Draping of aerial photographs on DTM LiDAR for the historical reconstruction of the vicus of Aequum Tuticum along the Via Traiana.

Paola Guacci[1], Rosanna Montanaro[1]

[1] *Università del Salento, Laboratorio di Topografia Antica e Fotogrammetria, Via Dalmazio Birago 64, 00174 Lecce, paola.guacci@unisalento.it*

[1] *Università del Salento, Laboratorio di Topografia Antica e Fotogrammetria, Via Dalmazio Birago 64, 00174 Lecce, rosanna.montanaro@unisalento.it; rosmontanaro28@gmail.com*

***Abstract* – This paper focuses on the lack of detailed coordinate references that consider also the altitude (z) as a recurrent limit of the historical aerial photography. Within the study presented in this paper, we show the "draping" process, using a merged, georeferenced triple stereoscopy image, and a high resolution LiDAR DTM with the aim to obtain a running association of the factor z to a historical airborne photographs.**

The territory chosen for this study is the area occupied by the roman vicus of Aequum Tuticum, on the oriental side of Campania region (Italy), where several aero-topographical and geophysics studies have been done by the LabTAF of University of Salento. This process, adopted in this territory for the first time, let to insert the surveyed archaeological evidences in the exact geomorphological context and to calculate the slope that influences the various reconstructed roman roads.

I. INTRODUCTION

In the frame of Landscape Archaeology and in particular for the historical and topographical reconstruction of the territory, the use of aerial photography as a precious source of information is widely adopted. The aerial photographs taken between the thirties and seventhies of the last century represent a unique historical document, because data and historical information could help to reconstruct territories that have been modified in recent times. Therefore, it is resonable to always take into consideration these photographs to better understand the history of a transformed and strongly anthropized landscape; this is also the primary subject of an integrated and multidisciplinary topographical study. For these reasons, flights though airplane, drones and satellite imageries too are widespread for the diachronic and correct study of the landscape, especially when they are associated and compared to the historical photographic documentation. Therefore, new ways to enhance the quality number of details arising from this documentation can be explored and adopted. (P. G.)

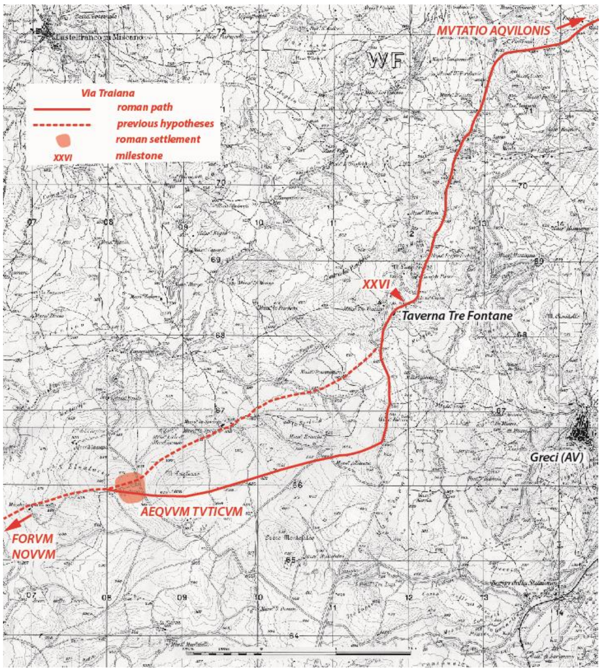

Fig. 1. The path of the via Traiana *as recognized from the topographical and archaeological studies led by the LabTAF of University of Salento (Ceraudo, Ferrari 2016).*

II. THE STUDIED AREA

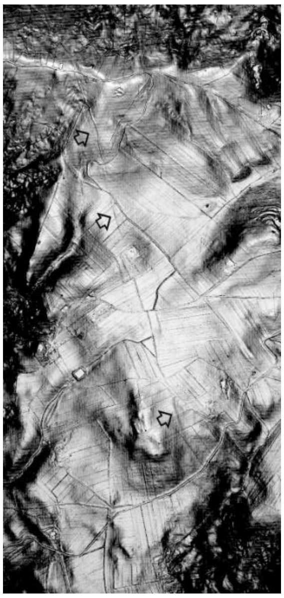

Fig. 2. 1m resolution LiDAR DTM of the Aequum Tuticum *aerea. The arrows indicate the path of the* Via Traiana *in the east side of the ancient city. Shaded relief visualization, H.90; Azimuth 315.*

