2020 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Trento, Italy, October 22-24, 2020

Warscapes: A "Submerged Information Basin". The Contribution of LiDaR Data to the Unveiling

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***Abstract* – The impact of the Great War militarization processes has transformed most of Europe's territories, creating a meaningful warscape both in a material and cultural way. As a result of the inevitable post-war landscape transformations, the dense networks of military buildings designed for the war, as well as the "traces" of destruction, have been reabsorbed in the dynamics of landscape transformation, and today they remain almost exclusively as isolated fragments and, especially with regard to field fortifications, often barely recognizable. The need to recover a "systemic look" to give strength to the network of vestiges as a system becomes a matter of primary importance. In this sense, the interpretations of LIDAR data and some specific visualizations of the same (Hillshade and Sky-view-factor visualization) can provide very useful elaborations to facilitate the recognition of the permanence of such vestiges in today's landscape, to constitute an indispensable base of knowledge on which to set future choices in terms of conservation, selection, and transformation.**

I. A FRAGILE HERITAGE AT HIGH COMPLEXITY. ISSUES OF RECOGNIZABILITY

More than a hundred years ago the face of the whole of Europe was profoundly transformed by the long and complex militarization process of the territories connected to the Great War, which shaped different contexts through the tangible "signs" of history. Permanent fortifications, trenches, barracks, and military infrastructures represent only a part of the dense set of fortified works linked to offense and defense, conceived and designed by the different military geniuses in symbiotic relation to the morphological features of the different territories. These artifacts designed for war, in addition to the "wounds" directly imprinted by the conflict on the orography of the different territories, have permeated the pre-existing landscape to such an extent that they have become distinctive features of these warscapes, understood as "*materia signata*", that for these reasons today it is recognized as a "material witness having the value of civilization". [1].

Over time, however, the inevitable natural and anthropic transformations of the landscape led to the fragmentation of the original military systemic planting, weakening above all the intrinsic connections between permanent fortifications and the relative entrenched systems, on whose symbiotic relationship the functioning of the great "war machine" was based. Despite being designed "more to resist than to last over time" and therefore "by nature" more exposed to post-depositional processes of degradation and changes in land use, these works constituted a much more pervasive tissue than the permanent fortifications: they were the load-bearing framework of the entire warscape, the arterial system that substantiated the network. Today most of these more minute systems have been reabsorbed in the different dynamics of landscape transformation, within which they remain as isolated fragments, not clearly recognizable and often "submerged" under more recent layers that have stratified on this heritage with high witness potential but at risk of loss [2].

Also following an examination of the projects launched after the promulgation of Law no. 78/2001, a fundamental regulatory framework as it recognizes the vestiges as a heritage to be protected and safeguarded, including the started/ended projects on the occasion of the Centenary celebrations, the issue of the difficult recognition of the most fragile works as permanence remains of primary importance. This issue raises questions of knowledge and "care", implicitly highlighting the need to identify methods and analytical strategies useful to facilitate the recognition of permanences within the multilayered contemporary landscape, to avoid their loss and thus preserve our "possibility of memory" through their evocative potential.

The ongoing research presented here moves in this direction, proposing the elaboration of a methodological tool useful to decode the codes according to which the landscape is written, to build a broad spectrum knowledge base that, through a holistic and interdisciplinary approach, represents the foundation for future design choices in terms of permanence, selection and transformation of this important heritage. Moving from the deep meaning of the word *vestigia*, which refers to the physical imprint of something that is no longer tangibly present but which leaves at the same time memory of its passage through the traces imprinted in the landscape, the elaboration of the method called

"stratigraphic telescope" is part of the line of research already known as "Archaeology of the Great War", recognizing the complex palimpsest of the vestiges, visible but also "submerged", as a wide and deep information basin to be investigated and recognized. [3].

This is an interdisciplinary contribution as it integrates the study of archive documentary sources and the constructive-typological features of the artifacts with the knowledge gained from the interpretation of a series of data obtained thanks to the potential offered by high-resolution remote sensing techniques and non-destructive tests. Satellite or aerial remote sensing, through the study of orthophotos and LIDAR data, is particularly useful to investigate the development of the transformation dynamics of territories in time, comparing the impact of the war event of a hundred years ago with the current reconnaissance of the permanences. In this perspective, the use of software for the creation of Geographic Information Systems such as ArcGis and QuantumGis assumes considerable importance, as these work environments allow overall coordination of the whole knowledge-based process: from the integrated management of the different input datasets (georeferencing of historical militarisation maps and military aerial photographs) to the elaboration of the expected outputs [4].

