

AN INTERDISCIPLINARY APPROACH FOR UNVEILING AND ENHANCING THE FIRST WORLD WAR HERITAGE IN THE LANDSCAPE

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ABSTRACT:

More than one hundred years ago, the European landscape was profoundly transformed by multiple factors related to the Great War, which altered its territorial and environmental ecosystems, giving the landscape the value of a cultural asset with a civilizational value. After more than a century, the "signs of history" remain in the contemporary world at different levels of recognition, very often in a state of abandonment and at risk of loss. This contribution presents the elaboration of a non-invasive and "from remote" operative method, based on the analytical interpretation of historical cartography and historical aerial photographs to reconstruct the evolutionary dynamics of the landscape and recognize the areas where the impact of the conflict has been stronger. The georeferencing process of the sources in the QuantumGIS environment made it possible to elaborate interesting overlaps between cartographies and photographs belonging to different temporal frames. In this way, the dynamics of landscape transformation and land cover/use have been analyzed in relation to the destructive impact of the war to identify the areas in which it is more likely to find material remains of the vestiges, whose recognition becomes a prerequisite for the future practices of protection, transformation, and enhancement.

1. INTRODUCTION

More than a hundred years ago, the First World War profoundly upset the landscape of the whole Europe: from the fields of Galicia to the French plains, from the Alps to the coasts of the Baltic Sea, the war of position and trench warfare caused transformations of the territory by carving out mountains, reorganizing territorial assets and original environmental ecosystems, leaving space for the stratification of new traces and meanings. These aspects, over time, contributed to the construction of what is now universally recognized as an important cultural heritage to be known and passed on to future generations.

However, the wartime landscapes have undergone both anthropogenic and natural transformations that altered their consistency, making them increasingly difficult to recognize. In the last twenty years, restoration/recovery/enhancement projects focused more on the permanent fortifications, leaving in the background the interest in the "care" of minor vestiges such as trenches, walkways, defensive posts, craters due to bombings, underground shelters. Despite this, their cultural potential is equal to that of the forts since they constituted the connection network of the entire war machine. Their recognition and its enhancement through outdoor museum routes and other activities could contribute to the revitalization of the territories in which they are inserted, also in relation to the contemporary phenomenon of repopulation of isolated and half-altitude mountain areas. The main problem lies in the difficulty of recognizing, within the contemporary multi-layered landscape, these "signs" that, in the past, identified the transnational borders between Italy and Austria, intended more "to resist than to last over time". In this regard, the analysis of LCLU (Land Cover/Land Use) changes through aerial photogrammetry and the specific study of historical aerial photographs represents an important contribution to identify the impact of the conflict on

the landscape and to locate the areas where the probability of finding war's remains is higher.

1.1 State of the art

The study of sites from above through the photo-interpretation of data obtained by various digital tools, from vintage aerial photographs to modern specialized applications related to remote sensing technologies, are the basis of further specific geomatic techniques of remote sensing. This approach represents a very fruitful research line that interweaves interdisciplinary skills (from conservation to geography, from geomatics to archaeology) in a non-invasive way, fully preserving the integrity of the territory and obtaining as much information as possible.

The simplest of these techniques, i.e. the analysis of bird's eye photographs, was introduced during the wartime through military aerial reconnaissances, which soon became a powerful new weapon. From that moment on, pilots and observers became the real "eyes of the armies", and aerial photography became the most effective means to obtain information about the conformation of entrenchments, their occupation, the tactics in place, and the drafting of summary mappings of friendly and enemy lines (Stichelbaut, 2006).

Since that time, the interest in this form of landscape study has gradually increased, partly in relation to the development of modern aerial survey techniques. The potential of these analytical techniques for the study of warscapes has already been recognized thanks to experiments carried out in the international context, especially those aimed at the research conducted in the study of the World War I sites on the fields of Flanders (de Meyer, 2006; Stichelbaut, 2006; Van Hollebeeke et al., 2014). Subsequently, the study of historical aerial photographs in military archaeology has been implemented through the refinement of digitization tools and programs, allowing for the development, albeit limited, of some interesting regional/national scale projects such as the English Heritage

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National Mapping Project (Winton & Horne, 2010) and the project of digitization and cataloguing of thousands of photos related to the Western Front in Belgium developed at Ghent University (Stichelbaut, 2006; Stichelbaut, Saey, Meeuws, Bourgeois, Van Mairvenne, 2011; Stichelbaut, Gheyle, Saey, Van Eetvelde, Van Meirvenne, Notes, Van Der Berghe, Bourgeois, 2016; Stichelbaut, Gheyle, Van Eetvelde, Van Meirvenne, Saey, Notes, Van Den Berghe, Bourgeois, 2017; Van Den Berghe, 2019; Stichelbaut, 2020).