The roman city of *Aequum Tuticum* is located on the northeast part of Campania, in the middle of Miscano Valley, at c.da S. Eleuterio of Ariano Irpino (AV). The site raised up on a plateau of 575 m a.s.l. and it was naturally protected by the Miscano river at the North and West side, by the S. Eleuterio rill at South and by the gentle mountains of Monte Pagliaro (678 m a.s.l.) at the East side. Moreover, this area was crossed by Regio Tratturo Pescasseroli-Candela for 4 km southward and by significant roman roads: the *Via Aemilia*, the *Via Traiana* and the *Via Herculia*.

The ancient *vicus* of *Aequum Tuticum* is correctly identified in c.da S. Eleuterio since the XVIII century [1] [2] [3] [4] [5]; according several ancient sources [6] [7] [8] that referred about the route of the *Via Traiana* [9] [10] [11]. The area was also examined by the Soprintendenza Archeologica di Salerno, Avellino and Benevento between 1989 and 1992. These investigations unearthed a number of buildings of the imperial age, such as *thermae* of the I century a.D. and *horrea* and *tabernae* of the II century a. D. These buildings were evacuated in the IV century a. D. when the site was evacuated after a terrible earthquake. After this event, the life of the city continued until the V century a. D., as suggested by some archaeological evidences of a building located near the *horrea*.

Lately, the plateau of S. Eleuterio was interested by some archaeological surveys and magnetometric prospections led by the LabTAF of University of Salento

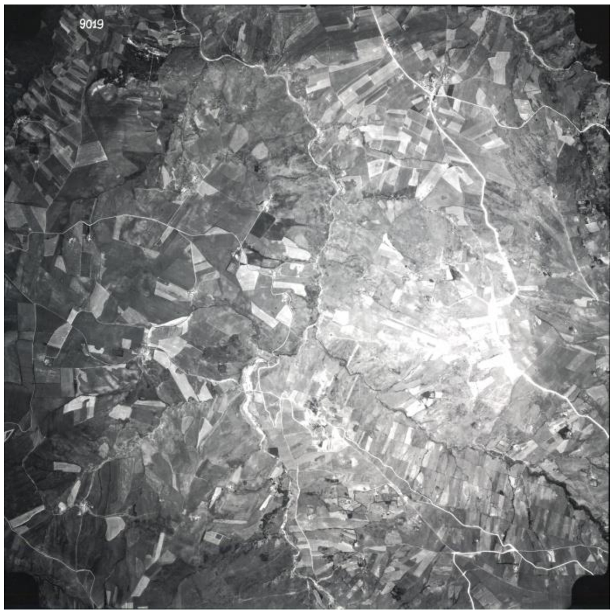

Fig. 3.One of the three historical ortho airborne photographs used in this study.

[12]. Thanks to these studies, a city area of 14 ha has been estimated. Many archaeological sherds were found overlaying the ground-level and these sample gave a chronological picture of the explored area, from the late imperial age to the late antiquity age.

Current data allow an accurate reconstruction of the path of the *Via Traiana*, a roman road constructed in the 109 a. D. that connected Benevento to Brindisi. When crossing *Aequum Tuticum*, this road cut across the late path of *Via Herculia*. Geophysics survey have clearly shown the intersection of these important routes in the center of the ancient roman site. Moreover, the aerial topographic investigations led by the LabTAF in the framework of the "Progetto Via Traiana"[4] detected the path of the incoming and outgoing roman road to and from *Aequum Tuticum* [12] [13] [14] [15] [16] (fig. 1). This evidence is also confirmed by LiDAR data (fig. 2). (P. G.)