Specifically, the important contribution that interpretations of LIDAR data (through some relative visualizations of the same) can provide in the identification of areas where the vestiges of the Great War remain with different degrees of readability within the topography of today's landscape is presented below.

II. LIDAR DATA AND RELATIVE VISUALISATIONS: A CONTRIBUTION FOR THE RECOGNITION OF THE PERMANENCES

LIDAR (an acronym for Light Detection and Ranging) is an "active" remote sensing technique that performs high-resolution topographic surveys through an aerial scan of the portion of territory to be analyzed. The topographic survey is based on the measurement of the distances between the laser beam emitter and the terrain surface: what is obtained is a cloud of points to each of which is associated a data relative to the geographical coordinates (according to the WGS84 system) and the altimetric altitude calculated based on the difference in time between the emitted and reflected impulse, and the intensity of the reflected signal itself. Among the different methods of remote sensing, LIDAR has assumed strategic importance also in the study of the dynamics of archaeological transformation of the landscape because of its ability to overcome the interference caused by the presence of vegetation. In fact, in addition to a digital surface model including each detected element (the DSM, Digital Surface Model), LIDAR returns also a digital model of the "clean" orography of the ground (the DTM, Digital Terrain Model), built only with the points that belong to the ground.

As far as the research under examination is concerned, this translates into the potential possibility of identifying "remotely" the permanence of some archaeological evidence of the Great War, otherwise not visible through the analysis of current orthophotos alone. In areas where the land cover/land use of the soil has varied compared to the immediate post-war period (e.g. in newly planted woodlands), the study of the DTM, therefore, makes it easier to identify the traces imprinted in the morphology of the terrain by reducing the number of necessary field inspections and detailed reconnaissance/detection, certainly more costly in terms of time and money.

But tackling the issue of the recognisability of the permanences with an archaeological approach means analyzing the warscape in its complexity, through a look that "scans" it in-depth, relating the "emerged" heritage to the "submerged" palimpsest of more unstable evidence, often covered by post-depositional layers of degradation but not disappeared. Recognizing these "footprints" means recognizing their narrative potential, and it is precisely in this perspective that the most interesting contribution of the use of LIDAR data is manifested, in particular through various techniques of data visualization (specifically hillshade and sky-view-factor visualization) that in recent years have been developed and borrowed from other disciplines to optimize the visibility of different archaeological features [5].

The Hillshade visualization represents the most common LIDAR processing and consists of the shading calculation for each grid cell referring to established lighting values from a hypothetical light source. The possibility to artificially set the light source position according to any desired angle (even those not possible "in nature") allows highlighting also features weakly marked on the ground. At the same time, however, each specific direction of the lighting angles can be parallel to precise evidence on the ground, which in this case would not produce a shadow, and therefore would not become visible. To overcome this gap it is advisable to use a hillshading algorithm from multiple directions, able to map different hillshade with different angles on a single view, to display all the pieces of evidence on the ground at the same time.

As far as Sky-view-factor visualization is concerned, the calculation algorithm consists of simulating a diffused illumination on each pixel of the DTM coming homogeneously from all directions from above, as if, above each point, there was a uniformly illuminated hemisphere. The sky visibility factor represents the measurement of the portion of the visible sky from each specific point on the surface and returns a non-dimensional parameter between 0 (no visibility - black color) and 1 (completely free view - white color). The

goodness of this visualization depends on the good resolution of the starting digital model, the number of directions that are considered in the analysis, and the maximum radius size in which to calculate the processing. With an appropriate calibration of the parameters concerning the reference context, this type of processing can return visualizations much clearer and sharper than the classic hillshade visualization, especially concerning the detection of small topographic depressions such as bomb craters, sinkholes, trenches, etc.[6].

The interpretation of the Digital Terrain Model through the types of visualization described above allows to take full advantage of the informative potential of the LIDAR data to obtain a clear and precise knowledge of the current morphology of the territory, recognizing on it also the permanence at different temperatures of the "footprints" left by the conflict on the landscape, hidden below the "one century deep archaeological deposit", but not disappeared. In this regard, the management of such visualizations in a QuantumGis environment also makes it possible to classify the different levels of visibility of the recognized permanencies expeditiously: areas with well-preserved surface features, identified as the SVF highlights clear and well-delineated edges and perimeters and the contrast in the visualization is strong; areas clearly recognizable but compromised by erosion and sedimentation; and finally areas with poor conservation, where the individual features are particularly difficult to "see".

The entrenched field that insisted around Forte Busa Verle on the Vezzena Plateau (TN) represents an interesting case to demonstrate the validity of the contribution that the different ways of interpretation of LIDAR data can provide in the recognition of the permanence of the warscape in the contemporary landscape [7].

