LiDAR APPLICATIONS BASED ON LAKI II PROJECT

Iuliana Maria PÂRVU, Geodetic Engineer - National Center of Cartography, iuliana.parvu@cngcft.ro
Iuliana Adriana CUIBAC PICU, Geodetic Engineer - National Center of Cartography, iuliana.cuibac@cngcft.ro
Adrian Grigore PÂRVU, Geodetic Engineer - National Center of Cartography, adrian.parvu@cngcft.ro
Margarita DOGARU, Geodetic Engineer - National Center of Cartography, margarita.dogaru@cngcft.ro

***Abstract**: The evolution of technology has led to significant advances enabling the development of precision laser scanning technology. LiDAR technology involves scanning a surface with laser waves. The ability to process dense point clouds in an efficient and cost-effective manner has facilitated a multitude of 3D data acquisition applications. This paper presents the ongoing project "Geographical Information for the Environment, Climate Change and EU Integration" LAKI II and some applications derived from it. One of the applications is the flooding risk analysis using LiDAR technology based products. Another application is the fusion of data from different sensors for some historical monuments, like Oradea Fortress. Improving the final products for cities by generating higher resolution digital surface models is one of our future goals.*

***Keywords:** LiDAR, point cloud, LAKI II, digital terrain model.*

1. Introduction - LiDAR technology

LiDAR technology (Light Detection And Ranging), is an active remote sensing technique that can provide high accuracy data on topography, vegetation, buildings, etc. LiDAR is also known as LADAR or laser altimetry.

Aerial laser scanning is a method of detecting distant objects and determining their position by emitting intense and concentrated light beams and measuring the time required for reflections to be detected by the sensor. This information is used to determine the distance to objects.

X,Y,Z objects coordinates are determined using: the time difference between the emitted and reflected laser pulse, the angle of the emitted beam and the absolute location of the sensor.

Due to the fact that LiDAR is an active remote sensing method, scanning can be done at night, when the atmosphere is cleaner and the air activity is diminished. The advantage of LiDAR technology is that the laser beam can penetrate the vegetation to accurately reproduce the terrain.

LiDAR technology uses 3 main systems:

- ✓ Laser Scanner for precise measurement of the distance from the platform to the target surface;

- ✓ Global Positioning System (GPS) for WGS 84 positioning of the airplane and the points on the surface;
- ✓ Inertial Measurement Unit (IMU) to record the movement of the airplane.

Thanks to the IMU system, it is possible to determine the exact position of the airplane. But this system loses accuracy over time (eg after one second). An evolved GPS system that records several types of satellite signals continuously updates the IMU system. GPS control information comes from virtual reference stations (VRS), reference stations operating continuously (CORS), points from the national geodetic network (RGN) or points of a reference network.

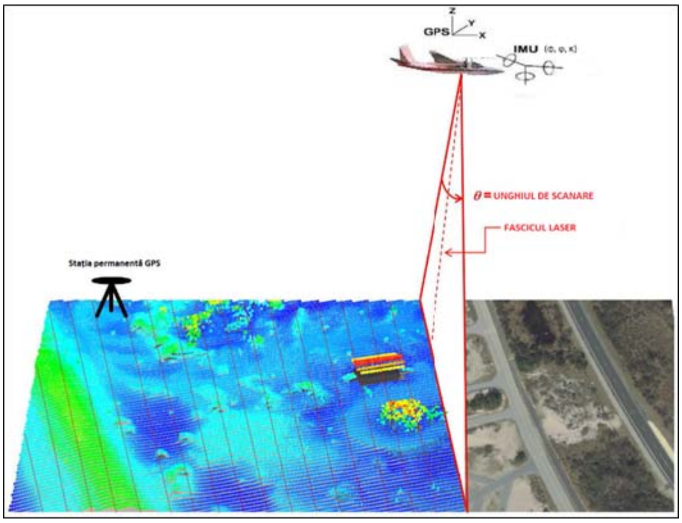


Fig. 1. Airborne LiDAR sensor

The laser beam passes through vegetation, and the return can be multiple (from 1 to 5 and 0 when it hits water surface) and is based on the number of obstacles the laser beam encounters on its way to the ground.

