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To cite this article: Joel Aldrighettoni and Alessandra Quendolo 2022 *J. Phys.: Conf. Ser.* **2204** 012051

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# Warscape biography: from historical air-photos to Lidar data. The revealing of the Great War's permanences on the contemporary landscapes.

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**Abstract.** One hundred years ago, the European landscape was radically transformed by a complex and articulated set of fortified works built in anticipation of the Great War and the "signs of destruction" inflicted on the territories by the conflict itself. These vestiges, recognized as "material goods having a value of civilization", today are characterized by different degrees of permanence that make it very difficult to read and recognize them. In response to the awareness of the "risk of loss" of this tangible heritage, and consequently of our "possibility of memory", this essay proposes a methodological path useful to face, at different scales, the theme of the recognition of what remains of the tangible impact that the Great War had on the European landscape, in order to understand better how to "take care of it" in the future. Inserting itself in the wake of the line of research already known as "Archaeology of the Great War", the research carried out recognizes the heritage of vestiges, visible but also "submerged", as a wide and "deep" information basin to be investigated and known through the diachronic comparison of different documentary sources and current territorial datasets. This method is based on the wide potential offered by GIS software. It aims to reconstruct the biography of the different warscapes by integrating the study of vintage military aerial photographs, properly geo-referenced, with the different uses and land cover, past and present, to precisely map the different degrees of impact the conflict has had on different territorial areas. Finally, in the areas with a higher Impact Factor, through the contribution of some specific visualizations of LIDAR (Sky-view Factor and Multihillshading Visualization), it was possible to reveal the actual permanence of the imprint of war still imprinted on the morphology of the contemporary landscape.

## 1. Introduction

The articulated and heterogeneous set of relics of the Great War represents a highly complex cultural heritage which, recognized as "material evidence having a value of civilization", is protected in Italy by law nr. 78/2001. This law constitutes an essential point of arrival of a progressive interest that, starting from the 70s, has developed in response to the "risk of loss" of material remains linked to the conflict. At the same time, this law has stimulated new prospects for the recovery and valorization of this particular heritage. However, in the light of all the interventions that in the last twenty years have been concerned with these fortified works, what we see today is a general inability to recognize this heritage as a "system", that is, as a network of punctual elements that are reciprocally linked through physical and visual connections, connected according to a logic of functionality. This translates into the current difficulty of bringing out the deep relationships that the permanent works had with their surroundings, and in fact, what is most "at risk of loss" are all those signs that are more fragile in terms



of permanence, such as entrenched systems, barracks, obstacle courses, field stations, temporary constructions, as well as the same "signs of destruction" inflicted on the landscape directly from the war event. In order to provide an important contribution to the future practices of "care" and enhancement of this heritage, in the context of the current research has been developed an operational method able to retrace the evolutionary history of the different warscapes and then to facilitate the recognition of the different permanences of vestiges within the contemporary multi-layered landscape, in a non-invasive way.

## **2. The Great War's "imprint": the definition of a method to facilitate its recognition**

The elaborated method represents a useful tool to learn to decode the contemporary landscapes through the lens of the stratigraphic-constructive observatory in order to be able to recognize the permanence of history, specifically of the Great War, even if "submerged" under the successive stratifications deposited over time.

A careful comparative study of the design and photographic documentary sources period/current and constructive characters-typological artifacts integrates the knowledge gained from the interpretation of a series of data obtained through the potential offered by the techniques of high-resolution remote sensing (remote sensing) and non-destructive testing. Satellite or aerial remote sensing, through the study of orthophotos and LIDAR data, is particularly useful to investigate the dynamics of transformation of the territories over time, comparing the impact of the war event of a hundred years ago with the current reconnaissance of the permanences. Metaphorically weaving the plots of the evolutionary biography of the contemporary landscape, this cognitive path allows unveiling the different temperatures at which the imprint of the Great War remains in the current morphologies of the territories.

### *2.1. Step 1. Data Collection and Materials.*

The preliminary phases to applying the method concern the retrieval of the available documentary materials and the input territorial datasets. As far as the historical documentation is concerned, it is a matter of archival and documentary research of the militarization plans of the areas under analysis, of the written and design documents of the fortified works and the period photographs preserved in museum collections and archives, with particular attention to those taken by the various air forces during the wartime aerial reconnaissance phases.

In parallel to identifying these basic materials, the non-invasive contribution of remote sensing and modern aerial photogrammetry technologies is of fundamental importance for the creation of informative datasets referring to the current morphology of the territorial areas of reference. Specifically, orthophotos and point clouds of geographic data collected with the Airborne Laser Scanner (ALS) are the foundational basis of the proposed method, providing a precise and detailed three-dimensional modeling of the current orography of the places.

