THE USE OF THE LiDAR TECHNOLOGY IN CALCULATION OF THE ECOSYSTEMS CARBON FOOTPRINT

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Abstract. *The majority of carbon emissions come from indirect sources. Often, the carbon footprint, cannot be determined with high accuracy, because one cannot know exactly the high amount of data resulted from the interactions between different factors involved in this processes. The LiDAR (Light Detection and Ranging) technology has been emerging lately, becoming more and more prevalent in more and more fields, starting from fundamental scientific research and going to application solutions in areas such as: environmental and biodiversity assessment, agriculture and precision forestry, heritage inventory and archeology, etc. This technology involves the use of a set of sensors that use laser beams in combination with GPS recordings. The ability to provide highly accurate information, giving the possibility of developing analytical models, makes it possible to use this technology in the calculation of ecosystem carbon footprint. A case study presenting an analysis of the structure of biostructures within a degraded forest ecosystem has been presented whose variations in development may be the response to the presence of limiting factors that betray the distribution and concentration of some pollutants. The habitat mapping methodology involved the creation of a GIS map, starting from satellite images, aerophotograms and detailed aerophotograms made with the help of drones. The modality of making the cartograms took into account the aimed detail (the target granulation) that was established taking into account the ecological-target traits associated with each criterion element that was the basis of the site designation. Given that the installation of the forest would have been successfully carried out, on the entire surface, ensuring a consistent density and a complete coverage degree, the potential for the presence of C at this level would have been approximately 4 times higher. Evaluating a possible ecological restoration scenario, the real potential of the ecological ecosystem services of the analyzed perimeter is foreshadowed, thus facilitating a calculation of the carbon footprint generated by the existing historical pollution.*

Keywords*: accurate information, case study, forest, pollutant*

INTRODUCTION

The carbon footprint may be defined as being the total emissions, expressed in carbon dioxide equivalent, produced by an individual organization, event, and/or product. At conceptual level, the carbon footprint is, namely, a component of the larger concept of ecological footprint (CHEEMA AND CHAICHANA, 2019; CORREA ET AL., 2019; HE ET AL., 2019; LIU ET AL., 2019). The ecological footprint is a concept aiming to elucidate, for example, the amount of nature inputs needed to support a branch of the economy (ALLEN ET AL., 2011; AL-MANSOUR AND JEJCIC, 2016; ANDÚJAR ET AL., 2016; DRUCKMAN ET AL, 2009; FREMSTAD ET AL., 2018; MORAN ET AL., 2018). The components of the ecological footprint are: the carbon footprint, the built-up land, forests, cropland and pastures, and fisheries, and it is expressed in global hectares. The LiDAR (Light Detection and Ranging) technology has been emerging lately, becoming more and more prevalent in more and more fields, starting from fundamental scientific research and going to application solutions in areas such as: environmental and biodiversity assessment, agriculture and precision forestry, heritage inventory and archeology, etc. (ANTONARAKIS ET AL., 2009; GONG ET AL., 2012; HUANG AND PRETZSCH, 2010; HOUBORG ET AL., 2009). This technology involves the use of a set of sensors that use laser beams in combination with GPS recordings. The ability to provide highly accurate information, giving the possibility of developing analytical models, makes it possible to use this technology in the calculation of ecosystem carbon footprint (CANATA ET AL., 2019; ROSELL AND SANZ, 2012).

The Turda Chemical Factories (UCT) have manufactured since 1964 a precursor of a product with broad spectrum insecticide, known under the generic name of ”Lindan” (hexachlorocyclohexane - HCH). From the production process of ”Lindan” resultes secondary chemical compounds, which were not subject to recovery, considered as waste, among which also compounds in combination with HCH. These products have a high degree of toxicity, without the possibility of being used in final applications. Starting from Note 10439/ 18.03.2008, sent to the Romanian Parliament by the Ministry of Environment and Sustainable Development, it is estimated that an amount of 15,000 to 60,000 t of waste from the former UCTs, which also contain the above mentioned products with HCH, will be found stored in several locations around Turda municipality.

For one of these locations, where it is estimated to be one of the most important volumes of such a waste disposal - the perimeter of the Poșta Rât, respectively (Fig. 1) - a proposal was submitted regarding the neutralization of dangerous chemical compounds and the ecological restoration of the entire perimeter covering an area of 10 ha (Fig. 2).