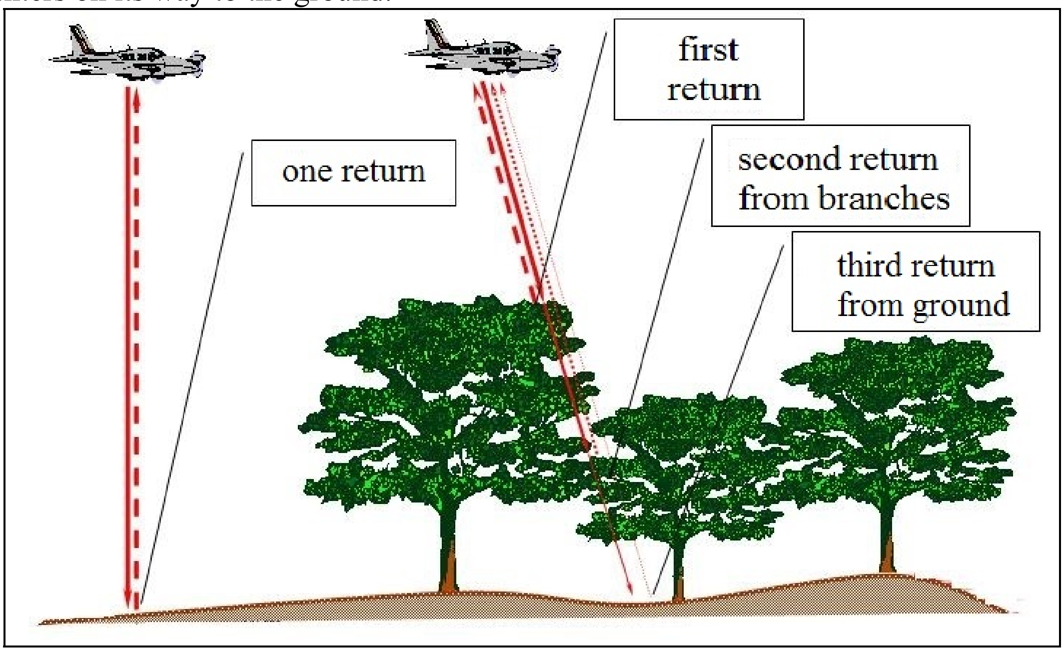


Fig. 2. Laser beam returns

When a LiDAR sensor is manufactured, it goes through calibration at the factory's laboratory to establish a very precise vertical alignment. Usualy, if the sensor is not damaged or altered, the laboratory calibration is done once. However, when the sensor is installed, reinstalled or placed in the aircraft, small changes in alignment may occur, requiring calibration parameters to be tested. LiDAR operators recalibrate the system by flying over a ground calibration area (which is not completely flat and contains 3D objects) for which precise field measurements have been made. The calibration process involves one or more flight lines in perpendicular directions. Native data is delivered as point clouds (millions of points with known X,Y,Z coordinates). From these points, after classification and processing, digital terrain models (DTM), digital surface models (DSM) and contour lines can be obtained.

A. Points

Point storage formats are LAS or ASCII. LAS is a "binary file format that maintains information specific to the nature of LiDAR data, while it is not too complex" (ASPRS, 2007). LiDAR data may contain, in addition to X,Y,Z point coordinates, the following informations: return intensity, point classification (if performed), return number, acquisition time, flight line. The point cloud is filtered by height classes (soil, vegetation, construction, etc.) to obtain digital elevation models and the process is called classification.

Classification Value and Meaning
0 Created, never classified
1 Unclassified
2 Ground
3 Low Vegetation
4 Medium Vegetation
5 High Vegetation
6 Building
7 Low Point (noise)
8 Model Key-point (mass point)
9 Water
10 Reserved for ASPRS Definition
11 Reserved for ASPRS Definition
12 Overlap Points
13-31 Reserved for ASPRS Definition

Fig. 3. LiDAR point classes

B. DTM, DSM

The term DTM was defined as "a statistical representation of the continuous terrain surface using a large number of points whose horizontal coordinates together with elevation are known, made in an arbitrary coordinate system" in 1958 by Miller and Laflamme. The point class from which DTM is generated is Ground.

These digital models are commonly raster files of type GeoTiff (.tif), ESRI Grid (.adf), Floating Point Raster (.flt) or ERDAS Imagine (.img), but they can also be TIN (triangulated irregular network).

The interpolation method depends on the data used and the purpose for which the DTM is made and can be simple techniques (nearest neighbour) up to the most complex ones (kriging).

DSM is a statistical representation of the land surface, including in the dataset ground and above ground points.

C. Contour lines

Contour lines are curves that connect points with the same elevation, based on a vertical datum. In LiDAR technology they are derived from digital terrain models and are available in vector format (.shp, .dxf).

