ALS DATA FOR VEGETATION ANALYSIS

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Abstract: *ALS is an active technique in remote sensing that offers on a large scale the possibility of analyzing in detail, the objects on earth's surface, whether it's low vegetation, trees or buildings. Thus said, this article classifies and analyzes the vegetation zones based on 3D point cloud, acquired through ALS technique. The purpose of this study is to identify areas of vegetation by point attributes. To achieve this, we used EchoRatio attribute based on surface roughness, which is described by standard deviation (SD) depending on the direction of ALS points. In other words, either we have a high or low density of points belonging to vegetation or buildings, separability is limited by the use of standard deviation. The final results were different topographic models (DTM, DEM, DSM, nDSM) on which the areas of vegetation delimitation was done.*

Keywords: *ALS, DTM, DSM, DEM, nDSM, EchoRatio.*

1. Introduction

The use of lasers as remote sensing instruments has an established history going back 30 years. Through the 1960s and 1970s various experiments demonstrated the power of using lasers in remote sensing including lunar laser ranging, satellite laser ranging, atmospheric monitoring and oceanographic studies (Flood, 2001).

The ALS system, usually called airborne ALS (Airborne Laser Scanning) in the commercial sector, is an active remote system. Airborne Laser Scanning (ALS) is characterized by the simple geometric measurement and is also known as the laser range finder (LRF). The computer system controls data acquisition, scanning and transmission media in real time using, a GNNS system for the determination of the spatial position and the INS system for determining different angles of inclination of the aircraft.

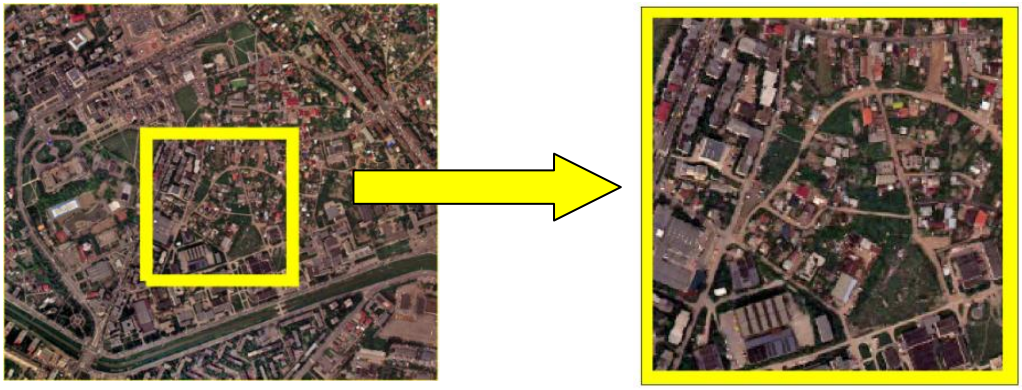
The ALS system emits a waveform, which is reflected by the land surface and at return, holds information about the number of echos, intensity, amplitude and others.

The usefulness of ALS systems has been demonstrated by a number of applications where traditional photogrammetric methods fail or become too expensive, for example, the acquisition of terrain elevation data over areas with dense vegetation (Kraus and Pfeifer 1998), acquisition of 3D city data (Haala *et al.* 1998), or the surveying and modeling of power lines.

2. Presentation of the Study Area, Materials and Equipment

2.1. Presentation of the Study Area

The study area is located in the Iasi city (Romania), on the left bank of the river Bahlui, in the vicinity of the Faculty of “Automatic Control and Computer Engineering” and covers an area of 98738.0517 m^2. The main selection criterion was the large acreage of vegetation compared to other vicinities (Fig. 1).



(a) (b)

Fig. 1 – The study zone, west side of „Gheorghe Asachi” University of Iasi (a) orthophoto 1:5000 scale and (b) detail

2.2. Materials and Equipment

The ALS data were acquired in March 2012 by SC TRP SRL, the beneficiary being the Water Basin Agency Prut- Bîrlad, comprising a total of 800 bands acquired with the Leica ALS50 sensor with a wavelength of 1064 nm. The ALS points have an accuracy of 70 cm in horizontal plane and 20 cm in vertical plane (Oniga, E. and Chirila, C., 2013), the plane rectangular coordinates were calculated in the National Projection System, namely "Stereographical on unique secant plan-1970" and the normal altitudes in the „Black Sea 1975” reference system for heights.