### *2.2. Step 2. Methodology.*

The entire methodology can be organized in three distinct but deeply interrelated phases that provide for successive and gradual levels of analysis about the different degrees of complexity recognized.

The first step consists of digitizing all the cartographic and photographic documentation to form a homogeneous database through which to easily process these data, comparing different sources, which are heterogeneous in time and space.

The translation of the metric and topological content of ancient maps into digital form, and then also in a quantitative and not only qualitative-descriptive, is preparatory to the next methodological steps as it allows the inclusion and management within Geographic Information Systems (GIS), thus allowing the conversion into a language directly comparable with the spatial datasets provided by remote sensing, such as DTM, DSM, and orthophotos. The potentiality of georeferencing historical cartographies is evident when the "new" historical cartographies, thanks to the planimetric and altimetric information automatically transferred during georeferencing, can be quickly superimposed

with precision to the Digital Terrain Model (DTM) and the current orthophotos. In this way, the diachronic comparison between the documentary sources does not remain exclusively qualitative but allows accurate localization of the "signs" designed for the conflict on the morphology of the contemporary landscape. Net of the precision of the elaborations, it is, therefore, possible to assign to each constituent element of the different warscapes, present on the militarization plans, real coordinates of geographical location to identify and possibly recognize the degree of permanence within the contemporary landscape. Regardless of the current degree of visibility, in fact, through this knowledge-based method, it is possible to begin to identify the specific areas in which not only the permanent works were built, but also the provisional and field support works that, fragile by nature, are more prone to be reabsorbed into the dynamics of landscape modification, and therefore more exposed to the "risk of loss".

However, the importance of the informative potential represented by military aerial photographs is also manifested in the fragrance of information available regarding the real situation of the various "war landscapes" during wartime. From the images obtained during aerial reconnaissance, a great deal of information can be deduced regarding the use/coverage of the land and, above all, regarding the actual impact that the destructive effects of the war had on the territories.

In this sense, the second phase of the proposed methodology develops, concerning the study of the evolutionary dynamics of the warscapes through investigations at a higher level of detail and the expansion to the landscape scale of the interpretative code of archaeological and stratigraphic investigations. Specifically, the methodology proposes two different lines of investigation to be conducted in parallel: the first aims to characterize the different land uses in three different time frames (before/during/after the war) in order to understand the changes caused by the war; the second focuses on the mapping of the "signs of destruction" inflicted by the conflict itself, documented in previously georeferenced historical photographs. Operationally, the mapping of these different analyses can be easily managed simultaneously in GIS working environments through the characterization of the single perimeter polygons using different attributes concerning the specific land use and the degree of influence/impact derived from the conflict. Concerning the analysis of the Impact Factor, which is the specific focus of this study, the proposed method has provided for the assignment of a numerical value, normalized on a scale from 0.25 to 1, resulting from the observation of the "signs of destruction" recognizable on photographic documentation and categorized in the same table of attributes concerning land use.

Following the phases described above and appropriate settings in the processing settings of the QGIS software used, it was possible to query the model built to process the information and obtain specific views of the two areas of investigation, very interested in terms of narrative potential. Overlapping and integrating these mappings with the elaborations obtained from the first methodological step, it was possible to obtain a more refined analysis according to which to operate a more precise recognition of the areas in which the impact of the conflict has manifested itself with greater strength, and therefore where it is more likely to find the permanence of these vestiges.

Finally, thanks to the information potential contained in the LIDAR data, it was possible to investigate the current morphology of the territory in more detail, even in areas affected by the conflict but with less impact. Concerning these contexts, some specific visualizations of the spatial datasets obtained through the implementation of GIS software with the Relief Tool Visualization have allowed probing in depth the microtopography of the contemporary landscape in search of any possible permanence of vestiges, perhaps "submerged" under the different post-depositional layers of degradation that over time have been layered on top of each other. After a careful evaluation of the different visualization possibilities of the LiDAR data obtainable through the Relief Tool Visualization, the Sky-View Factor and Multihillshading visualizations turned out to be the most effective ways to investigate the threshold-space between the visible and the "submerged". Specifically, by returning the portion of sky visible from each specific point of the earth's surface through an adimensional parameter between 0 (white color) and 1 (black color), the Sky View Factor has allowed not only to obtain a clear and precise picture of the current morphology of the territory, but also to recognize on it

the different depths of the "footprints" left by the conflict on the landscape, hidden under the "archaeological deposit a century deep" but not disappeared. The combination with the Multi-hillshading Visualization has also allowed us to recognize the geometric conformation of the uncovered evidence, distinguishing the presence of circular elements, identified as the permanence of the craters left by the explosion of bombs and mines, from other elements with longitudinal development, most likely referred to the original entrenched systems. Finally, the possibility of obtaining from the digital model specific and punctual territorial sections in correspondence of the original entrenchments, and the relative comparison of such elaborations with the project drawings or the typological-constructive references present in the military manuals, proved to be of fundamental importance to better understand the "physical thickness" of time that in the last century was deposited on the space-threshold in which the traces of the conflict existed, hiding them from view but preserving the value of testimony.

