this contribution is to introduce a novel approach for data collection during intensive surveys aimed at mapping surface ceramic density.

To realise density charts, surface potsherds must be collected with a gridded approach. Unlike the common procedure in archaeology, we used a grid based on absolute coordinates, instead of local coordinates. The advantages of reporting absolute geographic positions of archaeological surveys have already been demonstrated in the literature in the case of underground and urban areas [9]-[14]. We will also show how the entire data collection procedure can be done paperless with open access and free software, a procedure which has also been adopted in other survey campaigns, like the Roca Archaeological Survey.

2. METHODS

2.1. The grid

So far 1.8 ha of the total area was surveyed using the grid system (Figure 2) as areas where visibility conditions were low to zero had to be excluded. We chose to use a 5 × 5 m² grid. The measure is a compromise between the minimum estimated size of the ancient features we expected to find (kilns, huts, dumps, pits) and available time and workforce. Moreover, the numerous post-depositional taphonomic phenomena that are expected in scenarios such as this render the application of finer grids ineffective. The grid was planned using QGIS (open source software) ver. 3.22 and framed along the UTM 33 North grid based on WGS84 geodetic datum (ID: 32633 in EPSG Dataset). At first, the grid was materialised on the ground in a very small area (80 × 80 m²) using a geodetic Geomax Zenith 10 double frequency GPS-Glonass receiver.

Master stakes were placed in the ground every 20 m and intermediate stakes were placed using a measuring tape.

