

From the Sky to the Ground: A Spatial Approach to the Archaeological Research in the Srem Region (Serbia), the Case Study of Pusta Dreispitz site

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The “From *Aquileia* to *Singidunum*: reconstructing the paths of the Roman travellers – RecRoad” project was developed at Université Bordeaux, Montaigne in collaboration with the Sremska Mitrovica Institute for Protection of Cultural Monuments. Its main goal was to detect and map the Roman thoroughfare connecting the Roman cities of *Aquileia* (Aquileia, Italy) and *Singidunum* (Belgrade, Serbia) using different sources and methods, including Sentinel-2 multispectral images, historical maps and surface survey results. This paper focuses on the methodologies applied to identify buried archaeological features and on the results obtained combining data coming from different kind of sources in the Pusta Dreispitz site (Vojvodina, Serbia): in this area, a multi-layered archaeological site was identified through remote sensing analysis, while its chronological framing was determined thanks the surface surveys on the ground. The pottery fragments collected show a time-span going from proto-history to the Roman period as well as recent findings from the 18-19th centuries, confirming once more the necessity of integrating remote-sensing and digital techniques with field research and verification.

The project provides a first useful test-bed for Sentinel-2A images in archaeology for detecting the presence of buried archaeological sites and remains of Roman roads, with remarkable results in the Srem district (Serbia). The research workflow integrates remote sensing analysis with the interpretation of historical maps, namely the Josephinische Landesaufnahme (1763–1787), the Franziszeische Landesaufnahme (1808–1869), the Franzisco-Josephinische Landesaufnahme (1869–1887) and the Spezialkarte der Osterreichisch-Ungarischen Monarchie (1877–1914). The historical maps are geo-referenced and overlain on the satellite images within a GIS platform to interpret the anomalies detected in the Sentinel-2A images. Finally, a surface survey is performed to check the actual presence of the Roman road traces and of other buried sites.

Key words:

Remote sensing, Sentinel-2 images, Austro-Hungarian maps, GIS, Serbia.

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INTRODUCTION

The site of Pusta Dreispitz is located in the Serbian region of Vojvodina and is an interesting study case showing the possible results of a research aimed at identifying buried archaeological features from a combination of remotely sensed datasets. The findings presented here were obtained by integrating information from the analysis of different kind of satellite images, from the geo-referencing of four historical maps from the eighteenth to the twentieth centuries and from the archive and published materials of the Sremska Mitrovica Institute for the Protection of Cultural Monuments and of the Archaeological Museum of Zagreb. All this information was compared with the data

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collected during a surface survey, in conformity with the methodology developed for the RecRoad Project of which this study is an integral part.

Indeed, similar results were also obtained on other sites in the Srem region, but, in the case of Pusta Dreispitz, the general shape and layout of the buried structures were well readable from the satellite images. These circumstances were explained during the surface and the analysis of the archaeological materials collected, showing that the site had probably undergone several occupational phases, spanning from Proto-history to the Roman period, as well as 18-19th century phase. The Roman phase had already been attested by Brunšmid at the beginning of the 20th century [Brunšmid 1900:198]. The presence of a modern phase can explain the clarity of the correspondent crop-marks, since the remains of this latter phase will probably be located closer to the surface, with clearer evidence in the images.

It is, at the moment, impossible to better evaluate the importance of this site, since no archaeological excavation has been performed in the specific area, but this case study assesses once more two important methodological statements: first, remote sensing analysis can be very helpful in the perspective of preventive archaeology, in the identification of “sensitive” areas that might be further investigated in a successive time. The second is a strong reminder of the importance of the connection between remote sensing, and spatial techniques broadly speaking, with the research on the terrain aimed to verify the data, thus correctly interpreting the findings.

Geographic and historical framing

The Pusta Dreispitz site is located in the Srem District, one of the seven administrative districts of the autonomous province of Vojvodina. Srem or Syrmia is the western part of the province and it derives its name from the ancient city of *Sirmium*, founded on the site where the modern city of Sremska Mitrovica stands. Vojvodina is bounded by three rivers: the Drava to the north, the Danube to the east, and the Sava to the south. It is part of the Pannonian Plain, a very fertile region, where cereals are the main crop (about 70%) [Mihailović et al. 2014]. In the northern part of the Srem district, the mountain Fruška Gora is part of a National Park that includes 35 orthodox monasteries. The region, inhabited by the Illyrians, was conquered by the Romans at the end of the first century BC. The fortress of *Sirmium* was built beside the Sava and played an important part in the Great Illyrian Revolt in AD 6–9. When Pannonia was finally conquered, *Sirmium* became the area’s economic capital, largely because of its strategic position. In AD 293, with the constitution of the Tetrarchy, *Sirmium* became one of the four capitals of the Empire.

The Roman province of *Pannonia* was a region of great strategic and commercial importance. It connected Italy and the *limes* of the Empire along the River Danube. The region is crossed by some of Europe’s main waterways, which affected the layout of the Roman road network. The city of *Aquileia*, in the Augustan *X Regio*, was central to the eastward spread of Roman culture and counted among the Empire’s main ports and crossroads [Zaccaria 1994]. Burghardt [1979:4-5] reminds us that *Pannonia* had no proper cities before the Roman occupation, nor any real road network. Indeed, the network was designed primarily in response to the external needs of Rome as the political capital of the Empire [Burghardt 1979:7–12].

Sources indicate two land routes linking *Aquileia* to the Danube and, specifically, to the city of *Singidunum* (where Belgrade now stands): one ran beside the river Drava and the other beside the river Sava. Both the *Itinerarium Antonini* (*It. Ant.* 128.6-132.1) and the *Itinerarium Burdigalense* (*It. Burd.* 559.11-563.14) mention the Drava itinerary, passing *Poetovio* and *Celeia*. A third source, the *Tabula Peutingeriana*, provides information about the river Sava itinerary (Fig. 1). This unique document shows the main stages of the route from *Aquileia* to *Singidunum*, passing through *Nevidunum*, *Siscia*, and *Marsonia*, the main cities on the course of the Sava [Zanni 2017:150–152].

