

Multitemporal analysis of remote sensing data for the study of the ancient city of *Venusia* (Venosa, Basilicata)

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Abstract – This paper presents the results obtained from investigation methodologies related to analysis, processing and interpretation of historical and recent remote sensing data for the study of the ancient city of *Venusia* (today's Venosa, in Basilicata), and in particular of the amphitheatre area. The monumental building was built in the 1st century AD in a sector of the city previously occupied by a residential area, and its remains, partially brought to light starting from the 1930s, are today visible in the northern sector of the terraced plateau where the Latin colony was founded. This sector of the city today falls within an agricultural area and, therefore, it is suitable for aero-topographic studies. The multitemporal data set, mostly aerial photos, allowed for the documentation of the transformation of this site from the 1940s until today and the acquisition of important information about the layout of the monument and its surrounding area.

I. INTRODUCTION

Ancient *Venusia* is a Latin colony founded in 291 BC and it placed on an elongated *plateau* in SW-NE direction, between two tributaries of the *Fiumara di Venosa* river. A part of its remains was brought to light by archaeological excavations, carried out in the north-eastern sector of the plateau (Figure 1), while another part was obliterated by the original nucleus of the modern centre of Venosa (Basilicata), in the south-western sector of the same plateau. The remains of the amphitheatre stand out in the easternmost sector of the plateau. It was built in the first half of the 1st century AD in a sector previously occupied by a residential area and was restored in the 2nd century AD. In the medieval age, after centuries of abandonment it became an open-air quarry for the recovery of building materials. In particular, in the 12th century, it was affected by heavy plundering of stone material for the construction

of the nearby *Chiesa dell'Incompiuta*. Currently the ruins of the amphitheatre fall within the Archaeological Park managed by the Superintendency of Archaeology, Fine Arts and Landscape of Basilicata through the National Archaeological Museum of Venosa.

The research activities, carried out by the Archaeological Mapping Laboratory of the Institute of Heritage Science of the National Research Council of Italy, was part of the activities of the project "IDEHA" (Innovation for data Processing in Heritage Areas), co-funded by the European Union. It was aimed at acquiring information on the site where the amphitheatre is located through the use of a multitemporal documentation consisting of aerial photos and satellite images, in order to study the transformations of the area after the 1930s and acquire data on the topography ancient of the site.



Figure 1. North-eastern sector of the *Venusia* plateau with excavated structures of the amphitheatre area (on the left of SP18 road).

II. RESEARCH ACTIVITIES

The amphitheatre of *Venusia* is located within an area mainly intended for agricultural use, fortunately not affected by modern urban expansion, and, therefore, it represents an ideal context for detailed research based on non-invasive survey techniques. Some remains of this monument were only partially excavated in 1841 [1], but after these investigations they were buried again. New excavations in 1935 allowed more than half of the building to be brought to light [2]. They were followed by heavy restorations and limited new excavations in the 1960s [3]. New “official” archaeological investigations were carried out in the second half of 1980s and aimed to a better documentation of the previously discovered structures and to understand the relationship between the monument and the urban context contemporary with its construction [4, 5].

The focus of the research activities carried out by the Archaeological Mapping Laboratory of CNR-ISPC is the investigation of the study area through the collection and archaeological photo-interpretation of a multitemporal remote sensing data set. In particular, a large number of vertical and oblique aerial photos ranging from 1943 to 2003 was collected from the archives of *Istituto Centrale per il Catalogo e la Documentazione – Aerofototeca Nazionale* and *Istituto Geografico Militare* (Figures 2, 3 and 4); in addition, a space photo taken by a Hexagon KH-9 satellite in 1974 (ground resolution of 1.2-0.6 m) was collected from the United States Geological Survey, and some recent high-resolution satellite images and aerial orthophotos available online were consulted.

Furthermore, a GIS platform was created in order to have an integrated knowledge base useful to set up a historical topographical study of the organization and transformations of the area in relation to the urban context of ancient *Venusia*. Information layers of the georeferenced remote sensing data have been set up and uploaded. The GIS platform has also been integrated with other ancillary information (bibliographic data and plans of the ancient city sector brought to light by the archaeological excavations), and with data from the recent geophysical surveys carried out by the Geophysics Laboratory of CNR-ISPC in the areas adjacent to the amphitheatre (Magnetometry) and inside the Chiesa dell’Incompiuta (Ground-Penetrating Radar).



Figure 2. Excavated structures of the amphitheater area in a historical aerial photo taken by S.A.F. (*Società AeroFotografica*) in 1964.



Figure 3. Amphitheater area in a historical aerial photo taken by IGM (*Istituto Geografico Militare*) in 1990, which documents new excavated sector in the center of the arena (underground service rooms).