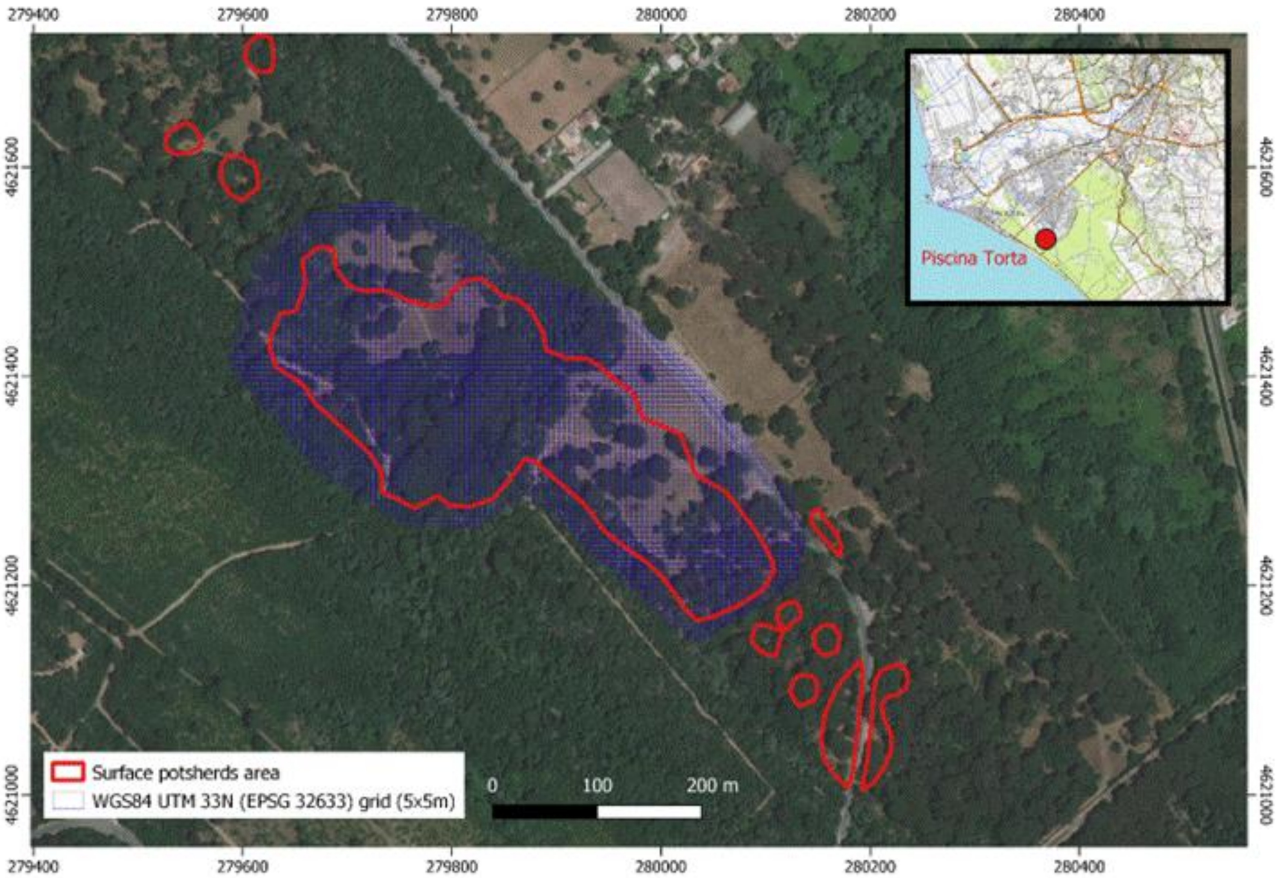

Figure 2. The WGS84 (EPSG 32633) grid on Piscina Torta site. Potsherd area from Pisani Sartorio and Quilici Gigli, 1984

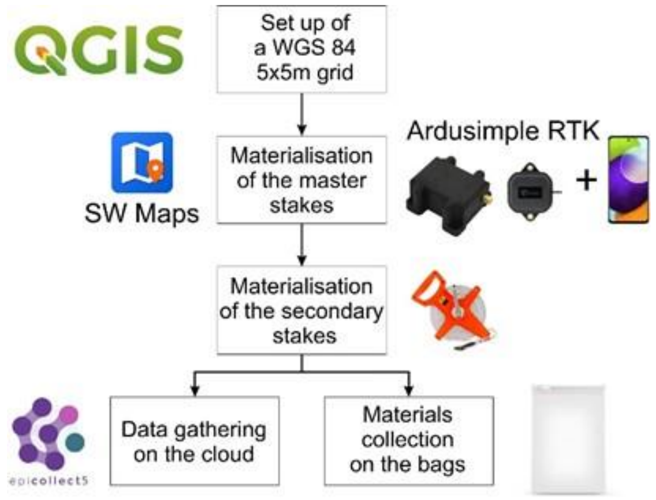

Figure 3. Survey operational flowchart: software and hardware.

However, soon we opted for a more accurate and quicker method better suited to the current state of technology in geomatics surveying. New devices, increasingly smaller in size and often contained in or connected to smartphones, with technical capabilities until a few years ago only accessible to geomatic experts, are now much more accessible both economically and in terms of ease of use. Such new devices are facilitating photogrammetric acquisition in the archaeological field [9]-[11] but also high-precision differential GNSS surveys [12]-[14].

For this reason, after the initial phase, we tested the relatively new Ardusimple RTK Portable Bluetooth Kit [15] to put the master stakes on the ground (Figure 3). The Ardusimple is a multi-constellation (GPS, GLONASS, Galileo, QZSS and Beidou capable) and multifrequency (L1, L2 and E5b support as example of GPS and Galileo signals) device which has to be coupled with a smartphone (in this case we used a Samsung Galaxy A52). The free GIS and mobile mapping app SW Maps 2.9.0.3 was installed on the smartphone to process the Real Time Kinematic (RTK) correction. We used the network of permanent stations operated by the Lazio region as a reference. So, in actual fact the correction we used was an NRTK, i.e. based on the data of several permanent stations of the regional network in Virtual Reference Station (VRS) mode; these data are then transmitted to the receiver using the well-known RTK protocol.

Starting from August 2022 the network has, however, been merged with the network of the neighbouring Abruzzo Region [16] giving rise to one of the largest public positioning networks in Europe (Figure 1).

For the sake of completeness, we would like to point out that the process of merging the two networks is not yet fully completed, so that as of today (August 2023) half of the permanent stations in the Lazio region's network are still undergoing maintenance [16]. For this reason, it has recently been observed (following the surveys that are the subject of this experimentation) that the most reliable correction mode in the area under study is currently the "nearest", which uses only the observations of the nearest permanent station (FIUM). In this case, although one connects to a network of permanent stations, actually only one is used at a time and therefore, strictly speaking, one cannot speak of NRTK correction but of simple RTK correction. This last consideration is obviously only valid until the process of merging the two networks is complete.

