Interreg CENTRAL EUROPE

Centralparks

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D.T2.1.4 EVALUATION OF LIDAR RESULTS AND FEASIBILITY STUDY FOR EXTERNAL PUBLIC AUTHORITIES

Final Version

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Possible use of the LiDAR data for conservation management purposes

Content

I. Introduction

Under the Centralparks Interreg CE1359 project, the determined area for the LiDAR record is implemented on 11.000 ha (1st figure).

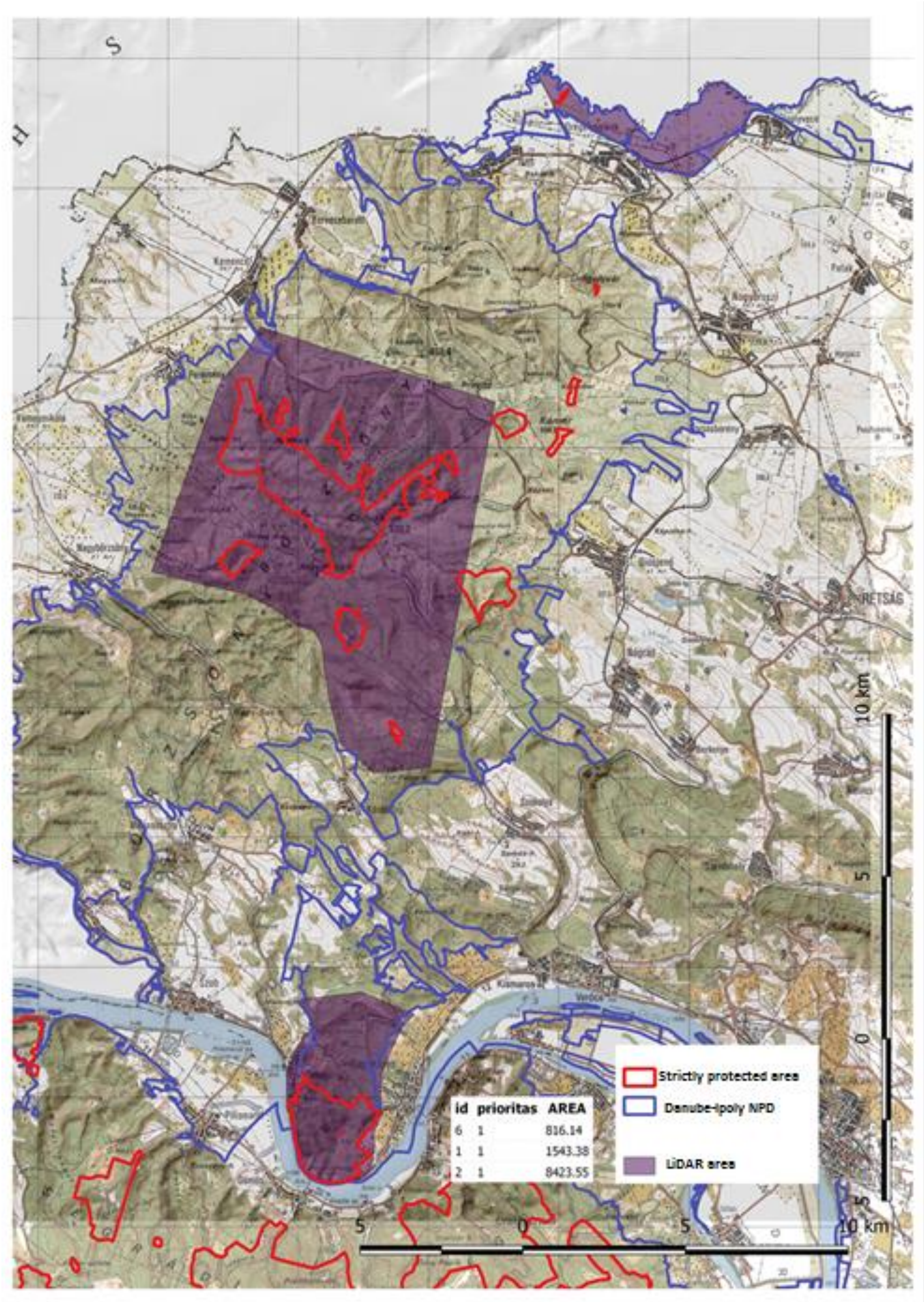

Figure 1.: The planned area for LiDAR and orthophoto from the Centralparks Interreg CE1359 project

The following areas have been determined for implementing the LiDAR laser scanning technology: the area located south to the Kemence-river's valley, which could be determined as the central area of the volcanic area, covering most of the planned 'A zone' (according to the IUCN criteria); the Szent Mihály-mountain's block and the smaller part of the Ipoly-valley (for testing purposes).