Figure 4. Excavated structures of the amphitheater area in a historical aerial photo taken by Avioriprese in 1995.

III. MANAGEMENT OF REMOTE SENSING DATA IN A GIS PLATFORM AND RELATED MULTITEMPORAL ANALYSIS

The collection and systematic study of a large data set of historical and recent aerial and satellite data available for the Venusia site represent the focus point of this study. The full documentation and the diachronic knowledge of a specific sector of the ancient city, in this case the amphitheatre area, is the basis in the planning of any investigation by innovative methods and techniques. In particular, historical remote sensing data document the appearance and conservation conditions of archaeological remains over the last century, which have inevitably affected by agricultural works and growing urbanization. In this regard, the research, selection and acquisition of all the historical and recent aerial photos collected from the archives of Aerofototeca Nazionale of the Istituto Centrale per il Catalogo e la Documentazione” (Figure 5) and Istituto Geografico Militare was a priority research activity (Figure 6).

Foglio	Ente	Data	strisciata	fotogramma	negativo	formato	Quota	Scala
187	RAF	2-9-1943	2052	5018-5019		(23x23)	26000'	1:54.000
187	VB	3-6-1955	199A	8516		(23x23)	6000	1:33.000
187	VB	9-6-1955	138	8940-8941		(23x23)	6000	1:37.000
187	SAF	6-12-1964	2	6165-6166-6167-6168	75081 75080 75079 75078	(24x24)		1:9.000
187	SAF	6-12-1964	Mosaico A	34656		(16x22)		1:10.000
187	ESACTA	6-10-1969	78	947-948-949-950		(24x24)	1900	1:10.500
187	SAF	1969	Mosaico B: (4-11-1970)	35766		(13x23)		1:18.420
187	ESACTA	1969 (?)	2C	834	87581	(23x23)		1:19.500
187	ESACTA	1969 (?)	1H	835	87582	(23x23)		1:19.500

Figure 5. Metadata of vertical aerial photos of Venusia collected from Istituto Centrale per il Catalogo e la Documentazione – Aerofototeca Nazionale.

Strisciata	Fotogrammi	Formato	Ente	Data	Quota	Scala
IX	92	30x30	IGM	14-7-1953	4700	1:24.000
XXIIB	2369, 2370	23x23	IGM	25-7-1974	2600	1:15.000
XXIIIB	2412, 2413	23x23	IGM	25-7-1974	2600	1:15.000
X	1619	23x23	IGM	13-9-1985	5220	1:34.000
10	54, 55	24x24	IGM	25-6-1990	6000	1:35.000
10	1100	24x24	IGM	5-3-1991	6000	1:35.000
90	4468	24x24	IGM	7-5-2003	4550	1:30.000

Figure 6. Metadata of vertical aerial photos of Venusia collected from Istituto Geografico Militare.

These photos were originally taken for both military and cartographic purposes and therefore cover a period of sixty years, which goes from 1943 to 2003. In particular, among the vertical photos, in the first archive the oldest aerial images preserved for the study area date back to the second world war and were taken by Royal Air Force in 1943. Other important images are from the so-called *Volo Base* or *Volo GAI* (*Gruppo Aeronautico Italiano*) taken in 1955, and from more detailed flights from SAF (*Società AeroFotografica*) and ESACTA (*Ente Specializzato Aerofotogrammetria Cartografia Topografia Aerofotogeologia*) companies taken in the 1960s. The second archive preserve instead IGM flights from 1953 to 2003. To these acquisitions is added a space photo taken in 1974 and the consultation of recent orthophotos and satellite images freely available online (from National Geoportal website, Basilicata Region website, and Google Earth).

The dynamic and spatial archiving, visualization, interpretation and management of many heterogeneous data (aerial photos, satellite images, cartographies, plans of the structures brought to light by archaeological

excavations, results of topographic and geophysical surveys) was obtained by the building of a GIS platform. Among the available solutions, the open-source software QuantumGis (QGIS) was exploited. As any geographical information system, it integrates multivariate data into a single archive, allowing interactions, and, subsequently, to summarise final evaluations and observations, which would otherwise be difficult to obtain.

The GIS project (Venosa Project.qgis) was set up using the geodetic-cartographic system with Universal Transverse Mercator (UTM) projection and WGS84 datum, and the overall data merged were organized into different information layers, on the basis of their typology (Orthophotos, Cartography, Historical Aerial Photos, Plans, Satellite Images, Geophysical Prospecting, Vectorization – Figure 7).

