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INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION  
POLISH ACADEMY OF SCIENCES  
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## PAST CARPATHIAN LANDSCAPE RECORDED IN THE MICROTOPOGRAPHY

**Andrzej Affek**

Institute of Geography and Spatial Organization  
Polish Academy of Sciences  
Twarda 51/55, 00-818 Warsaw: Poland  
e-mail: [a.affek@twarda.pan.pl](mailto:a.affek@twarda.pan.pl)

### Abstract

The objective of this study was to map traces of the past Carpathian landscape recorded in the microtopography in the chosen study area (25 km<sup>2</sup>) within the Wiar river basin. The area comprised two deserted villages (Boryslawka and Posada Rybotycka) that were abandoned and afforested after forced displacement of Ruthenian highlanders in 1940s. Three groups of complementary research methods were used: remote sensing (airborne laser scanning – ALS as the main data source), analysis of archival sources and field survey. Sky-view factor (SVF) was applied as the main visualisation technique of the LiDAR-derived DTM for mapping purposes. The results demonstrated that there are numerous, well preserved earthworks created before World War II lying under the tree canopy, such as hollow ways, agricultural terraces, remnants of settlements, border mounds etc. They form a unique cultural heritage of former inhabitants that deserves to be protected.

### Key words

abandoned villages • earthworks • LiDAR • Austrian cadastral maps • the Carpathians

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### Introduction

Up to now, the researchers analysing past landscapes have focused on the remains of cultural heritage visible to the naked eye, on the analysis of historical maps or on detailed field studies of small areas. Areas beyond single

archaeological sites were analysed by means of contemporary and historical aerial photographs. These only gave a general idea of man-made forms of relief with little recognition of microforms and their detailed shapes. Moreover, this was only possible in open areas with low vegetation (Sittler et al. 2007).

The situation has undergone significant change with access to new remote sensing techniques, such as airborne laser scanning (ALS) – the application of LiDAR technology (for more information on ALS see e.g. Ackermann 1999). As ALS enjoys the advantages of an excellent vertical and horizontal resolution range and has the capacity to record the topography under vegetation, it now offers new prospects for heritage assessment purposes (Sittler et al. 2007). Airborne scanning systems are capable of recording microtopographic details, while also being able to cover significant areas, large enough to place sites in their landscape context. A breakthrough in studying past landscape was a paper by Chase and co-authors published in 2011 which showed the results of laser scanning of the former Caracol Mayan city in Belize. The authors agreed that the effects had passed their wildest expectations and perceived the use of airborne LiDAR as a milestone on the road to understanding the culture and land management of the Maya.

The first, primarily archaeological studies whose aim was to identify microtopographic features of past landscapes in Poland by means of ALS have just been completed and have produced surprisingly good results (e.g. Zapłata et al. 2014, for review see Banaszek 2014). However, these studies have usually focused on particular features, like burial mounds or other chosen objects from the distant past. There is still a lack of work that applies a geographical approach where the past landscape as a whole is the subject of research.

Landscape in general is a dynamic feature that is in the process of continuous change. To grasp today the shape of a cultural landscape from the past one needs an area where human activity has ceased and the forms of landscape have somehow been conserved. This is what has apparently happened in some parts of the Polish Eastern Carpathians from where Ruthenian highlanders were displaced *en bloc* in the late 1940s and the land thus abandoned became afforested.

Therefore, the objective of this study was to map traces of the past Carpathian

landscape recorded in the microtopography in the chosen study area with the use of ALS.

## Study area

The area studied in the research is part of the Wiar river basin located on the fringe of the north-eastern Carpathians, close to the contemporary Polish-Ukrainian border. An area of 25 km<sup>2</sup> was chosen for the presentation of the past Carpathian landscape recorded in the microtopography. This comprised two villages completely depopulated in the 1940s – Posada Rybotycka and Borysławka.

In Borysławka not a single building has remained to our times (Affek 2011), while in Posada Rybotycka only a stone church dating from the 14th century survived the turmoil of war, being a unique remnant of an ancient Orthodox monastery. Borysławka has not been resettled again and is now almost entirely covered with forest, whereas the farmsteads in Posada Rybotycka that were located along the main road by the Wiar river have been partly rebuilt and repopulated.