III. MATERIALS AND METHODS

This study focuses on the "draping" of historical aerial photographs on a high-resolution LiDAR DTM. This process is the first attempt to enhance the geomorphological and archaeological characteristics of the landscape pictured in these imageries and to obtain a running association of the factor z to an historical airborne photograph, this process will eventually solve the problem of a lack of lens corrections of the camera that makes an orthorectified image of a difficult creation

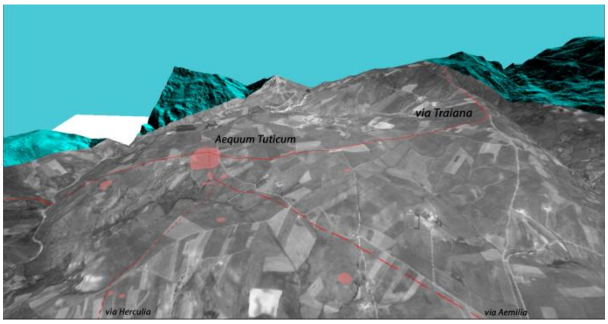

Fig. 4. The result of the draping process.

The selected images are three airborne black and white ortho photographs shot by an airplane and numbered respectively 9019, 9020, 9021 (fig. 3). These pictures belong to the airborne strip number 25 of the ESACTA flight of the 1974. All the frames cover the area of 39 square km, occupied by the ancient site of *Aequum Tuticum* and the neighbor landscape that belong to the modern towns of Ariano Irpino, Greci, Savignano di Puglia and Castelfranco in Miscano.

The high resolution DTM employed in this research is the LiDAR DTM acquired by the Italian Ministry of Environment and Protection of the Land and Sea to record the Italian riversides and coasts with a terrestrial resolution of 1m. The resolution of this DTM is certainly one of the most accurate among the commercial DTM supplied by local SIT (Territorial Information System), which have a terrain resolution of maximum 3m.

The DTM used, overlaid almost all the areas of the three sheets of the cartographical map at 25:000 scale that cover the interested area. Moreover, the LiDAR DTM itself is under analysis in order to detect archaeological features of this zone; numerous studies have already demonstrated the relevance of this data in order to detect archaeological evidences on the terrain [18] [19] [20].

Moreover, an IGM cartography at 25:000 scale of the region is employed as topographical support.

A. Processing of the airborne photographs

The following simple steps were followed to obtain georeferenced vertical historical airborne photographs:
- scanning of the three images at 1200 dpi resolutions;
- cutting out of the margins; on the top side is located the "datastrip" where are set the altimeter, the level the clock and the counter, all elements that permit to identify the characteristics of the flight. After cutting, only the main scene remained;
- merging of the triple stereoscopic images. In this phase, a union of the three photographs was done with a photo-merging software. The software allowed the vertical airborne photographs, with no geometric parameters related to the camera, to be processed. The union of the images was automatic: analogous points (tie points) among the images were recognized in the area (that is the 60% of the frame) where the photographs overlap. During

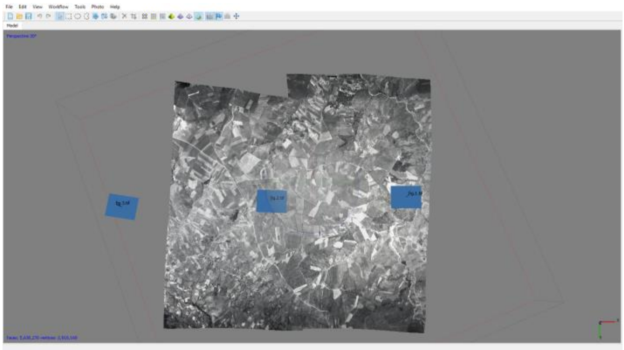

Fig. 5. Merge of the triple stereoscopic images.

this process, a dense point cloud was generated, and it represented the starting point for the creation of a texturized 3D model (fig. 5);
- exporting of the tiled high resolution orthophoto that represent the raster used in this work.
- the tiled raster is imported in a GIS platform. In this step, it is essential its georeferencing process, done considering an IGM cartography at 1:25000 scale the referring map, because there is a strictly correspondence between the historical photos and cartography. The geographical reference system adopted is the WGS84 associated to the UTM projection. The raster was thus corrected using 50 GCP (ground control points) well distributed over all the frames.