2. STUDY CASE

The entrenched system that developed on the Vezzena Plateau (TN) in the areas between Fort Cima Vezzena, Fort Busa Verle and Fort Campo Luserna, in the Autonomous Province of Trento (Italy) represents a useful case study to understand the operability of the developed method. In 1915, after Italy entered into the war, the front on the border between the Kingdom of Italy and the Austro-Hungarian Empire was the fulcrum of the first very hard phase of the conflict. The Busa Verle Fort, one of the strongholds of the Austro-Hungarian Empire defence line, built on the Vezzena pass and surrounded by a complex entrenched field constituted of fences, obstacles, and entrenchments, was the first to be involved in the short, but very intense, "war of the forts". During first weeks, the fort was stormed with more than 5,000 shots (including 305 mm grenades) coming from the howitzers placed in the Verena woods, but the fort managed to defend itself by firing about 20,000 shots with its four howitzers on the rotating steel domes and 6 cannons in the casemate. At the Trento State Archives, the militarization plans of the area have been identified (Fig.1), which identify in detail the different elements of the war machine, and for this reason, they will be of particular importance to geolocalize, on the current morphology of the territory, the positions where these vestiges were built.

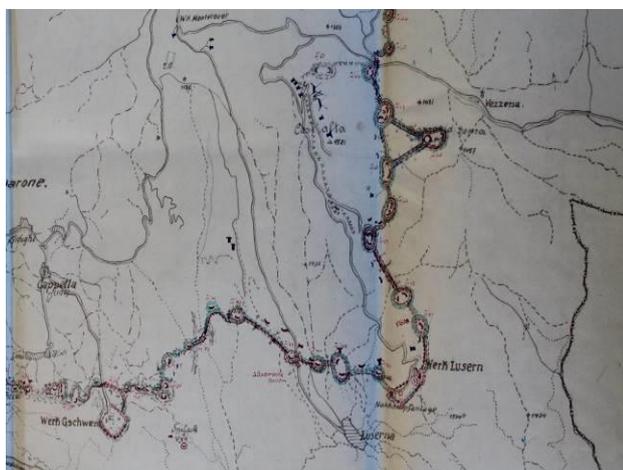


Figure 1. Vezzena Plateau: militarization projects

Furthermore, at the photographic archives of the Museo Storico Italiano della Guerra di Rovereto (TN)- Italy, several period aerial photographs, shot during repeated reconnaissance flights over the area, have been found. These documents testify to the real destructive impact that the conflict inflicted on the landscape of a hundred years ago (Fig.2). Recently, the external parts of Fort Verle (like those of other fortifications in the Folgaria, Lavarone, and Vezzena Plateau) have been modeled through 3D laser scanner and photogrammetric surveys, as part of the VAST (VALorizzazione Storia Territorio) project, promoted by the local authorities of the Autonomous Province of Trento to promote and enhance the cultural and exhibition

offer of the museums present in the "Plateau" area in Trentino, integrating the technical knowledge developed by FBK (Fondazione Bruno Kessler-TN) and the humanistic and historical skills of the other entities involved in the project.



Figure 2. Busa Verle fort: historical aerial photographs

3. METHODOLOGICAL APPROACH AND RELATED APPLICATION

An operational methodology has been developed to analyze the dynamics of transformation of the territories in relation to the impact caused by the Great War and the subsequent transformations that led to the construction of the current multi-layered landscape. This method consists in the interpretation of the previously found documentary sources, concerning three different time frames: the pre-militarization situation (Austro-Hungarian Cadastre about 1850), the wartime (period aerial photographs), the current situation (orthophotos 2015).

From the operational point of view, the first methodological step consists in digitizing all the cartographic and photographic documentation found in the preliminary phase to form a homogeneous database to quickly process these data, comparing different sources, heterogeneous in time and space. In this regard, a necessary consideration concerns the uneven resolution and quality of these images due to chronological differences and the rapid evolution of photographic techniques. For instance, with regard to black-and-white, aerial, and bird's-eye photographs taken during the conflict, the levels of sharpness and detail vary widely among sources and are always inferior to the more recent orthophotos, which are systematically in color and with high-resolution. Understanding these technical specifications is important because it determines the level of detail that must be adopted in the processing of the entire method. Analytical uniformity should prefer the maximum resolution of detail common to all the different inputs as the minimum mappable unit of analysis; in the study case that of historical photographs.

The acquisition of the historical documentation from the original paper support to the digital form is preparatory to the subsequent methodological steps as it allows the insertion 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 orthophotos.

In fact, to translate the metric and topological content of the historical maps also in a quantitative and not only qualitative-descriptive perspective, the proposed method provides for the subsequent georeferencing of historical maps through the use of specific software for the management and analysis of spatial data, such as ArcGIS and QuantumGIS (Fig.3). Georeferencing consists of the projection of geographic coordinates on each

pixel of the raster image in question to make it perfectly superimposable on current topographic maps. This operation is achieved through digital processes of geometric transformation and resampling, through which the raster data of the original image are transformed into a new grid, whose pixels are assigned radiometric values as a function of the values of the



Figure 3. Georeferencing of historical documentations

original pixels, preferring, depending on the case, global or local processes of geometric transformation. The geometric transformations applicable to a cartographic image can be classified into two categories: global and local transformations. Global transformations are those whose parameters, once the modeling of deformations present in the map to be georeferenced has been chosen, are valid for any point in the image. The position of each point will be calculated by applying the parameters calculated on the basis of the control points. On the other hand, local transformations are those in which the parameters are computed for each individual point in the image and have local validity. The purpose is to deform only part of the image without significantly changing the rest. The local approach has the advantage of allowing an excellent adaptation of the image to be modified with respect to the reference points in the face of a more difficult mapping (Balletti, Guerra, 2002; Boemi, Mogorovich, Mazzocchi, 2010).