2.3 Data processing

For the ALS point cloud processing, OPALS (Orientation and Processing of Airborne Laser Scanning data) software package was used, developed by the Technical University of Vienna (Mandlburger *et al.*, 2009). This software was realized to process a large number of points taken with ALS system. Opals software consists of 30 modules, each having a well-defined area of activity, such as: OpalsGrid for the DTM, DSM or nDSM calculation or OpalsImport for importing the *.las file into the program.

FugroViewer is an easy to use software, with an explicit graphical interface and various user functions. The data can only be viewed into different color palettes in either 2D or 3D format, depending on the points class (buildings, vegetation, ground, etc.), the number of echoes or signal intensity. The ALS point cloud can be prossessed, filtered, but the FurgoViewer software does not export information.

Matlab is a high performance language for technical computing. It integrates computation, visualization and programming in an easy to use environment, by this reason

was used in this paper to generate the DEM for the study zone using the spline bicubic interpolation method.

2.4. DTM, DEM, DSM, nDSM calculation

Digital terrain model (DTM) is simply a statistical representation of the continuous surface of the ground, by a large number of selected points with known X, Y, Z coordinates in an arbitrary coordinate field (Zhilin, L. *et al*., 2005).

Digital elevation model (DEM) is a simple, regularly spaced grid of points with known X, Y, Z coordinates.

Digital surface model (DSM) is similar to the DTM, except that the DSM contains the altitudes of the reflectance surface of buildings roofs, trees and other components of the earth's surface (Maun, 2007).

Normalized digital surface model (nDSM) is obtained by subtracting from the digital surface model, the digital terrain model (nDSM = DSM-DTM), being very useful because the heights of the objects situated above the bare earth terrain can be directly obtain (e.g. buildings, trees) (*Hollaus et al.*, 2010).

The sER (slope adaptive echo ratio) is a measure to describe the surface roughness, but also an indicator to determine the surface transparency (Höfle *et al.*, 2009).

3. RESULTS AND DISCUSSION

The total number of ALS points in the study area is 293 839, with elevations ranging between 38.600 m and 80.320 m, of which, a total of 122 165 points represents vegetation, with elevations ranging between 39.390 m and 68.410 m and a total of 109 351 points, with elevations ranging between 39.030 m and 54.020 m, belong to the bare earth. The remaining of 62 002 points represents constructions (Table 1*)*.

Table 1 - The study zone ALS data characteristics

Criteria	1	2	3	4	5	6
No. of points by return	283 167	10 470	174	18	10	-
Class	-	109 351	25 688	27 972	68 826	62 002

3.1 Obtaining the DTM and the DEM of the study area

The ALS point cloud was filtered through “OpalsExport” module, using the class filter “ground”, resulting a *.las file with the points belonging only to the bare earth. The “MovingPlanes” interpolation method was applied to this file, with a search radius of 2 m and a total of 10 neighbours, obtaining an initial DTM in raster format (Fig. 2a). It was observed that the resulted DTM, presents large areas without elevation information, due to fact that, extracting the points that belong to roof surfaces, canopy, etc., the resulted *.las file have many gaps. Therefore, parameters were modified so that: the interpolation method was changed to “movingAverage”, using 10 neighbours and 20 m search radius, resulting a continuous surface, but the model was determinated as a low precision model (Fig. 2b).

The solution for this problem was to use the Matlab software. The spline bicubic interpolation method was chosen for the grid generation, with 0.5 m grid size (Chirilă C. *et*

al., 2013), because the OPALS software has not implemented this interpolation method. Was created a *.txt file, containing the grid points coordinates that was then converted into a *.las file. This file was imported into Autocad Map 3D 2012, creating the DEM corresponding raster (Fig. 2 c, d).

Another way of obtaining the DTM can be achieved with FugroViewer software by interpolating points of class "ground" by the Delaunay triangulation method, which can be viewed in different color palettes.

