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UNHIDING FORESTED LANDSCAPES. THE ARCHAEOLOGICAL INDEX OF SOUTH-EASTERN CARPATHIANS

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Abstract: Starting with late 2018, a new archaeological research project has been unfolding in the framework funded by the Romanian Governmental Unit for Research and Development (UEFISCDI) dedicated to top fundamental research, as one of the few winners of 2016 edition (the single to date) of 'Complex Projects for Frontier Research' competition. The Project, whose aims and methods will be shortly presented further, is entitled 'Hidden Landscapes: Exploratory Remote-sensing for the Archaeology of the Lost Roads, Borders and Battlefields of South-Eastern Carpathians' (HiLands). It implements a systematic and diachronic investigation of the historic strategic circulation corridors crossing the South-Eastern part of the Carpathian Mountains – the main gate used along ages by people transiting between Transylvania and the Danube or the Black Sea. In order to achieve such aims we have been exploring, starting from large scale LiDAR surveys, the circulation corridors' diachronic archaeological fingerprint, preserved in the shape of repeatedly fortified landscapes. LiDAR surveys have been carried on continuously since 2018, by airplane, but also with portable sensors based on SLAM technology. The results of the LiDAR explorations were enhanced by field surveys, geophysical prospections and pin-pointed excavations, in order to elucidate the nature of anomalies or better contextualize the significance and layout of the roads' routes. The results of these activities are resumed in a constantly updated, open access, online data base of archaeological sites - The archaeological index of South-Eastern Carpathians (AISEC). The current contribution details the essentials of HiLands research (aims, concepts, methods), in order to introduce in the scientific circuit the AISEC's functions and instruments, ready to be used as citable work.
Keywords: *LIDAR; mountain archaeology; old roads; battlefield archaeology; forested areas archaeology; digital atlas; South-Eastern Carpathians.*

THE RESEARCH THEME: UNDERSTANDING THE ARCHAEOLOGICAL EFFECT OF GATEWAYS

With its fragmented geomorphology and mild ridges, the South-Eastern part of the Carpathians has been playing, since early prehistory, the role of main-avenue connecting Transylvania with the Danube and Black Sea. It is here, at the turnaround of the Carpathians, that three major mountain passes (Bran, Buzău and Oituz) allowing the commercial and military traffic on a systematic basis, converge all together into a single hub which is Țara Bârsei/Brașov-Târgu Secuiesc Depression.[1] This intersection of great commercial and military routes, distributed on the inner part of the mountain arch along a distance of only 70 km, is unique for the entire Carpathian range, as it is in the same time, the closest to the

[1] BINDER 1969; BOGDAN 1905, no. LXXV, 97-98.

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Black Sea and Danube Mouths. This fact had significant consequences in the regional organization of habitation, cultural patterns and power structures, along all ages. It is more than once that archaeologists observed how the material culture found in the inner Carpathians' Curvature is closer related to their extra Carpathian neighbours than those, even if nearer located, in the Transylvanian Basin.

The geomorphological accessibility of the Curvature Carpathians favoured, on part, the direct movement of people, goods and ideas, sometimes on large distances, coming from Central-Europe, Mediterranean or the North Pontic steppes, but, on the other hand, raised security problems for those communities located on either side of the Carpathians faced with such 'a gate'. During various times and under different political authorities, efforts were made to control the transit, defend or even block these passages. As a result, the ridge routes, mountain passes and inner Carpathian depressions were marked by fortresses, watchtowers and various other defensive lines, including kilometre long linear fortifications - vestiges of past stories about military strategies, battlefields, political interests, borderlines and cultural contact, but also about mobility and interaction along geomorphologically coherent pathways. Recovering the strategic potential of geomorphology by analysing the fingerprint of anthropically modified landscapes, especially the recurrent use of same spots along ages for defensive, border, road control or even habitation purposes, is the main indirect method of identifying the route of major corridors, leading in turn to uncovering of others, not yet discovered, or not completely understood elements functioning in relation with these roads.

What is a major corridor? Many have been the roads linking the extra-Carpathian lowlands with the South-eastern Transylvanian Depressions by mountains' crossing. From these, some have functioned only as secondary *pathways* - relevant in local contexts. It can be the case of routes used in the regionalized authority networks of the Dacian Kingdom period, but also the case of Medieval and Modern Age phenomenon of transhumance. However, others appear to have functioned as major gateways, constantly used along multiple stages, since prehistory to more recent history. In order to control territories and organize commercial traffic there is need for a certain kind of geomorphology, one which makes possible the flow of large groups of people, animals and wagons, with reasonable efforts and smallest risks. Such naturally favourable routes are likely to become strategic corridors (which usually function as an array of roads using the same main pass). They reveal themselves to us nowadays indirectly, in the traces left by people constantly working to fortify them, regardless of period.

The South-Eastern Carpathians region, especially the inner mountain depressions (Braşov-Târgu Secuiesc, Baraolt, Ciuc, Întorsura Buzăului) concentrate an impressive number of fortified places. For example, only for the Late Iron Age there are known about 40, even if for a quarter of these the location is not certain, or their entire chronological span completely clarified, being repeatedly used sites. Overall, this is more than double comparing to any other region relevant for what can be associated with the concept of Pre-Roman Dacia. Therefore, even if knowledge of these relics does not lack, from the Late Iron Age 'vultures' nests' built in dry masonry on top of rocky peaks, like Târcov in Buzău Mountains[2], at 740 m altitude, Cetăţeni (Argeş county)[3] at 720 m or Covasna - *Cetatea Zânelor*[4] at 930 m altitude, to the Roman camps aligned along the military road of *Limes Transalutanus*[5], Medieval forts like Tabla Buţii[6] at 1300 m altitude and Slon[7] along the Buzău Road, Oratea[8] in Rucăr - Bran Corridor, the Austro-Hungarian border fortifications, like the *Bem sánc* in Oituz Pass[9] or the First World War trenches blocking all the three passes[10], they remain, still, just isolated find spots in what is otherwise a sea of blank – the vast forested highlands of the South-Eastern Carpathians – an uncharted land of Romanian archaeology, remote, not so easy to survey, but with the potential to contribute significantly to the understanding of major historical events, archaeological cultures and periods. This fill-in-the-blanks process cannot be done outside a large-scaled effort and only by traditional methods. Moreover, even in the cases of known sites, much remains to be learned and clarified.

PROJECT OBJECTIVES AND METHODOLOGICAL PRINCIPLES

HiLands project was designed to fill in the blanks the archaeology and history of the South-Eastern Carpathians, one of the major European gateways connecting Central Europe with the Danube Mouths, at the Black Sea. The initiative, developed in early 2016, belonged to a team of archaeologists and historians representing the Romanian Academy Institute of Archaeology 'Vasile Pârvan' in Bucharest, 'Carol I' Museum of Brăila and the National

[2] MATEI 2016.
[3] MĂNDESCU 2006.
[4] CRIŞAN, SÎRBU 2010; ŞTEFAN/ŞTEFAN/BUZEA 2020.
[5] PETOLESCU/CIOFLAN 1995.
[6] CĂPĂŢÂNĂ *et alii* 2008.
[7] CIUPERCĂ 2018.
[8] CANTACUZINO 2001, 161-175.
[9] KARCZA/SZABÓ 2012, 351-354.
[10] ŞTEFAN/ŞTEFAN 2018.

Museum of the Eastern Carpathians in Sfântu Gheorghe. The project started in October 2019 and was bound to unfold for 48 months.

In order to be able to progress in the study of old roads and understand the social, cultural and political implications of gateway-areas, HiLands team recognized from the beginning the need to address the challenges of exploring large-scaled remote spaces, of finding the most suited themes and tools specific to mountain archaeology and forested zones archaeology – research fields practically undeveloped in Romania until quite recently.[11] Of the targeted survey zones, more than 80% of their surface is under canopy, from which two thirds is represented by ever green vegetation.[12] It was obvious that there was no other method, apart from LiDAR, that could reasonably (as regards time, resources and relevance) cover this hugely archaeologically and historically significant area (divided between eight counties). Only in a consistent funding effort and in a very large, interdisciplinary team, such investigation could be attempted. LiDAR based survey in archaeology has the great potential to achieve simultaneously four important heritage related goals: identification, accurate spatial documentation, contextualisation and digital preservation and, what is more important, can achieve all of these in the forested areas where no archaeologist has gone before.