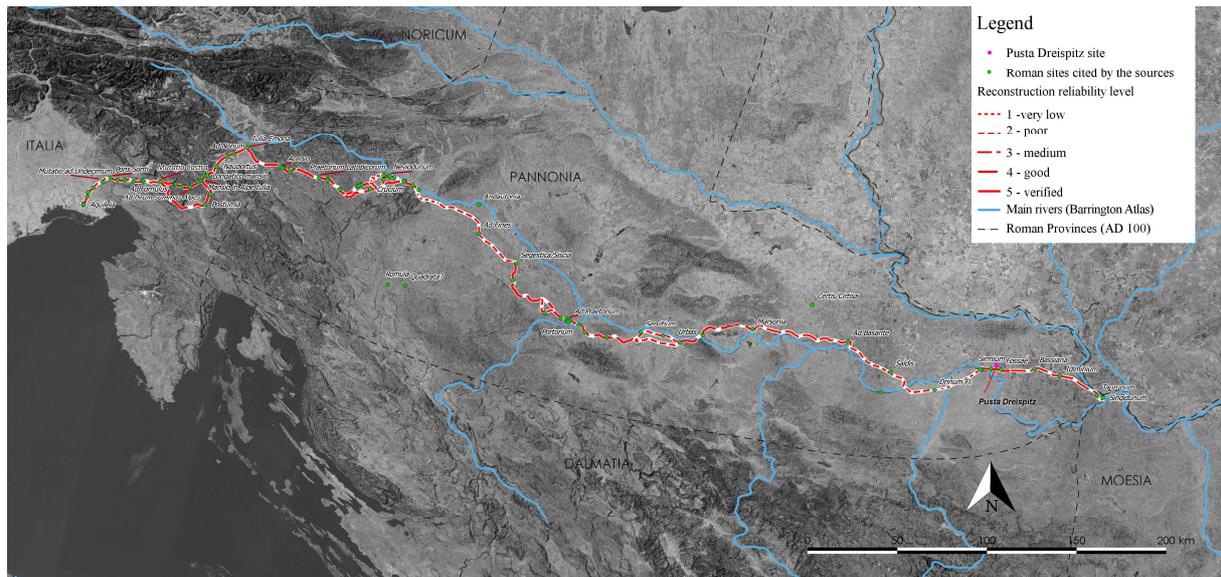


Fig. 1. General map of the Roman itinerary from Aquileia to Singidunum, elaborated by Sara Zanni.

Introducing the RecRoad project

The main objective of the RecRoad project is to map the Roman itinerary along the Sava River from *Aquileia* to *Singidunum*. This route does not form a *via*, but it is, more correctly an *itinerarium* [Hurtado 1987: 109, 113, Rebuffat 1987, 64]. Indeed, it might be useful to recall, in this context the different meanings of the terms *via* and *itinerarium*: while a *via* is a precise road, named by a proper name (e.g.: *Via Appia*, *Via Flaminia*) or by its *capita viarum*, the word *itinerarium* can define an itinerary source (e.g.: *Itinerarium Antonini*) or the itinerary of the journey that a traveler plans to achieve or has completed. An *itinerarium* can therefore be made up of several *viae* or parts of them. The *itinerarium* from *Aquileia* to *Singidunum* is indeed composed of several segments studied with varying degrees of precision by archaeologists in the past. In some cases, other scholars had already established good knowledge of the Roman road, documenting visible remains or excavating some segments of it. This is the case, for example, of the road from *Aquileia* to *Emona*, now *Ljubljana* in *Slovenia*, which was well documented by archaeological finds and archive records [Bolta and Gabrovec 1975, Horvat 1999, 2009].

The planned output of the research is an interactive online atlas, connected to a spatial database that will include full information about each segment of the itinerary and about the archaeological remains, archive documents, remote sensing and GIS analyses used for mapping. Because of large gaps in the documentation and research concerning the Roman itinerary, it was important to define a specific method for improving the resolution of the archaeological documentation. We decided that no source of information should be neglected and developed a workflow involving different research technologies so the Roman road might be mapped as completely as possible. The sources involved in the RecRoad project were:

1. Previous archaeological research (published materials)
2. Previous protection measures and preventive archaeology (archive materials from museums and institutes for the protection of cultural heritage)
3. Historical and modern maps
4. Remote sensing analyses (satellite and aerial where possible)
5. GIS and spatial analyses (cost and path analysis, watershed analysis)
6. Epigraphic inscriptions
7. Archaeological surface surveys.



Fig. 2. Geographic position of the Pusta Dreispitz site (in red) on the 1:25.000 topographic maps of Serbia (published in 1970). In the thumbnail, the extension of the topographic map detail is marked with a red rectangle.

At the beginning of the research, it was evident that the data already stored in the Institute for the Protection of the Cultural Monuments of Sremska Mitrovica archive corresponded with the data generated during the remote sensing analysis and this evidence already corroborated the validity of the methodology. Sixty crop-marks had been identified on different satellite images and thirteen of them matched with sites coming from the dataset of 50 archaeological sites already filed in the Institute's archive. In some cases, the evidence documented during archaeological research performed by the Institute in the late 60s could easily be integrated with stretches of the Roman road visible in the satellite images, so that the archaeological evidence already documented increased the probability that the traces found through the remote sensing images corresponded with the Roman road. The surface survey confirmed this hypothesis, allowing the researchers to collect pottery fragments and other autoptic materials verifying the precise outline of the Roman road over the 70 km from Sirmium to the confluence of the Danube and Sava rivers, passing by the Roman city of Bassianae.

The archaeological research performed on the territory of Sremska Mitrovica as part of the RecRoad project enabled a large number of archaeological sites of different periods to be mapped in addition to the main Roman road connecting the cities of Sirmium and Singidunum. In detail, 13 crop marks correspond to matching archaeological sites and stretches of the Roman road already documented by past researches, but still 47 anomalies do not correspond to any known site. Some of them, of course, can correspond to artefacts due to geo-pedological or artificial features. In the meantime, we also have 36 already known sites that do not match any of the crop marks identified in the remotely sensed data. This is probably due to the dimensions of these sites and to their inconsistency in terms of visibility (e.g.: isolated graves, hearth remains, etc.). Anyway, we can conclude that crossing the remote sensing results and the precedent information allowed us to better prepare the survey campaign and to focus on the areas where it was most probable that we could be able to find Roman sites, evidences of the Roman road, and sites connected with the road itself in a much shorter time than it would have taken with a more traditional survey method. We can conclude that, methodologically, implementing remote sensing with the archaeological record should lead to great improvements to the capacity of obtaining good results optimizing the resources spent on the field [Parcak 2017].

The archaeological site Pusta Dreispitz (Fig 3, no. 3) was chosen as a case study because it was one of the interesting examples that show us how important it is to combine different types of data, which we performed with each individual locality during the survey, and the necessity of caution in the examination of data obtained by multispectral analysis.

SATELLITE REMOTE SENSING ANALYSIS

An important part of the RecRoad Project involved the analysis of several kinds of satellite images for the detection of anomalies due to the presence of buried archaeological remains. The remote sensing analysis focused on the area where, according to earlier research, it was more likely that the Roman road would lie within a strip 10 km wide. In some cases, where there were no previous confirmed findings relating to the presence of the road, it was necessary to enlarge the research area to a strip as much as 30 km wide. The choice of the dimension of the research area depended on the amount of data available in the various parts of the territory involved into the project: mostly, precedent publication gave some general information about the layout of the road, with the exception of some very

precise findings mainly due to preventive archaeology [Bavec 2006]. Nevertheless, for its largest part, the itinerary from *Aquileia* to *Singidunum* runs quite close to the river Sava, within a distance often less than 10 km; therefore examining an average strip 10 to 30 km wide enabled us to detect the presence of eventual variants and modifications.