### 2.3. Results

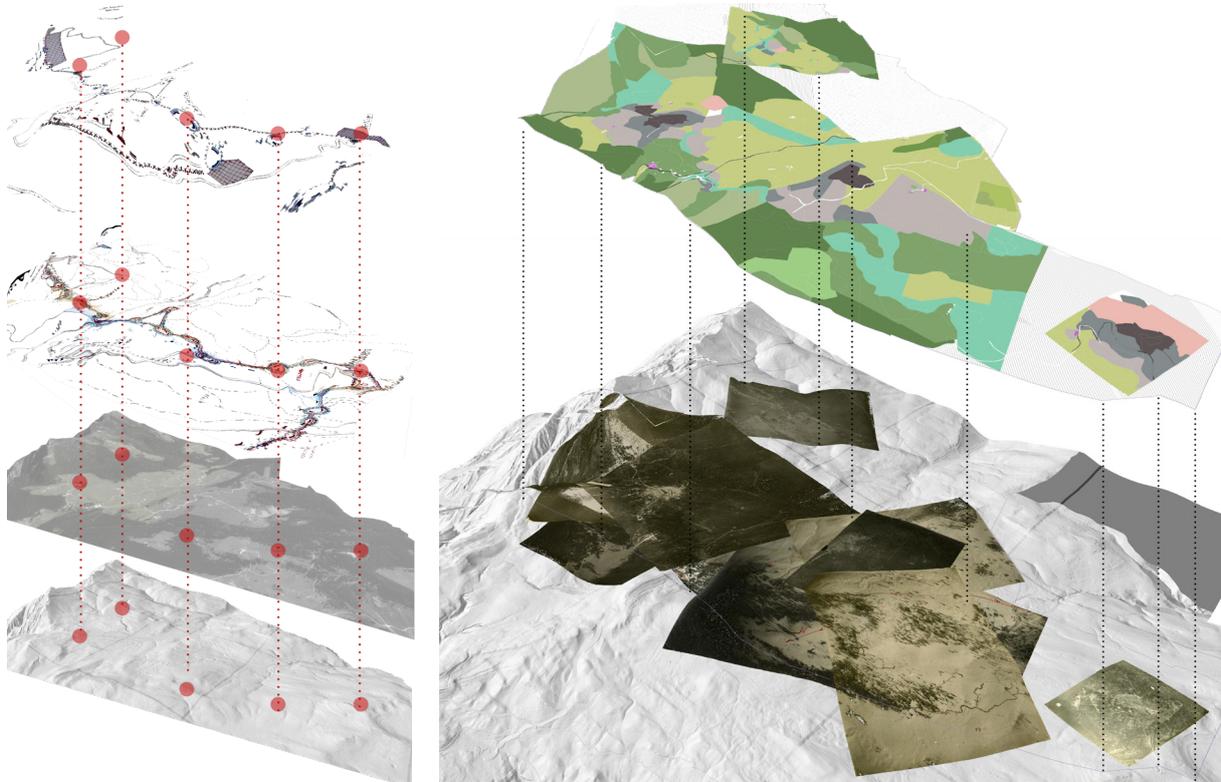
In the light of what has been described above, the important innovative contribution that the proposed method provides for recognizing the permanence of the remains linked to the Great War is evident.