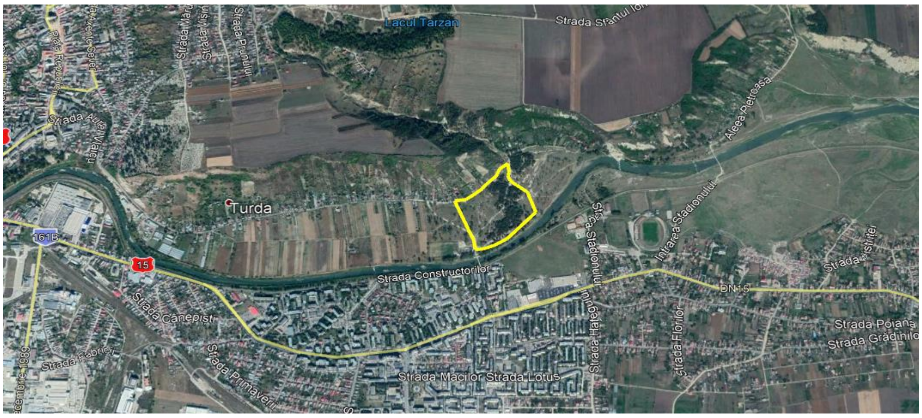


Figure 1. The way of making the cartograms starting from aerial images, through the digitization technique

Figure 2. The way of making the cartograms starting from aerial images, through the digitization technique (original)

Over time, the surface has undergone some restoration process, as a result of the installation of a succession of vegetal species and the start of natural detoxification processes, but there has been recorded migration of pollutants to proximal areas. Thus the affected areas gradually became grassed, limiting the extension of the skeletal soil surfaces and thus the wind erosion and the transport of contaminated particles (Fig. 3).

Figure 3. The way of making the cartograms starting from aerial images, through the digitization technique (original)

The present study aims to analyze the structure of a perimeter affected by pollution (contaminated site), using the LiDAR technology, in order to determine the ecological footprint generated by the remanence of the HCH pollutant, which determines the delay or even the impossibility of installing woody vegetation, as it was originally intended to be done at the level of this area.

MATERIAL AND METHODS

The habitat mapping methodology involved the creation of a GIS map, starting from satellite images, aerophotograms and detailed aerophotograms made with the help of drones.

The modality of making the cartograms took into account the aimed detail (the target granulation) that was established taking into account the ecological-target traits associated with each criterion element that was the basis of the site designation (Fig. 4).

Then the main biom categories associated with phauna species were selected. Thus, built areas of rural type, ▸gardens, orchards, and vineyardss, the folowing categories were delimited: ▸agriecosystems, ▸roads and accession ways, ▸built areas of urban type, ▸gardens, orchards, and vineyards, ▸forestrs, ▸artificial wood plantations, ▸shrubberies and forests in transition, ▸ mosaics of shrub habitats alternating with pastures, ▸ natural and semi natural pastures, and meadows, ▸ pastures, ▸ wet lands; riparian areas, ▸ water courses and slides, ▸ other artificialized fields.