Even if the use of satellite images allowed us to find many traces of the Roman roads that had never been identified before, it was necessary to remember that the nature of the anomalies thus detected must be verified on the ground, so that it can be possible to connect them to chronological or cultural data. The remote sensing analysis shows the presence of buried structures or remains, but they may include modern features such as gas or water mains. The remote sensing analyses were therefore only one step in a more expansive workflow; specifically, they were preliminary and necessary to a surface survey programmed by the Ausonius Institute and the Sremska Mitrovica Institute for the Protection of Cultural Monuments in late March 2017.

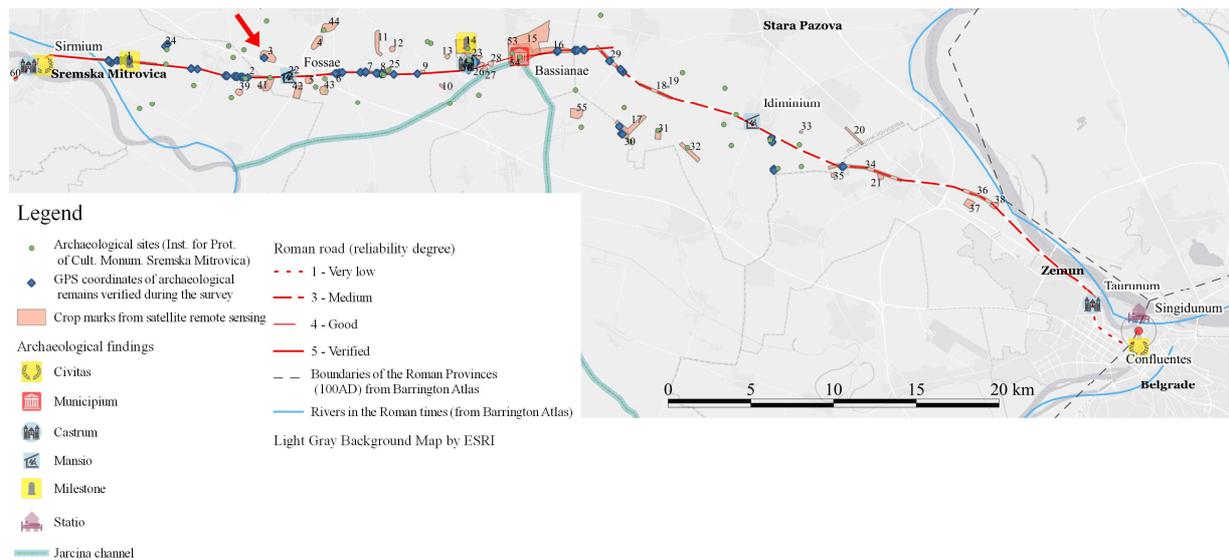


Fig. 3. Map presenting the results of the surface survey performed in the territory from Sremska Mitrovica and Belgrade, to verify the nature and chronology of the anomalies detected through remote sensing techniques. The blue dots correspond to the GPS coordinates of the archaeological remains identified during the surface surveys. Pusta Dreispitz corresponds with the crop mark n. 3.

The satellite remote sensing analyses were particularly proficient in the district of Srem, allowing us to map the Roman road in detail over the whole 70 km from Sremska Mitrovica (the Roman city of *Sirmium*) to the suburbs of Belgrade (Fig. 3). The Srem district is mostly farmland with few built-up areas: 60% of the district is cropland (maize, wheat and soya) [Mihailović et al. 2014]. This characteristic, together with the strategic role of the city of *Sirmium* and of the area of the confluence of Danube and Sava rivers under the Roman Empire, increased the potential for successful remote sensing analysis in the Srem district.

Also, the collaboration between the Université Bordeaux Montaigne and the Institute for the Protection of the Cultural Monuments of Sremska Mitrovica was of primary importance for the success of the research in this area. Thanks to this collaboration, it was possible to map the position of fifty archaeological sites already known from previous surveys and excavations, filed in the archive of the Institute [Lučić n.d.]. These sites cover a wide time-span and some of them were clearly produced the anomalies identified in the satellite images. It was nevertheless interesting to remark how remote sensing data integrate the already assessed archaeological record and vice versa.

Among the anomalies detected, one stood out because it was not interpretable as a segment of the Roman road, not being a linear but a polygonal anomaly, and because of the clear definition of its shape. It was located by the border between the territories of Šašinci and Voganj, at a place-name identified as Pusta Dreispitz. Several satellite images covered the area interested by the anomaly, but the anomalies were only visible in a few of them, as we discuss below.



Fig. 4. Details of the GoogleEarth images used to identify the Pusta Dreispitz site. a) Image acquired on 3 April 2017; b) Image acquired on 6 August 2016.

Visible range satellite images

Some of the images available for Pusta Dreispitz were in the visible range while others were multi-spectral images. Obviously, the different kinds of images yielded different results and were processed using different methods. For this specific area, we used the following images in the visible range:

- 1 GoogleEarth image acquired on 3 April 2017¹ (Fig. 4a);
- 1 GoogleEarth image acquired on 6 August 2016² (Fig. 4b);

¹ GoogleEarth V. 7.1.15.1557 (April 3, 2017). Šašinci, Serbia. 403776.94m E 4980365.51m N (WGS 84 UTM 34N), eye alt. 4,10km. CNES/Airbus 2018 and DigitalGlobe 2018. <http://earth.google.com> (retrieved on January 15, 2018).

² GoogleEarth V. 7.1.15.1557 (August 6, 2016). Šašinci, Serbia. 403776.94m E 4980365.51m N (WGS 84 UTM 34N), eye alt. 4,10km. DigitalGlobe 2018. <http://earth.google.com> (retrieved on January 15, 2018).



Fig. 5. SPOT image n. N45E019 (10 February 1986). Data available from the U.S. Geological Survey. On the right, detail of the Pusta Dreispitz site area.

The three visible range images of the Pusta Dreispitz area do not reveal any significant trace of the presence of a buried archaeological site. Indeed, only in the Google Earth image of 3 April 2017 (Fig. 4a) is it possible to distinguish the corner of a rectangular shape. Although Google Earth Pro™ provides access to a gallery of 16 different images only 3 of them were taken in a season when the vegetation was in the growth phase that enables crop-marks or soil marks to be observed. The first days of April 2017, when the image in Fig. 3a was acquired, is the best period of the year for revealing soil marks, since it is the ploughing period.

The SPOT image available free of charge through the EarthExplorer³ of the U.S. Geological Survey is a panchromatic image with a pixel resolution of 10 metres. As can easily be observed from Fig. 4, analysis of this image did not provide any useful information for the identification of a buried archaeological site.

³ <https://earthexplorer.usgs.gov/>.

Table 1. Sentinel-2 bands with the correspondent wavelengths and spatial resolutions. Source: ESA.