In order to make explicit the understanding of the validity of the proposed method also in quantitative as well as qualitative terms, Fig.01-02-03 shows the graphical elaborations concerning the application of the analytical steps described above to the Fortified System of the Altipiani di Vezzena e Luserna, in the province of Trento (Italy). Thanks to the georeferencing of period military photographs found at the Museo Storico Italiano della Guerra of Rovereto, it was possible to precisely locate the areas where the impact of the conflict was greatest, i.e., the areas around Fort Verle, Fort Campo Luserna, and the defensive post of Basson, where historical sources testify to the bloody battles that took place in 1915. Through the superimposition of military aerial photos of the period and the analysis of the transformations of the uses/coverings of the land to the current Digital Terrain Model, it was possible to map the areas in which the war event had the greatest impact, leaving its mark on the morphology of the territory, recognizing the permanence of the most evident remains. The graphic elaboration of the impact factor relative to the wartime reported in Fig.02 has made it easy to understand the areas in which the influence of the war has been greater, and therefore where today there is a greater probability of finding remains of vestiges. Focusing the attention on one of these "hot zones" that is the area around Forte Campo Luserna, Fig.03 shows the elaborations relative to the application of Step 3. Using the reciprocal combination of Multihillshading and Sky-View Factor Visualizations, it was possible to investigate more deeply the orography of the contemporary landscape to unveil the conformational imprinting left by the War more than a hundred years ago and still present in the contemporary world, even if latent under the most recent layers deposited in the last century. It was also possible to classify the "unveiled signs" according to three classes of visibility (visibility level 1 - higher - red; visibility level 2 - intermediate - orange; visibility level 3 - lower - brown). As an example, in Fig.03, we can see how this contribution has been of fundamental importance in allowing the recognition of over 3000m of trenches and 1000 bomb "craters" around Forte Campo Luserna that, without such visualizations, would not have been identified.

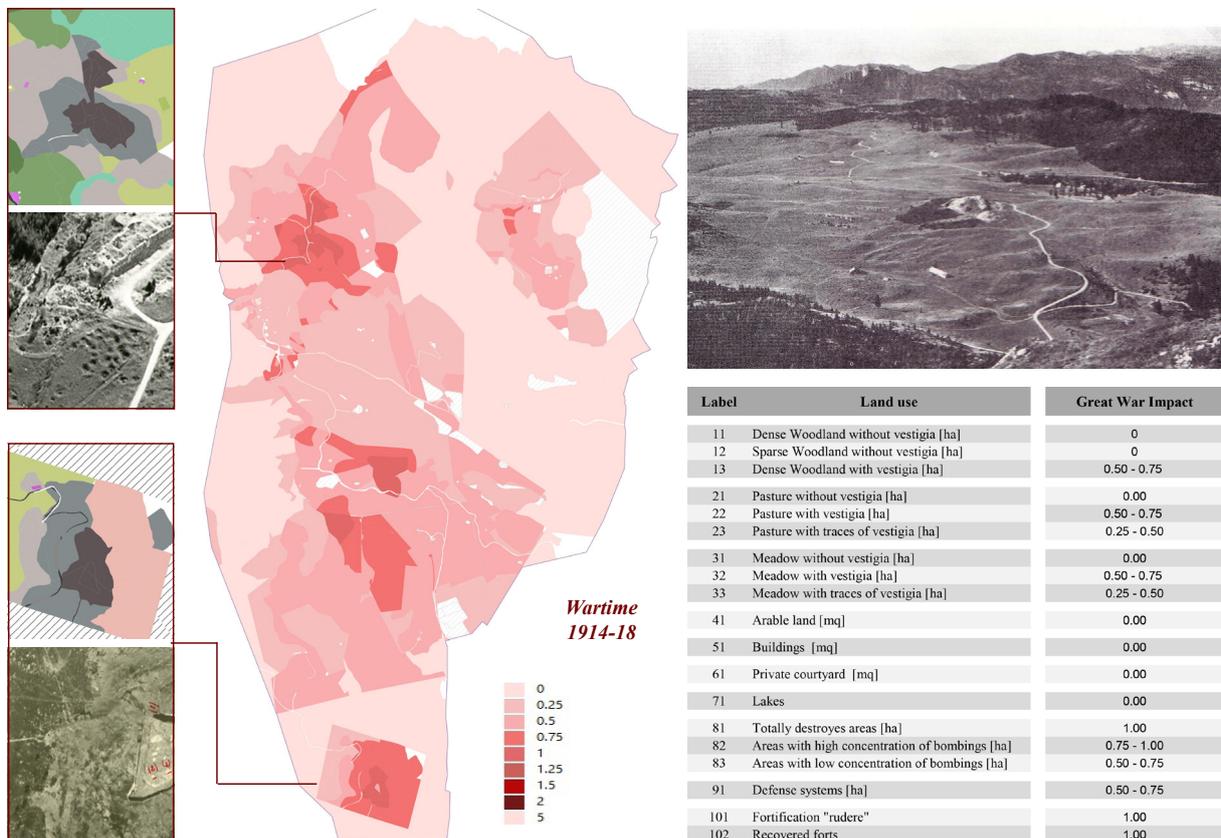
### 3. Conclusions

In conclusion, it is clear that the proposed methodology, totally non-invasive, provides a fundamental contribution to the knowledge of the evolutionary biography of the different warscapes, which is essential for those who want to "take care" of this heritage. The potentialities offered by GIS software have allowed to compare and integrate documentary sources of different nature such as vintage aerial photographs and territorial datasets obtained by remote sensing to develop an innovative multiscale approach, which can recognize the different degrees of permanence of the remains within the contemporary landscape. Combining the diachronic analysis with the "unseen glances" obtained through the Sky-View Factor visualizations has allowed bringing to light the significance of a submerged heritage highly significant in terms of narrative potential.