LiDAR (Light Detection and Ranging) or ALS (Airborne Laser Scanning), the great technology which in the last two decades revealed to the world the Angkor Vat lost landscape[13], brought to light the former demographic complexity of Mesoamerica jungles[14] or revealed the true scale of the Stonehenge complex[15] is an active, airborne telemetry method, used to obtain high density 3D measurements of the terrain topography. It uses a rotary mirror to send towards the terrain's surface laser impulses (tens or hundreds of thousands of impulses per second). When these laser impulses are transmitted over forested areas, the majority of them are reflected back by the canopy (first echo) or by vegetation in intermediary position. However, a part of these impulses can penetrate vegetation and be reflected by the soil (last echo). This capacity opens the possibility to obtain accurate, high resolution (centimetre level) digital terrain models of the bare-earth type.

In contrast with other countries (like Poland or Great Britain) where LiDAR data sets are widely and openly available to archaeologists, in Romania we can mainly refer to just two, small scaled (even if with remarkable results) LiDAR applications for archaeology – at Roman Porolissum[16] (by a German service provider) and Dacian Sarmizegetusa Regia[17] (within a BBC cultural project). More recently, several previously Late Iron Age fortifications located to the East of Carpathians have been individually presented as LiDAR views.[18] The data used in this case belonged to the National Agency for Water Control, meaning they were not collected for archaeological purpose at the highest available resolution. Moreover, the data were presented strictly as images, not as analysed DEM files. Despite the limitations, the project is a worthy example of data sharing between state institutions, an attempt to supplement the lack of LiDAR coverage for archaeological purpose in Romania.

In the case of HiLands project, it was also considered a prerequisite to implement a diachronic perspective on the vestiges and landscapes, in order to be able to reproject, in a reverse engineering process, the more recent strategic exploitation of certain sites into older or unaccounted for ages, while also acknowledging the fact that LiDAR prospection does not allow any chronological filters. You find what you find, not what you want – a challenge, but an opportunity, nevertheless. This is why, for example, the battlefields and fortifications of the World War One were treated as archaeological sites of great importance. As expected, many events reported for the First WW can be precisely located on the maps due to LiDAR documentation. Data comparison showed yet that many things are still to be found out, and although that war is better documented than others, there are still a lot of unknown facts to be studied. As the marks of the war are relatively fresh, being one of the latest layers of anthropization in the landscape, they are still relatively easy to find; on the other hand, almost all those marks are made just by dislocating the soil, with few solid constructions, therefore they are quickly decaying and will be far more difficult to find in a future not very distant. Therefore, the LiDAR documentation made within our project is the base of present and future research of the First WW, for the given area as a micro-regional example. Already some of the most relevant battlefields of WW1 documented in HiLands projects have been proposed for protection and registration in RAN as archaeological sites.

Resuming and narrowing down the main research objectives, we can now say that HiLands aims to explore large expanses in the South-Eastern part of the Carpathians (Romanian counties of Argeș, Brașov, Buzău, Covasna, Dâmbovița, Harghita, Prahova, Vrancea) by using airborne LiDAR specifically engaged for archaeological purpose, that of identifying and documenting archaeological sites, old roads and battlefields and by doing so, to make progress in behavioural modelling of major corridors' routes and of their effects in what concerns frontier establishment, political fragmentation, high-elevation habitation, fortification activity and cultural contact, for all chronological compartments, since Prehistory till Modernity.

The exploration areas are as follows:

- the mountainous sector of *Limes Transalutanus* (Câmpulung, Nămăești, Dragoslavele, Rucăr, Cetatea Carului, Bran);

[11] BOBÂNĂ 2015; DRAGOMAN *et alii* 2015; 2017 – for a project specifically declared as dedicated to mountain archaeology (though not in forests) in Rodna Mountains, in the Eastern Carpathians. We share the same approach to diachronic inclusion of identified anthropic vestiges. About archaeological research in forested areas see ROMAN *et alii* 2017.

[12] Data kindly offered by the National Institute for Forestry Management based on their Digital Inventory with data resolution of 2 km.

[13] EVANS/FLETCHER 2015.

[14] INOMATA *et alii* 2017.

[15] BEWLEY/CRUTCHLEY/SHELL 2005.

[16] OPREANU/LĂZĂRESCU 2014; OPREANU/LĂZĂRESCU 2016; ROMAN *et alii* 2017.

[17] OLTEAN/HANSON 2017; OLTEAN/FONTE 2019.

[18] BERZOVAN/OANCĂ/MAMALAUCĂ 2020.

- the Northern gate of Buzău Road – the Tartar Road (Drajna de Sus, Slon, Tabla Butii) and mountain exits towards Vama Buzăului, Covasna, Boroșneu or Teliu;
- the Southern gate of Buzău Road on the Middle Buzău Valley (Pietroasele, Sărata Monteoru, Bozioru, Nehoiu);
- the Moldavia Road through the Oituz Pass and adjacent territories in Vrancea county (including the World War One battlefield from Oituz);
- the archaeological areas that close on the inner side of the mountain communication corridors through major corridors – basically those in Brașov, Baraolt and Târgu Secuiesc Depressions;
- the western gates of the South-Eastern Carpathians passes (Bogata Forest, Olt Gorge at Racoș, Rica forest, Vîrghiș).

The research was designed so as to also take in consideration a small selection of key-archaeological sites that close the mountain communication corridors outside the Curvature Carpathians. Even if not in mountainous environment, they were regarded as having the potential to clarify the meaning of long-distance transit routes using mountain passes - like the fortifications associated with the Roman-Dacian Wars (for elucidating the use of the Carpathian Gates during the conflict) or the Early Medieval linear earthworks, of the 8th-9th century, in Brăila, that can be related with contemporaneous counterparts in Harghita and Perșani Mountains, revealing possible defences strategies involving the Byzantine-Bulgarian states.

2. Another objective is to conduct experiments with portable LiDAR sensors (either UAV carried or hand-held) in order to increase the applicability of the technology in the field of archaeology. If in Romania, the airborne LiDAR is limited to 8 points/meter, the portable sensor allows limitless resolution, specifically useful for documenting archaeological vestiges in surrounding forested context.

3. On a larger perspective, we aim to contribute to the methodological and theoretical progress for the following disciplines: archaeology of old roads, of mountainous areas, archaeology of forested areas, archaeology of battlefields, archaeology of the First World War.

THE PROJECT AS PROGRAMME

Considering the ambitious scope and large scale of the project (funds, period) HiLands was regarded as having the potential of a research programme, allowing the following up of more than a single topic of interest. Therefore, the opportunities raised were used such as to allow progress on a variety of specific sub-themes branched from the main engaged topic (transit corridors, mountain archaeology, battlefield archaeology). Each HiLands team member, or more often, groups of researchers inside the team together with their external collaborators, identified and proposed investigation subjects to be carried on within the HiLands project, in the spirit of its cultural and technological objectives. In this way, more themes and areas could be explored simultaneously by supporting the emergence of small and mobile teams which acted with a high degree of independence. Based on their specific individual knowledge and expertise (geographic, chronological, cultural), these teams managed to cover a larger variety of subjects and travel more ground than if acting just as a single unit. This approach required an optimum organisation of the field expeditions – with interchangeable complementary human resources and technical equipment (GPS units, UAVs, geophysical and drilling devices, excavation tools and so on). Of course, the investigations methodologies and workflows, or the recording of results was done in a common framework, allowing data sharing at the level of the team and the implementation of common quality standards.