Sentinel-2 Bands	Central Wavelength (μm)	Pixel resolution (m)
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation Red Edge	0.705	20
Band 6 – Vegetation Red Edge	0.740	20
Band 7 – Vegetation Red Edge	0.783	20
Band 8 – Near-infrared (NIR)	0.842	10
Band 8A – Vegetation Red Edge	0.865	20
Band 9 – Water Vapour	0.945	60
Band 10 – SWIR – Cirrus	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

Since the analysis of visible-range satellite images failed to yield any meaningful results, we decided to apply more advanced remote sensing techniques in order to better map the presence of archaeological remains in the area of Srem. Luckily, the RecRoad project began close to the time when Sentinel-2A, the first satellite of the Sentinel-2 constellation, was launched on 23 June 2015, and the images produced by its sensors were made available for any purpose through the Copernicus Space Component Data Access Portal.⁴ In February 2016, a group of researchers from Cyprus were the only ones who had attempted to evaluate the potential of the Sentinel-2 images for archaeological purposes [Agapiou et al. 2014]. They had published the results of their evaluation before the launch of the first satellite, basing their work on the technical specifications released by the ESA, trying to figure out a specific index aimed at looking for buried archaeological features specifically conceived for the Sentinel-2 sensor. Indeed, the analysis of multi-spectral satellite images requires one to better understand the nature of the available data. Multi-spectral images are not simple pictures, but record also data in non-visible regions of the light spectrum. In the case of Sentinel-2 satellites, there are 12 sensors recording data on 12 different bands of the spectrum (Table 1). While the exam of one band at a time can of course give some information about what cannot be seen by the human eye, the most interesting thing is to combine different bands in order to extract the type of information necessary to identify buried archaeological remains. Because of the recent availability of the Sentinel-2 images, when we started working with them we had to face the problem of defining which combination of bands would give the best results.

For the RecRoad project, the researchers needed to select the images produced during the season of most prolific plant growth and photosynthetic activity, which peaks between late spring and early summer, before the harvest that usually takes place at the end of the summer. Consequently, the analysis focused on the images acquired from May to July 2016 and 2017. The results presented in this paper were obtained by processing an image acquired on 29 June 2016.⁵

First, we tested some Vegetation Indexes (VI) developed to enhance and exploit the contrast among the different regions of the electromagnetic spectrum for agricultural and archaeological purposes [De Guio 2015:119]. These included the Normalized Difference Vegetation Index (NDVI), which is often used to measure the health of crops, comparing the infrared and red spectral reflectance measurements by the following formula:

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$$

The NDVI calculated for a given pixel results in a number that ranges from -1 to +1, with the highest values indicating the highest possible density of healthy crops [Weier and Herring 2000].

⁴ <https://spacedata.copernicus.eu/>.

⁵ Reference n. S2A_OPER_MSI_L1C_20160629T150301_A005324_T34TCQ.

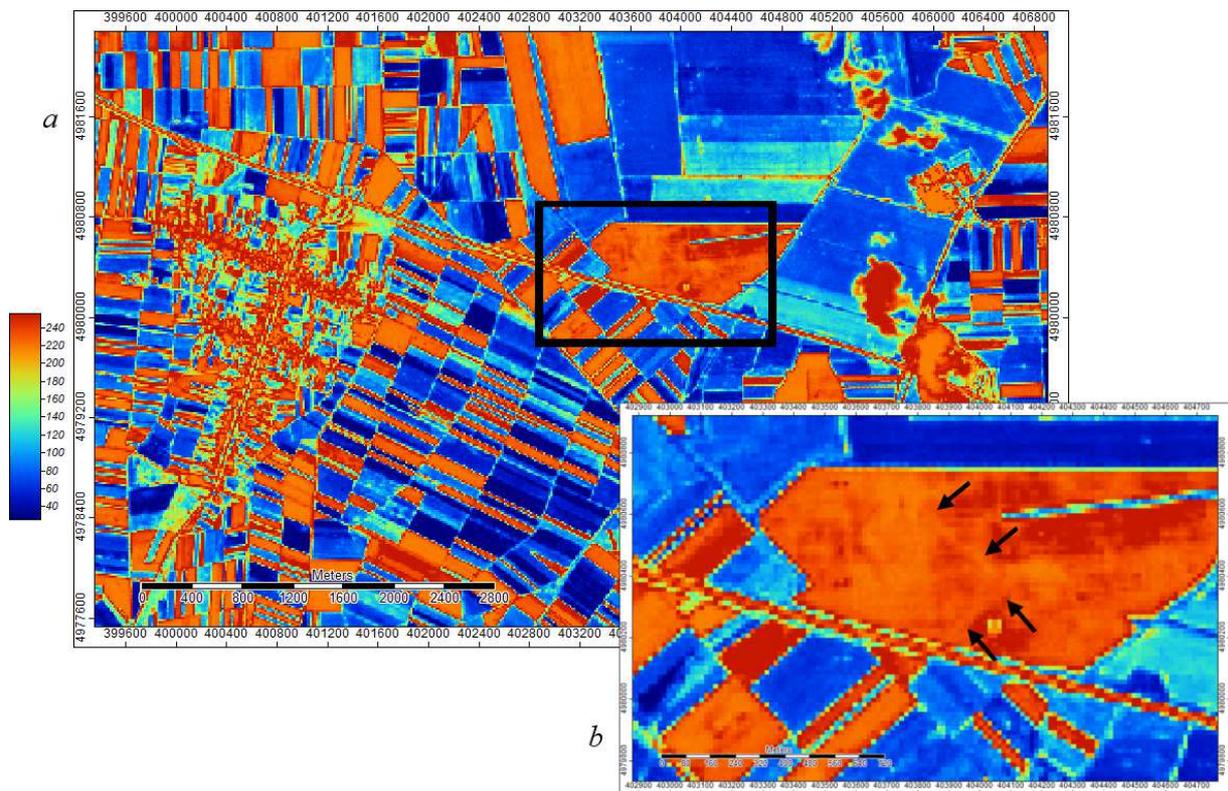


Fig. 6. Result of the calculation of the NDVI on the Sentinel-image registered on 29 June 2016. The results were normalized to a range value of 0-255 for easier comparison with the results of other processing methods. a) Šašinci area. b) Detail of the Pusta Dreispitz site: a rectangular anomaly can be seen in the field to the north of the highway (highlighted by black arrows).

Application of the NDVI to the Sentinel-2 image revealed several anomalies throughout the study region (Fig. 6). Nevertheless, we decided to test other algorithms to improve the results and detect other anomalies caused by the presence of archaeological remains.

Another vegetation index that we used to determine the presence of buried archaeological remains was the Normalized Archaeological Index (NAI) [Agapiou et al. 2014:2183–2185]. This index compares the best spectral regions for the detection of the archaeological crop-marks in the reflectance region between 700 μm and 800 μm . In the case of Sentinel-2A images, this means bands 5 (VRE) and 7 (VRE) for which the formula is:

$$\text{NAI} = (800\mu\text{m} - 700\mu\text{m}) / (800\mu\text{m} + 700\mu\text{m})$$

Even though this index was specifically designed to exploit the spectral characteristics of the Sentinel-2 images, the resulting images have poor spatial resolution, since bands 5 and 7 have a pixel size of 20 m (see Table 1), consequently, the resulting image did not show any meaningful crop-marks in the area of Pusta Dreispitz.