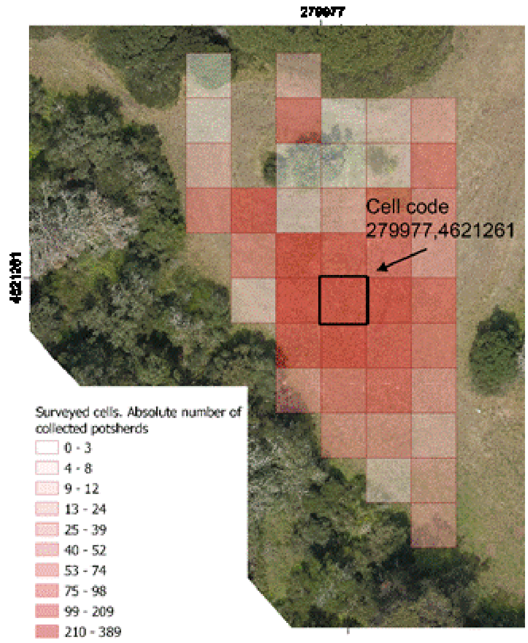

Figure 4. Cell code assignment procedure.

2.2. The data collection

We assigned a single code composed of its coordinates to the NE corner of every single cell (Figure 4). For each cell, information was recorded, such as total number of finds and, importantly, ground visibility. The latter variable is one of the most important biases affecting the interpretation of results from artefact collection as it determines the probability of detecting surface material. For the same number of potsherds on the ground greater visibility results in more pieces being collected. To overcome this problem, it is necessary to collect, for each grid cell, the parameters that affect the degree of visibility, usually on a scale of 1 to 5: the amount of vegetation, the number of stones, the percentage of the ground in shade, and soil condition (ploughed or not). The number of potsherds collected is then calibrated according to those parameters, using different algorithms [17], [18], [19]. To collect these data, we used a free mobile app that was installed on the smartphones of all participants: Epicollect 5 (E5). E5 is a mobile data-gathering platform in the cloud which turned out to be easily customizable to project needs and very easy to use (Figure 5). During the survey, 40 % or 80 % of the surface potsherds were collected from each unit and put in plastic bags. The code of the plastic bag is the code of the cell from which the potsherds come (Figure 6).

3. RESULTS OF THE COMPARISON

The differences between the measurements (Geomax and ArduSimple) range from 68.5 cm (at E279992, N4621281) to 1.2 cm (at E279992, N4621266).

The 68.5 cm difference was observed in a place partially hidden by a tree, so it can be due to a multipath effect. The 1.2 cm difference was observed in an open area. Both the setup of the GPS RTK receiver and the setup of the SW Maps were fast and easy to perform even for non-skilled people.

It was then decided to check how the grid materialised from the stakes at the vertices and subsequently infilled using the measurement tape could be consistent with the corresponding