These explored sub-themes within HiLands framework were either A. geographically organized (1. Diachronic circulation and strategic reinforcement of the Rucăr-Bran Corridor; 2. Diachronic circulation and strategic reinforcement of the Buzău Road and identification of its specific variants); B. with cultural-chronological relevance (3. The mountain habitat of the earliest humans in Curvature Carpathian during Middle Palaeolithic. 4. The major European circuits of raw resources during Middle Bronze Age. 5. Early Bronze Age hilltop tumuli cemeteries; 6. The earliest horse-riders in Transylvania through mountain gates. 7. The elusive chronology of Prehistoric multi-layered hillforts in South-Eastern Carpathians. 8. Mountains as sanctuaries and fortified habitat during the Iron Age. 9. Late Iron Age discrete funerary practices – a secret hidden in the forests. 10. The Roman period Carpathian frontiers. 11. The Byzantine and Bulgarian States military works at the Lower Danube and Carpathian gates (8th-9th centuries AD). 12. Austro-Hungarian fortified Carpathian border of the 18th -19th centuries. 13. The First World War battlefields and the fights for the shortest road to Bucharest; or C. technic and methodological (14. The archaeology of old roads; 15. Comparison between results in data acquisition with either portable LIDAR, airborne or UAV aerial photogrammetry for certain types of sites; 16. Establishing classes of fortified landscapes; 17. Establishing classes of LiDAR anomalies in mountainous environment).

RESEARCH WORKFLOW AND INSTRUMENTS

During the past two and a half years the team has undertaken the long and intricate journey of establishing the best suited workflow and conceptual framework in a research they were grounding for the first time in this part of Europe – archaeology of major roads and battlefields taken in a composite, diachronic perspective and LiDAR exploration of remote and forested mountain landscapes. We managed to go from first step (not only at the level of the team, but of much of the Romanian archaeology), when we just knew the potential of LiDAR technology (and the theory of its methods and instruments) and were projecting its much anticipated impact on themes of great historical and archaeological relevance, to the high level of being already able to estimate the data management strategies to be applied to our research after the project ends, that is - to have gained practical experience, consistent body of data and, above all, perspective. From 'hopeful expectation' to obtaining the first sets of 'meaningful data' and then store, analyse and communicating them, we navigated, though,

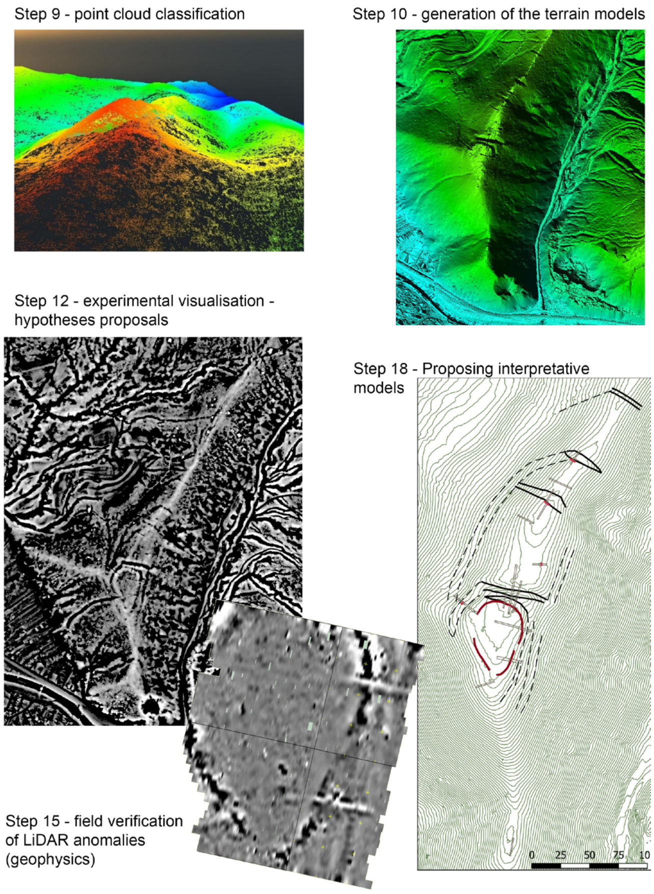


Fig. 1. Illustrating steps of HiLands workflow, here using the example of Teliu Cetatea Mare[19].

all the meanders of the implementation challenges, either technical or logistic, raised by the need to put together many people, old and new equipment, new themes, remote landscapes and large survey areas and, further along the project, by the need to ensure the huge amount of new data management and develop new research skills. Instruments for data management were created, methods of processing and analysis selected as best suited for the particularities of the analysed area, and models of interpretative processes tested. Above all, the main effort remained to find a way to integrate the discourses of the technological project component and the cultural-historical research themes. How can they be approached and overlapped such as to make both fields grow, like in a reflexive reasoning process, going back and forth, from traditional data to theoretical model, to exploratory data? This does not mean that our learning curve has ended, only that we have managed to find the 'good ride' and that from now on the times to destination will shorten. Efficiency will increase and more focus will become possible in the future interval to be placed on analysis and communication. In conclusion, only in a longer project like this, such an endeavour could be attempted, especially when the research, of innovative and experimental nature, has started from zero (plus some good intentions).

From the beginning, a LiDAR research unit was established and equipped with powerful calculation machines. It included personnel with both archaeological and technical skill, involved in communicating with the provider, handling and managing all LiDAR data. This research unit centralised requirements coming from the rest of the team regarding areas needing documentation – arranged in a list of priorities - and provided back classified and interpolated data, based on which the beneficiary researchers made their own interpretations. Some researchers were able to work directly with DEM files, making their own measurements, elevation profiles and visualisation experiments, while others preferred to use LiDAR just as simple images already rendered and exported as .kml files. For them, the collaboration with the LiDAR unit was essential in the interpretation process of anomalies and relief. The LiDAR unit also ensured the data organisation and storage (hardware copies of data are archived in each institution, separately, while the entire body of data has a back-up version in a cloud platform). The airborne LiDAR data was divided and stored in squares of 1 sq. km, labelled in a system reflecting the location in latitude and longitude (at the level of degrees). An interactive Map Server was implemented in the Project website, for registered users only. This application was used to depict in real-time, to team members, the available LiDAR covered areas as general polygons, allowing the researchers to personally check the status of their area of interest and to follow its dynamic update.

The usual workflow consists, but it is not limited to the following steps: 1) contextual research, mapping known archaeological finds, proposing models; 2) designation of the target areas (usually as blocks or corridors in the range of 50 to 600 sq. km for LiDAR exploration; 3) design of the aerial missions together with the team's provider; 4) calculation of the GNSS trajectories after the aerial mission was performed; 5) postprocessing of the trajectories based on GNSS and inertial (IMU) data; 6) point cloud extraction from the LiDAR sensor recorded signal; 7) Point cloud referencing and attribute generation, saving data in standard format (*.laz); 8) data filtering for low and high noise based on various automatic algorithms; 9) classification of the ground based on various automatic algorithms with manual parametrisation (according to the type of local relief), automatic classification of buildings and different types of vegetation (for some selected areas); 10) generation of the terrain models (DTM and TIN) and initial assessment of the quality of the model (in fact, the quality of the classification process); 11) improving and fine tuning of the digital terrain models based on various manual classification techniques aiming artefact filtering and ground points preservation in the digital models; 12) generation of main and derived georeferenced textures based on various visualisation techniques (analytical and multiple hillshading, various histogram and local adaptive histogram equalisation, simple or anisotropic sky-view factor, atmospheric-view factor, PCA of hillshading, slope gradient etc.); 13) interpretation of the identified topographic anomalies; 14) Updating the Data Base of LiDAR anomalies; 15) field verification of LiDAR anomalies; 16) updating the online Data Base of Field-Surveyed sites; 17) MapServer update; 18) proposing/updating archaeological/historical/cultural models.

The workflow is presented here in a logic and linear chain but, in practice many of the steps (especially in the

[19] ȘTEFAN/ȘTEFAN/BUZEA 2019.

range of 8 to 13) are intertwined in a back-and-forth research process. Also, the assessment of the initial terrain models based on automatic classification (step 10) and continuous refinement of this models (step 11 to 13) was made and are to be done gradually as much as there is a clear demand from the field teams. Finally, the airborne LiDAR workflow is complemented by ground LiDAR missions performed with portable 3D scanner based on a LiDAR sensor application of lighter sensors. The above LiDAR workflow resemble the general guides and procedures established in many other fields and teams working with this technology[20], but many details and order of the operations are highly adapted to the needs and the logic of the project. They will be presented in the near future in dedicated technical publications.