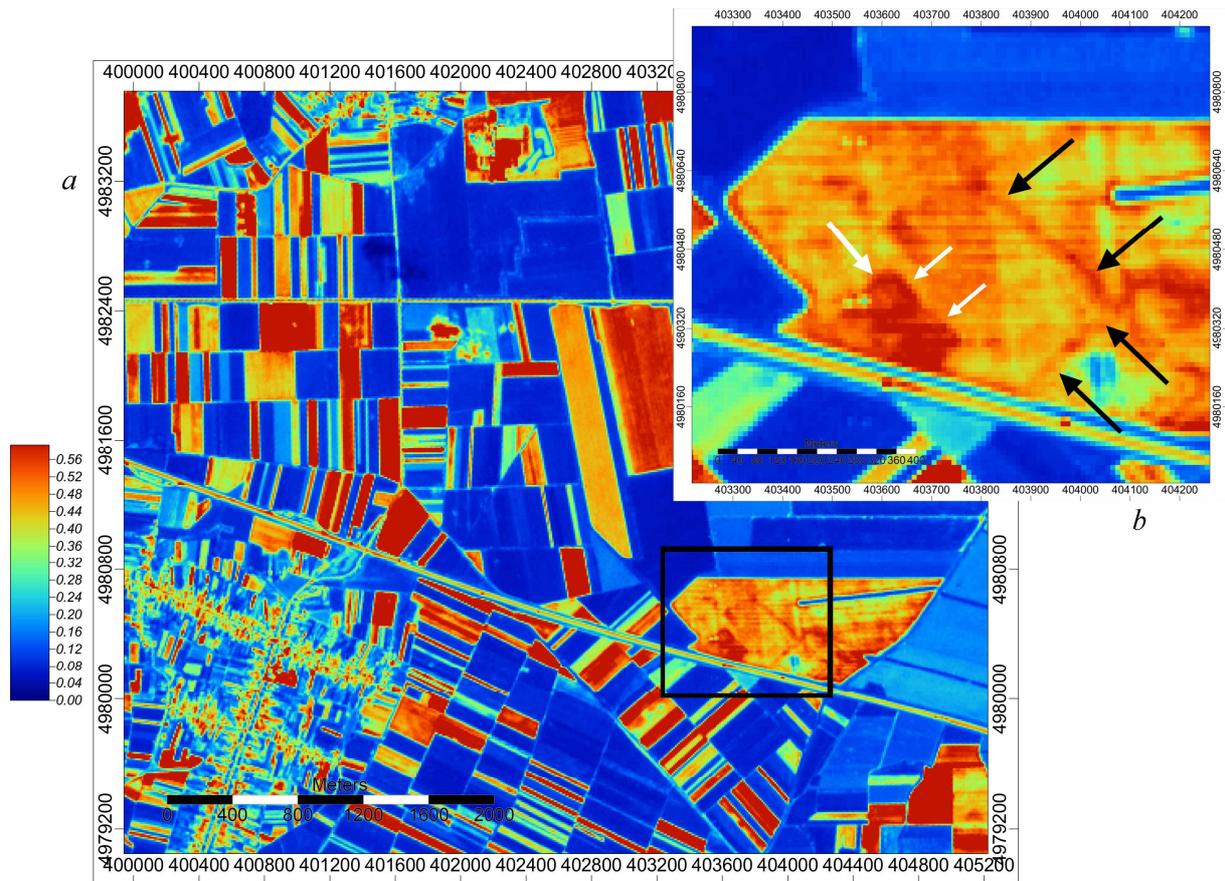


Fig. 7. Result of the Red+NIR band combination of the Sentinel-2 image acquired on 29 June 2016. The results were normalized to a range value 0-1. a) Šašinci area. b) Detail of the Pusta Dreispitz site: a bigger rectangular anomaly can be seen (highlighted by black arrows) and, between this crop-mark and the road, a smaller darker rectangle is visible too (marked by white arrows).

Nevertheless, since the fluctuation of the Red and Near-infrared spectrum during crop's phenological cycle is the main parameter to detect archaeological remains with spatial remote sensing techniques [Agapiou et al. 2014: 2177], it is clear that the reflectance range between 665 μm and 842 μm has the highest potential for the purposes of this research. Some more interesting results came from the combination of the Red and NIR bands [Parcak 2009:91-92], through the use of the band-set function of the Semi-Automatic Classification Plugin [Congedo 2016]. This technique exploits the smaller pixel size of these bands, generating images with a spatial resolution of 10 m (see Table 1). The band combination shows some crop-marks that were invisible with the NDVI (Fig. 77), even if it had the same spatial resolution. This occurrence should not arouse amazement, since the visibility of crop marks does not depend only on the pixel size of the images, but can be more or less visible as a consequence of the different processes of manipulation of the bands. So, it is clear that different band combination or Vegetation Indexes can give very different results.

In addition, again trying to extract the best possible results from the Sentinel-2 images, we tested the orthogonal equations developed to detect the presence of archaeological remains [Agapiou 2016]. The algorithms are based on the Tasseled Cap transformation [Kauth and Thomas 1976, Agapiou et al. 2013, Yarborough et al. 2014], which is widely used to map vegetation using Principal Components Analysis.

