

# Rectification of Historic Royal Air Force Aerial Photos and Generation of an Aerial Image Mosaic of the Sarno River Basin, Italy

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**Summary:** Within the geoarchaeological project “Reconstruction of the Ancient Cultural Landscape of the Sarno River Basin” a rectified high resolution aerial image mosaic of 1943 was generated to subsequently analyze ancient land fragmentation (centuriation). Because today the Sarno River basin is a highly urbanized and populated area, many landscape structures such as ancient roads, field boundaries or remains of the natural river network can be better verified on the historic photographs than on recent ones. Therefore Royal Air Force (RAF) aerial photographs from 1943 were rectified and georeferenced using recent digital Italian topographic maps on a scale of 1 : 25,000.

**Zusammenfassung:** Entzerrung von historischen Luftbildern der Royal Air Force und Erstellung eines Luftbildmosaiks des Sarno-Beckens, Italien. Innerhalb des geoarchäologischen Projektes „Rekonstruktion der antiken Kulturlandschaft des Sarno-Beckens“ wurde ein hoch aufgelöstes Luftbildmosaik von 1943 erstellt, anhand dessen später die antike römische Landeinteilung (Zenturiation) näher untersucht werden soll. Da das Sarno-Becken heute einen stark urbanisierten und dicht bevölkerten Raum darstellt, sind viele der alten Landschaftsstrukturen wie zum Beispiel antike Straßenverläufe, Flurgrenzen und Reste des natürlichen Flussnetzes auf den historischen Photos besser zu verifizieren als auf heutigen. Aus diesem Grund wurden Luftbilder der Royal Air Force von 1943 mit Hilfe Italienischer topographischer Karten im Maßstab 1 : 25.000 entzerrt und georeferenziert.

## 1 Introduction

Until today the archaeological research activity of the Vesuvius region in Southern Italy was particularly focused on urban settlements like Pompeii, Nuceria and Stabiae. However the cities cannot be considered in isolation from their hinterland in which they were geographically, politically and culturally embedded and from which they were economically dependent. Consequently in the year 2006 the German Archaeological Institute initiated a geoarchaeological project which is entitled “The Reconstruction of the Ancient Cultural Landscape of the Sarno River Basin”.

The aim of this project is to expand the focus of research in the Vesuvius region from cities like Pompeii into the surrounding Sarno River basin by investigating the natural condi-

tions of this landscape and the anthropogenic influence in the Roman period. This project brings together scientists of different disciplines such as archaeologists, archaeobotanists, geographers and pedologists from different institutional and national backgrounds of Germany, Italy and Great Britain (SEILER 2007, 2008).

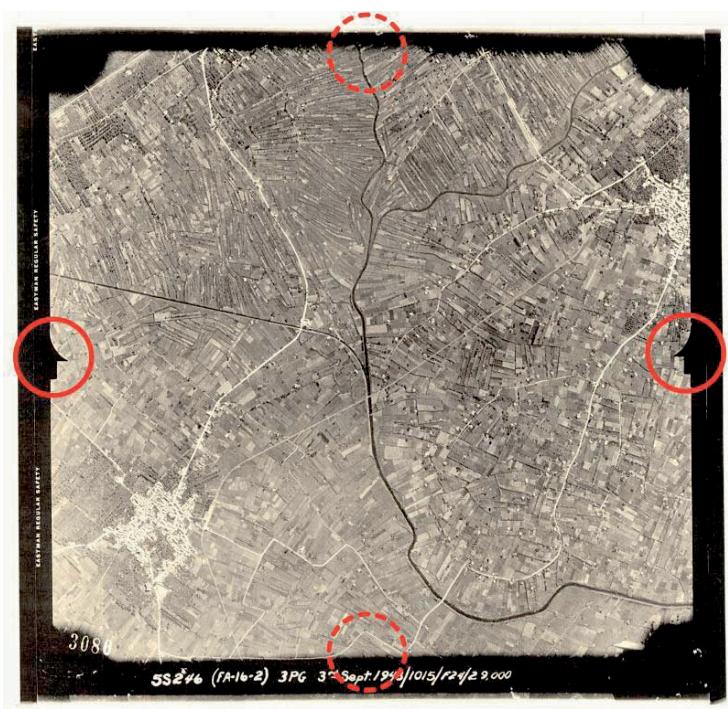
One important anthropogenic and political factor that influenced the spatial structure and organization of the Sarno River basin in Roman times was the ancient land fragmentation or the so-called centuriation. Some past research projects have already enabled the identification of relics of ancient land fragmentation by using present-day cartographic material and aerial photographs of the Sarno River basin. They show that in spite of time and volcanic eruptions ancient landscape structures

can be passed on over centuries. Volcanic depositions directly blur or even erase many landscape structures of an affected area. However due to the continuity of settlement in the respective territory those former structures often re-emerge (CASTAGNOLI 1956, 1958; CHOUQUER et al. 1987; SORICELLI 2001).