INTERPRETATION AND VALIDATION

From the team's previous experience in using remote-sensing for archaeological prospection[21] we already knew that having bare-earth maps of various topographic anomalies is the break-through step of the research but was certainly not enough. If some of these identified land-marks are self-explanatory (for example, recent military world war trenches excavated in their very specific zigzag layout), many others remain ambiguous, either as functionality, chronology or even as origin – anthropic or geological. LiDAR usually offers a non-selective and thus 'messy' perspective of the physical landscape in almost overwhelming detail. The interpretation of the LiDAR results is specifically more challenging in a mountainous relief as it is our case. For example, the stripping effect of the horizontal geological stratification upon relief morphology can be mistaken for anthropic terracing or even linear ramparts, while steep slopes could allow less return signals and thus just smaller resolutions and blurring of archaeological meaningful traces.

Therefore, the interpretation process of the LiDAR palimpsest is not a simple and straightforward procedure, but an interdisciplinary effort based on personal experience and repeatedly performed analytic exploration of available data with the help pf a GIS platform. It is a back-and-forth reasoning between personal knowledge of each scientist, the behavioural or natural models estimated on the basis of previous known (archaeological, historical, environmental, cartographic) information – mapped in contextual layers, and LiDAR data which is constantly seen in a different way. Interpretation of LiDAR data evolves either through various visualisation algorithms applied on the digital elevation models of the terrain, or by fusing it with the results of other geomorphological analyses. In some cases we already enhanced the airborne LiDAR data perspectives by performing additional missions with lighter hand-held LiDAR sensors in critical points (for verifications, enlargements of the covered areas or complementary surveys with different sensor parameters).

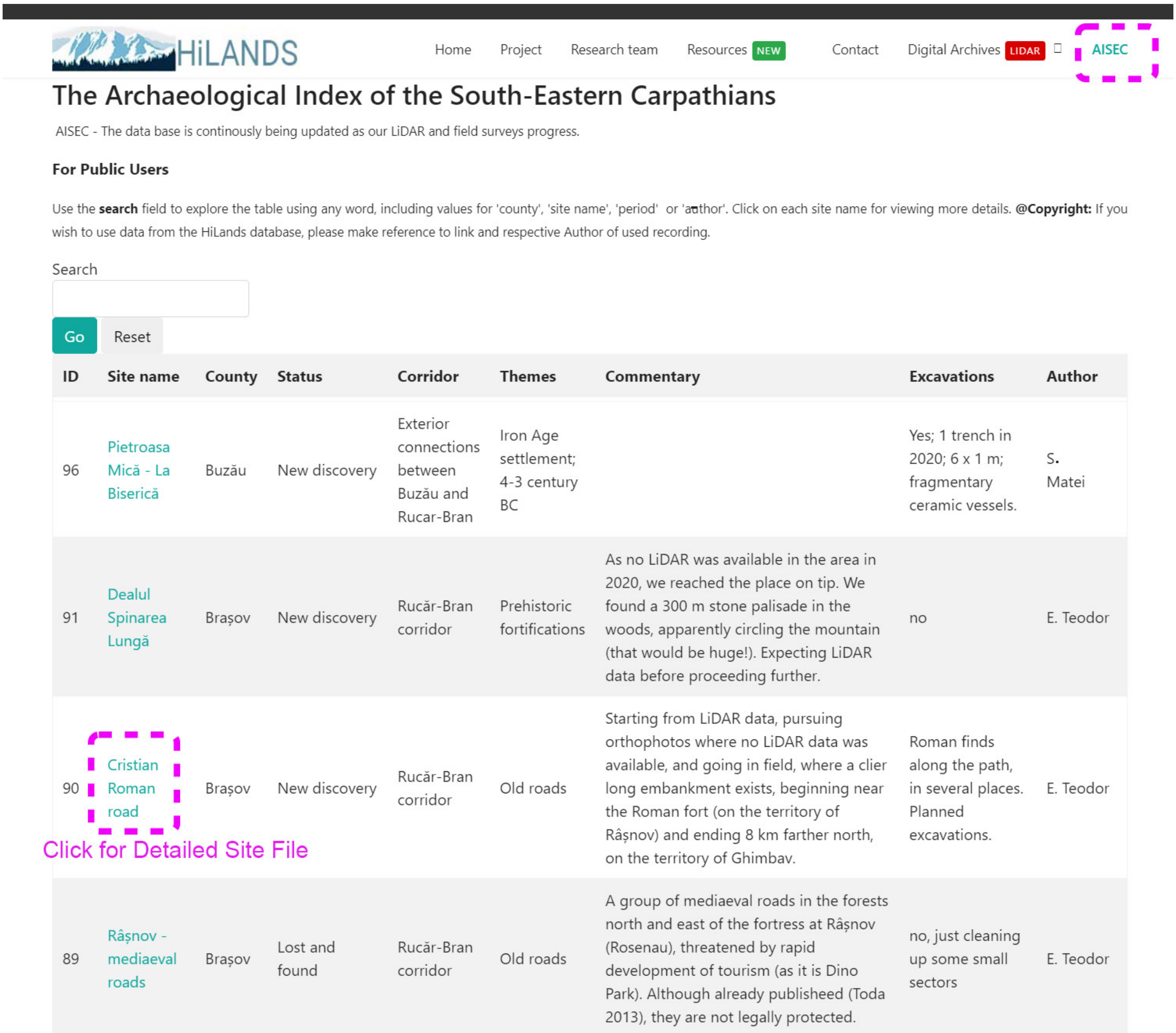
During the second part of 2019, an extensive practical assessment of the technical capabilities of portable LIDAR sensors, available on the market, were done in collaboration with the most significant developers and vendors in Europe. The aim was to decide what equipment will best suit our project. The conclusion of the analysis indicated that GeoSLAM based sensors may offer the power, portability and efficiency we needed. The selection of this particular model was done by its using of SLAM technology which allows the reconstruction of the 3D scenes without the support of additional GPS systems – an essential advantage when you work under the canopy or in caves. The equipment was acquired[22] and put to work from the ground, not from the air, in 2020. The equipment represents the latest international development in the hot field of 3D scanners and portable LiDAR sensors, bringing the research in HiLands in the front row of exploratory remote-sensing for archaeological purpose. We needed its portability in order to access and document difficult locations, and also the potential of obtaining higher resolutions in point clouds (to document unclear anomalies or located on steep slopes). It has also the advantage of making LiDAR survey repeatable, something that is still not available for us in case of airborne LiDAR. It was initially planned to be used paired with an UAV, however it proved to be much more useful if just handheld, especially in conditions of high relief and difficult and forested environment with almost no visibility or flight opening. Its main quality seems to be the ability to easily connect interior and exterior spaces. The UAV platform remains an option for quick recording of local areas in open field, where no airborne is available.

The majority of archaeological LiDAR projects include nowadays a stage, either final or during the process of data interpretation, of real ground observations, in order to verify some of the identified anomalies and, eventually, to check the surroundings for missed out elements.[23]. In cases, teams opted to survey totally new areas in order to gather additional archaeological information[24] or they used previously assembled archaeological inventories.[25] A preferred method seemed to be that of having a sample zone for throughout ground verification, based on which correction factors could be inferred on a generalized scale.[26] We included all these approaches in our research.

Our project first phase (2018) was one of assembling, mapping and classification of known-data (build archaeologic and numismatic repertories with spatial component, explore historical cartography), in order to contextualize the future LiDAR analysis of circulation corridors, but also to observe blank areas or any significant spatial pattern that could guide the selection of new target areas to be explored with LiDAR in the next phases. The second project segment (2019) was dedicated to collecting new data for known archaeological sites and landscapes (by LiDAR and field survey). The field surveys were done both following LiDAR analysis, but also before, in order to be able, at some point, to compare efficiency and relevance. Phase 2 may also be regarded as an absolutely necessary, even if quite long, opening act,

[20] OPREANU/LĂZĂRESCU 2014; OPREANU/LĂZĂRESCU 2016; OLTEAN/FONTE 2019; GRAMMER *et alii* 2017; KOKALJ/HESSE 2017.
[21] TEODOR/ȘTEFAN 2014; ȘTEFAN/ȘTEFAN/BUZEA 2015; ȘTEFAN/ȘTEFAN 2016.