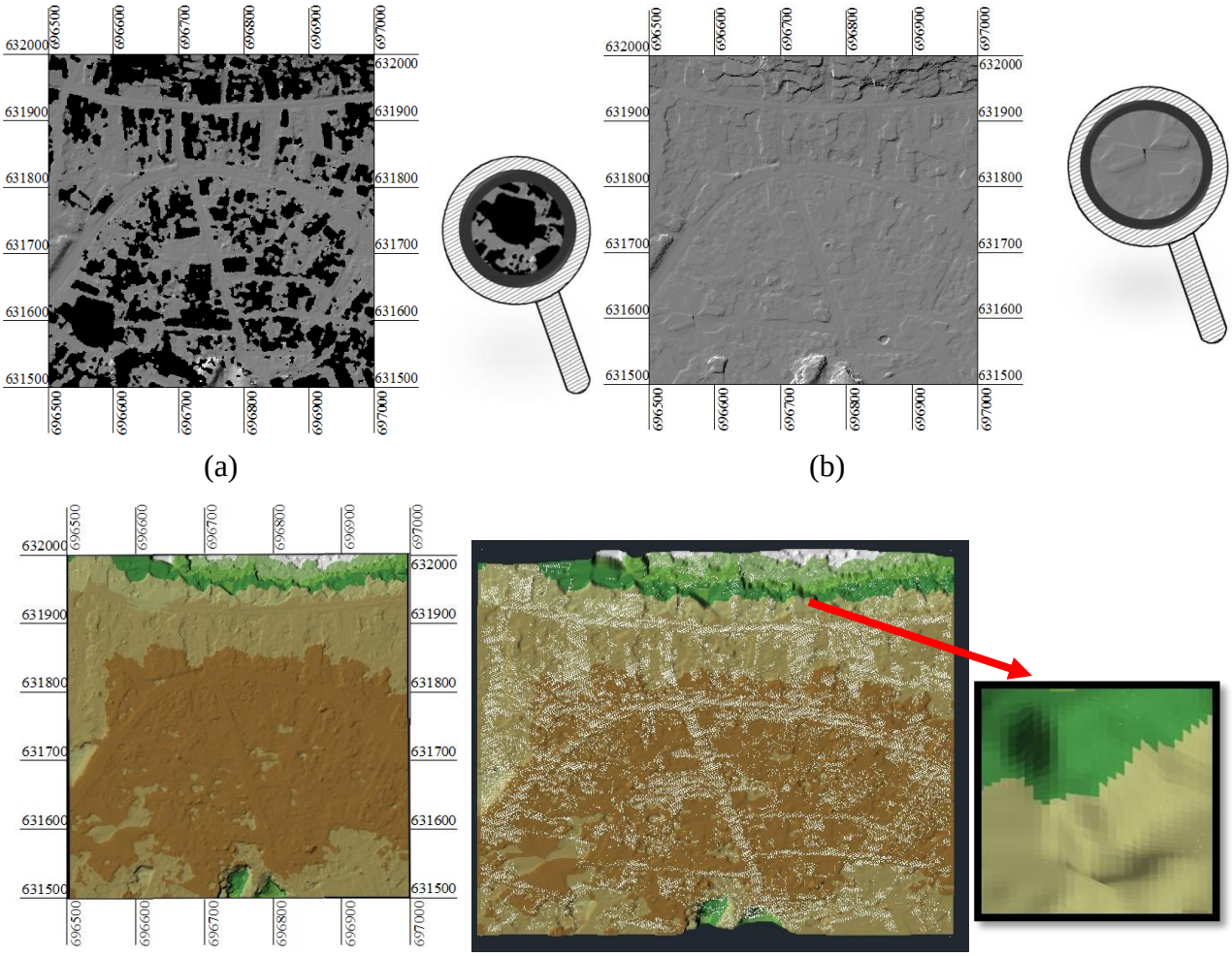


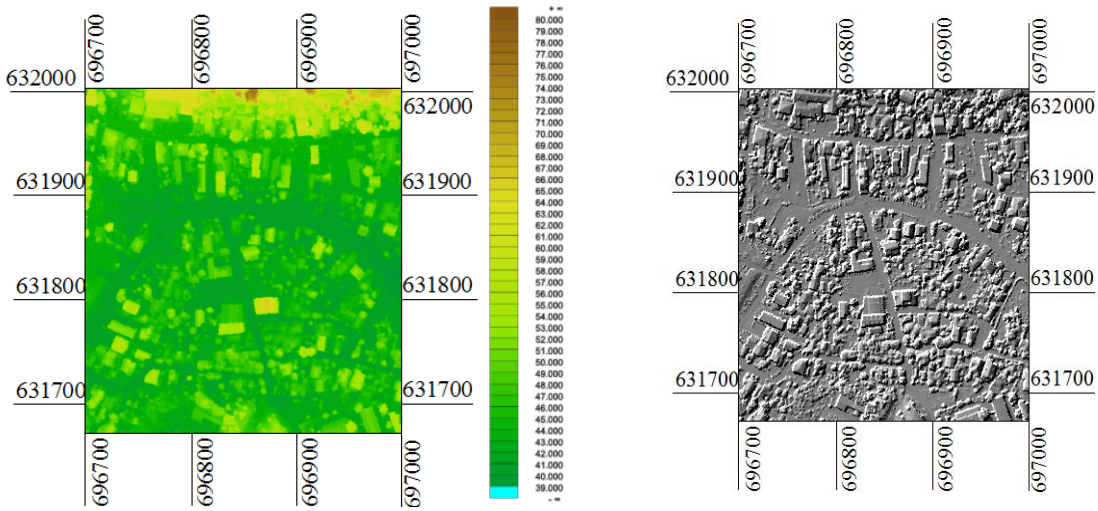
Fig. 2 – (a) DTM raster obtained by ”movingPlanes” interpolation method (0.5 m cell size; 10 neighbours; 2 m search radius), (b) DTM raster obtained by “movingAverage” interpolation method (0.5 m cell size; 10 neighbours; 20 m search radius) (c) DEM raster obtained by spline bicubic interpolation method, (d) perspective and detail view in AutocadMap 3D 2012

3.2 Obtaining the DSM of the study area

The Digital Surface Model in raster format was first obtained, by using the "OpalsGrid" module, interpolating all ALS points using the “movingPlanes” method (Lancaster and Šalkauskas, 1990), using 10 neighbours, 2 m search radius and applying a filter that