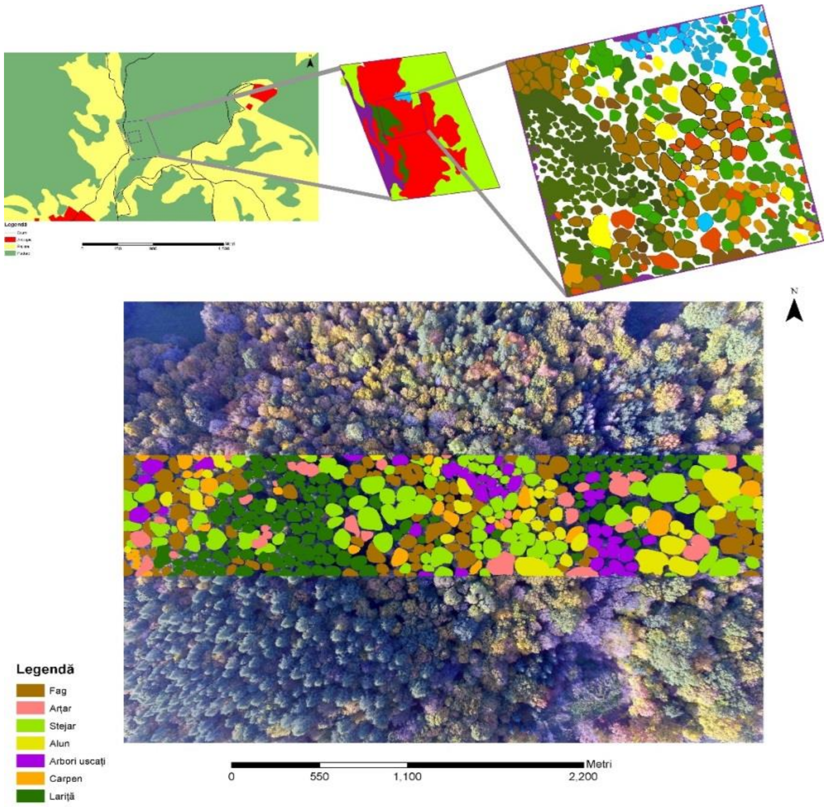


Figure 4. The way of making the cartograms starting from aerial images, through the digitization technique using the GIS technology - At the top: approaching an in-depth habitat by increasing the digitization details (granulation increase); at the bottom: evaluation of forest habitats using the technique of analysis bands

The LiDAR technology was also used in the analysis process, as it was able to generate information with exceptional accuracy, not only on soil configuration, but also on some elements of the vegetation layer. In this regard, a UAV Phantom DJI Matrix 600 Pro assembly, equipped with LiDAR Riegl MiniVux sensor, were used.

RESULTS AND DISCUSSIONS

The DTM (Digital Terrain Model - Digital Terrain Model) was realized, by filtering the reflected points only from the ground level, eliminating all other recorded points that mark the presence of biostrates (Fig. 5a). Thus, a very precise first layer has been obtained which presents the extremely precise morphology of the soil surface, with an accuracy below one cm on the x, y and z axes. Analysis of the DSM (Digital Surface Model) allows the generation of the upper blanket (last layer) of the recorded points. The difference between the two sheets (layers) of information is represented by biostructures, on which primary attributes can be established related to the volume occupied by them, the height (maximum, average, minimum) and the spatial distribution, respectively (Fig. 5b).

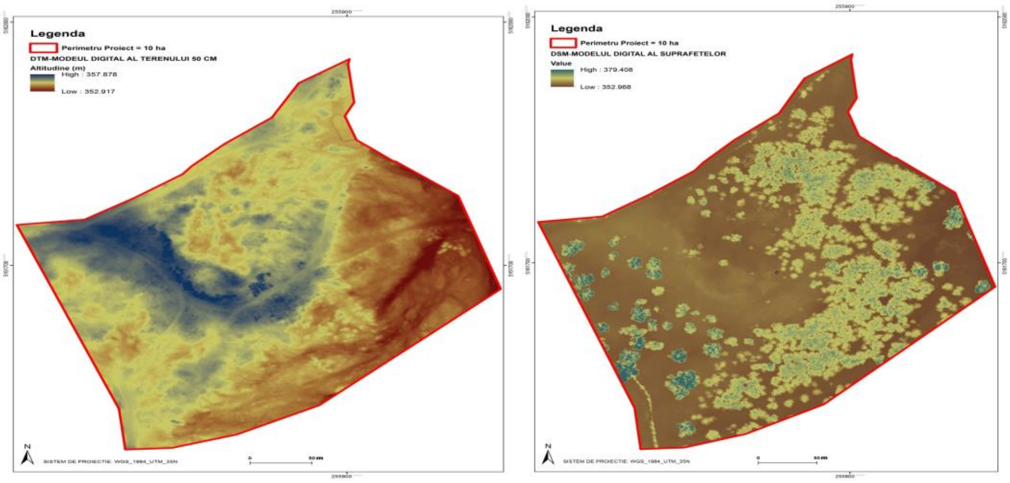


Figure 5. Digital Terrain Model (a) and Digital Surface Model (b)

The whole process was also tracked by identifying a number of control trees, by marking with GPS and registering the attributes, thus generating a verification and calibration model of the digital model. A number of 188 trees were considered in this control scheme.

According to the present analysis, a number of 4,144 trees were identified, with an accepted error of +/- 5%. In this case, it is also considered that some trees are difficult to identify, define and individualize, at least from an ecological point of view, because there are trees that deliver 2 or even 3 growth trunks from the same place, or from a height under 1 m, which was established as a shrub removal area, thus limiting the accuracy of the interpretation. The profile obtained for the calculation of the volumes opccupied in the LiDAR points in the cloud is presented in Fig. 6.

