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The study of Limes Arabicus using aerial and satellite remote sensing documentation. The case of Umm ar-Rasas (Amman, Jordan)

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***Abstract – Limes Arabicus* is an excellent laboratory for experimenting with the enormous potential of historical and modern remote sensing data for the identification and recording of fortified centres located along this sector of the Roman Empire's eastern frontier, which then also became the Byzantine Empire's eastern borderline. Remote sensing, in conjunction with modern survey techniques and tools such as photogrammetry and laser scanner surveys, enables the identification, documentation, and study of ancient settlements in this area, as well as the development of site valorisation programmes such as the design of real and virtual routes for better use of archaeological areas. In this paper, a preliminary contribution focused on aerial and satellite remote sensing documentation concerning the site of Umm ar-Rasas (Amman, Jordan), a fortified settlement along the Via Traiana Nova, is presented.**

I - INTRODUCTION AND STUDY AREA

Umm ar-Rasas, in the current governorate of Amman, is about 30 kilometres southeast of Madaba (Fig. 1). Since the early 1800s, some explorers have recorded this locality, which is marked by the presence of a Tetrarchic castrum, a Byzantine settlement to the north, and the stylite tower complex even further north. It has been the subject of archaeological study since the second half of the 1980s. The excavations, conducted by the missions of the Studium Biblicum Franciscanum of Jerusalem [1] and the Swiss Max van Berchem Foundation [2], involved a small portion of the castrum and some sectors of the settlement north of this fortified site, bringing to light precious mosaic floors that have made Umm ar-Rasas famous.
Since 2013, the Institute for Heritage Science (CNR-ISPC) of the National Research Council has been carrying out topographical and 3D surveys in the town north of the castrum both to document the state of conservation of the mosaic floors of the churches and to prepare access to the area for a better tourist visit [3, 4, 5, 6]. Starting from 2021, the CNR-ISPC investigations then also extended to the castrum and to the areas north and east of the Byzantine settlement. The previously diverse study group has increased even more, and work on the castrum and surrounds has restarted utilising remote sensing analyses and surveys (architectural, archaeological, as well as photogrammetric and laser scanners).
In summary, during the history of exploration and research in Umm ar-Rasas, a series of archaeological investigations were done that only partially affected the castrum and almost entirely the churches of the Byzantine-Umayyad village. The last two archaeological missions, conducted by the CNR-ISPC, have made it possible to identify from above and check numerous archaeological traces from the ground, with the goal of resuming and deepening the archaeological and architectural study of the castrum, as well as starting and expanding the archaeological-topographical investigation on the settlement and the surrounding areas. A substantial amount of data was collected in this manner, which was useful for the reconstruction of the topography and ancient landscape in

preparation for the creation of the archaeological map of the site, as well as for planning new visit itineraries aimed at improving the accessibility of the archaeological area [7].
This work aims to demonstrate the potential of historical and recent remote sensing data by presenting the study, analysis, and processing phases of the documentation gathered on Umm ar-Rasas.