[22] 3D Scanner with LiDAR sensor GeoSlam ZebHorizon
[23] GRAMMER *et alii* 2017; KOKALJ/HESSE 2017.
[24] HARE *et alii* 2014.
[25] INOMATA *et alii* 2017.
[26] CRUTCHLEY/CROW 2010.



HiLANDS

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The Archaeological Index of the South-Eastern Carpathians

AISEC - The data base is continously being updated as our LiDAR and field surveys progress.

For Public Users

Use the **search** field to explore the table using any word, including values for 'county', 'site name', 'period' or 'author'. Click on each site name for viewing more details. **@Copyright:** If you wish to use data from the HiLands database, please make reference to link and respective Author of used recording.

Search

Go Reset

ID	Site name	County	Status	Corridor	Themes	Commentary	Excavations	Author
96	Pietroasa Mică - La Biserică	Buzău	New discovery	Exterior connections between Buzău and Rucar-Bran	Iron Age settlement; 4-3 century BC		Yes; 1 trench in 2020; 6 x 1 m; fragmentary ceramic vessels.	S. Matei
91	Dealul Spinarea Lungă	Brașov	New discovery	Rucăr-Bran corridor	Prehistoric fortifications	As no LiDAR was available in the area in 2020, we reached the place on tip. We found a 300 m stone palisade in the woods, apparently circling the mountain (that would be huge!). Expecting LiDAR data before proceeding further.	no	E. Teodor
90	Cristian Roman road	Brașov	New discovery	Rucăr-Bran corridor	Old roads	Starting from LiDAR data, pursuing orthophotos where no LiDAR data was available, and going in field, where a clier long embankment exists, beginning near the Roman fort (on the territory of Râșnov) and ending 8 km farther north, on the territory of Ghimbav.	Roman finds along the path, in several places. Planned excavations.	E. Teodor
89	Râșnov - mediaeval roads	Brașov	Lost and found	Rucăr-Bran corridor	Old roads	A group of mediaeval roads in the forests north and east of the fortress at Râșnov (Rosenau), threatened by rapid development of tourism (as it is Dino Park). Although already publisheed (Toda 2013), they are not legally protected.	no, just cleaning up some small sectors	E. Teodor

Click for Detailed Site File

Fig. 2. Snapshot of the AISEC table list view in public mode. Click on site name for Detailed Site File with Image.

as it continued previous year's effort to centralize known archaeological data for the considered areas (regardless of historic period) while grounding the basics of the LiDAR data processing workflow starting from known, certain and verifiable archaeological structures, followed by extending the exploration of landscape around known anthropic activity aggregators. Having in mind all these, we can say that Phase 2 was the most difficult segment of the project to date. Despite being known, a significant percent of these isolated strongholds were not documented in the last 50-70 years, some even were not included in RAN – the National Registry of Archaeological sites, therefore they remained unprotected. The documentation made in HiLands, based on LiDAR data, will be essential for their official recognition. We expect that by June 2021, a consistent set of individual site files (for new and redocumented sites) will be sent by various team members to the Ministry of Culture, proposing their recognition and protection, and the process will continue. Even in the cases of well-known sites, where excavation works have been recently done, the LiDAR analysis and research activity made within HiLands, brought new insight in each and every considered case, revealing additional unknown anthropic elements and, especially, it gave the much needed perspective and connection with the surrounding environment, network of roads, strategic relief points.

The initial focus on 'known' and 'redocumentation' gave us time to learn and validate procedures before attempting to deal with unknown landscapes and anomalies (which was started systematically in Phase 3 (2020). In time, certain 'classes' of anomalies characteristic for the mountainous space become apparent, becoming, thus, a reference for the further interpretation of unknown, unexplored anomalies. This approach ensured the following: calibration of the LiDAR point clouds classification and interpolation algorithms; testing of software, visualisation methods advantages and disadvantages according to the type of analysed features; the settling of communication

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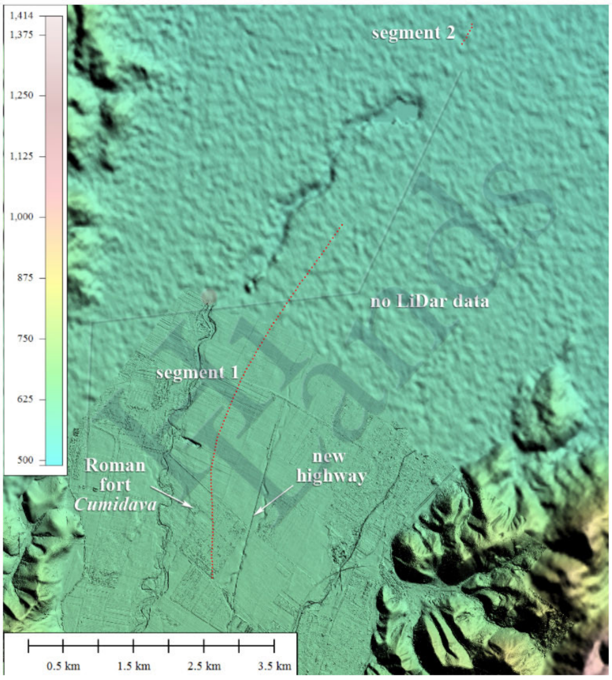
AISEC - Individual Site File for

Site no. 90 Cristian Roman road by E. Teodor

County	Brașov
Corridor	Rucăr-Bran corridor
Themes	Old roads
Status	New discovery
RAN	No

Image



Forest	No
LiDAR	Airborne
UAV	DSM & orthophoto
Geophysics	area in ha/method/results
Soil samples	No
C14	No
Commentary	Starting from LiDAR data, pursuing orthophotos where no LiDAR data was available, and going in field, where a clier long embankment exists, beginning near the Roman fort (on the territory of Râșnov) and ending 8 km farther north, on the territory of Ghimbav.
Excavations	Roman finds along the path, in several places. Planned excavations.
Area field surveyed	8 linear km (from two segments, 5.1 and 0.337 km)
Team	Teodor, Popescu
Published	No
Author	E. Teodor
	Back to List View

Fig. 3. Detailed Site File for site no. 90 'Cristian Roman road', recorded by E. Teodor.

procedures and data transfer with the provider; the identification of the requirements for labelling, organising, storing and backing-up LiDAR data – and implement them in specially developed instruments.

THE ARCHAEOLOGICAL INDEX OF SOUTH-EASTERN CARPATHIANS

The intense field activity of the last two years (consisting of surface survey, metal detecting, magnetic prospection, small trial trenching, soil samples collecting, portable LiDAR documentation), developed by simultaneously working teams on very different themes, meant that data needed to be systematically recorded and centralized, in digital archives, especially in advance of the expected integrative analyses of the months to come. For this we developed instruments for data management and sharing on a section of the project website. They serve also as a primary publication tool.

These new tools are: 1) an online data base for recording information about those sites and archaeological areas which got to be field surveyed within HiLands project – by trial trenching, geophysical prospection, systematic coring or simply by surface survey; this data base is focused on archaeological information which even if derived from LiDAR observation has a consistent degree of confidence; 2) a data base meant for organising archiving data obtained in geophysical survey and 3) a data base focused on systematization of LiDAR anomalies for sites and areas which were or were not yet field surveyed (or which will not even get to be surveyed within the project calendar). Being online, the forms are available to all the team members based on granted access privileges by the Project administrator. The data bases have an English language interface. The choice for English was made in order to allow the communication of results to a wider scientific public. In this way also the enlargement of the collaborators and partners' network can be made without limitations, including in the future, when the project ends.