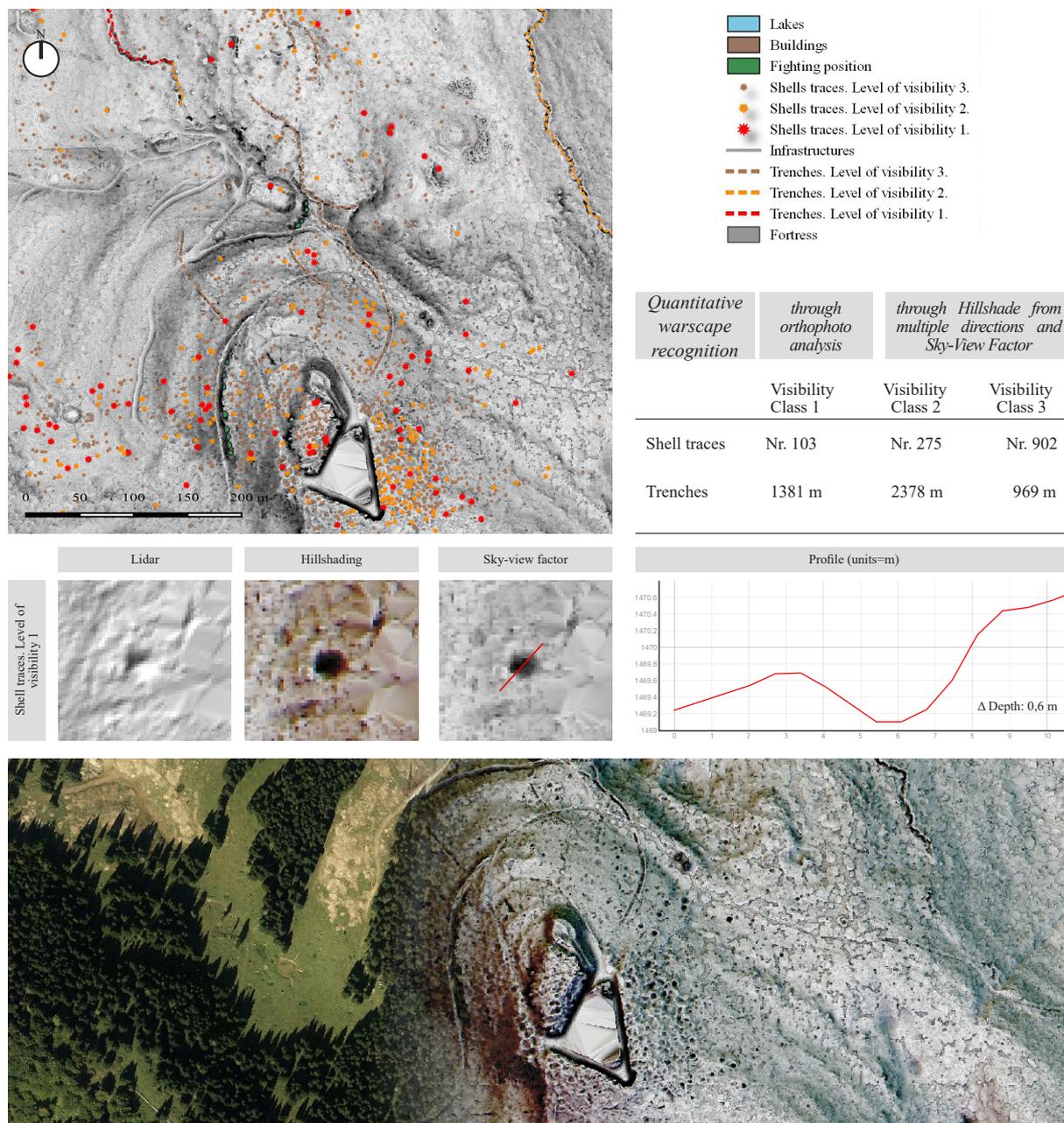
**Fig. 01** Step 1: The georeferencing of historical documentation in QGIS environment



**Fig. 02.** Step 2: Diachronic analysis for the recognition of the Great War's Impact Factor



**Fig. 03** Step 3: SVF and Multihillshading visualizations to reveal the Great War's permanences



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