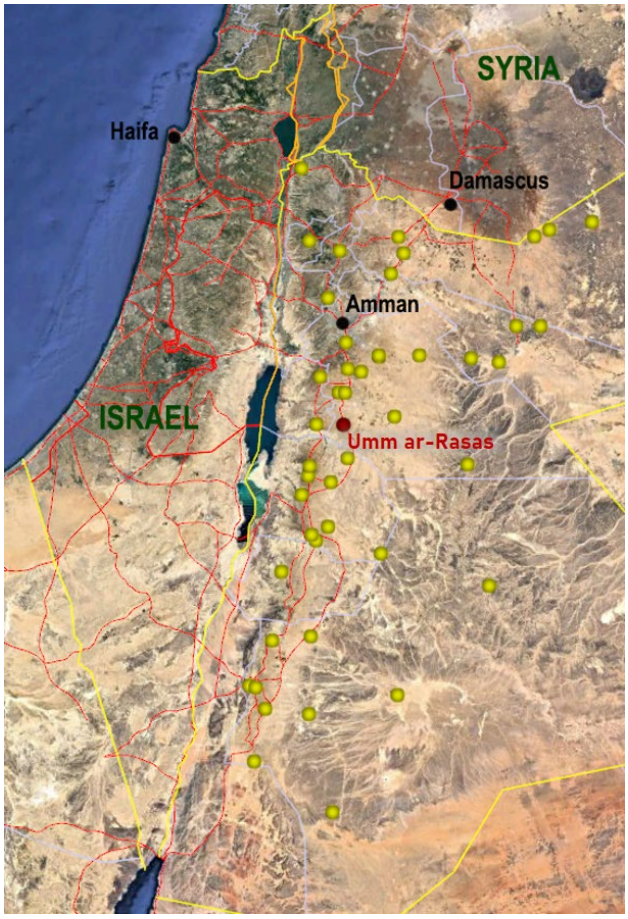

Fig. 1. Location of Umm ar-Rasas (Jordan).

II - PROCESSING AND ARCHAEOLOGICAL INTERPRETATION OF HISTORIC AERIAL AND SPACE PHOTOS IN INTEGRATION TO RECENT SATELLITE IMAGES

To begin, historical aerial photographs taken by Sir Marc Aurel Stein in 1939 and space photos taken form the Corona KH-4B and Hexagon KH-9 satellites throughout the 1960s and 1970s were georeferenced, processed, and interpreted (Fig. 2). The analysis of aerial photos taken from 600 to 1200 feet in altitude and space photos with spatial resolutions ranging from 1.8 to 0.6 m allowed for the documentation of preserved structures as well as the identification of archaeological crop-, dump-, and shadow-marks linked to buried ancient features. This research endeavour enabled the design of ground checks for the investigation and reconstruction of the site's ancient topography and historical landscape. Furthermore, the panchromatic and multispectral data from two very high-resolution satellite images (the first one acquired on October 30, 2020 by the Pléiades 1A satellite and the other acquired on November 11, 2022 by the Pléiades Neo-4 satellite) allowed us to test the potential of remote sensing applications through specific data processing chains for the investigation of the ancient topography of the site and its territory. The most performing processing chains were applied for the identification of the archaeological marks in the two recent satellites images of Umm er-Rasas, with resolutions of 0.5 and 0.3 m in panchromatic mode and 2 and 1.2 m in multispectral mode, and are already widely used in consolidated remote sensing studies applied to archaeology: the datafusion (Fig. 3), the RGB Colour Composite (Fig. 4), and the Principal Component Analysis.
The archaeological elements acquired from multitemporal recording improved the site's archaeological map when combined with comprehensive plans of the castrum and excavated sectors of the inhabited area made during recent topographical surveys or previous studies. The data are being combined into an archaeological map integrated to a GIS platform to document the ancient topography of Umm ar-Rasas.

III - CONCLUSIONS

The multitemporal remote sensing data collected for Umm ar-Rasas (historic aerial photos, space photos and recent very high-resolution satellite images) allowed for the documentation of the study area from 1939 until today and the acquisition of important information about the ancient layout of the site and its surrounding area. These heterogeneous data managed in a GIS platform, allowed for an integrated knowledge of the site, also documenting some archaeological and palaeo-environmental features not visible on the ground, but identified by an accurate photo-interpretation of the processed and analysed available images. The new acquired information is also useful for a better contextualization of data obtained by the topographical surveys in order to produce a general plan of the site, useful also to serve as a knowledge base for the site's valorisation initiatives.