In the specific case, the georeferencing of the militarization projects of the Vezzena Plateau has been implemented taking as reference cartographies the current orthophotos, intrinsically georeferenced since their acquisition.

The degree of accuracy of this process of geographic characterization depends essentially on the precision with which the various GCP (Ground Control Points) are identified on which resampling and geometric transformation will be carried out. For the georeferencing of each historical photograph of the area around Forte Busa Verle, more than 8 "control points" have always been identified, evenly distributed, to optimize the result by reducing distortions. More in detail, given the inhomogeneous quality of the photographs to be processed, the Thin Plate Spline (TPS) algorithm was chosen, combined with the method of resampling the nearest neighbor, which allowed to assign geographical properties to the historical documents, greatly reducing georeferencing errors.

The importance and usefulness of these processes of cartographic transformation are 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 to the current orthophotos. In this way, the diachronic comparison between the documentary sources does not remain exclusively qualitative-descriptive but allows accurate localization of the "signs" designed for the conflict on the morphology of the contemporary landscape.

If the accuracy of the obtained elaborations is confirmed by the correct location of the permanent works and of some military infrastructural systems currently still clearly visible, the most interesting contribution of these superimpositions concerns the possibility of assigning actual coordinates of geographical location to each constituent element of the different warscapes present on the militarization plans, to be able to identify and eventually recognize the degree of permanence within the contemporary landscape (Fig.4).

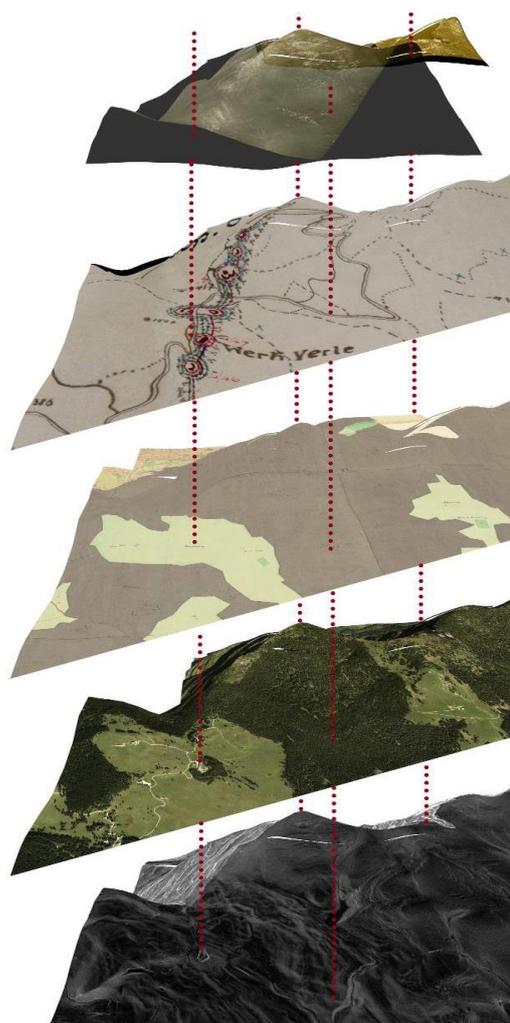


Figure 4. Overlapping of different temporal layer: DTM, orthophotographs 2015, Austro-Hungarian Cadastre, militarization projects, period aerial photographs.

Thanks to this process, it is therefore evident that the "signs" designed in anticipation of the war can be easily located on the current morphology of the territories. However, as regards the "wounds" inflicted directly by the conflict on the landscape, it is necessary to resort to georeferencing and relative analysis of period aerial photographs.

Precisely with this objective, the second phase of the proposed methodology focuses on studying the evolutionary dynamics of warscapes through investigations at a higher level of detail and expanding the interpretive code of archaeological and

stratigraphic investigations to the landscape scale. Specifically, the method is developed in two simultaneous lines of investigation: the first aims at characterizing the different land uses in different time frames to understand the changes caused by the war; the second one focuses on the specific mapping of the "signs of destruction" inflicted by the conflict itself and documented in the historical photographs.

From the operational point of view, as explained in the next paragraph, the mapping of these different analyses can be easily managed simultaneously in GIS working environments through the characterization of the single perimeter of polygons through different attributes, concerning both the specific land use and the degree of influence/impact derived from the conflict. The different ways of displaying these attributes will then allow obtaining specific mappings of the two areas of investigation, but also to compare and reciprocally integrate such mappings to obtain a more refined analysis according to which to operate a more precise recognition of the permanence of the remains.

In the broad spectrum of geographical and territorial analysis, the investigation of land use and land cover in different periods is one of the necessary bases for the definition of a knowledge framework of the biography of a given landscape.

Extending this analytical method to the study of the transformative dynamics of the different warscapes also means recognizing the war event as the main driving force of change and evaluating, also from a quantitative point of view, the degree of impact on the landscape.