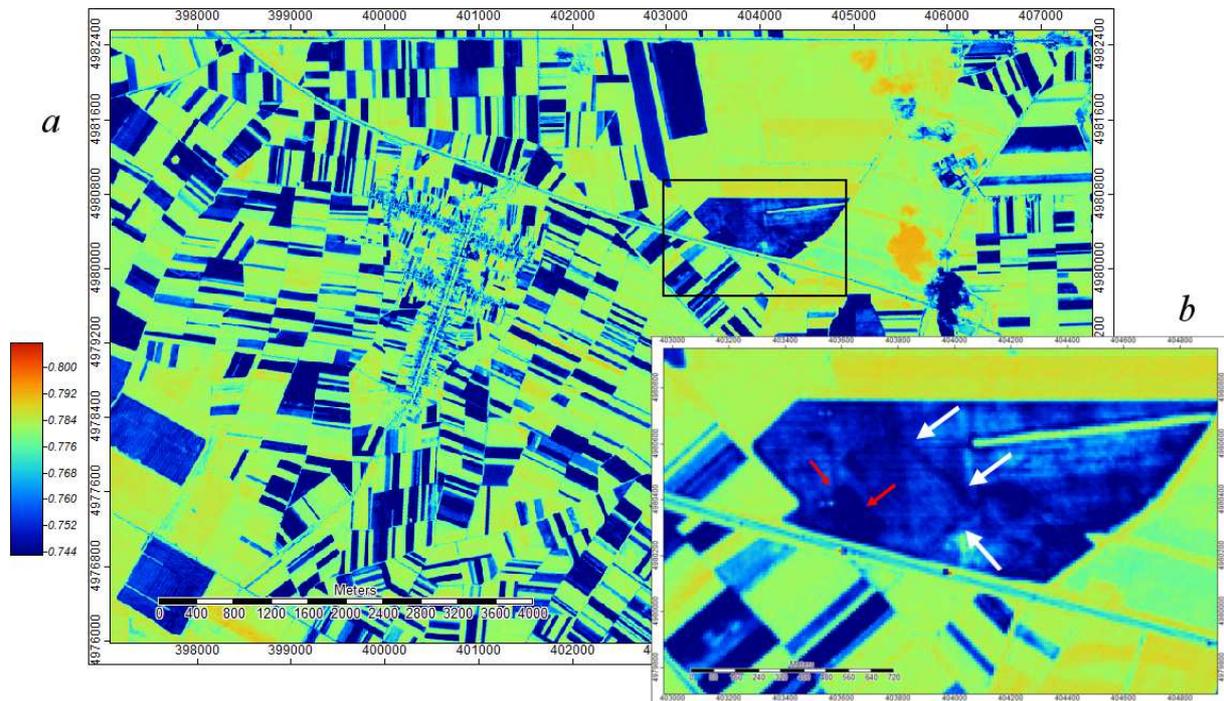


Fig. 8. Results of the application of the original CC3 formula to the Sentinel-2 image acquired on 29 June 2016, normalized to a range value of 0-1 for easier comparison of the different algorithms. a) Šašinci area. b) Detail of the Pusta Dreispitz site. Also in this case the two rectangular crop-marks identified in 7b can be seen (the bigger rectangle is marked by white arrows, the smaller one by red arrows).

These equations, specifically the Crop Coefficient 3 (CC3), had already been tested on the images produced by other space missions (Quickbird, IKONOS, Worldview-2, GeoEye-1, ASTER, Landsat 4TM, Landsat 5TM, Landsat 7ETM) [e.g., Agapiou et al. 2013], with interesting results from an archaeological perspective. Because the Sentinel-2 mission was new, its applicability to this kind of data still needed to be proved. The original formula developed by Agapiou et al. [Agapiou 2016; Agapiou et al. 2013:6568-6569] enabled the identification of more anomalies in the Sentinel-2 images (Fig. 8).

$$CC3 = 0.19 * \rho_{\text{Band 1TM}} + 0.56 * \rho_{\text{Band 2TM}} - 0.81 * \rho_{\text{Band 3TM}} - 0.04 * \rho_{\text{Band 4TM}}$$

Nevertheless, we tried to further improve the results by introducing a variant to the formula (Fig. 9 9):

$$CC3_DR = 0.19 * \rho_{\text{Band 1TM}} + 0.56 * \rho_{\text{Band 2TM}} / - 0.81 * \rho_{\text{Band 3TM}} - 0.04 * \rho_{\text{Band 4TM}}$$

The CC3_DR, applied to the Sentinel-2 images changed the relationship among the components of the algorithm's structure, yielding an image with a higher definition of the crop-marks and of the principal components of the ground. We tested the applicability of this new formula on images produced by other sensors (GeoEye-1, Worldview-2, Quickbird), and it gave better results for detecting archaeological anomalies, while the Sentinel-2 images revealed their main flaw: the lower spatial resolution did not allow a clear improvement of the results.

After analysing the images from the remote-sensing processing, it was possible to identify 60 crop-marks hypothetically due to buried archaeological structures in the portion of Serbian territory stretching from Sremska Mitrovica to Zemun. Of these crop-marks, some were linear, possibly connected to the Roman road that we seek to reconstruct for the RecRoad project, while others were polygonal. It was necessary, at this stage of the research, to verify the reliability of these data and to assign a more precise chronology to each of the anomalies identified. An archaeological surface survey was planned in collaboration with the Sremska Mitrovica Institute for the Protection of Cultural Monuments, which also provided important data about the previous surveys and archaeological research in the area.

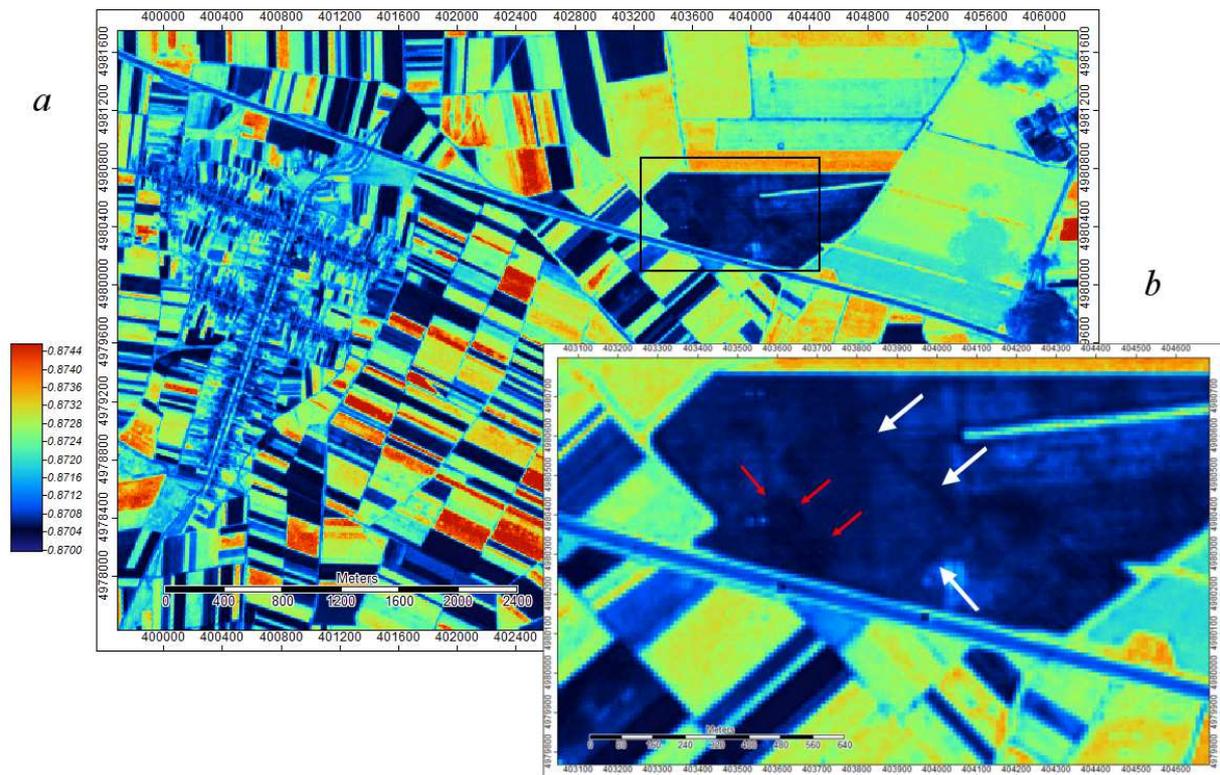


Fig. 9. Results of the application of the modified CC3 formula, normalized to a 0–1 range value for easier comparison. a) Šašinci area. b) Detail of the Pusta Dreispitz site. Again in this case, the two rectangular crop-marks identified in Fig. 6b and 7b can be seen.

Combining the information from past research and the results of the remote sensing analysis, we established an optimized procedure, integrating mobile mapping technologies, to confirm the presence of archaeological remains in the crop-marks area and prove the reliability of the remote sensing processing. In this way, it was possible to confirm the exact route of the main road from *Sirmium* to *Statio ad Confluentes* over a distance of about 70 km. Beyond this result, it was possible to identify some archaeological sites that were not previously known, like Pusta Dreispitz, and precisising the exact location of others, already known from past surveys.