HiLANDS

The Archaeological Index of the South-Eastern Carpathians

AISEC - The data base is continously being updated as our LiDAR and field surveys progress.

For Public Users

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AISEC - Individual Site File for

Site no. 1 Teliu Cetatea Mare by M. Ștefan

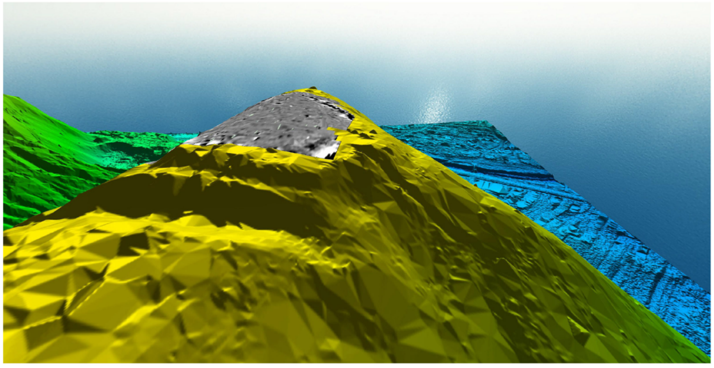
Site name	Teliu Cetatea Mare
County	Brașov
Corridor	Buzău Pass
Themes	Iron Age Fortifications; Dating Wallburgen; Fortifications with burnt elements
Status	Lost and found
RAN	Yes, but needs corrections
Image	
Forest	Yes
LiDAR	Airborne
UAV	Oblique images
Geophysics	0.4 ha magnetic 2019
Soil samples	Yes
C14	Yes, dated
Commentary	LiDAR based survey combined with a geophysical investigation (magnetic method) in Cetatea Mare allowed a better reconstruction of this site's plan and layout of fortifications, revealing a more complex design in which the fortification ditches were continued with terraces on the two main site's slopes. An additional fortification ditch, unknown before, was identified in the northern site sector. In total, the area affected by anthropic works in Cetatea Mare can be recognized now on a 2 ha surface, while the number of enclosure lines reached 5.
Excavations	1 trench/2019 (2 x 6 m) Rampart with burnt elements; At least two major moments in which the site was affected by large scale levelling associated to enclosure rebuilding could be noticed, once dated in Hallstatt C-D (which could have relocated previous Schneckenberg and Wietenberg materials) and the other in the late 1st C. BC - early 1st c. AD. We date the large relief modifications affecting the entire site, based on radiocarbon and stratigraphy, in the Augustan period.
Area field surveyed	5 ha
Team	M. M. Ștefan, D. Ștefan, D. Buzea
Published	Yes M. M. Ștefan, D. Ștefan, D. Buzea, New investigations in the fortifications from Teliu, Brașov County, in Angvstia 23, 2019, 229-256.
Author	M. Ștefan

Fig. 4. Detailed Site File for site no. 1 'Teliu Cetatea Mare', recorded by M. Ștefan.

The table categories include site name; county; reference to RAN if any; mentioning of the research sub-theme to which it belongs; mentioning of the major corridor with which it can be related; geographic coordinates, details about involved research methods; areas of the surveyed surfaces; results of excavations or surface surveys in short; type of surveyed site/observed anomaly, author of data base recording; componence of the investigation team). For the LiDAR data, each anomaly was linked with the corresponding LiDAR unit label and with a LiDAR Snapshot. These anomalies can be categorized according to a list of predefined types (linear earthwork, fortification of enclosure type, tumuli, anthropic terracing, road, rectangular structure, ditch, etc). As we preferred to analyse the LIDAR based on 1 sq. km unit, multiple selection of anomalies' categories was made possible. These listing views allow searching within the table after any desired term. All the three digital archives (of LiDAR Anomalies, of Field Surveyed Sites and of Geophysical Surveys) are linked with a Map Server. For the moment, except for the Data base of Field Surveyed Sites which accounts for a research with a higher degree of confidence, the rest of the mentioned instruments are not available for the larger public. They will become public gradually, once the research progresses, the anomalies are verified, the new sites recorded and protected in RAN.

Because the publication of detailed and interpreted reports for each and every surveyed site within HiLands will take years to complete, a process which will surely transcend the current project time limits, the field surveyed sites table was made free for public use (except the coordinates, though). The location restriction functions until all new sites will be recorded in RAN and thus protected against possible treasure hunters. The open-access instrument was called the

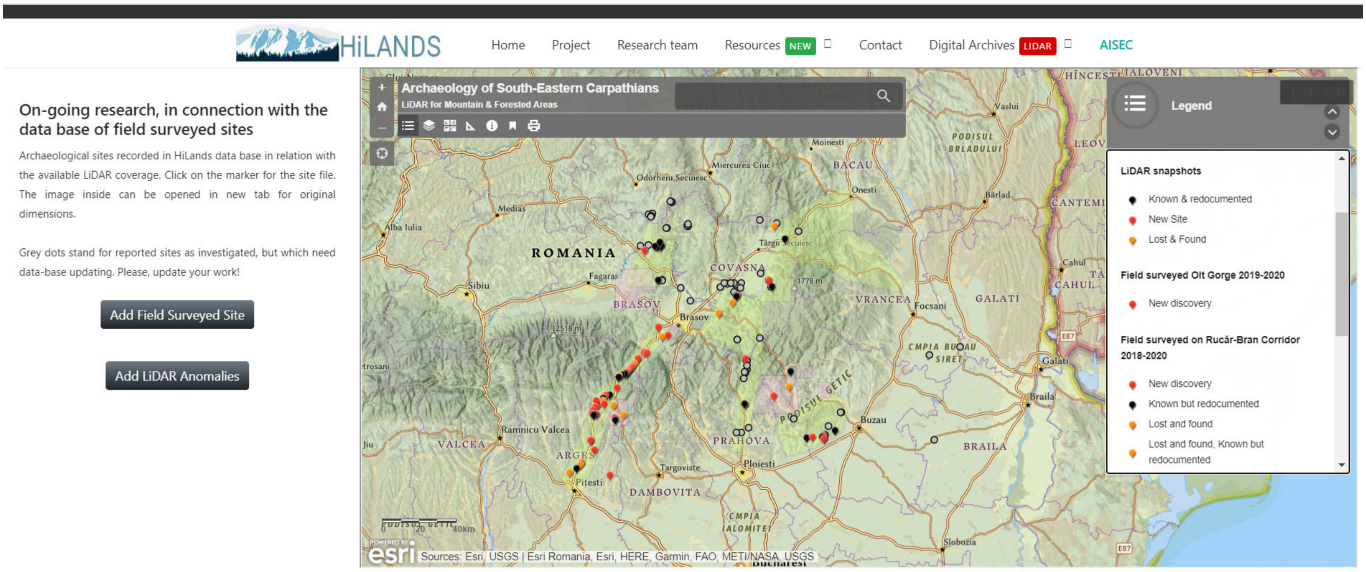


Fig. 5. Online GIS map of the archaeological sites and areas investigated in HiLands project (for the moment only for recorded users).