III. THE ENTRENCHED SYSTEM AROUND BUSA VERLE FORT (TN): A STUDY-CASE

Because of its strategic position on the Vezzena/Luserna Plateau, in 1915 Forte Busa Verle was the first Austro-Hungarian fortification to be involved in the short but very intense "war of the forts". During the first year of the conflict, the fortress was repeatedly attacked by Italian troops, who bombarded it with over 8,000 artillery shots of different calibre, radically transforming the entire surrounding environment into a lunar landscape, marked by rubble, craters left by bombs and destroyed entrenches. The meaning of these "wounds" is universally recognized and it is an integral part of the complex value of the testimony of this warscape, to be protected and handed down. For this reason, the recognition of the permanencies of this palimpsest of vestiges becomes a necessary condition. Although at the wartime these vestigia were deep and well recognizable, today they have been reabsorbed in the inevitable dynamics of transformation of the landscape and therefore they are more unstable, fragmented, and often "submerged" under new layers deposited in the last hundred years.

A first examination for the recognition of what remains of these "signs" was carried out through the study of aerial photographs dating back to the years 1915-1918 kept at the Italian Historical War Museum of Rovereto (TN-Italy), and the georeferencing of them in the *QuantumGis* environment. With the observation of these photographs, it was possible to reconstruct the situation of the war landscape during the conflict, identifying not only the effects of the bombings on the fort but also on the surrounding landscape, on the fighting positions, and the trenches. The geolocation of both of the elements built for the war and of the "wounds" inflicted by the conflict itself has allowed to precisely identify the areas potentially affected today by the presence of permanencies. These areas have been studied in more detail, in the first instance through the direct survey (inspections) and the analysis of current orthophotos. In this way, the most evident "traces" of the permanencies (Visibility Class 1) have been identified, as summarized in Table 1. More than 1761 meters of reentrants clearly traceable to the original trenches around the fort and nr. 77 circular depressions or small "holes" evidently referable to the craters produced by repeated bombardments have been detected (in Fig.2 the elements referred to Visibility Class 1 are drawn in red color).

Table 1. Quantitative warscape recognition through orthophoto analysis

	Visibility Class 1
Shell traces	Nr. 77
Trenches	1761 m

However this first classification proved to be partial, as the study of the surrounding area of the fort through the analysis of the Digital Terrain Model with the different views previously described (Sun angle 315°, Hillshade from multiple directions, and Sky-view Factor) has made it possible to recognize and identify a further significant amount of vestiges less explicitly visible, but distinctly imprinted in the morphology of the ground, below the turf that indiscriminately covers everything.

As specified in Table 2, in fact, in addition to what is already recognized in the previous step, other 3849 meters of reentrants that can be traced back to trenches and nr. 1265 circular depressions of medium and small size referred to the craters produced by the bombardments have been identified (in Fig.2 the elements referred to the Visibility Class 2 are drawn in yellow color while those referred to the Visibility Class 3

in brown color).

Table 2. Quantitative warscape recognition through Hillshade from multiple directions and Sky-View Factor

	Visibility Class 2	Visibility Class 3
Shell traces	329	936
Trenches	854 m	2995 m

In conclusion, as shown in Fig.1, the potentiality of the integrated visualizations of Hillshade from multiple directions and Sky-View Factor has proved to be indispensable in the recognition of these entrenches and "footprints" of craters present in the contemporary landscape at different degrees of readability to be protected and handed down, even though they are less visible as they are probably produced by the shelling of artillery of medium and small calibre (low destructive power and consequently limited crater depth) and subjected to more consistent post-depositional layers that have compromised their direct readability (Visibility classes 2-3).

IV. CONCLUSION

In light of the above considerations, it is clear that the LIDAR data constitute an informative dataset of considerable importance for the integrated study of the dynamics of landscape transformation. The different visualization modes available define some "privileged looks" through which to investigate in depth the Digital Terrain Models to recognize the complex stratification.

Specifically, concerning the surroundings of Forte Busa Verle, the interpretation of the Sky-view-factor has allowed identifying with greater ease the permanence of even minute and fragile fortified tissue, often "submerged" under other layers deposited over time but still meaningful and full of identity values (Fig.2).

Table 3. Quantitative shell craters recognition with/without DTM analysis

	Nr.	%
Total	> 5000	100
without DTM analysis	77	1,54
with Hillshade +SVF Analysis	1342	26,84

Only by way of example, a simple comparison between the number of "craters" recognized exclusively through the observation of the orthophotos (nr. 77) compared to those identified also with the integrated analysis of the DTM (nr. 1342) shows how these visualizations have allowed the recognition of about 1265 "wounds" (about 25% of the total), unstable but still present in the contemporary landscape, that otherwise would have remained unidentified (Table 3).