By analyzing documentary sources of reference previously established (Austro-Hungarian Cadastre for the pre-militarization situation; period aerial photographs for wartime; orthophotos 2015 for the current situation), the information regarding the relative land cover and land uses were obtained, which were mapped in the QGIS working environment. Fig. 5 shows, for example, the analysis regarding wartime, based on data obtained from the georeferencing of historical aerial photographs.

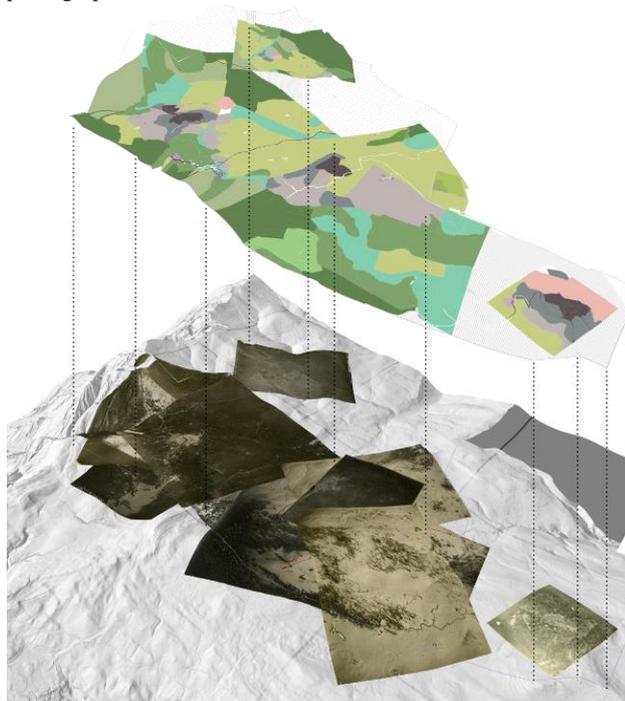


Figure 5. Vezzena Plateau: LCLU wartime

The association of the informative data belonging to the different time frames, relative to each identified area, takes place through the compilation of a specific table of attributes

connected to each polygon and specifically designed to simultaneously assign to each area both the information regarding the use of the land (HLC, Historical Landscape Characterization) and the degree of influence of the war event (INFL, influence degree) as well as some relative interpretations. The developed method proposed to update the categories of characterization of land use and land cover derived from the Historical Landscape Characterization (HLC), already codified in the 90s of last century, with the degree of influence determined by the processes of militarization and the event of war.

In this sense, the methodology suggests a greater specification of the previously listed land uses with respect to the presence of vestigia within them and their degree of recognition, which is declined in the inclusion of additional specific fields called INFL_1850, INFL_1918, and INFL_2018 to be completed according to a simple binary numerical system (0-absence; 1-presence).

Label	Land use	1850	1914-18	2018
11	Dense Woodland without vestigia [ha]	858,21	179,99	760,37
12	Sparse Woodland without vestigia [ha]	0,00	120,72	118,55
13	Sparse Woodland with vestigia [ha]	0,00	183,22	0,00
21	Pasture without vestigia [ha]	626,48	0,00	427,71
22	Pasture with vestigia [ha]	0,00	0,00	88,17
23	Pasture with traces of vestigia [ha]	0,00	0,00	69,50
31	Meadow without vestigia [ha]	2,45	28,04	12,06
32	Meadow with vestigia [ha]	0,00	1,10	0,00
33	Meadow with traces of vestigia [ha]	0,00	3,31	7,52
41	Arable land [ha]	0,41	0,00	13,60
51	Buildings [ha]	0,44	0,95	0,88
61	Private courtyard [ha]	0,37	0,00	3,16
71	Lakes	0,00	0,00	0,00
81	Totally destroys areas [ha]	0,00	19,71	0,00
82	Areas with high concentration of bombings [ha]	0,00	43,89	0,00
83	Areas with low concentration of bombings [ha]	0,00	1,07	0,00
91	Defense systems [ha]	0,00	17,80	0,00
101	Fortification "rudere" [ha]	0,00	0,00	0,87
102	Recovered forts [ha]	0,00	0,00	0,86

Figure 6. Table land use categorizations and quantitative summary of LCLU in the three time frames of study

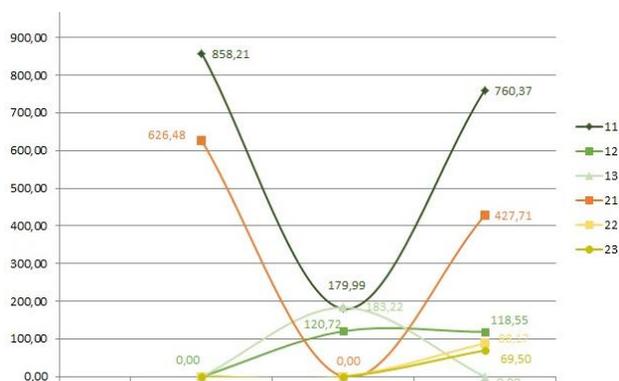


Figure 7. LCLU transformations: summary chart

Thanks to appropriate settings of the software, it was possible to query the built model to process the information and obtain very interesting visualizations in terms of narrative potential. In Fig.6 are inserted, for each category of land use, the changes in quantitative terms, which are related in the interesting graph of Fig.7. In Fig.8, instead, is shown the overall overlap of the different LCLU referred to the three temporal frames of reference.