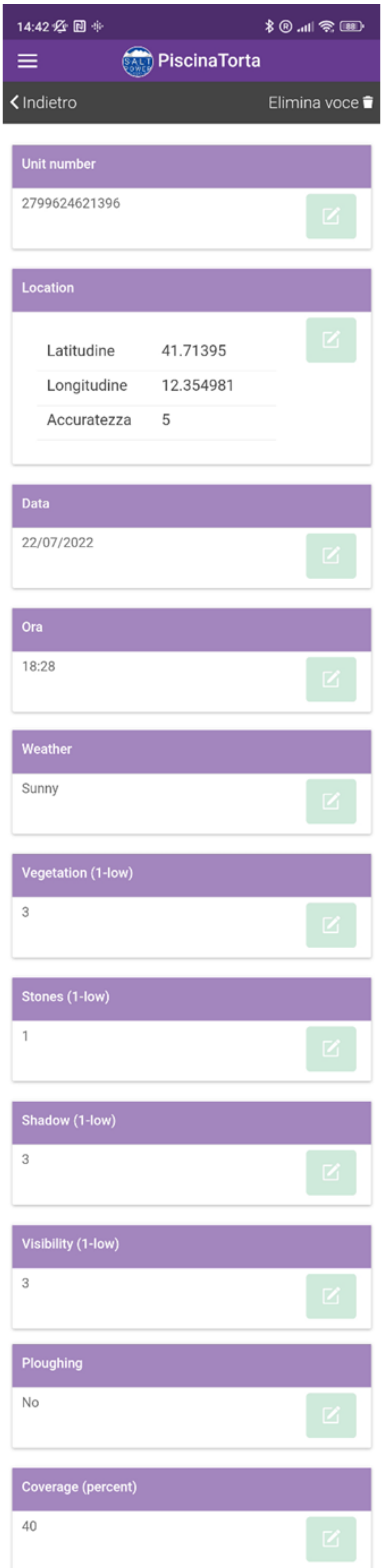

Figure 5. Screenshot of the Epicollect 5 interface on the A52 smartphone, tailored to the project needs

positions in integer values of the UTM grid. To this end, each vertex of the materialised grid was measured with the geodetic Geomax GNSS receiver. The deviations (Figure 7) are always very small in a range of a few centimetres (the scale of the vectors is 200 times the scale of the map).

The greatest deviation that we can see in the second figure (Figure 8) is probably due to issue in carrier phase ambiguities integer fixing in areas where the signals were disturbed by the vegetation coverage.

Vegetation cover from trees or scrub is actually the biggest problem we encountered in the development of this experiment: vegetation cover in fact creates, as is well known, considerable disturbance to GPS-GNSS measurements. Disturbance by vegetation cover, in fact, creates problems by simply obstructing areas of the sky by reducing observable satellites, but this problem is even greater where leaves, due to the action of even a small breeze, have cyclic movements that constantly interrupt the contact between satellite and receiver, introducing 'cycle slips' and requiring the calculation algorithms to continually re-estimate the initial phase ambiguity (N) to the detriment of reliability, accuracy and initialisation times. In the present experiment, it was to be expected that the worst results would be obtained where the vegetation cover was greatest, but we wanted to test uniformly over the entire grid precisely to assess how much the accuracy deteriorated. In actual fact, one of the strengths of the proposed procedure is that it is not necessary to survey all the grid nodes with GPS-GNSS (which is in any case advisable in the case of an open area without obstructions because it is the fastest and most accurate method) but only a few and then materialise the others with the classic metric tape. In this case, it is suggested to survey at least three of them (two for the correct orientation and scaling of the grid and one for verification), choosing points that are fairly uncovered and possibly far apart from each other because taking just a few points in one area of the grid could lead to appreciable deformations in the grid meshes further away from the measured points.

4. DISCUSSION

Prior to the availability on the market of low-cost GNSS-RTK receivers, the grids supporting the archaeological surveys were laid out in the field using traditional instruments as total stations. To georeference the grid only a few stakes would be measured (usually surveying geographical/mapping coordinates of at least two corners and one reference elevation of a benchmark, used as origin of levelling measurements). An expensive differential GPS-GNSS receiver and trained people were needed. The alternative was to use the smartphone built-in standalone GPS-GNSS capabilities with a variable planimetric accuracy from 5 to 20 m precision and 1.5 times worse for the heights. This usually resulted in quite imprecise localization of the grids, preventing the relocation of surveyed cells on the ground again for resurvey or follow-up (invasive) research. The availability of very intuitive GNSS-RTK receivers with potential few centimetres plano-altimetric accuracy now opens up the possibility to record cells very precisely and pinpoint locations for follow-up research in later campaigns.

The grid can be planned in advance and based on the corresponding standard or national grid or preferably the WGS84 worldwide datum and its realizations. During the survey, the potsherd bags from each cell are named with a code. The latter is traditionally a consecutive number which is also the name

Figure 6. The master and intermediate stakes placed on the ground in one area of the site. We used to place the empty corresponding bags on the NE corner of the cell. In this way the "walkers" could immediately know the cell code. Further, the lack of the bag indicated that the cell had already been surveyed (and the corresponding bag filled with the collected potsherds).

of the cell. Alternatively, using the coordinates of the NE corner of each cell as the name of the bag (like for example 279977,4621261; Figure 3) would make the content of every single bag "georeferenced" even if the corresponding maps are lost. Further, the use of a cloud-based app like Epicollect5 allows us to conduct a completely paperless survey.