The cartographic base with a scale of 1:5,000 and the orthophoto taken in 2013 with a resolution of 20 cm were loaded in the GIS by WMS connection to the geoserver of the Basilicata Region website. The availability of suitable topographic reference bases was a necessary prerequisite in order to georeference the single aerial photos. This operation performed by the Georeferencer Plugin in QGIS allowed to transform, through a “mapping function”, the raster files of the simple scanned aerial frames into georeferenced raster files (.geotiff). These processed data have been all merged into information layer of the remote sensing data, ready to be analysed and studied.

IV. RESULTS AND CONCLUSIONS

The multitemporal data set collected for *Venusia* and in particular for the amphitheatre, mostly aerial photos, allowed for the documentation of the transformation of the study area from the 1940s until today and the acquisition of important information about the layout of the monument and its surrounding area. Indeed, the multi-temporal analysis of aerial photos, managed by the specially developed GIS platform, allowed for an integrated knowledge of the site, also documenting the various

different phases of the archaeological excavations (especially those of the 1960s, which have not been published), showing some structure brought to light that which are no longer visible today. Therefore, the new acquired data are also useful for a better contextualization of data acquired by the topographical surveys carried out by the Digital Heritage Innovation Laboratory of CNR-ISPAC in order to produce a general plan of the monument, which constitutes the base for its 3D reconstruction.

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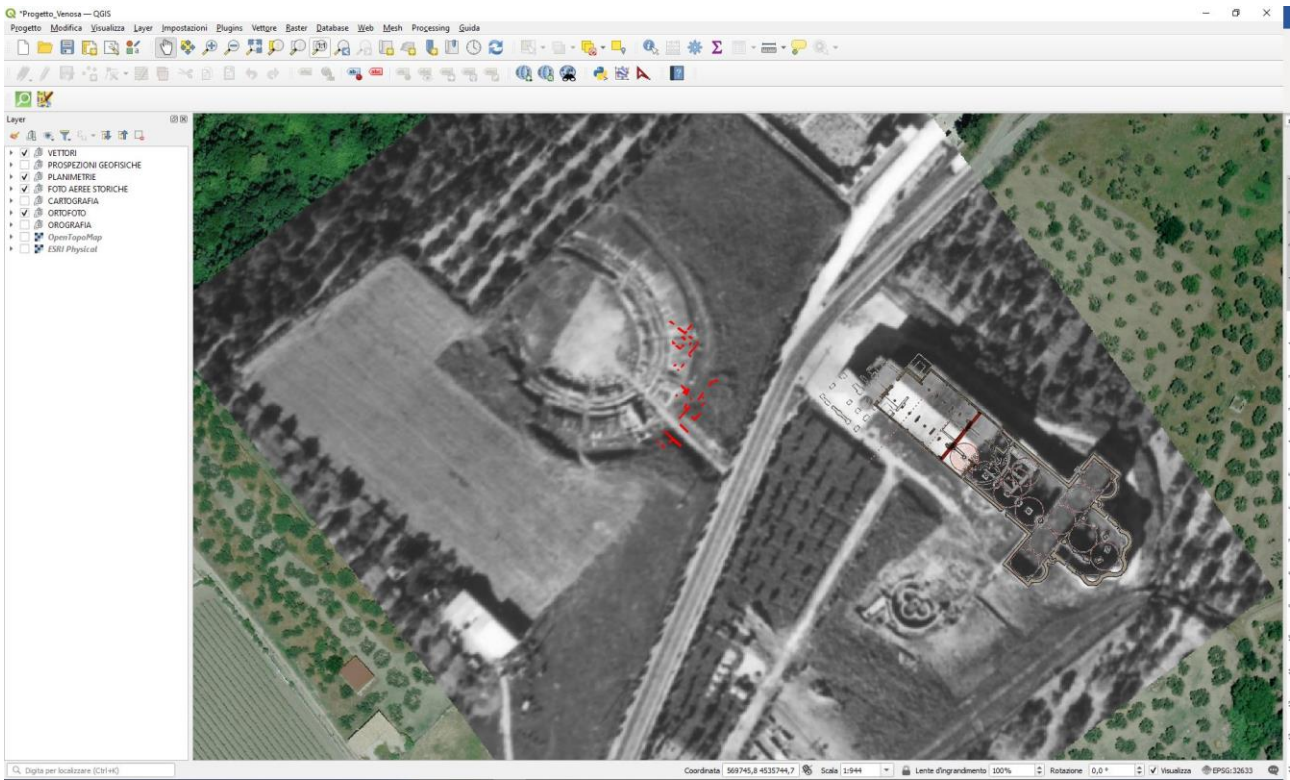


Figure 7. Multivariate data organized in the GIS platform of Venusia with example of a georeferenced ESACTA aerial photo of 1969 and visualization of the residential spaces highlighted below the amphitheatre (in red).