From these elaborations can be drawn interesting considerations concerning the dynamics of transformation of the landscape. As far as the pastoral activity is concerned, for example, if in the

late nineteenth-century mapping it was very consistent, testifying to how the local economy was based on the primary sector, during the wartime the presence of pasture areas has become almost nil, in relation to the wartime needs of visibility

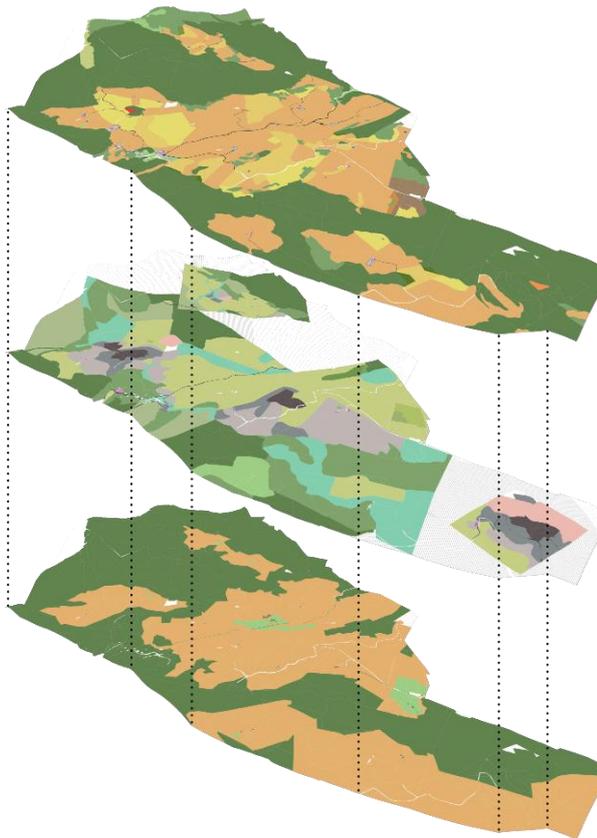


Figure 8. Overlapping of different LCLU Analysis in the three time frames of study: 1850, wartime, 2015 (bottom to top)

and space, which have almost entirely compromised the existence in favor of numerous areas left free, and then to meadow (Fig.9). In the post-war period, however, pasture was gradually restored in many areas where the "signs of destruction" had become evident, thus representing a partial cause of the physical alteration and/or cancellation of the most fragile traces of the remains.

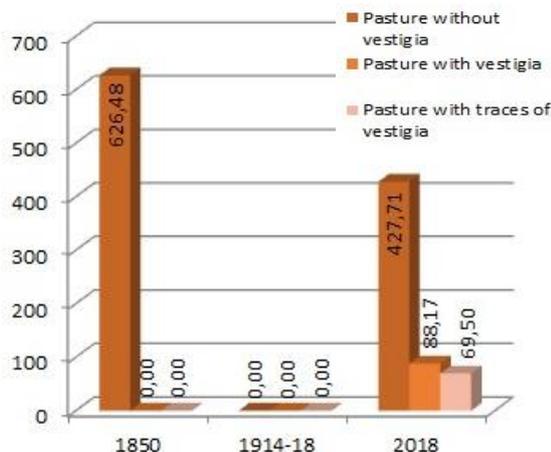


Figure 9. The quantitative trend of pasture areas (hectares) in the three time frames

Concerning the investigation of changes in land use and land cover and in addition to the visualizations concerning the different mappings referred to individual periods, the method proposes an interpolation of the obtained data to set up an analysis of the main trajectories of change in the landscape. From an operative point of view, this survey is based on the reciprocal comparison between the use classes of a specific area with respect to two determined timeframes through a binary numerical analysis (Fig.10).

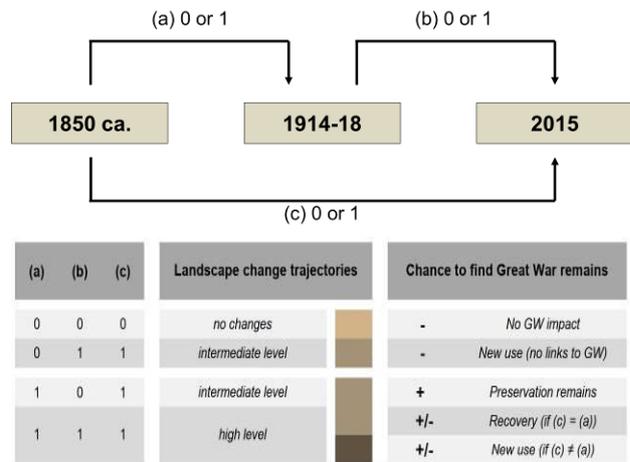


Figure 10. Trajectories of landscape's change: outline methodological approach

The trajectories of change concern the comparisons between pre-militarization/wartime and wartime/ current situation: if the classes of use do not change (value 0), it means that, concerning that specific temporal comparison, there is a conservation of the same land use; if instead the categorizations show differences (value 1) it means that due to precise driving forces the land use has changed over time. By comparing the different trajectories, it is possible to understand not only whether the landscape structure of a given area has been influenced by the war event but also to what extent these tangible influences have been "treated" since the war.