For the first time this past hypotheses on Roman centuriation are to be verified using aerial photographs of the Royal Air Force (RAF) from 1943 (National Aerial Photography Archive, Central Institute for Cataloguing and Documentation, Rome) to prospectively carry out a structural analysis of the landscape of the Sarno River basin by means of geographic information systems (GIS) and remote sensing. This analysis will be based on a high resolution aerial image mosaic from 1943 showing the rural landscape of the Sarno River basin before the last eruption of Somma-Vesuvius in March 1944 and the strong urbanisation process of the last 50 years.

## 2 Methodology

The generation of the aerial photo mosaic of the Sarno River basin to subsequently analyze ancient land fragmentation (centuriation) was carried out by rectification of historic RAF aerial photos of 1943 using present day topographical maps (Italian Military Geographic Institute (IGM) 1:25,000). The RAF aerial photographs were of rather fair quality because only scans of paper copies were available for the restitution process. Furthermore the photographic material was relatively inhomogeneous as the photos had different scales of approximately between 1:10,000 and 1:30,000. In order to prepare the data in GIS and combine them with other available geographical data especially from the local Italian authorities (e. g., Autorità di Bacino del Sarno, Soprintendenza Speciale per i Beni Archeologici di Napoli e Pompei) the Italian Gauss-Boaga-coordinate system was used.



**Fig. 1:** Example of an RAF aerial photograph of 1943. Note that only two fiducial marks are visible on the left and right hand side.



**Fig. 2:** Example of control points measured in both IGM map (left) and RAF aerial photograph (right) (screenshot from LISA software). Clearly to be seen is the different angle between the map and the photo and the distortion because of central perspective in the photograph before rectification.

The basis of the rectification of the RAF aerial photos were the following 8 sheets of the present day IGM map on a scale of 1:25,000: Pomigliano, Nola, Ercolano, Sarno, Torre del Greco, Nocera Inferiore, Sorrento and Amalfi. Therefore they were scanned and georeferenced by means of Gauss-Boaga coordinates given on the respective sheets.

The calculation of the RAF aerial photos could only be made by means of a simple two-dimensional instead of a true photogrammetric three-dimensional rectification since the scanning of the photos was not carried-out according to photogrammetric factors. Hence most of the images did only hold two or less fiducial marks as to be seen in Fig. 1.

In a first step the topographic maps as well as the aerial photographs were scanned. The scanning was carried out at 600 dpi. Because of the rather poor quality of these images no higher resolution was recommendable; hence a higher resolution would have caused a significant increase of noise. Digitizing the topographic maps (1:25,000) at a resolution of 600 dpi resulted in a pixel size of 1.05 meters. Amplification of the digital topographic maps produced a control point accuracy of 2 to 3

meters which can be assumed for the topographic maps as well as for the aerial photographs, reaching a scale of 1:25,000 on average. Having in mind noise and scanning artefacts and taking also into consideration the aspect of generalization the geometric resolution (pixelsize) was set to 2 meters.

The RAF aerial photographs were cut off, clipping the frame and the fiducial marks. Then the image data were imported into the operating software (LISA) and turned by approximately 90° in order to achieve a nearly northern orientation. Thus control points in both maps and photos could be identified more easily. These control points were the basis for the rectification process (cf. Fig. 2). 30 to 40 in particular cases even more control points were measured on each aerial photo. One has to take into consideration that the control points have to be well distributed to cover the whole area of a certain photograph (LINDER 2003). Every photo was rectified (x and y) by a plane affine transformation within the flat areas of the Sarno River basin whereas in the adjacent mountainous regions rubber-sheet stretching was used. Afterwards outliers were removed manually (HECK 2006). In a last step the recti-

fied RAF aerial photographs were assembled to an aerial image mosaic of the Sarno River basin of 1943.