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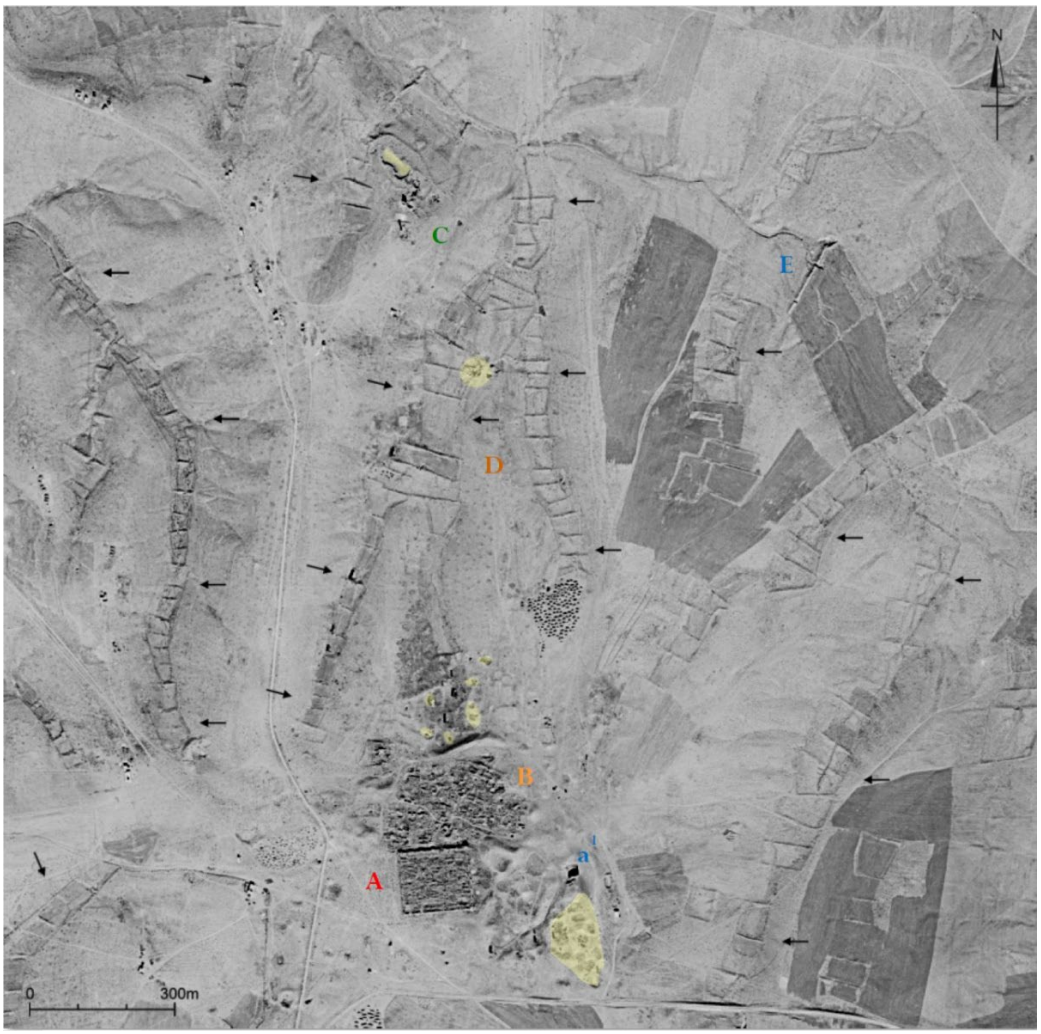

Fig. 2. Historical images. Hexagon KH-9 space photo taken in 1974/12/01. Roman castrum (A), hydraulic reservoir (a^1), Byzantine and Umayyade settlement (B), Stylite tower complex (C), system of irrigated plots (channels and dams) (D), hydraulic channels (indicated by arrows), dam (E), quarries (highlighted in yellow).