B. The draping

The term draping refers to the possibility to project over a three-dimensional terrain model a raster image, in order to obtain a realistic virtual model of the examined territory. Through this process, the image could be associated to all the spatial information of the DTM, that is the x,y,z coordinates. Thus, the more accurate and high resolute are the DTM used, the more impressive and detailed measurement we can carry out on the surveyed landscape: a 1m resolution LiDAR DTM is therefore used and this study, considered appropriate for this scope.

Several GIS software allow a similar process, either commercial (ArcGis, Global Mapper etc.) or open-source (Qgis, GRASS etc.), overlaying the historical georeferenced image to the DTM LiDAR (fig. 4).

C. The digitalization of the archaeological features

In this study, it was paid attention to the identification and digitalization of the archaeological feature recognized both on the historical aerial photographs and on the LiDAR DTM. This operation was made through the digitalizing tool used in the GIS workspace.

Although the detection of potential archaeological features through LiDAR DTM is still under analysis, it was possible to detect, as already stated, the trace of the via Traiana, located in the eastern area of the city (fig. 2). In this area, the trace of the roman road is visible on the hill shade visualization from a different orientation (azimiuth) and

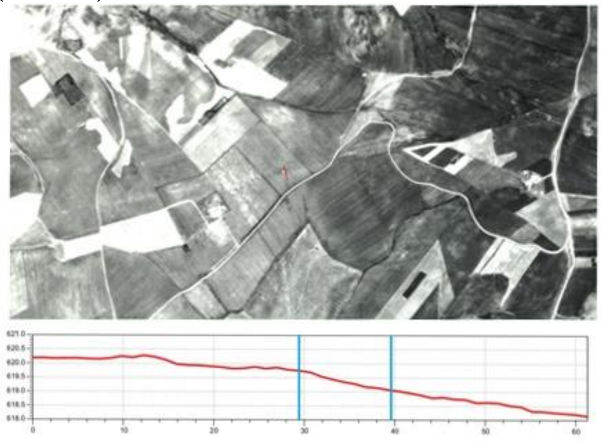

Fig. 6. Path profile of a sector of the via Traiana*, eastward to* Aequum Tuticum*.*

altitude of the artificial light. This is an important evidence that opens new thoughts about the typology of this archaeological trace and its nature and formation indeed. Furthermore, other possible archaeological features are recognized nearby, but they are still under debate. (P. G.)

IV. DISCUSSION OF THE RESULTS

Fig. 4 shows a 3D view of the studied area generated by the draping of the historical airborne photographs with the high-resolution LiDAR DTM. This visualization allows to familiarize with the actual geomorphological formation of the area on the historical photographs, giving them a more accurate and realistic visualization. Furthermore, it is possible to note that the digitalized archaeological feature detected by the optical analysis of the photographs and by the other topographical surveys, led by the Soprintendenza and the LabTAF of the University of Salento, are also draped on the surface, in particular on the historical photograph one.

Despite the resolution of the photographs is degraded, due to the 3D visualization process, it is possible to highlight the path of the *via Traiana* and speculate on the choice made by roman engineers when tracing its course with the intent to adapt the road to the geomorphological condition of the area.

Another contribution of the draping method and the adoption of the GIS software for the comprehension of the factor z enabled in the historical aerial photography is the possibility to draw the terrain or path profile of a chosen area directly on the historical image. The top side of (fig. 6) shows the range of land analysed by this tool (marked by a line in red) while, in the right side, there is the representation of the section of that land portion. The diagram shows on the y axe the altitude of the area analysed, while the x axe indicates the length of the area, all expressed in meter. In this given example, the selected area correspond to a part of the *via Traiana* course, on the east side of the city. The drawn profile shows the slope where the roman road was built and it is possible to detect the profile of the road itself (it is marked between blue strips in the diagram). Therefore, this kind of archaeological feature is easier to visualize in a three-dimension way, that is otherwise very difficult to identify on a normal georeferenced historical image.

The LiDAR DTM accentuates the detection of a trace in a three-dimensional way and the best contribution of this technology for the reconstruction of the ancient landscape is the possibility to recognize the micro-elevation produced by certain archaeological marks. In this case study, the attention was stressed on the archaeological trace of the *via Traiana* that is visible in its real dimension and not only as a soil or crop mark: the research presented in this paper has shown the successful outcome produced by the association of the evidences provided by the LiDAR DTM with the historical airborne images. (R. M.)