The LiDAR survey is included in the 3D scanning procedures, sensory remote sensing technologies, in our case the survey is a distance measurement through laser rays from a plane, to the direction of the Earth-Centerpoint and surface modeling from the generated point-cloud. With the current instruments (e.g. Leica) we are collecting the part-reflection of the discharged pulse, so we have the information from the absolute route of the given bunch; the different part-reflections from the given bunch can be aggregated separately: the first (canopy level), the lowest (ground level) and the reflections in between. The method's specialty is that the reflection from the different heights can be aggregated, filtered, that is why we can prepare a surface model (from the closest points – DSM) and a digital relief model (from filtering the furthest reflections – DEM) from just one measurement. Between the two extremities, the reflections coming from the different heights could give a picture, e.g. in the case of a forest from the diversity within the stand (e.g. presence /absence of the middle layer or its patchiness, mapping the closed clearings - Figure 2. and 3.).

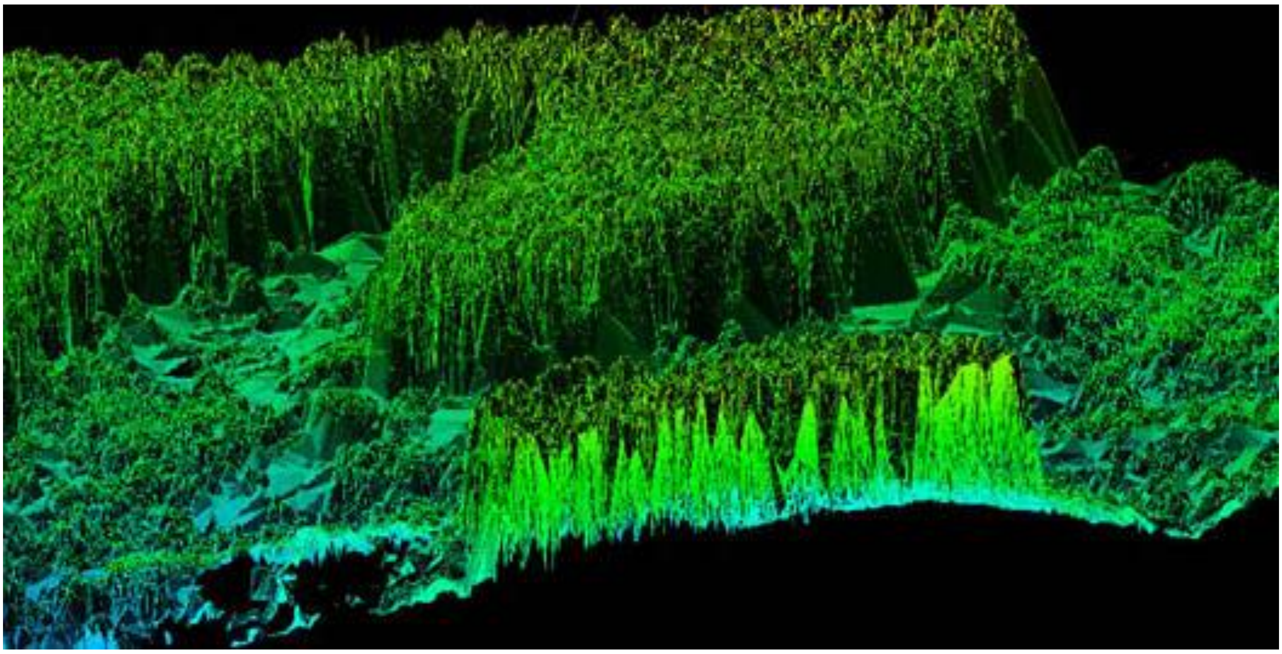

Figure 2: LiDAR point cloud from side-view. We can clearly see the canopy, the ground level, and the last reflection's level. (Source: arbonaut.com)