Most of the settlements in the Wiar river valley, including Borysławka, were founded under Wallachian law in the 15th century within a planned colonisation performed after the incorporation of Ruthenia into the Kingdom of Poland. Posada Rybotycka, in turn, belongs to those few villages of Ruthenian origin that had already existed at that time. Sparse archaeological findings showed that people had already come to the area in the Neolithic Age.

Up to World War II this area was a densely populated Polish-Ukrainian ethnic borderland. After the forced displacement of Ruthenian highlanders in the 1940s, the human population density in the Wiar basin decreased from 80/km<sup>2</sup> in 1939 to less than 10/km<sup>2</sup> in 1950. As a result, more than 90% of the area mapped is currently covered by forest, compared to only 30% in the mid-19th century. A traditional agricultural Carpathian landscape disappeared and was mostly transformed into woodland (Affek 2016).

## Materials and methods

An integrated approach was applied to detect and interpret past landscape features. Three groups of complementary research methods were used:

- remote sensing: airborne laser scanning (ALS), aerial photographs taken simultaneously with laser scanning;
- analysis of current and archival cartographic and descriptive materials: cadastral maps from 1852, 1965 and 2010, the Polish Archaeological Record (pol. Archeologiczne Zdjęcie Polski), other topographic and thematic maps (e.g. First, Second and Third Topographic Surveys of Galicia, military topographic maps from the 20th century, forest maps);
- field survey: verification of microtopographic landforms detected on the LiDAR-derived DTM, gathering additional information regarding the time and cause of creation (e.g. interviews with residents

and Forest Office workers), photographic documentation.

All the ALS parameters (data collection and processing) were selected so as to obtain the most accurate picture of the earth's surface (Tab. 1). Airborne laser scanning was conducted by MGGP Aero in April 2013, after the retreat of the snow and before the trees started to green (Fig. 1). The mean effective ground point density was close to 12 points/m<sup>2</sup>.

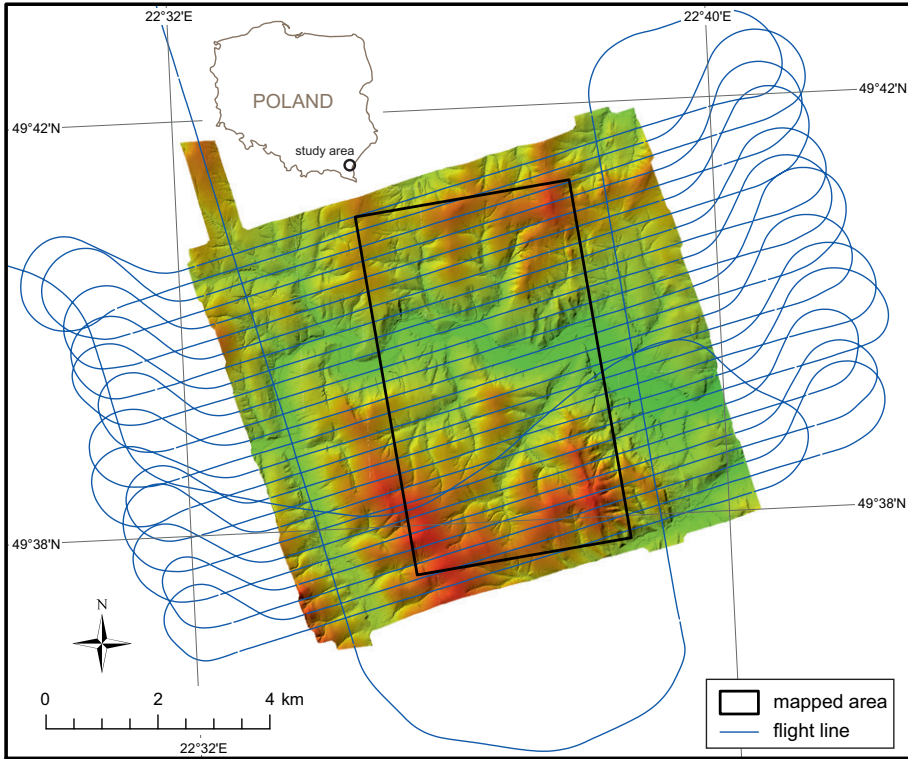
As a result of a flight mission, the following remote sensing data were obtained for the study area chosen:

- a classified 3D point cloud (25 points/m<sup>2</sup>) in LAS1.2 format with the following point attributes: xyz coordinates, intensity value, scan angle, class, number of returns per pulse, return number, time UTC,
- digital terrain model (DTM) and digital surface model (DSM), both in 0.5 m resolution,
- aerial images of 9 cm resolution, orthophotomap of 10 cm resolution,
- flight lines.

**Table 1.** Airborne laser scanning metadata

Scanner technical data	
Model	Riegl LMS-Q680i
Scanning system	Full Waveform
Laser wavelength	1550 nm
Laser pulse energy	8 μJ
Laser beam divergence	< 0,5 mrad (beam diameter increases by 50 cm every 1000 m)
Laser pulse width	4 ns
Digital echo sampling	1 ns
Ranging accuracy	2 cm
Flight and scanning parameters	
Flight date	19th April, 2013
Scanned area	63.5 km <sup>2</sup>
Flight speed	100 kn (51,5 m/sec)
Flight altitude above ground	ca. 700 m
Laser pulse repetition rate (PRR)	300 kHz
Scan speed	114 lines/sec
Scan angle	±25°
Strip overlap	> 60%
Laser beam footprint	ca. 0.21 m
Point density in a single strip	> 5 points/m <sup>2</sup>
Effective ground point density	12/m <sup>2</sup>
Effective point cloud density	25/m <sup>2</sup>

Source: own calculations, MGGP Aero post-completion report, Riegl (2012), Wężyk (2014).



**Figure 1.** Colour shaded LiDAR-derived DEM of the study area (part of the Wiar river basin) with marked flight lines and area of detailed mapping

Three main visualisation techniques of the LiDAR-derived DTM were applied in order to detect features: analytical hill-shading with elevation differentiation (colour shading), Sky-view factor (SVF) – a geophysical parameter that measures the portion of the sky visible from a certain point (Zakšek et al. 2011), and Local Relief Model (LRM) representing local, small-scale elevation differences after removing the large-scale landscape forms from the data (Hesse 2010). Out of these, SVF values proved to provide maximum benefits in the complex topography of the Carpathians and were used as a basis for mapping. The 3D visualization of point cloud and cross-sections served as additional sources of information. Analysis, visualisation, and mapping were carried out in ArcGIS 10.2 Advanced with LP360 Advanced extension dedicated to LiDAR-derived point clouds. The SVF grid

was computed by means of Relief Visualization Toolbox (RVT), while LRM grid was computed by Local Relief Model Toolbox for ArcGIS (Novák 2014).

Interpretation of the features detected was carried out by means of several complementary methods. Visualisation, interpretative mapping, topographical analysis, field visits and historical documentary research were done in an interactive and iterative way. The key issue was to extract pre-war earthworks from all other microtopographic features, namely modern earthworks and forms of relief created by nature, such as former riverbeds, landslides, ravines, fallen tree pits, etc. To do this properly, all types of features detected needed to be recognised. The identification of earthworks created after forced displacement (e.g., by forestry and collective farming) was primarily based on the analysis

of RGB orthophotomap, LiDAR intensity data, post-war cadastres, fieldwork and interviews with foresters and local people. Pre-war features were identified with the help of Austrian cadastral maps from the mid-19th century, other historical maps and archival sources, the documentation of the Polish Archaeological Record project, literature, fieldwork and, last but not least, interviews with senior members of the local community. The integrated approach applied and multiple data sources used, resulted in the recognition of the vast majority of the features detected.

The final product of the research is a map showing traces of the past Carpathian landscape recorded in the microtopography. It includes those man-made objects detected on LiDAR-derived DTM that were interpreted as originating from before World War II.