5. CONCLUSIONS

The adoption of a UTM grid based on the geodetic datum WGS84 (RDN2008: EPSG 32633) was only possible due to the availability of a low-cost RTK device with few centimetres accuracy comparable to traditional and more expensive devices. Indeed, the implementation of high resolution positioned grid carries many advantages:

1) The accurate and absolute georeferencing allows comparing results with other georeferenced spatial maps such as land use maps, geological maps etc;

2) Several permanent stations with known coordinates are essential for the maintenance of the grid over time. When working in local coordinates, the team leader should create and maintain these permanent stations over time. This implies a significant risk of losing data in the near future. In an international framework, such as WGS84, they are maintained by state mapping agencies. This implies extreme accuracy, precision and a very long life expectancy;

3) Knowing only the unit extension and the coordinate reference system, everyone can place the unit in the right position. This makes the preparation and conservation of printed maps, which can be lost, useless.

Besides, the use of a cloud-based app like E5 and the paperless approach has some other clear advantages:

- Limiting paper waste;
- The collected data are immediately digitalised and stored in a safe place in the cloud. Afterwards, data are ready to be downloaded and imported into a local database like the open-source PostgreSQL;
- People with manager rights can see and check in real time the work progress as data are continuously synchronised.

Figure 7. The first test site in an open area.

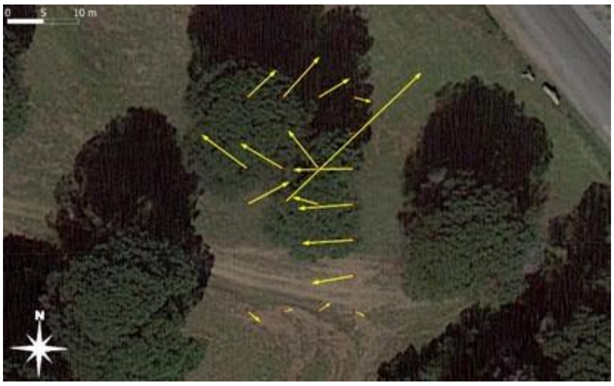

Figure 8. Second first test site where three canopy is heavier.

However, alongside these positive points, it's important to remember a problem that affects all digital data: preservation. Digital documents are more delicate compared to most physical ones. Adding to this, we don't yet know how long the storage devices they rely on will last. This means that if we solely rely on digital formats for our data, there's a risk that the storage method or the technology used might become outdated, making the database impossible to access at some point in the future.

The matter of digital document preservation falls beyond the scope of this contribution; nevertheless, it is imperative to bear in mind that the periodic migration of the database onto fresh storage devices, coupled with their re-encoding, form indispensable procedures for ensuring their enduring preservation.

REFERENCES

[1] G. Pisani Sartorio, S. Quilici Gigli, Trovamenti arcaici nel territorio laurentino: annotazioni di topografia e prospettive di ricerca - Archaic finds in the Laurentian territory: notes on topography and research perspectives, Bullettino della Commissione Archeologica Comunale di Roma 89 (1984), pp. 9–26. [In Italian]

[2] A. Harding, Salt: White Gold in Early Europe, Elements in the Archaeology of Europe. Cambridge University Press, Cambridge, 2021.
DOI: 10.1017/9781009038973

[3] A. Harding, Salt in Prehistoric Europe, Sidestone, Leiden, 2013.