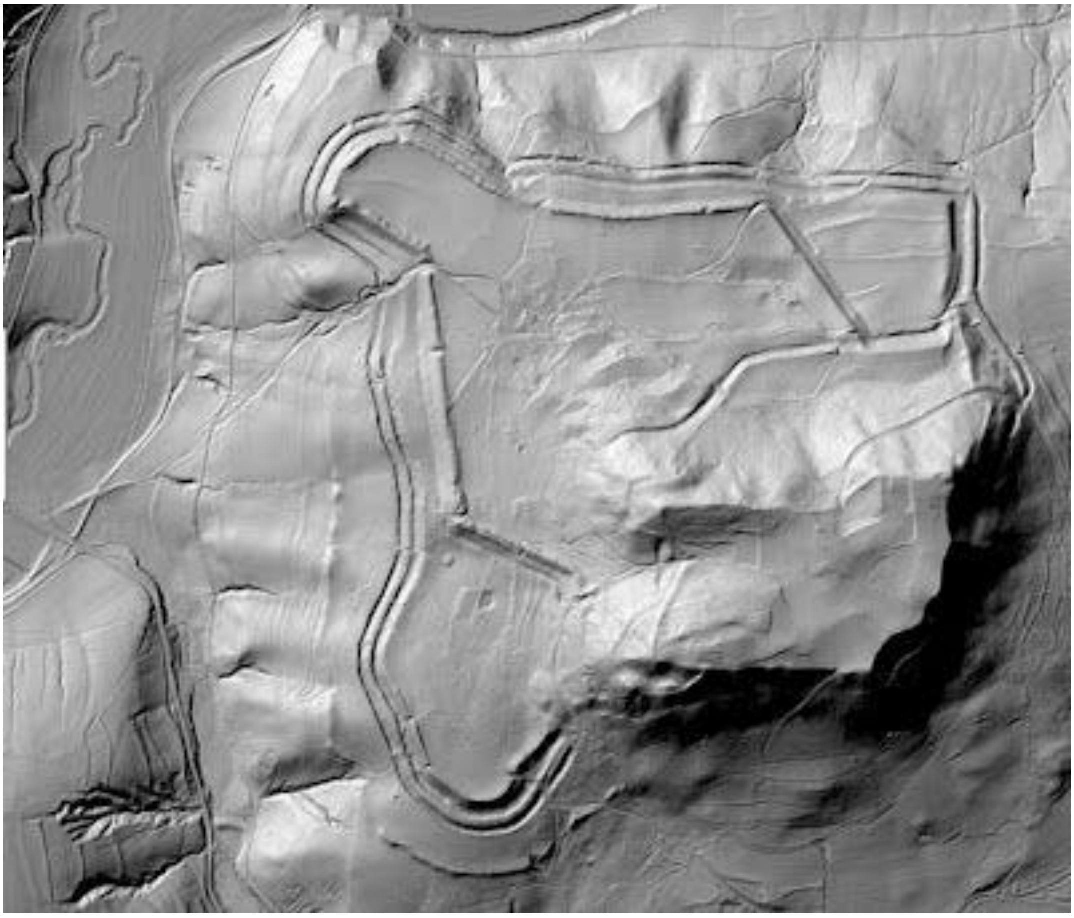

Figure 3: Archaeological aimed relief model, prepared by the University of Bratislava

In the case of LiDAR, the resolution is crucial and determining for the obtainable information. The resolution is measured in point/m^2. The 1-4 point/m^2 resolution is very limited, while the >16 points/m2 resolution could be able to hedge in the diameter of the individual trees (in the case of bigger trees). The expansion of the point density is enhancing the expenses exponentially and the calculation input for the analysis. That is why we should be aware of the tasks/questions' resolution purposes.

From the Hungarian national parks directorates, Aggtelek and Fertő-Hanság National Park carried out already a large-scaled LiDAR survey. In the administration area of the Danube-Ipoly National Park Directorate was a small-scaled recording of LiDAR data within the framework of the SH4/13 project in the Királyrét Forestry.

Due to the limited experiences of the method's usage in nature conservation (the Hungarian national parks used only DEM so far, without the possible use of biotic analysis), we aimed to prepare a feasibility study to analyze the possible contribution of the LiDAR method in nature conservation management planning.

II. Feasibility study

The LiDAR's specificity and the greatest advantage is the ability to "see in-depth"; to see the different structures located above each other. That is why these models can analyze not just the relief, but the heterogeneity between stands and detect the structures at the same time. Tews et al (2004) analyzed 85 publications between 1960, and 2003, and led to the conclusion, that the most evaluated taxa showed a positive relationship between habitat heterogeneity and species diversity. At the same time, this relation seemed detailed, for example when in case of some species distribution's presence, a special, often found habitat-element was crucial, and in the absence of this element, the high summarized heterogeneity would not compensate it (Sullivan and Sullivan 2001, soil-dwelling small mammas – soil structure/thickness of the humus/topsoil). To generate the question for the structural determination the authors suggest the following delineation showed in the 1st table.