Comparing the crop-marks and the archive documents, most of the polygonal anomalies could be associated straight away with already known archaeological sites from different eras, but not so for the Pusta Dreispitz site. For this reason, closer research was performed on the site, both on the terrain and in the archive documentation, in order to collect all the information available about this location.

HISTORICAL MAPS AND GIS

Today, Pusta Dreispitz is located on the boundary between the towns of Šašinci and Voganj, and it is very difficult to reach, because the construction of the adjacent highway has cut it off from the local road network. The first step to better understand the nature of the crop-mark was to determine whether the site had hosted any settlement in recent centuries. To do so, we collected the military maps produced by the Austro-Hungarian Empire from the final years of the 18th century to the first half of the 20th century, to integrate them in the GIS platform of the RecRoad project.

Four different maps cover the location of the site:

1. First Military Survey of the Austrian Empire (*Josephinische Landesaufnahme*) produced in 1763–1787
2. Franciscan Cadastre (*Franziszische Landesaufnahme*) produced in 1806–1869
3. Third Military Survey of the Austro-Hungarian Empire (*Franzisco-Josephinische Landesaufnahme*) produced in 1869–1887

4. Special Map of the Austro-Hungarian Empire (*Spezialkarte der Osterreichisch-Ungarischen Monarchie*) produced in 1877–1914.

Each of these historical maps needed to be geo-referenced for inclusion in the GIS platform of the project. Because each map was drawn using a different technique a specific method had to be devised for each.

The First Military Survey of the Habsburg Monarchy,⁶ known also as the Josephine Survey, is not based on a geodetic network and does not rely on a cartographic projection system. It was drawn on a scale of 1:28,800 and only a few points were measured trigonometrically [Affek 2013:377]. The measurement method was very imprecise, and the distances were determined from the average length of a horse's step and it is known that the mapping of the details was performed with a compass, a ruler and the use of a surveyor's table, while non-military details were positioned *à la vue* [Podobnikar 2009]. Nevertheless, the First Military Survey is thought to be the most detailed cartographic work before the end of the 18th century [Affek 2013:377].

Since the First Military Survey was not based on a geodetic network, the best way to geo-reference it was by matching it to a reference layer [Affek 2013:377]. For the RecRoad project, we used as a reference layer the Former Yugoslavia Topographic Map on a 1:50,000 scale, produced by the U.S. Defense Mapping Agency, made available in the public domain by the University of Texas Libraries in the Perry-Castañeda Map Collection.⁷ Matching was done by using Ground Control Points (GCP), assigned to characteristic objects on both of the maps [Lisek and Navratil 2014:484]. In most cases, we used churches, bridges and crossroads, where the layout of the road network had not changed over the last two centuries. After matching, we used a polynomial transformation with cubic resampling, which maintained the continuity and smoothness of the geo-referenced layer.

While it was possible to geo-reference the portion of the First Military Survey and to overlay it on the satellite images and the modern maps, it did not contain any clue about any previous settlement in the area of Pusta Dreispitz. This lack of information could either mean that there were no buildings in the Pusta Dreispitz area or it might be because the main objective of the cadastre was to define the boundaries of the areas of land plots, with less attention to the graphical documentation [Affek 2013:378].

The Franciscan Cadastre is more accurate thanks to the development of eight independent coordinate grids, which made it one of the first maps produced using a mathematical and geodetic method [Molnár and Timár 2009]. Nevertheless, since the excerpt of the Franciscan Cadastre focused on Pusta Dreispitz was of very limited extent, we decided to geo-reference it by matching it once more with a reference layer. The choice of the reference layer fell again on the Former Yugoslavia Topographic Map produced by the U.S. Defense Mapping Agency and we employed the same methodology as for the First Military Survey.

Again, the geo-referencing procedure enabled us to overlay the historical map on top of the crop-marks identified in the satellite images, but in the Pusta Dreispitz area nothing was marked to indicate the presence of any buildings or other settlements. However, on the Second Military Survey of the Austrian Monarchy, a place-name was annotated: *Od Sela* (From the Village).

The Third Military Survey and the Special Map of the Austro-Hungarian Empire were produced between the second half of the nineteenth century and the beginning of the twentieth, when the achievements in the geodetic fields much improved the reliability and level of detail of the maps [Molnár and Timár 2009:117–120]. The best method for geo-referencing the Third Military Survey of the Austro-Hungarian Empire was described by Molnár and Timár [2009], and it was mainly applicable to the Special Map of the Austro-Hungarian Empire without any significant loss of precision: both of them were imported into the GIS environment with a resulting error of less than 25 m, that is acceptable since the project focuses on a landscape scale.

⁶ This map can currently be consulted via the portal <http://mapire.eu>.

⁷ https://legacy.lib.utexas.edu/maps/topo/former_yugoslavia/.



Fig. 10. Excerpt from the Third Military Survey Map, sheet 37-45 - Mitrowitz, corresponding to the Sremska Mitrovica territory. Scale 1:200,000.⁸ In red: the location of Pusta Dreispitz.

In Fig. 10 it is possible to see for the first time, circled in red, the indication of the place-name “Pusta Dreispitz” and the presence of a small black rectangle, the symbol for the existence of at least one building. This clue suggests that in the area where we identified the rectangular crop-marks, there could still have been a house or a rural settlement in the second half of the nineteenth century.

This information was confirmed and even improved by examination of the excerpt from the Special Map of the Austro-Hungarian Empire for our study location. As can be seen in Fig. 11, a label indicating the Pusta Dreispitz site indicates the presence of a small settlement, enclosed by a fence and composed of four small black rectangles, representing buildings. We could therefore be sure that, between the final years of the nineteenth century and World War I, a small but well-defined rural settlement was still to be found in Pusta Dreispitz.

⁸ Available through the website: <http://lazarus.elte.hu/hun/digkonyv/topo/3felmeres.htm>, courtesy of the Eötvös University, Department of Cartography and Geoinformatics.