## Results

The analysis of the LiDAR-derived DTM showed that there are numerous, well preserved earthworks created before World War II lying under the tree canopy (Tab. 2). These corresponded to a great extent with the spatial pattern of land use presented on cadastral maps from the mid-19th century (Fig. 2). Although 70 years have passed since they lost their dedicated function, earthworks such as hollow ways, agricultural terraces and field boundaries continue in the landscape in almost unchanged shape (Fig. 3). The remnants of settlements (cellars, stone wells, foundations) are also reflected on the DTM (Fig. 3). Most of them did not exactly match the location shown on the cadastral maps, however they did not change location among the parcels, only within the boundaries of a given parcel (Affek 2015a). In addition, specific ruderal vegetation found in the forest indicates the location of former buildings.

The initial strip structure of land ownership, dating from the period when villages were founded in the 15th century, is still clearly visible. Former arable land can be distinguished from permanent forest on the basis of traces of ploughing. Some fields have

well preserved evidence of medieval ridge and furrow patterns from ploughing with non-reversible ploughs.

Old state roads, marked on the first topographic survey of Galicia from the 1780s, whose traces are still clearly visible in the microtopography, must have already been unsuitable for use in the 19th century as they were marked as strips of forest or shrub on Austrian cadastral maps. New roads were laid out adjacent to them. Logging roads within forest parcels were not marked on the cadastral maps, so it is difficult to date them precisely. However, contrary to the author's expectations, it seems that they had deep ruts and several parallel lines long before mechanised forestry came to the Carpathians. Traces of pre-war ploughing were detected on top of older logging roads, particularly at the forest edges. It appears that only draft animals and logs left traces that last for centuries.

Village boundaries are usually marked by embankments or ditches. Often boundary corners are marked by small mounds (Fig. 3), while tripoints are marked by three middle-sized mounds. No burial mounds were detected in the study area. Some mounds visible on DTM turned out to be piles of decomposing branches formed as a result of forest maintenance. The existence of one medieval stronghold was confirmed (Zoll-Adamik 1958).

## Concluding discussion

Past landscape patterns reflected in the microtopography are best preserved in areas afforested directly after resettlement (former axis of settlements, farmland). Old traces were mostly wiped out on arable land taken over by the State Farm Holding in the 1950s, due to intensive farming (Affek 2015b). A complete lack of pre-war features was observed on the DTM on former State Farm land which was afforested in the 1990s. The modern way of planting forest, involving deep ploughing, together with the small number of pulses reaching the ground through the dense young coniferous forest, resulted in not a single feature being detected.