### 3 Results

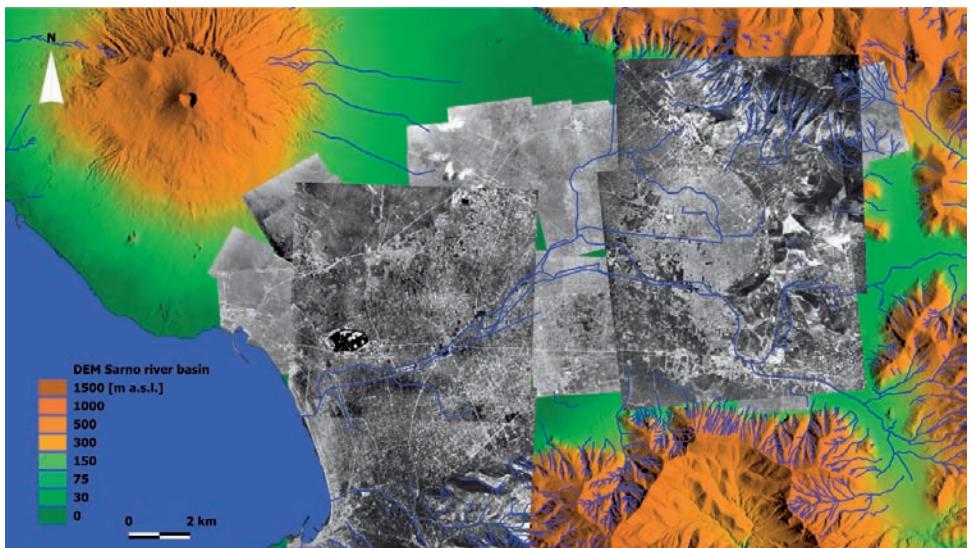
The obtained aerial image mosaic of the Sarno River basin 1943 (cf. Fig. 3) can provide important data for geoarchaeological landscape research because it shows the rural landscape of the Sarno River basin before the last eruption of Somma-Vesuvius 1944 as well as the vast urbanization process respectively.

The eruption of Somma-Vesuvius in March 1944 on one hand had a considerable impact especially on the northern and northwestern territory of the Sarno River basin due to depositions of ash and pumice falls as well as small pyroclastic flows. On the other hand nowadays the Sarno River basin is a highly urbanised and populated area. This urbanization process that particularly took place within the last 50 years has also erased many natural landscape structures. Consequently features like ancient roads, field boundaries or remains of the natural river network are expected to be much better and more reliable verified on the historic orthophotos than on recent ones. Fig. 4 illustrates the effect of this urbanization process in

terms of the consumed area exemplarily for a 40 km<sup>2</sup> sector around the excavations of Pompeii. On the RAF aerial photograph of 1943 (left) an area of 1.7 km<sup>2</sup> can be considered as urbanized, which is a total of 4.3 %. On the aerial photograph of 2001 (right) the urbanized area has increased by six to 10.3 km<sup>2</sup> or 25.8 % of the total area. Even outside the urbanized area the change of landscape patterns within the last 60 years is clearly to be observed. Consequently carrying out a structural analysis of the landscape of the Sarno River basin by means of the RAF imagery of 1943 to analyze ancient land fragmentation (centuriation) is much likely to yield more detailed data than using present-day aerial photographs.

It is noticeable that the RAF aerial photos were inhomogeneous regarding flying altitude (6,400 to 8,800 meters), flying direction and the seasonal aspect between the individual flights (May 1943 and August/September 1943). This results in different lighting conditions, scales and levels of detail of the aerial image mosaic. Furthermore it is evident that certain areas of the Sarno River basin were repeatedly covered by several flights whereas others were missed out.

Most of the rectified RAF aerial photographs fit well. The results within the Sarno River basin are more trustworthy than in the



**Fig. 3:** Digital elevation model (DEM) of the Sarno River basin with the mosaic of the rectified RAF aerial photographs of 1943 on top of it.



**Fig. 4:** Urbanized area around the excavations of Pompeii (red) shown on rectified aerial photos of 1943 (left) and 2001 (right).

surrounding mountain chains. In flat areas residuals were 2 to 5 meters in x and y direction. In mountainous regions deviations of up to 10 meters are locally to be found. This is due to the simple two-dimensional rectification and the generalisation of the topographic maps. Especially dislocations of roads and canals within the 60 years between the date of the photo flight and the creation of the IGM map may also have contributed to these deviations. Despite the high amount of in total 85 rectified RAF aerial photographs some gaps remain that were not covered by the available photographic material. To fill those gaps and to yield more precise data in the adjacent mountain regions in a next step Italian AMI aerial photos of 1943 will be rectified by means of a real photogrammetric three-dimensional restitution. Subsequently the historic image data will be used to carry-out a structural analysis of the landscape of the Sarno River basin to analyze ancient land fragmentation (centuriation).

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