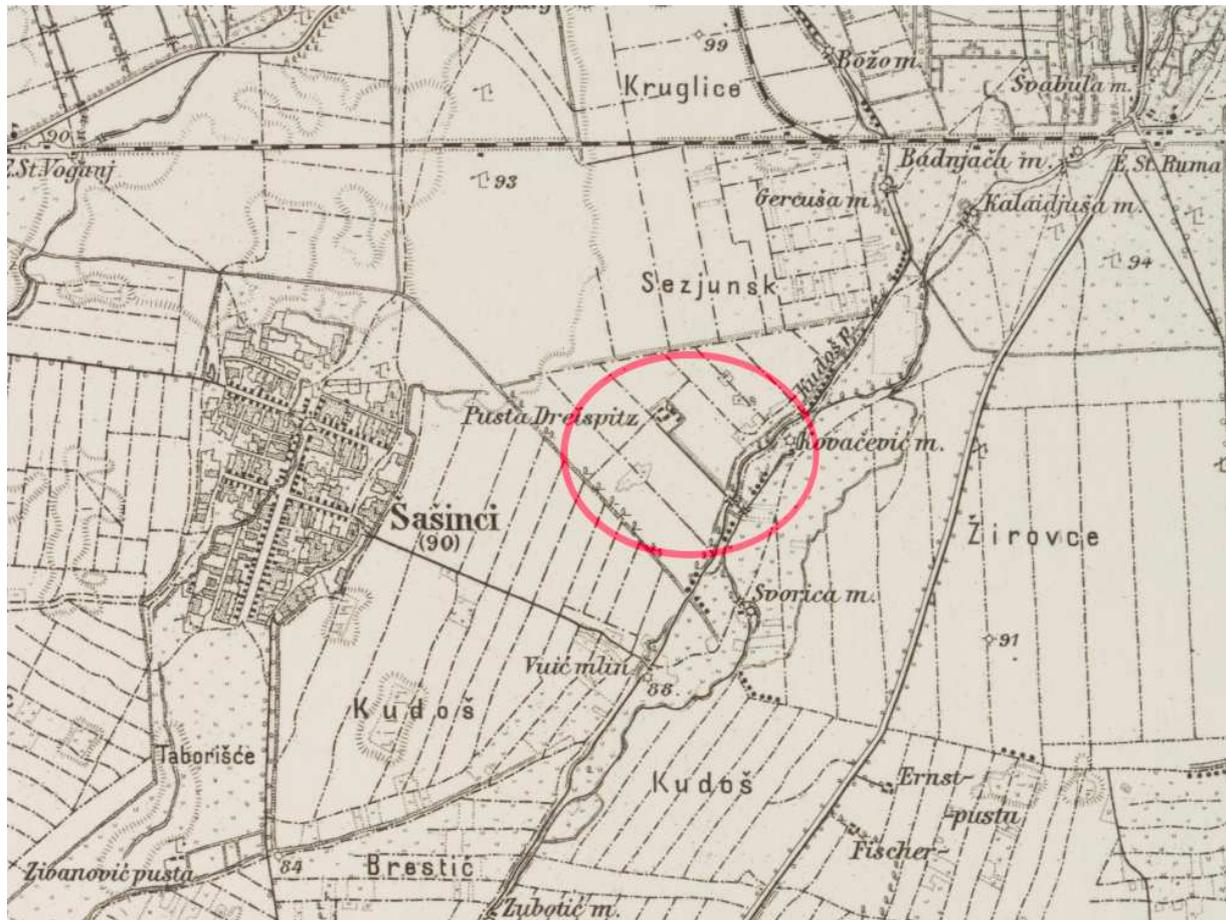


Fig. 11. Excerpt from the Special Map of the Austro-Hungarian Empire, scale 1:75,000, Mitrowitz sheet.9 In red: the location of Pusta Dreispitz.

THE ARCHAEOLOGICAL RECORD AND THE SURVEY RESULTS

Analysis of the archive documentation provided information about the previous archaeological finds in the Pusta Dreispitz area and the surface archaeological survey helped us to more clearly interpret the crop-marks identified. Data supporting the conclusion about a multi-layered site were provided during systematic survey of the Srem region in the 1980s, which determined the existence of the site, covering an area of 400 x 200 m. The presence of archaeological materials at this site is mentioned for the first time in the early twentieth century: Brunšmid gives us information about finds of a Roman bronze fibula and a key on the location [Brunšmid 1900:198]. Some additional data come from a nearby site in the area named Kudoš. The Kudoš site was investigated in the 1980s during the construction of the E-70 highway. Remains were found of a typical medieval settlement from the fifteenth century [Gačić 1995:236-237]. The archaeological material found during the 1960s survey and during the archaeological survey performed in March 2017 as part of the RecRoad Project is very similar. It consists primarily of fragments of atypical pottery from the proto-historic and Roman periods, as well as yellow-ochre glazed pottery of good quality typical of the 16th–18th and 19th centuries (Fig. 12). The spatial extent of cultural material on Pusta Dreispitz site extends beyond the previously determined area. The complex of objects, due to the findings of movable archaeological material found on the surface of the site and data from historical maps, can be roughly dated to the eighteenth–nineteenth centuries. Besides the pottery material from this period, additional data includes a Hungarian bronze coin from 1896.¹⁰

⁹ Available from the website: <https://digitalcollections.nypl.org/collections/spezialkarte-der-osterreichisch-ungarischen-monarchie>, courtesy of the New York Public Library Digital Collections.

¹⁰ Two-filler Hungarian bronze coin of Franz Joseph I, the reverse inscription: MAGYAR KIRÁLYI VÁLTÓPENZ 1896.



Fig. 12. Sample of the pottery fragments collected during the archaeological surface survey performed in the Pusta Dreispitz area for the RecRoad Project. Photo by Biljana Lučić, courtesy of the Sremska Mitrovica Institute for the Protection of Cultural Monuments, 2017.

CONCLUSION

Integrated data from the systematic archaeological survey and archaeological research of the Srem region [Lučić n.d.] gave us useful test-bed to Sentinel-2 multispectral images. Through the cooperation on the RecRoad project, we have succeeded to improve precise positioning of the segments of the main Roman route [Popović 1980: 101-108; Gračanin 2010, 9-69] that connected *Sirmium* with *Bassianae* and *Singidunum* and to give directions for future explorations of the side roads. The data obtained from the multispectral analysis were also important for detecting wider archaeological site areas showing us that if the field survey is not combined with remote sensing analysis it often gives a limited understanding with poorly understood sites. The spatial approach allows broader view and it turns out that it can be useful in detecting horizontal stratigraphy. The project showed, too, how the integration of different sources of information and techniques could greatly improve both our knowledge of the archaeological heritage and the performance of the researchers who need to survey, map and protect that heritage too. In the case of the Pusta Dreispitz site, it was possible to match the data from the archives of the Institute for the Protection of Cultural Monuments with the information derived from the remote sensing analysis and from the study of the historical maps. The combination of all these sources of information enabled the identification of a multi-layered archaeological site that has seen several phases of use, spanning from Proto-history to the late 19th century, passing through the Roman time. In this context, we can say that, while the site might look like a Roman site and has a Roman occupation, the rectangular features detected in the satellite imagery most likely date to its later occupation phases.

The research performed on this site showed also the potential of the Sentinel-2 images for archaeological research, providing new information about the shape and extension of the site, while the field survey was a necessary step to confirm the reliability of the remote sensing results and to specify the chronological duration of the site. To attain these results, was nevertheless necessary to elaborate and test new indexes specifically conceived for the Sentinel-2

images. In particular, it should be marked that the ones that gave the best results were the band combination of Red and NIR bands (Fig. 7 p. 10) and the CC3 formula (Fig. 8 p. 11) [Agapiou 2016]. These results are encouraging in the perspective of a broader use of Sentinel-2 images in the archaeological research, since they have proven that, despite their lower spatial resolution in comparison to other satellite products, their free availability and their spectral characteristics can supply very interesting data.

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