The potentialities of this analytical-archaeological approach have been operationally manifested and constitute one of the founding aspects of the "stratigraphic telescope" method elaborated within the in-progress research at UniTN-DICAM, to explore the processes of construction/transformation of warscapes at different scales. The recognition of the permanence of the remains in the current state of the places can take full meaning through the comparison with the maps of the impacts of the conflict referred to as the original wartime. This comparison will allow identifying the different gradients of permanence within the contemporary landscape, whose recognition becomes the necessary condition to understand how to 'take care' of this complex set of signs within the future transformations of the landscape.

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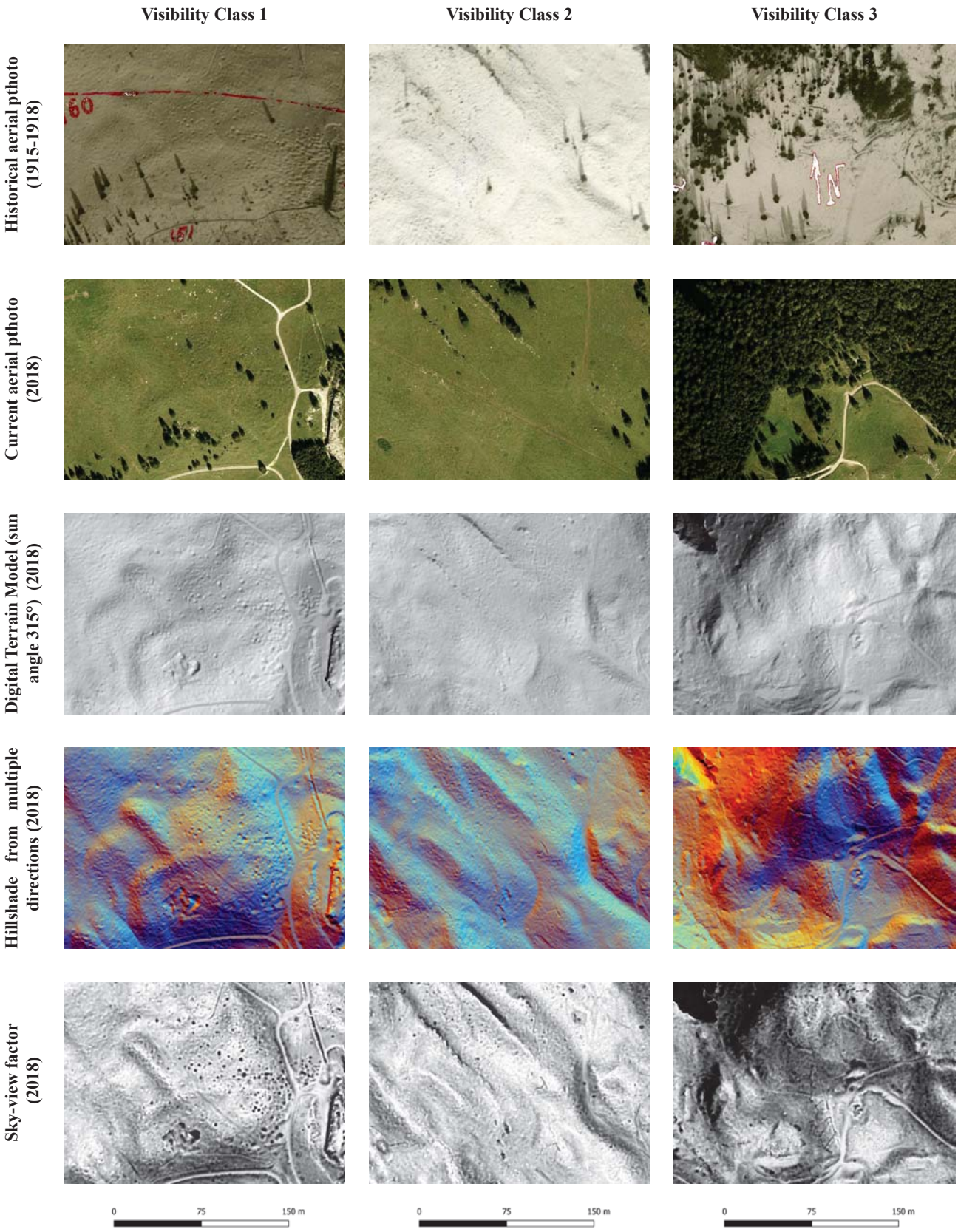

Fig. 1. Different degrees of visibility of the entrenched system around Forte Busa Verle (Altopiano di Vezzena - Trento - Italy). Analysis conducted by comparing historical photographs, current orthophotos and different views of DTM data, that are freely provided by the Autonomous Province of Trento: Digital Terrain model with sun inclination angle 315°, Hillshading from multiple directions, Sky-view Factor (radius 32).