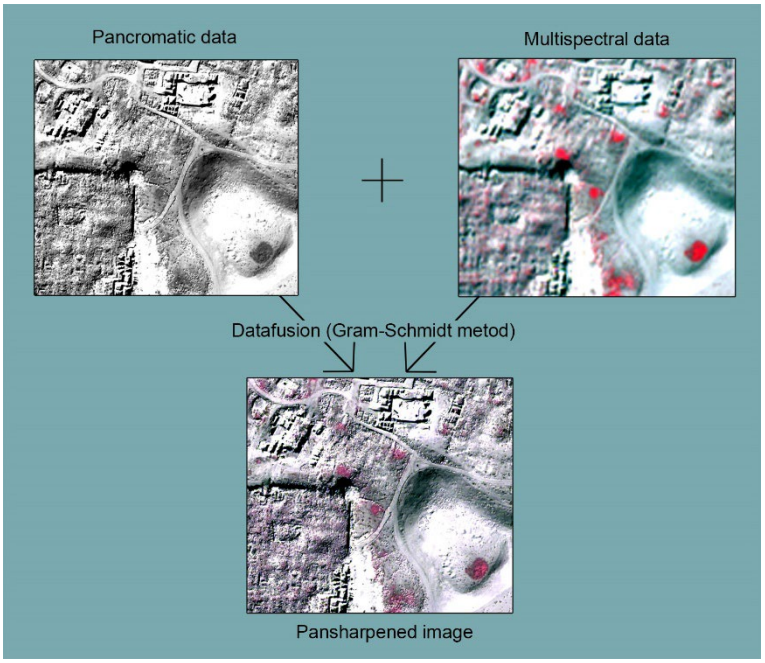

Fig. 3. *Scheme that compares a detail of the Umm ar-Rasas site in the panchromatic data, in the multispectral data and in the pansharpened image produced by their datafusion.*

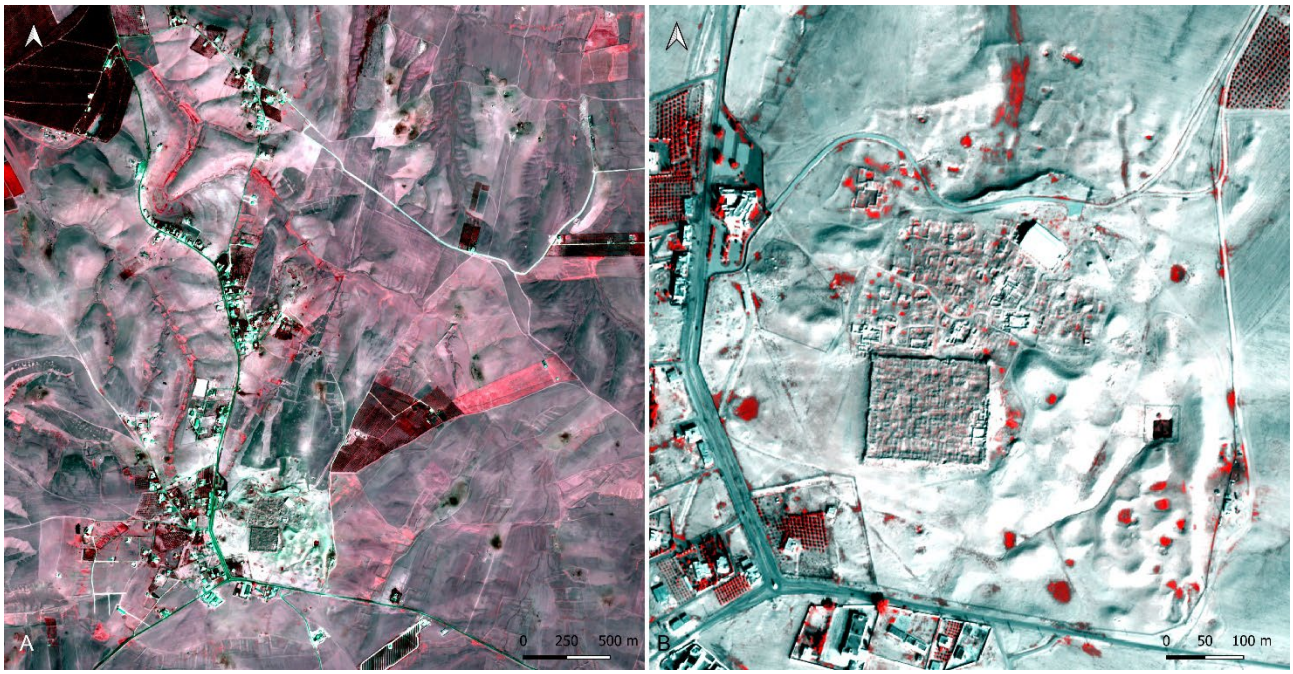

Fig 4. RGB Colour Composite in false colour of the Pléiades 1A image showing the general view of the Umm ar-Rasas area, and of the Pléiades Neo-04 image showing a detailed area of the late antique castrum and the Umayyad village.