Table 1: Description of the habitat-structural elements based on the 2 types of variables (discreet or continuous variables)

Sampling site	Discreet variables (structural elements)		Continuous variables (structural quality)	
	One	*More*	*One*	*More*
Definition	Number of the structural elements	Consistency of the structural elements	Distribution of the individual structural elements	The structural differences between the different areas
Name	Structural richness	Structural diversity	Distribution / spatial extent of the structural element	The gradient of the structural element
Measurement	Number of the structural elements	Shannon diversity	Quality of the structural element	Length of the gradient, euclidean distance
Example	Types of the habitats in the landscape	Diversity of habitat types in the landscape	Heights/coverage of the vegetation	Diversity of the habitat structure between the sampling areas

For the appropriate questioning, it is necessary to have a thorough knowledge of the given taxa and the predictive factor must be selected from the measurable elements, which can be "captured" with the given methodology. The authors suggest choosing and analyze the "cornerstone" structures for nature conservational predictions, which are covering more species' needs. Special attention is to be given to the targeted taxa's dispersion ability and the size of the area (home range) passages by the individual (scale-dependency). This could be treated in accordance with wide ranges in the case of LiDAR scanning.

Simsonson et al. (2014) emphasize in their review paper (analyzing 169 studies) that the habitat-structure elements should be categorized and analyzed in which cases could LiDAR detect the examined variables. The result of these studies is summarized in the 2nd table. The authors categorized the structural elements' distribution according to vertical, horizontal, and other types and found out that laser scanning can detect 3 of the 14 variables, and to conclude in itself or with additional data (in the visible spectrum, multispectral, or with 2D recordings).

Table 2.: categorization of the collected structural element, their localization, and detection

ID	COMPOSITION	HABITAT STRUCTURAL ELEMENT	CANOPY	SHRUB	HERBACEOUS	SOIL	LiDAR's ability
1	VERTICAL	coverage values	1	1	1	0	1
2	VERTICAL	vertical levels of the leaf	1	1	0	0	1
3	VERTICAL	medium and top heights of the vegetation	1	1	0	0	1
4	VERTICAL	varinty of the vegetation's heights	1	1	0	0	1
5	VERTICAL	leafcontact measurement (horzintal)	0	1	1	0	1
6	VERTICAL	FHF (thick)	0	0	0	1	1
7	VERTICAL	FHF (thin)	0	0	0	1	1
8	HORIZONTAL	number of the vegetation/habitat/patch-types	1	1	1	0	1
9	HORIZONTAL	their coverage (%)	1	1	1	0	1
10	HORIZONTAL	size and density of the patches	1	1	1	0	1
11	HORIZONTAL	border length	1	1	1	1	1
12	OTHER	diversity of plant species	1	1	1	0	1
13	OTHER	altitude sum/min/max/variability	0	0	0	1	1
14	OTHER	NVDI data	1	1	1	0	1

According to the recording, not only the potential habitat patches, satisfactorily implemented for the given species, could be a rectangle (which could be controlled and multiplied), but those patches could also be eliminated, which may be adequate in some aspects, but other important factors are absent, and the replacement of the aspects may be suggested.

Leeuwen and Nieuwenhuis (2010) studied the forestry usage possibilities of LiDAR in all 3 main scanning forms (from satellite, from the plane, and the ground) and elaborated the methodology family's fitness for use for more, questioned variables (3rd table).

Table 3.: The potentially measurable forestry/ forest ecological variables with LiDAR

ID	VARIABLE	Lidar's availability	ACCURACY
1	H (heights of the stand)	1	1,0- 1,5 m
2	canopy heights	1	uncertain in dense stand's underside levels
3	h (heights of the tree individual)	1	the separation of individuals is questionable, high uncertainty on slopes
4	tree-mapping	0,5	Swiss example: instead of 2000 individual, only 1200 could be segmented in Pinus montana and P. cembra populations
5	leaf area index, canopy's heterogeneity	1	uncertain in dense, more levels stands
6	tree weights	0,5	8-20% defect
7	d_{13}	0	very high defect level
8	species identification	0,5	depending on the species, the quality of the reflection differs

In the 3rd table, we can see that for 4 of the 8 variables, the methodology is more or less suitable, and so the heights data and the canopy heterogeneity can be measured and predicted very precisely. The ground-level scanning and the traditional methods (ground geodesy) are more capable of tree-mapping. The species identification could be very accurate with the use of additional data (multispectral recording). The quality of the data related to the chest heights-diameter (d_{13}) are very bad for a proper prediction, a very high point density is needed, which is limited by the capacity, as well as this variable can be measured from the ground very easily (which questioned the point of LiDAR usage for this variable).