passes only the points corresponding to the first echoes. By using „OpalsZColor” or „OpalsShade” modules, digital models can be viewed in different modes and in different color

palettes such as standard palette, grey palette, hillshade, slope, and so on. As it has been observed also in the above figures, the interpretation and the experience of the operator is the most important mechanism for information processing.

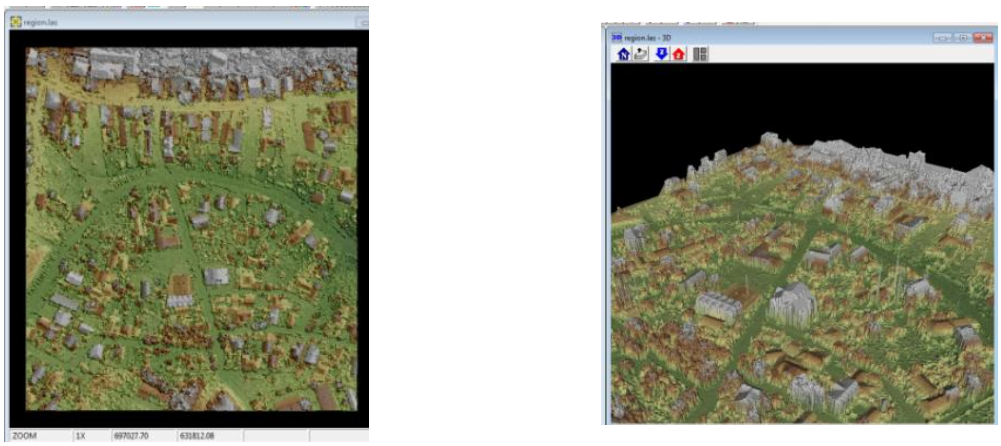
In Fig. 3a, DSM is highlighted by a colored raster using the “standard” color palette, and in Figure 3b by a hillshade raster, with a spatial resolution of 0.5 m. DSM, represented by hillshades, was obtained using a separate module of the "OpalsShade" by a lighting function.