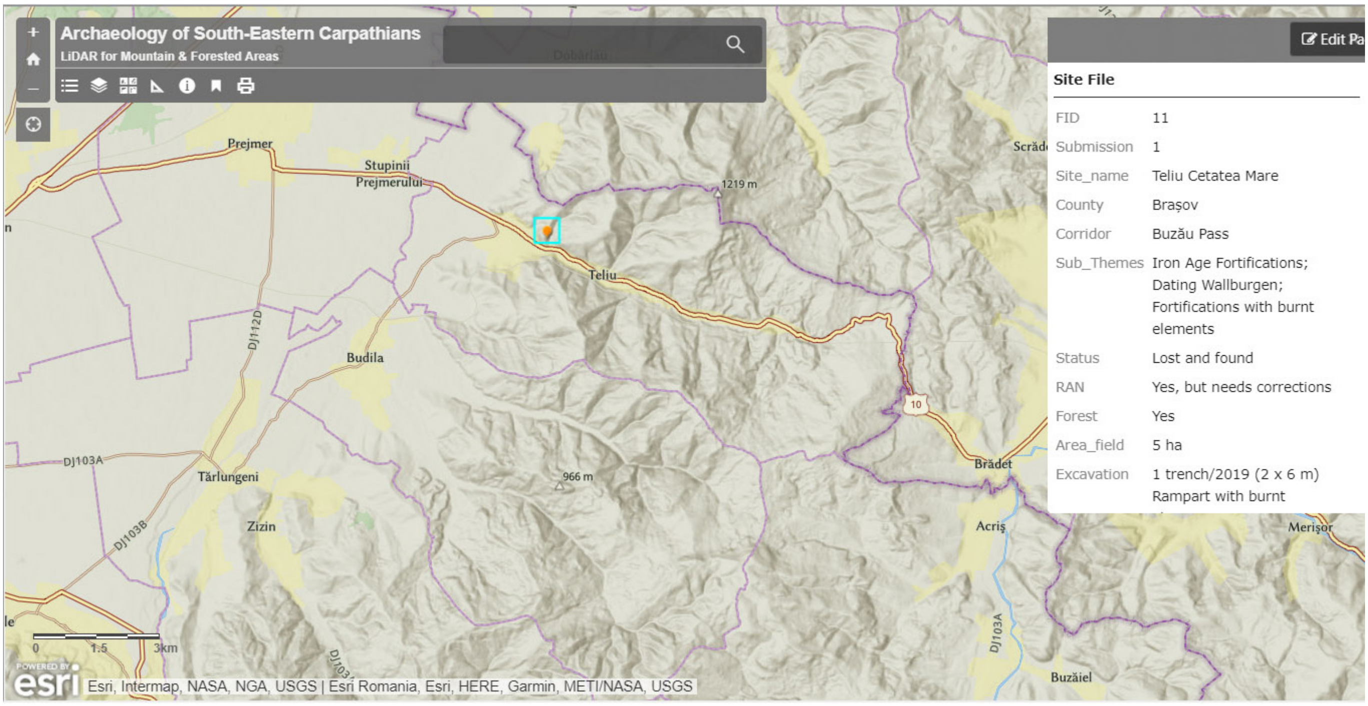


Fig. 6. Detail map view with related site-file for of 'Teliu Cetatea Mare'.

Archaeological Index of South-Eastern Carpathians (AISEC).[27] The data base can be viewed as a list of recordings with each entry possible to visualise separately as an independent file with additional details, including image, if loaded. In many situations these images are precisely the LiDAR snapshots.

AISEC offers thus a condensed overview of the field surveyed sites within HiLands, both of the 'already known but redocumented' and 'newly identified' categories. AISEC is constantly updated, including in what concerns the sites already recorded, for which the presented information can expand (as the expeditions are still on-going). Considering the potential and size of the already acquired LiDAR data sets, to which more is to be added in the next 20 months, we expect AISEC to grow even after the projects ends, as the interpretation and analysis process will continue in the framework of the individual research plans of the institutions and people involved in HiLands consortium.

Until now, there are 72 public entries recorded in AISEC, of which 19 represent field surveys in known-sites, 12 were sites previously mentioned in the literature, but difficult to locate precisely only with traditional means, thus labelled 'lost and found', while 41 are newly identified sites, mainly based on LiDAR analysis, but also few through traditional surface survey.

27 Accessible at https://hilands.net4u.ro/index.php/aisec

In total, until the end of the field season of 2020, HiLands researchers reported activities in 156 archaeological sites and areas. Of these, 112 sites benefitted of LiDAR documentation. In this group we find: the Iron Age hilltop sites from Pietroasa Mică *Gruiu Dării* (Buzău), Cârlomănești *Cetățuia* (Buzău), Teliu *Cetatea Mare* (Brașov)[28], *Tipia Ormenișului*, *Piatra Detunată*, *Vărărie* (Racoș-Augstin, Brașov), Crizbav (Brașov), Homorîciu (Prahova), Gura Vitioarei (Prahova), Covasna *Cetatea Zânelor* (Covasna)[29]; the Roman forts at Vârful lui Crai (Prahova), Drajna de Sus (Prahova), Brețcu (Covasna), Rucăr (Argeș), Râșnov (Brașov), Jidava (Argeș); the Bronze Age hilltop sites at Sărata Monteoru (Buzău), Năeni Zănoaga (Buzău), Lutoasa (Covasna); the Medieval fortifications from Jigodin II (Harghita), Sînzieni (Covasna), Slon (Prahova), Racoș *Tipia Racoșului* (Brașov), Vîrghiș (Covasna) or the Modern age ones in Oituz, Buzău and Bran Passes (ramparts, forts, border facilities, quarantines, roads, inns). To these we have to mention the throughout LiDAR documentation obtained for the World War One battlefields around Câmpulung, Rucăr, Dâmbovicioara (Argeș) and Buzău Pass, at Tabla Buții (Prahova, Covasna).

Public users of AISEC should cite the current article as reference, also adding the author credentials for each archaeological site entry referred to, as well as the date (day/month/year) for the website visitation.

FUTURE PERSPECTIVES

HiLands project will run until October 2022. Until then the team will focus on further exploring the already recorded LiDAR data, specifically in blank-areas, between known sites, will continue to carry on as many as possible field surveys meant to verify anomalies in uncharted territories, while also working on data modelling and interpretation. The data bases will be constantly updated and, as the HiLands researchers will progress with the RAN recording, parts of the Map Server will become publicly available. The process of LiDAR data interpretation and detailed site scientific publishing is expected to continue, however, beyond the time span of the project.

HiLands consortium has already acquired 37 times more airborne LiDAR data than anticipated when the project started (over 7400 sq. km in comparison with the initial estimated 200 sq. km); and the acquisition process will continue. We assess that at least 1200 square kilometres will also be covered in the following two years. This makes HiLands the potential largest remote sensing for archaeology project in Eastern Europe, specifically focused on forested and high-altitude landscapes. This increase was possible on one hand due to the emergence of local services providers that made negotiation feasible, but also by performing all the data processing (including classification and interpolation) in house, diminishing the costs. Even if, sometimes in the future, a democratization of LiDAR data access in Romania is bound to happen eventually, like in Great Britain or Poland, the HiLands LiDAR archive will not lose its relevance, as in our case the data was acquired in the best parameters suited for archaeological purpose, in the limits permitted by actual national legislation, it was done so for a very large area – allowing thus the establishment of coherent and relevant workflows and interpretative models. Above all, its potential resides in the interpretation process and identified of classes of anomalies, paired with a systematic field verification programme – all of which can be taken as references for any future similar endeavour.

[28] ȘTEFAN/ȘTEFAN/BUZEA 2019.
[29] ȘTEFAN/ȘTEFAN/BUZEA 2020.

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REFERENCES

BERZOVAN/OANCĂ/MAMALAUCĂ 2020
Berzovan, Al./Oancă, M./Mamalaucă, M., Contribuții privind topografia unor cetăți din perioada de început a celei de-a Doua Epoci a Fierului situate în sudul Podișului Moldovei (sec. 5-3 î Hr). In: Forțiu, S. (ed.), *Arheovest VIII. In Honorem Alexandru Rădulescu- Interdisciplinaritate în Arheologie și Istorie, Timișoara, noiembrie 2020* (Szeged: JATEPress Kiadó), 155-207.

BEWLEY/CRUTCHLEY/SHELL 2005
Bewley, R./Crutchley, S./Shell, C., New light on an ancient landscape: Lidar survey in the Stonehenge World Heritage Site, *Antiquity* 79, 636–647.

BINDER 1969
Binder, P., Drumurile și plaiurile Țării Bîrsei, *Studii și Cercetări de Istorie Veche și Arheologie* 14, 207-218.

BOBÎNĂ 2015
Bobînă, B., Mountain Archaeology in Romania: The status of research, *Terra Sebus* 7, 149-164.

BOGDAN 1905
Bogdan, I., *Documente privitoare la relațiile Țării Romanești cu Brașovul și cu Țara Ungurească în sec. XV și XVI*, vol. I 1413-1508 (București).