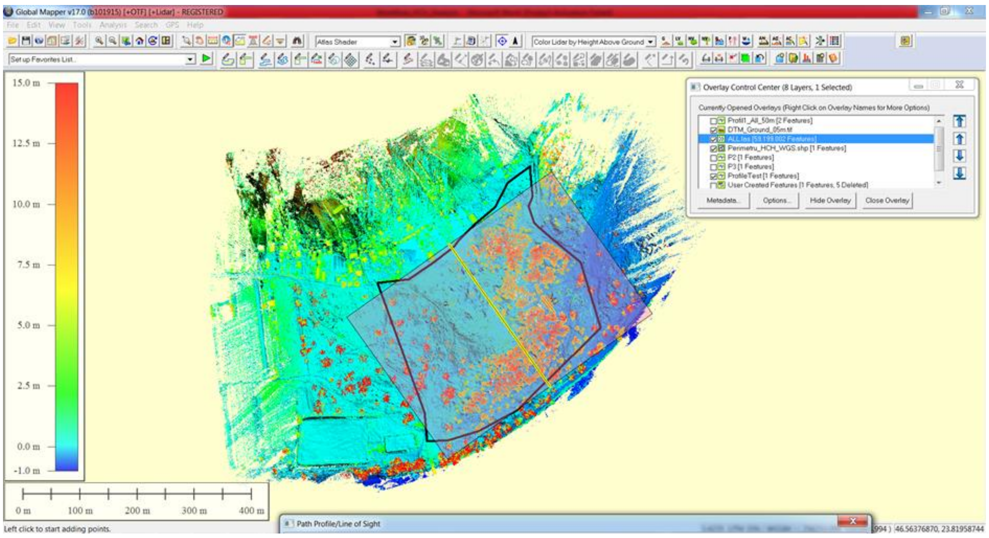
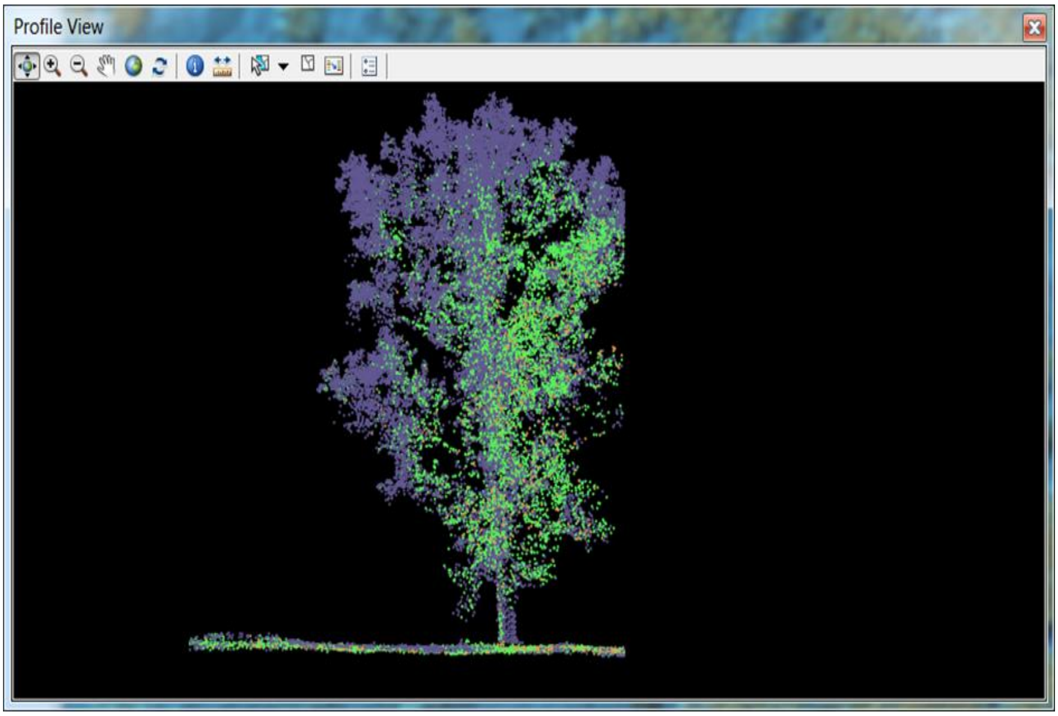


Figure 6. The profile obtained for the calculation of the volumes opccupied in the LiDAR points

The degree of coverage (density) of the trees was calculated at 2,949 ha, but the projection of the crown (its extension), achieves a coverage of 7,616 ha.