V. CONCLUSIONS AND FINAL REMARKS

The draping process presented in this paper enables the association of the altitude coordinate (z) of a high resolution LiDAR DTM to geo-referenced historical ortho- photographs that lack of information; the intent was to create an orthorectified image through a traditional photogrammetric way. However, the running method here practiced allows the first vivid and realistic visualization of an historical image and of the precious archaeological features that they show. In this way, archaeological traces are easily insert in their real geomorphological context.

Moreover, the potential of the LiDAR DTM to detect archaeological features could eventually produce new information that can be adopted for the comprehension of the development of the archaeological traces and, also, of their acquisition. The process is especially successful when archaeological traces are strictly associate to airborne images, in particular the historical ones.

The attempt here described does not provide a real orthorectified historical image and the images lack, in the final process, of a high resolution. However, the findings here observed, allow to a greater contextualization the landscape shown in the historical image and in the LiDAR DTM. Then, the further step that this research suggests is to create an orthorectified historical photograph using the z factor furnished by the LiDAR DTM [21]. (R.M.)

REFERENCES

[1] T. Vitale, Storia della Regia città di Ariano Irpino e sua diocesi, 1974.

[2] D. Romanelli, Antica topografia istorica del Regno di Napoli, 1815.

[3] H. Nissen, Italische Landeskunde, Vol. II, 1902, p.

816.
[4] CIL IX, p. 122.
[5] A. Sogliano, Aequum Tuticum. Contributo alla toponomastica e alla topografia antica, in Atti della Reale Accademia di Archeologia, Lettere e Belle, n.s., v. 11, parte 1, 1929-1930, p. 245.
[6] Cicero, *Ad Atticum*, 6, I, I.
[7] Cicero, *ad Aen*. 8,9.
[8] Porfirio, *ad Horat. Sat.*, 1, 5, 87.
[9] *Tab. Peut.* VI, 3-VII, 1.
[10] *It. Ant.* 112, 1-2; 116, 1-118, 2.
[11] *It. Burd.* 609, 9-610, 11.
[12] G. Caldarola, L. Castrianni, G. Ceraudo, I. Ditaranto, V. Ferrari, I. Gennarelli, F. Pericci, Reading an ancient vicus with non-invasive techniques: integrated terrestrial, aerial and geophysical surveys at Aequum Tuticum (Ariano Irpino-AV), in Archeologia Polona, 53, 2015, pp. 193-197.
[13] G. Ceraudo, Sulle tracce della via Traiana. Indagini aerotopografiche da Aecae a Herdonia, 2008.
[14] Th. Ashby, R. Gardner, The Via Traiana, in PBSR VIII, 1916, pp. 104-171.
[15] G. Alvisi, La viabilità romana della Daunia, 1970.
[16] V. Russi, La via Traiana tra il Sannio e la Daunia. Indagini topografiche ed archeologiche, in Archivio Storico Pugliese LX, 2007, pp. 31-56.
[17] V. Ferrari, 2013, Il tracciato della via Traiana al confine tra Puglia e Campania, in Archeologia Aerea VII, 2013, pp. 65-70.
[18] Devereux B.J., Amable G.S., Crow P., Cliff A.D., The potential of airborne Lidar for detection of archaeological features under woodland canopies, in Antiquity 79/305, pp. 648-660.
[19] M. Doneus, C. Briese, Full-waveform airborne laser scanning as a tool for archaeological reconnaissance, in S. Campana, M. Forte (eds.), From Space to Place. 2nd international conference on remote sensing in archaeology, CNR – National Research Council, Roma 4-7 December 2006, BAR Oxford 2006, pp. 99-105.
[20] R.S. Opitz, D.C. Cowley (eds.), Interpreting Archaeological Topography. 3D data, visualisation and observation (Occasional Publication of the Aerial Archaological Research Group, 5), Oxford 2013.
[21] G. Pulighe, Ortorettifica di foto aeree storiche per lo studio delle dinamiche ambientali in regioni montane, in GEOmedia n.3, 2009, pp. 18-21.