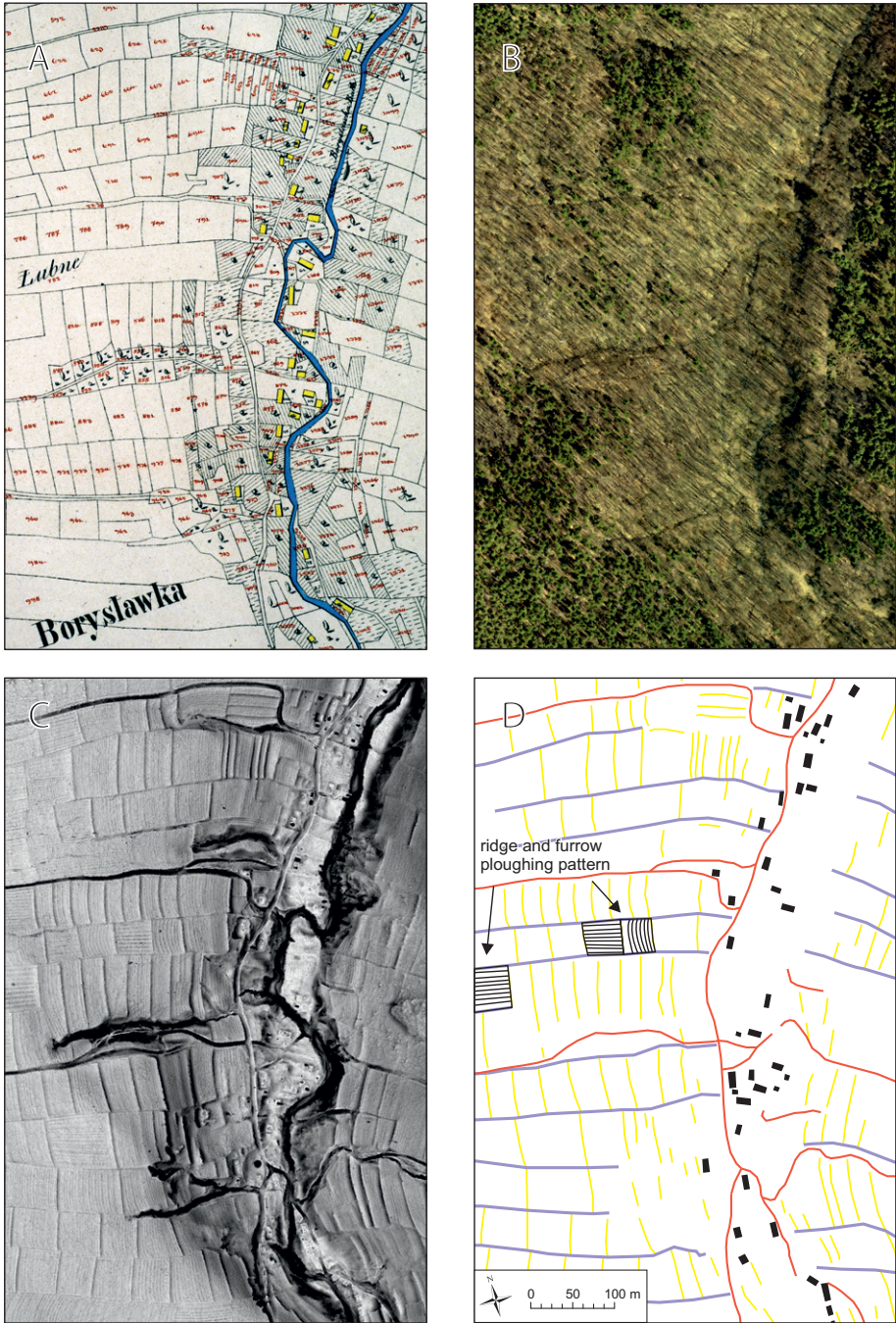
**Table 2.** Microtopographic man-made features created before World War II and detected on the LiDAR-derived DTM in the mapped area

Microtopographic man-made features from pre-war times	Description
Remains of buildings	<ul style="list-style-type: none"> <li>• elevated flat regular forms, usually rectangles, often with holes (former cellars) or mounds (remnants of bread oven and chimney) inside</li> <li>• constructed from earth and stones</li> </ul>
Hollow ways	<ul style="list-style-type: none"> <li>• elongated and narrow hollow marks</li> <li>• along steeper slopes with embankments on both sides</li> <li>• when leading through muddy areas in manor forests, often in multiple parallel tracks</li> <li>• when climbing up the steep slope often two adjacent deep and narrow hollow ways</li> <li>• up to 3 m deep, often only 1.5 m wide</li> <li>• old long distance ridgeways have banks that are even 6 m high</li> </ul>
Agricultural terraces	<ul style="list-style-type: none"> <li>• steep field margins (earth embankments) across the slopes created to ease ploughing and to reduce erosion and surface run-off</li> </ul>
Patterns of ploughing	<ul style="list-style-type: none"> <li>• parallel marks of alternate ridges and furrows</li> <li>• wide and deep patterns resulted from decades of ploughing with primitive non-reversible ploughs used back in the Middle Ages</li> <li>• ridges up to 4.5 m wide and 0.5 m high</li> </ul>
Farm boundaries	<ul style="list-style-type: none"> <li>• linear features interpreted mostly on the basis of Austrian cadastral maps from the 1850s</li> <li>• depending on topography, they may be ditches, escarpments, or just virtual lines separating different patterns of ploughing</li> <li>• delineating strips of land granted to a farmer or parish when founding the settlement</li> </ul>
Crown land boundaries	<ul style="list-style-type: none"> <li>• delineating former royal estates, mainly forests</li> <li>• very well preserved and clearly visible 0.5 m deep ditches surrounding the Turnica Forest</li> </ul>
Border mounds	<ul style="list-style-type: none"> <li>• earthworks about 0.5 m high marking the vertices of village boundaries</li> <li>• tripoints are usually marked by three mounds</li> </ul>
Medieval stronghold	<ul style="list-style-type: none"> <li>• situated on the hill in the Grabnik Forest on the southern slopes of Mt. Kopystańka</li> <li>• levelled on top, encircled by a ditch up to 2.5 m deep and 12 m wide, 150 m in diameter</li> <li>• inhabited in 11-12th century</li> </ul>
Forest vistas	<ul style="list-style-type: none"> <li>• straight and long, slightly hollow microtopographic forms about 4 m wide leading through forested areas</li> <li>• once deforested and used for forest maintenance and logging activities</li> <li>• marked on pre-war topographic maps</li> </ul>