Müller and Brandl (2009) carried an exact biotic data – habitat structure analysis in the Bayer Forest National Park (the first author is the co-worker of the national park), based on a LiDAR recording. The main focus was the forest bugs, the flights were implemented among 4 transects at an altitude between 650 and 1400 m, then 171 sampling points were determinate among the flight transects, where insects were collected with flying and soil traps. The study was complemented with ground-level data collection (coverage of the levels, number of species, soil level pH, and humidity of the topsoil level, annual medium ambient temperature, and coverage of the deadwood). According to the LiDAR data, a terrain and surface model was created, using the following data: altitude, tree heights, upper heights, variety of the stand's heights, and penetrant (number of laser bunches in the heights of 2 m divided with the number of laser bunches in 50 m heights). The variables were normalized to the 1000 m^2 quadrats around the traps. The number, species number, diversity, and size of the trapped insects were tested.

As a result, the background variables (both groups) explained well the trapped species and aggregations both with soil and flying traps (the 15-44% of the sum-variety can be explained with the two background-variety groups originated from two sources). The LiDAR resulted in a 60-90% value, which counts outstanding. The authors highlighted the cost-efficiency of the LiDAR method – next to the German staff cost amounts (LiDAR: 15 €/ha while the ground data collection is 100 €/ha, trapping and data analysis: 260 €/ha). We must emphasize that the cost of LiDAR detection is highly dependent on the point density.

Bässler et al. (2009) studied the LiDAR usage possibilities in the Bayer National Park for Natura 2000 habitat mapping purposes. During their pilot experiment, a flight was carried out among transects, complemented with 237 pieces of 200 m^2 sampling points ground data collection (habitat characterization, soil data collection). With the application of variables mentioned in the previous article (Müller and Brandl 2009), the habitats were modeled (besides with SAGA_GIS models - solar radiation, shadow, soil humidity, etc.) and their result was an average 67% accuracy level. As a whole, the result is mixed, the distinction between the Asperulo-Fagetum and the Luzulo-Fagetum was not reliable only based on the remote sensing data.

Hungarian studies based on the results of the SH4/13 project (Belényesi et al. 2013a, 2013b) showed that the LiDAR recording by itself is capable of preparing DEM and DSM models, predicting closure, localizing/mapping disturbances, and partly capable of isolating tree individuals (65-80% accuracy). Based on the authors' data, the cost of the recording, depending on the parameters (1-60 point/m^2, vertical accuracy: 2-20cm), is between 310 and 46.500 HUF/ha (0,86 – 129,17 EUR/ha) (compared to the results of Müller and Brandl (2009), the cost was decreased significantly with the time elapsed).

III. Goals with the purchased data

The nature conservation usage possibilities of the LiDAR methodology are still at early ages in Hungary. Attention is drawn to the fact that the Centralparks project is a pioneer and pilot study implementation of LiDAR technology.

During the public procurement procedure, the Danube-Ipoly National Park Directorate aimed the following goals for the usage of purchased LiDAR data:

1. *Rare, unprocessed dataset (orthophoto: .tiff, LiDAR: .las, hyperspectral record: BSQ format) and semi-processed (radiometric and geometric correction), orthorectification and mosaic dataset, in UTM and HD72-EOV coordinate system.*

Orthophoto itself has a century-wide usage history within Hungarian nature conservation. It seemed an important tool for the time-series comparisons (development of cuttings, monitoring of natural disturbance). The practical use of the LiDAR connected aerial records data is to prepare an object validation, including the exploration of rock-towers, eliminations, and the measurement of lying deadwood. The collection and storage of rare data are important for the evolving future post-analysis (new photogrammetric procedures).

2. *Processed LiDAR data: the filtering and classification of the.las dataset should happen according to the following: Underground points; Low vegetation (0-1 m); Medium vegetation (1-10 m); High vegetation (10 < m); Buildings; Noise data (not adequately determined points) and Water surface points.*

The above description of the processed LiDAR data is a standard contract term in the Hungarian and international practice, included the further specific goal-oriented analyzed data and rare data form as well. The far-reaching objective is the comparison of the collected biotic data for species prediction, where the rare data are needed for the base of the modeling procedure. The selection of the wetlands, water-related habitats, and the water level is easier from the rare data source.