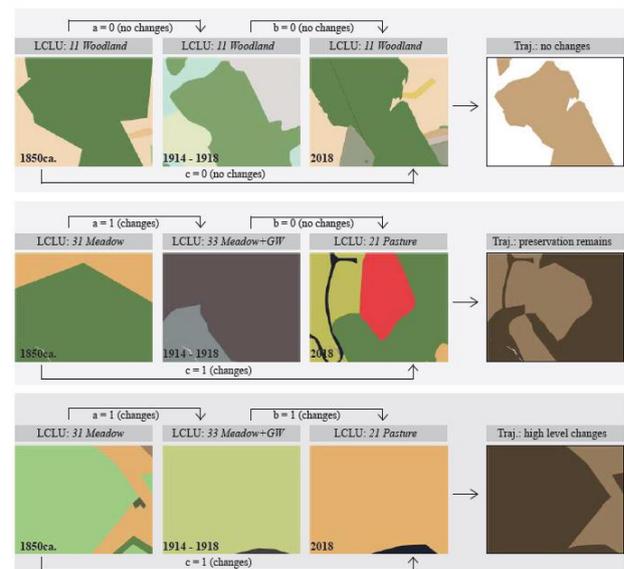


Figure 11. Mapping attitudes to change: operative steps.

As can be seen in Fig. 11, by assigning parameters relative to the conservation or transformation of land use to the various

polygons, it was possible to draw up a sort of map of the "attitude to change" of the various areas surrounding the fortified area of Busa Verle Fort, highlighting where it is more likely to find remains of the Great War.

The overall view can be seen in Fig.12, where the dark brown color indicates the areas particularly prone to change, which, over time, have undergone continuous changes in land use, while the light brown color identifies areas not involved in militarization processes or in the direct impact of war (such as wooded areas and other contexts that have remained unchanged over the past two centuries), while with the intermediate brown color were defined the "intermediate" areas, affected by the processes of militarization (between 1850 and the wartime) or by the conflict itself (during the wartime) but which were then altered, modified, restored or reconfigured over time. In these areas, the impact of the conflict has certainly always been decisive in the changes, but the probability of finding remains is higher in those contexts where no changes have been voluntarily made from the post-war period to today (1-0-1), that is, the areas near the three forts Campo Luserna, Busa Verle and Spitz Vezzena, as well as the fortified post of Basson.



Figure 12. Trajectories of landscape's change: general overview mapping

Contextually to these operations, for the areas within which the more or less visible presence of vestiges is recognized (i.e., those in which the fields INFL_1850, INFL_1918, and INFL_2018 are not null), the proposed method also provides for the quantitative characterization of the degree of impact of the war itself. This translates into the assignment (always in the same table of attributes) of a numerical value, normalized on a scale from 0.25 to 1, resulting from the observation of physical "signs" related to the offense and defense and recognizable on photographic documentation (see Figs.2,3,4,5).

Through the association of graduated colors in relation to the greater or lesser density of "war signs" in the landscape, it was possible to obtain a synthetic image of the areas in which the

processes of militarization and the war event itself have left a stronger imprint of their passage (Fig.13).

Lastly, the overlapping of the Impact Factor analysis with the mapping of the trajectories of change in the landscape previously elaborated (Fig.14) allowed us to settle the results and facilitate the identification of the areas in which the vestiges are potentially more present, albeit at different degrees of recognition.

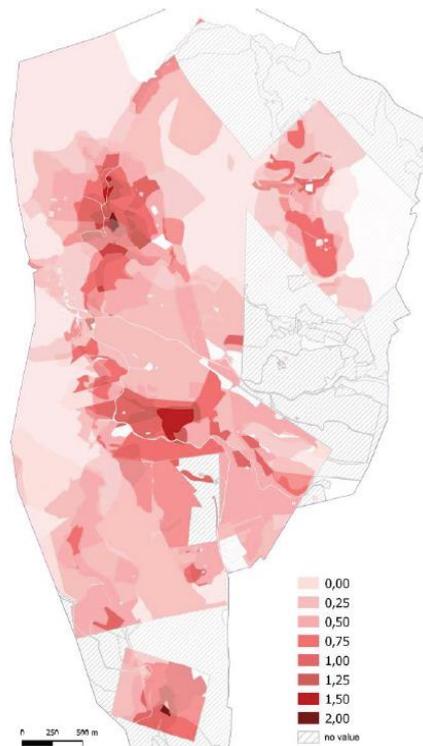


Figure 13. Great War Impact Factor: general overview mapping

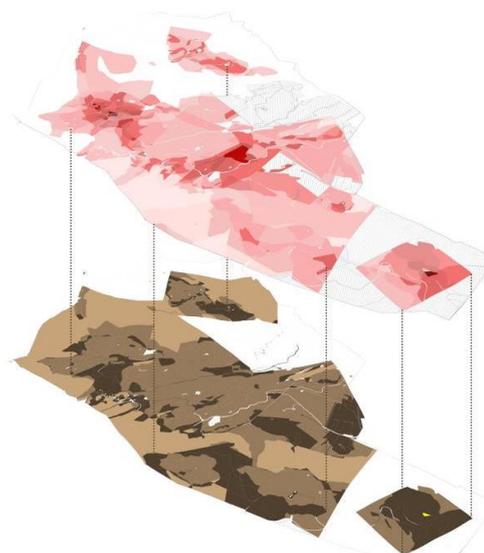


Figure 14. Great War Impact Factor and trajectories of landscape's change: general overlapping mapping