CANTACUZINO 2001
Cantacuzino, G. I., *Cetăți medievale din Țara Românească în secolele XIII-XVI* (București: Editura Enciclopedică), 161-175.

CĂPĂȚÂNĂ *et alii* 2008
Căpățână, D./Teodor, E. S./Ioniță, A./Ciupercă, B./Bădescu, Al., Cetatea de la Tabla Buții (com. Cerașu, jud. Prahova) – campaniile arheologice 1995–1996, 1998, *Materiale și Cercetări Arheologice S.N.* 4, 157-182.

CIUPERCĂ 2018
Ciupercă, B., Some observations from the point of view of the Slon fortifications about power centres in the Lower Danube between the eighth and tenth centuries. In: Pallagst, K./Hartz, A./Caesar, B. (eds.) *Grenzregionen, Raumstrukturen und herrschafliche KontakteBorder regions, spatial structures and contacts between power holders* (Hannover), 275-289.

CRIȘAN/SÎRBU 2018
Crișan, V./Sîrbu, V., Covasna – Fairies Fortress, a Carpathian Mountain Fortified by Dacians. In: Pop, H.-Bejinariu, I.-Băcueț-Crișan, S.-Băcueț-Crișan, D. (eds.), *Identități culturale locale și regionale în context European. Studii de arheologie și antropologie istorică. In Memoriam Alexandri V.* Matei (Cluj-Napoca: Mega), 265-285.

CRUTCHLEY/CROW 2010
Crutchley, S./Crow, P. The light fantastic. Using airborne

Lidar in archaeological survey. In: *100 years ISPRS – Advancing Remote Sensing Science* (Swindon: English Heritage Publishing).

DRAGOMAN *et alii* 2015

Dragoman, R.-Al./Pop, D./Bobînă, B./Ardeleanu, M./ Şuteu, C./Astaloş, C./Săsăran, Vl., O arheologie a munţilor din Maramureş, România: cercetările din 2014 şi 2015, *Marmatia* 12, 197-234.

DRAGOMAN *et alii*. 2017

Dragoman, R.-A./Bobînă, B./Ardeleanu, M./Șuteau, C./ Astaloș, C., O arheologie a munţilor din Maramureş, România: cercetările din 2016 şi 2017 / An Archaeology of the Mountains in Maramureş, Romania: The Surveys from 2016 and 2017, *Marmatia* 14, 2017, 77-102.

EVANS/FLETCHER 2015

Evans, D./Fletcher, R., The landscape of Angkor Wat redefined, *Antiquity* 89, 1402-1419.

GRAMMER *et alii* 2017

Grammar, B./Draganits, E./Gretscher, M./Muss, U., LiDAR-guided Archaeological Survey of a Mediterranean Landscape: Lessons from the Ancient Greek Polis of Kolophon (Ionia, Western Anatolia), *Archaeological Prospection* 24, 311–333.

HARE *et alii* 2014

Hare, T., Masson, M., Russell, B., High-Density LiDAR Mapping of the Ancient City of Mayapán, *Remote Sensing* 2014, 6(9), 9064-9085.

INOMATA *et alii* 2017

Inomata, T./Pinzón, F./Ranchos, J. L./Haraguchi, T./ Nasu, H./Fernandez-Diaz J. C./Kazuo A./Hitoshi Y., Archaeological application of airborne LiDAR with object-based vegetation classification and visualization techniques at the lowland Maya site of Ceibal, Guatemala, *Remote sensing* 9, 563.

KARCZA/SZABÓ 2012

Karcza, Á./Szabó, T., *Erdély, Partium és a Bánság erődített helyei várak, várkastélyok, városfalak, templomvárak, barlangvárak, sáncok és erődítmények a honfoglalástól a 19. század végéig* (Budapest: Semmelweis).

KOKALJ/HESSE 2017

Kokalj, Ž./Hesse, R. *Airborne laser scanning raster data visualization: A Guide to Good Practice* (Ljubljana : Založba ZRC).

MATEI 2016

Matei, S., Elements for a Chronological Framework of the Dacian Fortress from Târcov, Buzău County. In: Berecki, S. (ed.), *Iron Age Chronology in the Carpathian Basin, Proceedings of the International Colloquium from Târgu Mureș, 8–10 October 2015* (Cluj-Napoca: Mega), 389-394.

MĂNDESCU 2006

Măndescu, D., Cetățenni, Stațiunea geto-dacă de pe valea Dâmboviței superioare (Brăila: Istros).

OLTEAN/HANSON 2017

Oltean, I., Hanson, W., Conquest strategy and political discourse: New evidence for the conquest of Dacia from LiDAR analysis at Sarmizegetusa Regia, *Journal of Roman Archaeology* 30, 429-46.

OLTEAN/FONTE 2019

Oltean, I./Fonte, J., Microtopographies of Dacian upland settlement strategies and community aggregation trends in the Orăştie Mountains, Romania. In: Cowley, D./Fernández-Götz, M./Romankiewicz, T./Wendling, H. (eds.), *Rural Settlement. Relating buildings, landscape, and people in the European Iron Age* (Leiden: Sidestone Press), 251-261.

OPREANU/LĂZĂRESCU 2014.

Opreanu, C. H./Lăzărescu, V. A./Roman, A./Ursu, T. M./ Fărcaș, S., Newlight on a Roman fort based on a Lidar Survey in the forested landscape from Porolissvm, *Ephemeris Napocensis* 24, 71-86.

OPREANU/LĂZĂRESCU 2016

Opreanu, C. H./Lăzărescu, V. A. (eds.), *Landscape Archaeology on the Northern Frontier of the Roman Empire at Porolissum. An interdisciplinary research project* (Cluj-Napoca: Mega), 2016.

PETOLESCU/CIOFLAN 1995

Petolescu, C. C./Cioflan, T., Castrul roman de piatră de la Câmpulung (Pescăreasa, jud. Argeş). Cercetările din anii 1978-1989, *Argesis* 7, 17-29.

ROMAN *et alii* 2017

Roman, A./Ursu, T.-M./Lăzărescu, V.-A./Opreanu, C. H./ Fărcaș, S., Visualization techniques for an airborne laser scanning derived digital terrain model in forested steep terrain: Detecting archaeological remains in the subsurface, *Geoarchaeology* 32, 549-562.

ȘTEFAN/ȘTEFAN 2016

Ștefan, D./Ștefan, M.-M., The drones are coming. What to choose? Low and medium altitude aerial archaeology on Limes Transalutanus, *Journal of Ancient History and Archaeology* 3/2, 25-35. DOI:10.14795/j.v3i2.187

ȘTEFAN/ȘTEFAN 2018

Ștefan, D./Ștefan, M.-M., Remote-Sensing for Mountain Archaeology in the Curvature Carpathians. The Fortifications around Crai's Peak / Teledetecție și arheologie montană în Carpații de Curbură. Fortificațiile de la Vârful lui Crai, *Istros* 24, 219-288.

ȘTEFAN/ȘTEFAN/BUZEA 2015

Ștefan, M./Ștefan, D./Buzea, D., Studii de arheologie aeriană în situri dacice din sud-estul Transilvaniei, *Angvstia* 19, 133-162.

ȘTEFAN/ȘTEFAN/BUZEA 2019

Ștefan, M./Ștefan, D./Buzea, D., Noi cercetări asupra fortificațiilor de la Teliu, jud. Brașov / New investigations in the fortifications from Teliu, Brașov County, *Angvstia* 23, 229-256.

ȘTEFAN/ȘTEFAN/BUZEA 2020

Ștefan, M./Ștefan, D./Buzea, D., Rezultate preliminare ale cercetărilor geofizice și de teledetecție de la Covasna - Cetatea Zânelor. In: Cândea, I. (ed.), *Tracii și vecinii lor în antichitate: arheologie și istorie / The Thracians and their neighbours in antiquity: archaeology and history* (Brăila: Istros), 521-534.

TEODOR/ȘTEFAN 2014

Teodor, E. S./Ștefan, D., Technological challenges on the *Limes Transalutanus*. *Antiquity Project Gallery* 88(342): http://journal.antiquity.ac.uk/projgall/teodor342.

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