3. *Production of relief model (DEM), with raster file output, in 1x1 resolution from LiDAR data.*

With the fine resolution relief models, the rangers will be able to map the existing archaeological pieces of evidence (castles, soil castles, and firewalls) with field visits. A further goal is the mapping of the high-valued rock-towels, rock-flows, and deep valleys as an important nature conservation value.

4. *Production of the surface model (DSM), with raster file output, in 1x1 resolution from LiDAR data*

In forested areas it is necessary indirectly to the generation of point data, directly it shows the location of the patches lacking the closure (cuttings, natural disturbance). The exact mapping of these clearings will be possible with the model.

5. *Relief' model of land cover, with raster file output, in 1x1 resolution.*

The tree heights (vegetation heights) models are very important factors to describe the quality of the given habitat; it is the first quality value for the dental vegetation, it can indicate the unnatural stands (e.g.: oak plantation could grow less intensively in improper habitats), while the young stands will be visible plastically.

6. *The density picture of the first and the last reflection, with raster file output, in 4x4 resolution, from LiDAR data.*

The inner structure is one of the most biologically important values of wood stands, which means the presence of the different levels in the forest, including the presence of the shrub level and the heights of the dominating canopy. The more reflection we gain indicates the more natural state of the forest, as well as, the less reflection we gain, the more monotonic, economical the stand is. That is why the comparison with the forest state evaluation methodology based on the pilot study implemented within the project will be crucial to evidence the LiDAR study results. Furthermore, based on this record, habitat prediction can be fulfilled for several specific species (e.g. bats).

Summarizing these are the main areas of application, what we are focusing on within the framework of the Centralparks project.

A. Abiotic variables / patterns:

- The DEM based on the digitalization of the EOV 10 altitude lines are not fulfilling our purposes (the altitude lines are not correct in the baseline maps), there are plenty of failures e.g.: the presence of the rock-towels. A LiDAR recording can cover all of these variables including several further dates (potential nesting sites and lynx resting places) (>1 point/m^2).
- The topic of the soil castles: the data from the soil castle registry can be vilified with LiDAR and possible new castles can be discovered (>2 points/m^2).
- Elimination of the old artificial routes /linear infrastructures (narrow-track wheeled train's duct buildings, coal combustion sites, forest houses, and other cultural values) (>4 points/ m^2).
- Prediction of the damage caused by approximating routes and approach, the possibility of the expansion in m3 (>4 points/m^2).
- Preparation of flood and flow models based on fin scaled DEM (>1-2 point/ m^2).

B. Biology

- The DEM based on the digitalization of the EOV 10 altitude lines are not fulfilling our purposes (the altitude lines are not correct in the baseline maps), there are plenty of failures e.g.: the presence of the rock-towels. A LiDAR recording can cover all of these variables including several further dates (potential nesting sites and lynx resting places) (>1 point/m^2). Old gradient areas (signs of eroded root-platters) (>6 points/m^2)
- Vertical structure of the forest stands: highly dependent on the point density (>3-4 point/m^2)
- Tree heights: outstanding trees (as unique values and as habitat characteristic) (>2 points/m^2)
- Closure (>1 point/m^2)
- The exact determination and mapping of the gradient sites in the Csarna-valley (the gradient between Csarna and Rózsás sites exactly, as a planned "A" zone, strictly protected area (>1 point/m^2).
- If the point density is high (>6-8 point/m2), the amount of the lying deadwood is predictable on the evaluated sites.
- Biotic and LiDAR data (e.g.: structural diversity, rock-towers, emerged stones), the presence of some taxa could be predicted.
- Elimination of the high species diversity areas (based on structural information).
- Based on further data collection (multispectral recording) attempting of the habitat mapping.

The relevant collected information is affected by the point density and the time of the flight. For abiotic variables, the winter flights are more appropriate, while for the structural variables and information on the tree-stand inside, the flight needs to be carried out during the vegetation period.

We also have to keep in mind that the LiDAR is only able to produce supplementary information, which must be complemented with biotic data and field experiences. That is why we suggest the determination of targeted species to represent other species' needs (selection of umbrella species) and the analysis of its distribution to aggregate with the LiDAR data.

The interest and goal of the elaborator must be selected carefully, the most promising and cost-effective studies are the ones carried out with low point density with a winter flight.

IV. Literature

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