[4] O. Weller, R. Brigand (Eds.), Archaeology of Salt: approaching an invisible past, 2015

[5] L. Alessandri, K. F. Achino, P. A. J. Attema, M. de Novaes Nascimento, M. Gatta, M. F. Rolfo, J. Sevink, G. Sottili, W. van Gorp, Salt or fish (or salted fish)? The Bronze Age specialised sites along the Tyrrhenian coast of Central Italy: New insights from Caprolace settlement. PLOS ONE 14 (2019).
DOI: 10.1371/journal.pone.0224435

[6] L. Alessandri, P. Attema, Dal briquetage alle saline nella protostoria dell'Italia centrale. IpoTESI di Preistoria 14 (2022), pp. 161–168. [In Italian]
DOI: 10.6092/issn.1974-7985/14338

[7] J. Sevink, W. De Neef, L. Alessandri, R. van Hall, B. Ullrich, P. A. J. Attema, Protohistoric briquetage at Puntone (Tuscany, Italy): principles and processes of an industry, based on the leaching of saline lagoonal sediments, Geoarchaeology, vol. 36, issue 1, January/February 2021, pp. 54-71.
DOI: 10.1002/gea.21820

[8] L. Alessandri, V. Baiocchi, F. Monti, Intensive archaeological survey at Piscina Torta: use of a low-cost RTK portable kit to materialise a UTM grid on the ground, IMEKO TC4 Int. Conf. on Metrology for Archaeology and Cultural Heritage University of Calabria, Consenca, Italy, 19-21 October 2022, pp. 181-185.
DOI: 10.21014/tc4-ARC-2022.035

[9] L. Alessandri, V. Baiocchi, S. Del Pizzo, M. F. Rolfo, S. Troisi, Photogrammetric survey with fisheye lens for the characterization of the La Sassa cave. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2-W9-25-2019 (2019).
DOI: 10.5194/isprs-archives-XLII-2-W9-25-2019

[10] V. Baiocchi, S. Del Pizzo, F. Monti, G. Pugliano, M. Onori, U. Robustelli, S. Troisi, F. Vatore, F. J. León Trujillo, Solutions and limitations of the geomatic survey of an archaeological site in hard to access areas with a latest generation smartphone: the example of the Intihuatana stone in Machu Picchu (Peru), Acta IMEKO, vol. 11, no. 1, article 20, March 2022, 8 pp.
DOI: 10.21014/acta_imeko.v11i1.1117

[11] A. Masiero, F. Fissore, M. Piragnolo, A. Guarnieri, F. Pirotti, A. Vettore, Initial evaluation of 3d reconstruction of close objects with smartphone stereo vision, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-1 (2018) 289–293.
DOI: 10.5194/isprs-archives-XLII-1-289-2018

[12] U. Robustelli, V. Baiocchi, L. Marconi, F. Radicioni, G. Pugliano, Precise Point Positioning with single and dual-frequency multiGNSS Android smartphones, CEUR Workshop Proc., Tampere, Finland, 2-4 June 2020, vol. 2626. Online [Accessed 24 April 2023]
https://ceur-ws.org/Vol-2626/paper10.pdf

[13] P. Dabove, V. Di Pietra, Single-baseline RTK positioning using dual-frequency GNSS receivers inside smartphones, Sensors 19, 2019, 4302.
DOI: 10.3390/s19194302

[14] U. Robustelli, V. Baiocchi, G. Pugliano, Assessment of dual frequency GNSS observations from a Xiaomi Mi 8 Android Smartphone and Positioning Performance Analysis, Electronics 8, 2019, 91.
DOI: 10.3390/electronics8010091

[15] Ardusimple.com, RTK Portable Bluetooth Kit. Online [Accessed 24 April 2023]
https://www.ardusimple.com/product/simplertk2blite-bt-case-kit/

[16] Regione.Abruzzo.it, GNSS Train station Abruzzo region. Online [Accessed 24 April 2023]
http://gnssnet.regione.abruzzo.it/indexvisual.php?type=2

[17] P. Attema, A guide to good practice in Mediterranean surface survey projects, JGA, vol. 5, Jan. 2020, pp. 1-62.
DOI: 10.32028/9781789697926-2

[18] T. C. A. de Haas, Fields, Farms and Colonists: Intensive Field Survey and Early Roman Colonization in the Pontine Region, Central Italy (2 vols.). Groningen archaeological studies, 15. Eelde; Groningen: Barkhuis; Groningen University Library, 2011. xi, 487. ISBN 9789077922934.

[19] Iacono, F., Spagnolo, V., De Neef, W., Coluccia, L., 2020. Roca Archaeological Survey: Inquadramento e primissimi risultati. FOLD&R - Archaeological Survey Series, 2020.13. [In Italian]