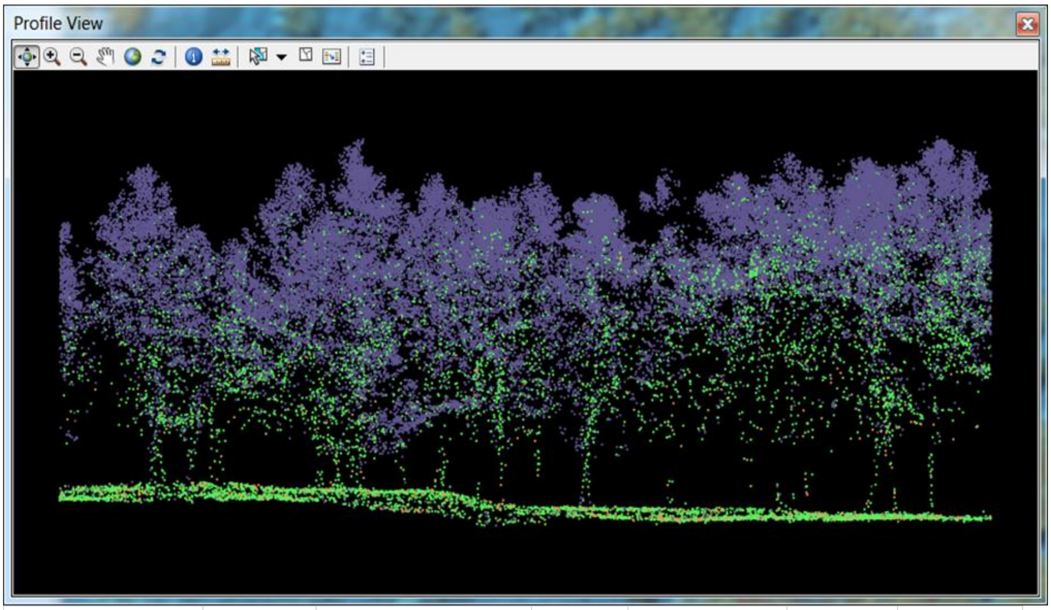
The volume of green biomass of the trees was calculated, by the difference between the upper (maximum) levels of the layer (layer) having the value of 37545 m^3 and the one recorded at a level of 1m above the ground (9745 m^3), resulting in 27,800 m^3. Examples of volumes resulted from several reference trees are presented in Fig. 7 and Fig. 8.

Starting from the assessment of the carbon level of the green mass as it was defined as the entire volume of green mass of the woody and grassy vegetation, above the ground level, including stems, branches, bark, seeds and leaves and representing 47% of the volume of its total, the volume of carbon contained in this forest blanket was calculated as 13,066t C.



NAME	LAYER	CUT_VOLUME	CUT_AREA	FILL_VOLUM	FILL_AREA
P238239	Measurement	8.3084349 cubic meters	0.01295 ha	30.428905 cubic meters	0.01977 ha
Plop236	Measurement	0.35739556 cubic meters	0.001006 ha	0.91311108 cubic meters	0.002594 ha
Plop252	Measurement	16.491177 cubic meters	0.01007 ha	5.3940983 cubic meters	0.00682 ha
Pin104	Measurement	0.11220184 cubic meters	0.00057 ha	1.0479917 cubic meters	0.002157 ha

Figure 7. Example 1 for the volumes obtained for reference trees



		Above ground green vegetation				
CUT_VOLUME_cubic meters	CUT_AREA ha	FILL_VOLUM_cubic meters	FILL_AREA ha	BASE_HEIGH	PROFILE_Width	PROFILE_LENGTH
37545.460	5.122	9749.982	2.494	0 m above ground	250 m	304.61 m
7173.777	1.607	55537.549	6.009	1 m above ground	250 m	304.61 m
3289.899	0.982	74500.516	6.634	1.3 m above ground	250 m	304.61 m
114.528	0.070	124637.550	7.546	2 m above ground	250 m	304.61 m
5.339	0.004	162607.990	7.612	2.5 m above ground	250 m	304.61 m
0.027	0.000	200682.300	7.616	3 m above ground	250 m	304.61 m
0.000	0.000	27391480.000	7.616		250 m	304.61 m

Figure 8. Example 2 for the volumes obtained for reference trees

CONCLUSIONS

Given that the installation of the forest would have been successfully carried out, on the entire surface, ensuring a consistent density and a complete coverage degree, the potential for the presence of C at this level would have been approximately 4 times higher.

It can thus be concluded that the ecological footprint due to the existing pollution, manifested by the limitations of the installation of the forest mass produced at the target perimeter is 39.198t C.

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