4. RESULTS AND FINAL REMARKS

In the light of the previously described methodological steps, it is clear how this analytical approach constitutes a useful operational tool to investigate a given fortified landscape in its

breadth and vastness, specifically declining the need to recognize the physical remains of the vestiges through the understanding of the evolutionary dynamics of the context in which they are inserted. In other words, the most significant contribution of this method is to be a kind of telescope through which to highlight the areas in which the probability of recognizing the physical remains of the vestiges is the greatest. From the operational point of view, this translates into the elaboration of "concentration maps" that identify the different visibility degrees of the material remains of the Great War and the different intensities of their evocative and memorial potential.

In Fig. 15 the results obtained through this analysis concerning the presented case study are shown: the landscape insisting around Fort Busa Verle and the place, further south, where one hundred years ago the defensive post of Basson was located, emerged as the main areas where the imprinting of the conflict more heavily impressed the landscape between Fort Cima Vezzena and Fort Campo Luserna.

Thanks to this important mapping, it was possible to refine the view and analyze these areas of high semantic concentration at a more detailed scale.

As shown in Fig. 16, through the precise diachronic comparison between the geo-referenced photographic documentation of the period and the current remote sensing, about 1761 meters of depressions and backfills referable to the original traces of the trenches that developed around the fort, and 77 circular depressions or small "holes" clearly referable to the craters produced by repeated bombardments were recognized.

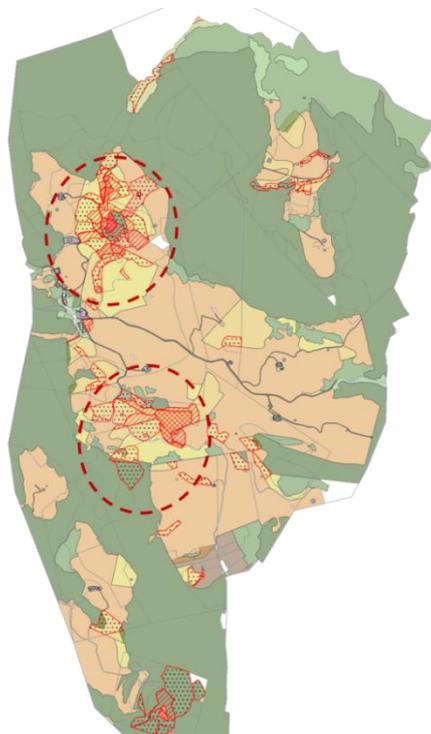


Figure 15. Identification of major concentrations of the Great War remains

As shown in Fig. 17, these vestiges of the Great War have been repeatedly modified over time by the signs of history and of the natural and anthropic transformations that have taken place for an entire century, weakening their recognizability considerably. In this regard, it is appropriate to make a necessary clarification. As previously stated, the presented methodology constitutes a valid analytical tool whose operability is best manifested at the

landscape scale in recognition of areas of different semantic significance. As regards, instead, the specific recognition of the single vestigia within these areas, the study of historical photographic documentation allows locating the most evident historical traces with precision. However, it does not allow to reveal in detail the globality of the permanence of the vestigia. As shown in Fig.18 near the tracks that can be traced back to the entrenched paths and the "wounds" imprinted on the ground by the bombardments, other irregularities in the ground's microtopography can be identified whose meaning, however, is not easy to understand.

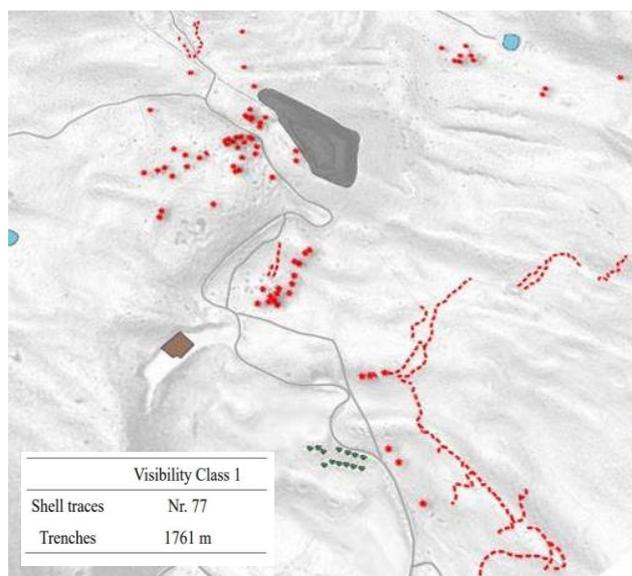


Figure 16. Remains localization on the current Digital Terrain Model (LIDAR data 2015)



Figure 17. Identified remains: current state of conservation.