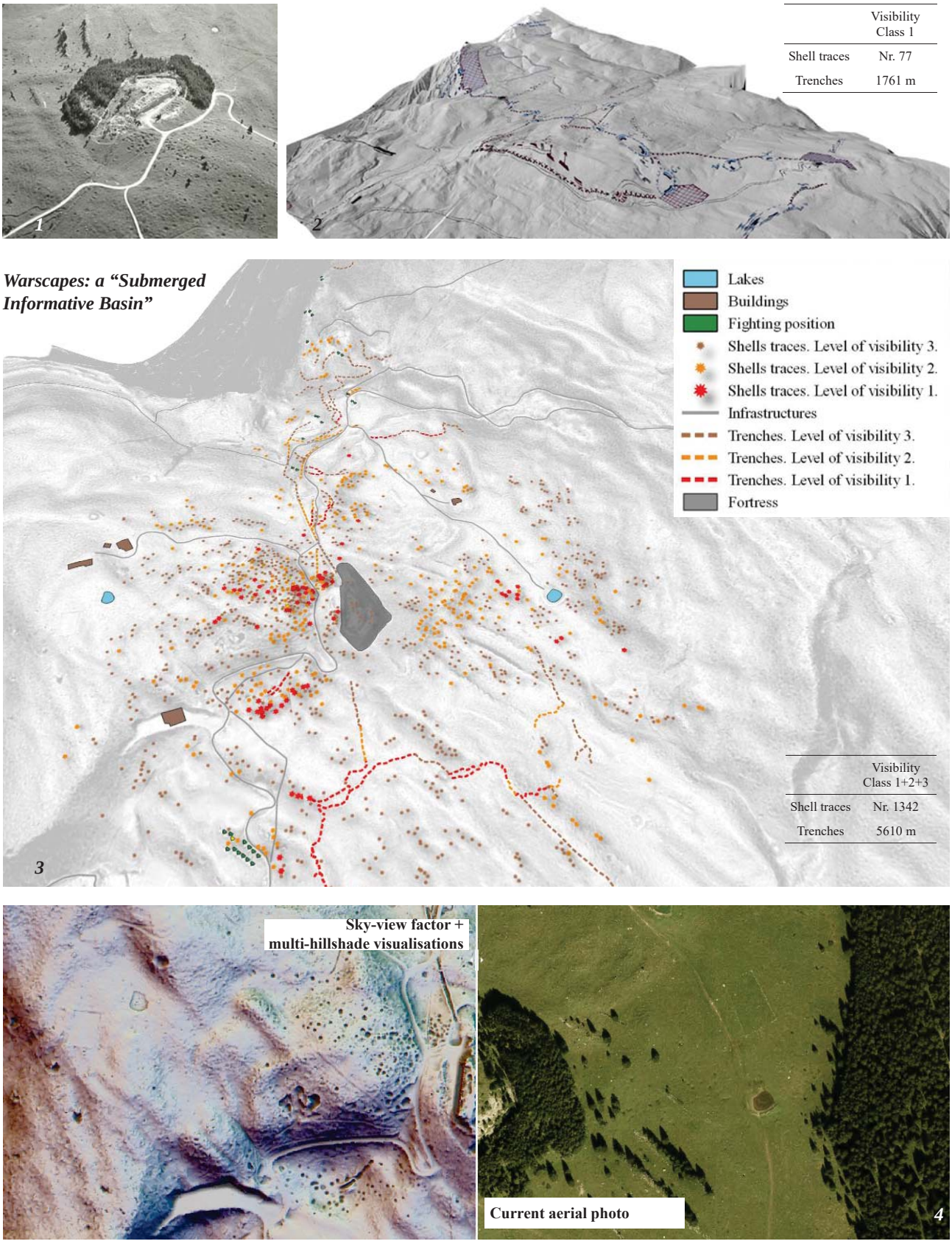

Fig. 2. Warscapes: a "Submerged Informative Basin". Historical photo 1915 - Museo Storico Italiano della Guerra di Rovereto (1). Overlapping of original Austro-Ungarian militarization projects on the current DTM to identify the permanencies (2). Traces of the Great War unveiled through the Hillshade from multiple directions and Sky-view Factor visualizations (3). Comparison between Sky-View Factor visualization and current orthophoto (4).