(a) (b)

Fig. 3 – Digital Surface Model of the study area represented in raster format (0.5m cell size) (a) standard color palette, (b) hillshade

The ALS points corresponding to the first electromagnetic signal reflection were interpolated by triangulation Delaunay, using the FugroViewer software, obtaining the DSM represented as as triangulated irregular network -TIN.



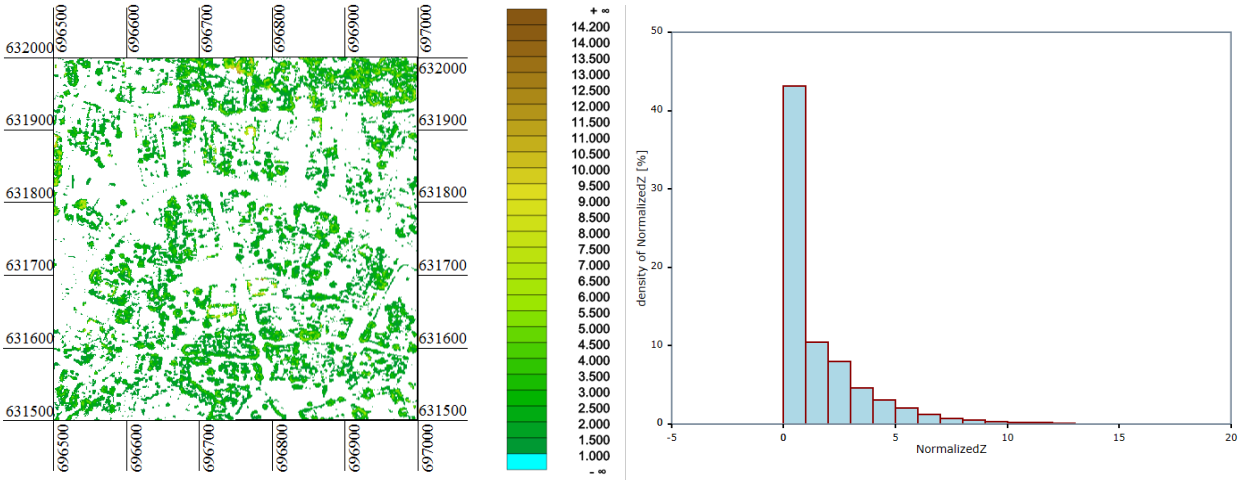
(a) (b)

Fig. 4 – Digital Surface Model of the study area represented in FugroViewer using the "earth tones" color palette (a) plan view, (b) perspective view

3.3 Obtaining the nDSM of the study area

The ***Normalized Digital Surface Model*** for the study area was obtained using the OPALS package based on the DTM and the DSM, created above. Using the module

„OpalsAddinfo”, first was calculated the „NormalizedZ” attribute for each ALS point, belonging to vegetation class, as the difference between the point elevation and the corresponding DTM cell elevation (0.5 m). Then, the "MovingAverage" interpolation method was applied for the points defined by a ”NormalizedZ” attribute, with a grid of 0.5 m using the „OpalsGrid” module, resulting the nDSM in raster format (Fig. 5a). The objects heights distribution analysis, can be observed using a histogram of objects heights created with the "opalsHistro" module (Fig. 5b).



(a) (b)

Fig. 5 – (a) The nDSM of the study area in raster format using the “standard” color palette, (b) the histogram of vegetation heights

3.4 Analyses performed on existing vegetation in the study area

The “class” filter was applied, using the OPALS software on the ALS point cloud extracting only points from classes: „lowvegetation”, „mediumvegetation” and “highvegetation”, corresponding to the study zone.

The vegetation classification was made by the American Society of Photogrammetry and Remote Sensing (ASPRS), depending on the vegetation type. Therefore, new *.las files were obtained, that can be viewed in TIN format in the FugroViewer software using different color palette.