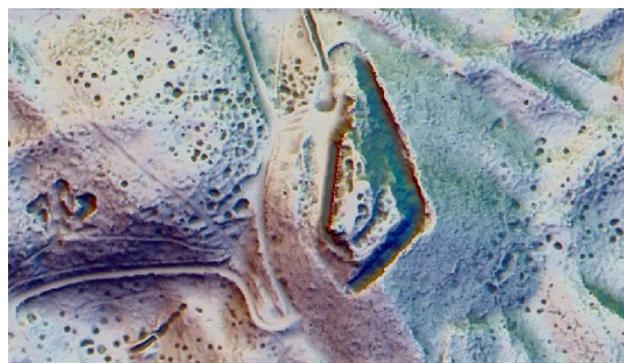


Figure 18. Sky-View Factor and Multi-hillshading visualization Lidar Data, Busa Verle Fort

To solve this gap, this research has identified a valuable methodological contribution in analyzing current terrain microtopography through the interpretation of a series of data obtained by high-resolution remote sensing techniques such as LIDAR data. Although they are not the main focus of this contribution, the outcomes of this approach are presented in Fig. 18. In particular, the potentialities offered by some specific

visualizations of such datasets (Hillshading from multiple directions, Sky View Factor, for example) allow some typological and dimensional comparisons of the irregularities present in the current terrain not identified, both with the most evident and fully recognized remains as such, and with the design documents of the time. Therefore, proceeding by reciprocal comparisons, it is easier not only to recognize the remains' permanences with respect to other natural irregularities of the terrain, but also to distinguish the different types of remains present. For example, it is possible to distinguish the imprint left by a bombing (closed circular perimeter) from the remains of a defensive post (straight or circular perimeter with an opening-entrance).

In the same perspective, it can be understood how the possibility of obtaining local territorial sections in correspondence of the depressions recognized as the remains of the original trenches (Fig.19) allows the comparison with the original project documentation to understand, also dimensionally, the thickness of soil deposited in one hundred years of multi-layering (Fig.20).

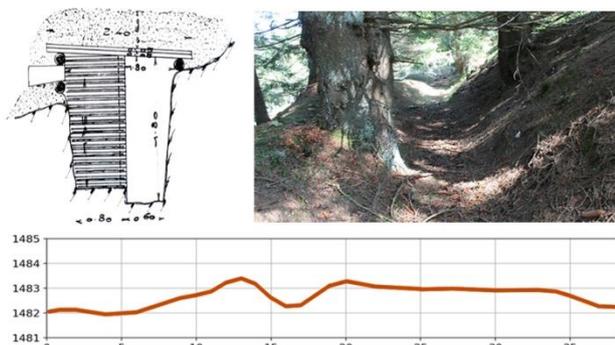


Figure 19. Territorial sections obtained in QGIS environment in correspondence of the original tracks of the trenches.

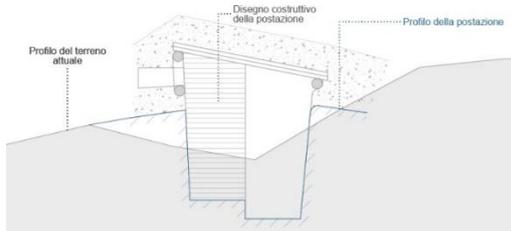


Figure 20. Superimposition of the current territorial section (Lidar data) with the profiles drawn on the project documentation (blue lines)

The accuracy error of these identifications comes from the degree of definition of the reference spatial datasets. In the case study, the LIDAR data used were acquired during a remote sensing survey of the entire Province of Trento between October 2006 and February 2008 (integrated in 2014 and 2018) and now available in ascii-grid format with a 1x1 meter.

Ultimately, in the light of the previous considerations and the results obtained, we can understand the real potential of this innovative approach: an operational contribution to facilitate the recognition of many material remains of the Great War that hold an essential value of historical and memorial testimony and that, if not recognized, could not be preserved and enhanced for the future.

In conclusion, this methodology allows applying, in a totally non-invasive and remote way, the techniques of spatial analysis to the study of photographic documents even belonging to temporal frames very distant from each other, being able to

provide an important contribution to the knowledge of the multiple dynamics of landscape transformation.

In the case study, the historical heritage "unveiled" through this approach was the one related to the material remains of the Great War, but the diachronic comparison between documentary sources belonging to different eras, as well as the overlap with specific mapping related to certain "driving forces" of change (in the case presented, War Impact Factor), can have interesting and useful spin-offs in multiple disciplines, from the traditional ones of spatial analysis and geomatics to geography and landscape, from ecology to agriculture, from environmental engineering to investigations on cultural heritage. Just as an example, the approach is well suited to the study of the effects that climate change may have on the environment, the analysis of the causes of urban densification or abandonment of rural centers, and finally for the monitoring of the impacts that some industrial plants may cause on environmental ecosystems.

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