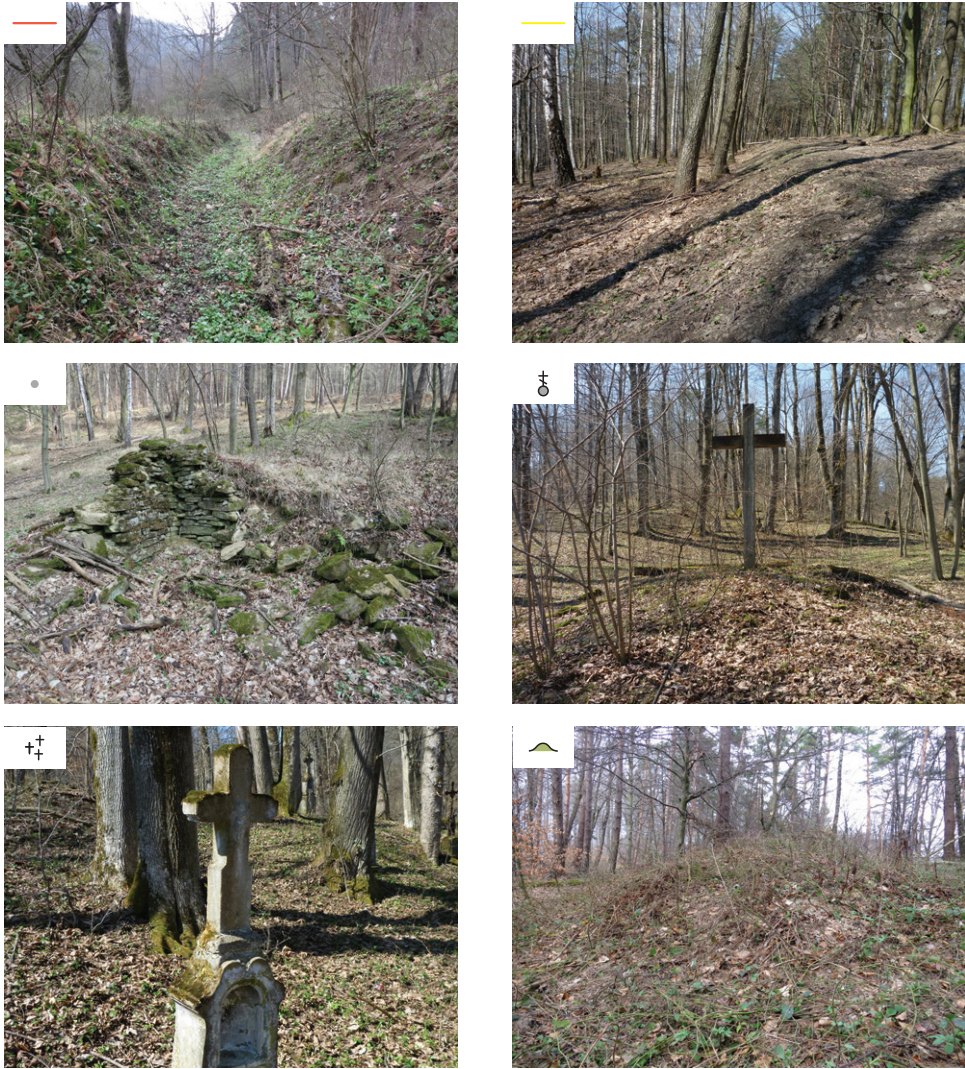
The floodplain of the Wiar river is another area with no older earthworks. Only a few concrete or stone foundations of buildings (like the sawmill in Trójca) survived to our times. Field boundaries or traces of ploughing did not resist the flood water and changes to the Wiar riverbed.