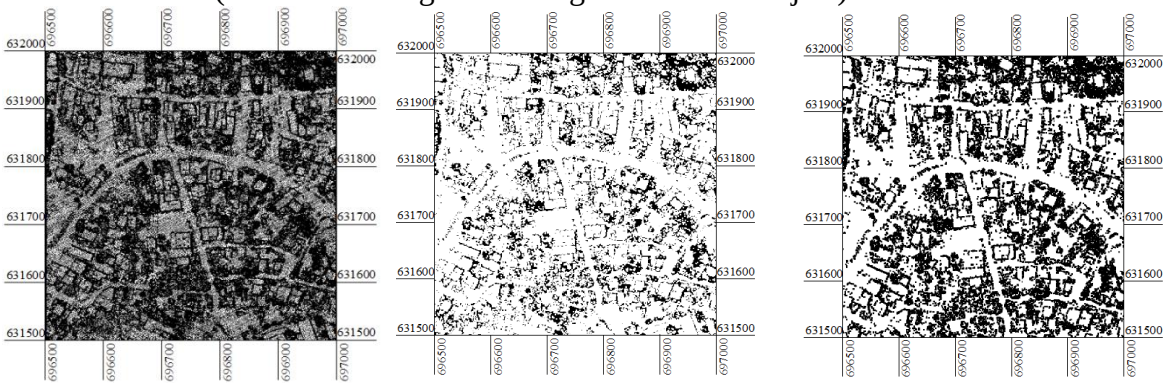
Another way, and a more precise one, of filtering vegetation areas located in the study zone, is to use the surface roughness and the slope adaptive echo ratio (sER) parameter. The echo ratio attribute (ER) is an indicator for the penetrability of a surface, but with increasing slope of the roof surface, even if the surface is non-penetrative, the ER gradually decreases from the correct value of 100% (*Höfle, B., et al.*, 2009). In this case were used more modules, such as: opalsEchoratio, opalsCell, opalsColor and opalsAlgebra.

The sER parameter was calculated for each ALS point, then were retained only those points which have a sER value lower that 85%, in order to removed the buildings roofs.

In other words, all vegetation points were extracted, but also those points belonging to the edges of neighborhood buildings. The result is a binary image, which has value “0” for vegetation and value “1” for buildings (Fig. 6 a).

The next step was to remove from this raster the power lines, using the morphological operation of dilation. The dilation enlarges the boundary of vegetation areas by adding new pixels of value 0. For example, the outline of buildings appears as pixel bands and these are removed with dilated operator (Fig. 6 b).

After dilating the boundary vegetations areas, was needed to use another morphological operator, that is the erosion operator, considered the opposite of dilation, but not inverse in the algebraic sense. The result (Fig. 6c) is that concave corners are rounded and cracks are filled (where the background brings out into the object).



(a) (b) (c)

Fig. 6 – (a) The binary image corresponding to ALS points with sER<85%, (b) the binary image obtain after applying the dilation operator, (c) the binary image obtain after applying the erosion operator

Using "OpalsAlgebra" module, were combined, both sER and erosion rasters being obtained a new raster (Fig. 7a), by applying the following condition:

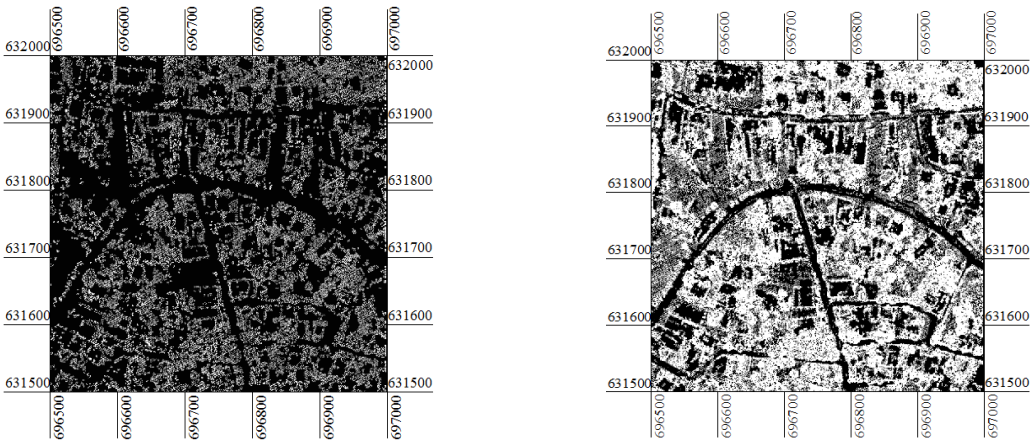
if (r[1] == 0) then r[0], else 100

where: r[0] – value of the first raster pixel (sER);
r[1] – value of the second raster pixel (erosion).