The medieval strip structure of land ownership is best preserved in the village of Borysławka. On the basis of microtopographic features detected on the LiDAR-derived DTM and cadastral maps from the mid-19th century the shape of the initial ownership

structure can easily be reconstructed. The regular strip pattern resulted from the fact that Borysławka village was founded on bare ground within a planned colonisation in the 15th-century and no earlier spatial divisions needed to be taken into account. The axis of settlement was determined by the narrow and steep valley of the local stream, later named Borysławski. The large manor area, located at the end of the valley, originally consisting exclusively of forests, was clearly distinct from the land of the peasantry without permanent internal boundaries.



**Figure 2.** Village of Borysławka abandoned and afforested after forced displacement in the 1940s. A – Austrian cadastral map of 1852 (original scale 1:2880) from the State Archive in Rzeszów; B – orthophoto taken simultaneously with ALS (pixel size: 10 cm); C – Sky-view factor visualisation of the LiDAR-derived DTM (pixel size: 0.5 m); D – interpretation of the microtopographic features, for the legend – see the main map



**Figure 3.** Examples of earthworks detected on the LiDAR-derived DTM and interpreted as originating from before World War II. Meaning of the symbols – see the legend to the main map

Much less structured was land ownership in the neighbouring Posada Rybotycka. This resulted, on the one hand, from the fact that, at the time of the granting of the Wiar river basin to Stefan Węgrzyn for colonization in 1368, an Orthodox monastery, *Honofry*, with a small settlement founded under Ruthenian law already existed in the area. On the other hand, the Posada Rybotycka axis of settlement had a fairly complex course in itself. Although it forms almost a straight

line when viewed from above, it goes through various landforms. It begins in the north-east on a gentle slope and then enters the Wiar floodplain. After a while it leaves a main valley and goes along a small creek, and ends at the flat-topped hill by the former state road connecting two district towns – Dobromil and Bircza. The traces of old settlements and farming which were found in the deserted part of the village (further away from the Wiar river) are particularly well preserved.



The initial land ownership boundaries, if the topography so requires, also took the shape of embankments. When the slope gradient was perpendicular to strip parcels, ownership terraces were complemented by additional parallel embankments, often related to further ownership divisions. In turn, when strips ran directly up the slope, agricultural terraces were created crosswise which resulted in a regularly gridded field pattern.

Not all the buildings shown on the cadastral map left marks in the ground that could be detected on LiDAR-derived DTM. On the one hand, this is the result of the later land use that often distorts or destroys older forms (palimpsest landscape, see Mlekuż 2013), while on the other hand, a significant number of currently existing microtopographic features were not recorded on the DTM, as was demonstrated during field verification. This occurred when earthworks were covered by low and dense vegetation. In such areas, due to the limitations of the scanner expressed by the multi-target resolution

(MTR) value, there is no possibility of obtaining an accurate shape of the earth's surface, even if some of the pulses reach the ground (Affek 2014). In such cases, the nominal ranging accuracy of 2 cm (for single returns) increases up to 60 cm.

In conclusion therefore, it is ironic that villages such as Borysławka, abandoned and destroyed after World War II and afforested directly afterwards, are those where the past Carpathian landscape is best preserved, even though only in microtopography.

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Editors' note:

Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

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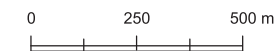
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by Andrzej Affek



- village boundaries from the 19th century
- Wiar river and major streams
- marks of state hollow ways
- marks of local hollow ways
- traces of initial farm boundaries
- agricultural terraces
- traces of old forest vistas
- ditch delimiting former royal forests
- medieval stronghold
- remains of a farmhouse
- remains of a brickyard
- remains of a sawmill
- remains of a Greek Catholic church
- pre-war graveyard
- a mound marking village boundary
- ridge and furrow ploughing pattern
- a hole after extracting limestone
- trenches
- existing Greek Catholic church
- existing pre-war farmhouse



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