Therefore, buildings being erased, using the "OpaslAlgebra" module, a binary raster was generated containing only vegetation zones (Fig. 7b), by applying the following condition:

if (r[0] == 0) then return 1, else 0

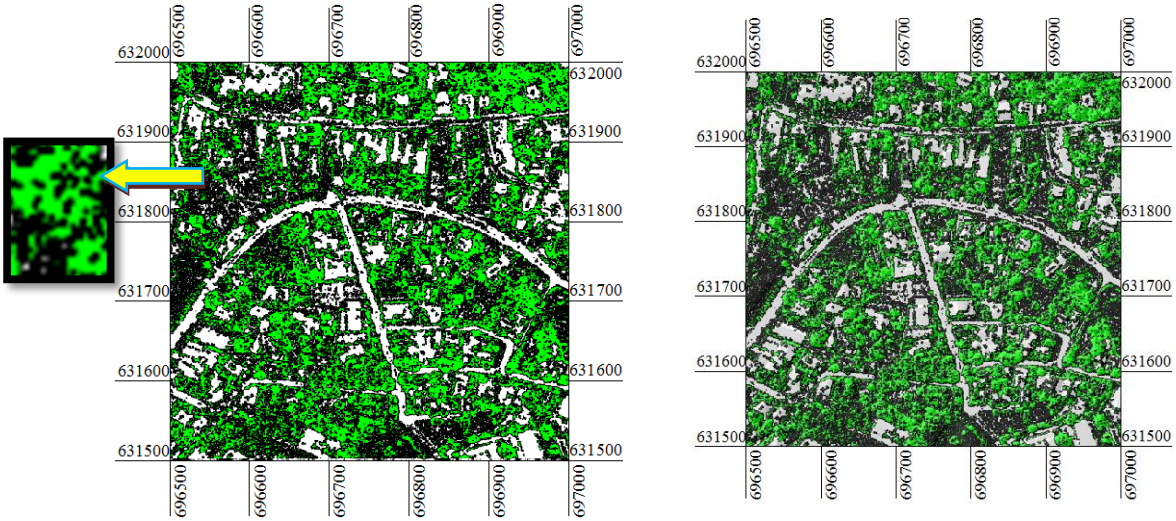
where: r[0] – value of the first raster pixel (binary image of the sER<85%);
r[1] – value of the second raster pixel (nDSM).



(a) (b)

Fig. 7 – (a) The panchromatic raster representing vegetation zones, (b) the binary raster representing vegetation zones

Finally, the minimum contouring area was chosen (0.01 m^2), and using the "OpalsContouring" module, were obtained vectorized contour polygons, representing the limits of areas covered by vegetation. Then, this contours were exported as ESRI SHAPE files (Fig. 8). The shape file contains 1 523 polygons, summing 53 469.25 m^2, from the 98738.0517 m^2 total area, which represent the study zone surface.



(a) (b)

Fig. 8 – (a) Vegetation polygons view in QuantumGis software, (b) vegetation polygons superimposed over the DSM

4. Conclusions

In this paper a workflow for deriving vegetation outlines from ALS data was presented. Also, the study highlights the usefulness of ALS data to perform spatial analyzes, either related to vegetation or buildings.

The purpose of this study was to clearly delimit vegetation areas in urban zones using the OPALS software in order to perform a statistical study. Of the total area surveyed, about 56% is represented by vegetation, so we can say that there is a balance between areas covered by vegetation and buildings.

In order to, eliminate noise and to smooth the outline of objects was necessary to apply a series of morphological operators, such as: dilation and erosion based on binary mathematical morphology.

The ALS data can be used, in a completely automatic process, to obtain different products in raster or *.TIN format, such as digital terrain model, digital surface model, digital elevation model, normalized surface model or a map on which vegetation areas are marked.

5. References

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