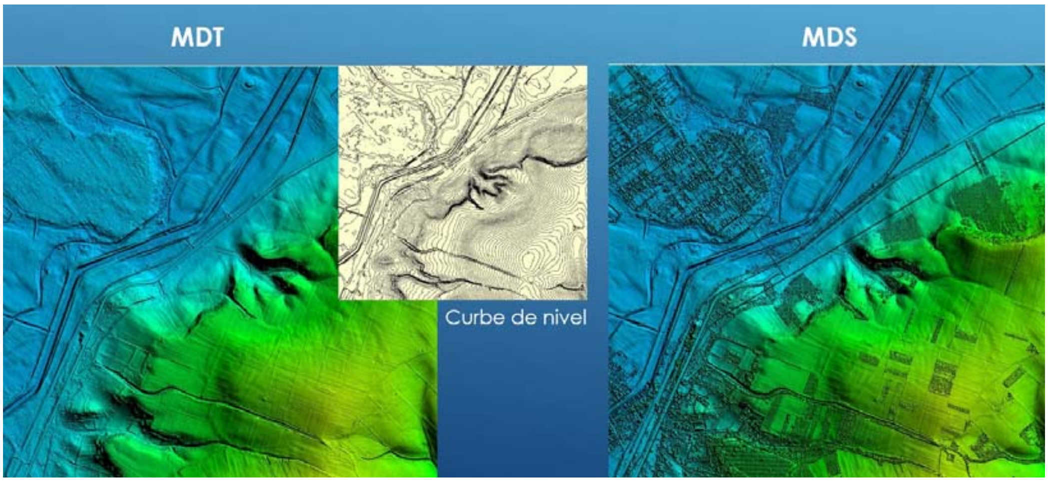


Fig. 4. LiDAR products

2. An overview of LAKI II project

In 2014, the National Agency for Cadaster and Land Registration, as project promoter organised in Bucharest the launching conference of the project *"Geographic Information for Environment, Climate Change and EU Integration (LAKI II)"* funded within the EEA Grants 2009-2014 thru the programme RO03 "*Environmental Monitoring and Integrated Planning and Control"*.

The main activities of the project comprise the production of a detailed terrain model through LIDAR scanning, new maps and orthophotos for approximately 50.000 km^2 of Romania's surface area.

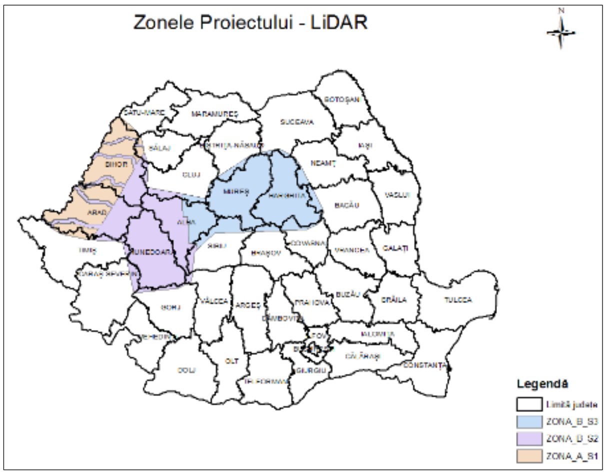


Fig. 5. Project area - LiDAR

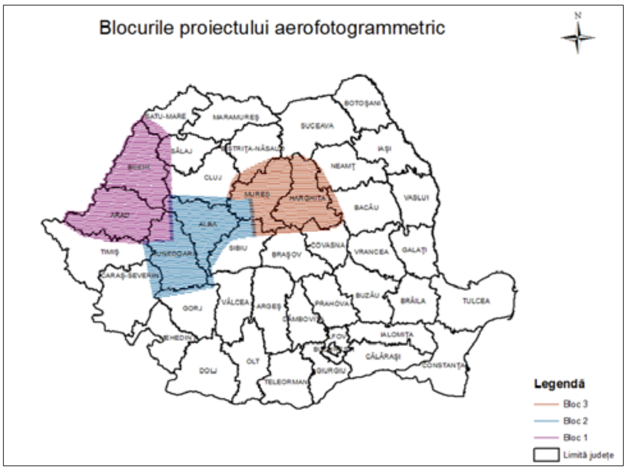


Fig. 6. Project area - aerial photography

- Digital terrain model (DTM)

- of high precision, for areas with high flood risk at the border of Romania with Hungary, in Arad and Bihor counties (surface of 10.000 km^2, with 8 points/m^2 density);

- of high precision for the county's capital cities corresponding to the 6 counties of the project, with 16 points/m^2 density;

- of adequate precision in the counties Hunedoara, Alba, Mureş, Harghita (surface of 40.000 km^2, with 2 points/m^2 density).

- Aerial photography and color orthophotomaps for the counties Arad, Bihor, Hunedoara, Alba, Mureş, Harghita (surface of 50.000 km^2);

- 3D vector maps for the counties Arad, Bihor, Hunedoara, Alba, Mureş, Harghita (surface of 50.000 km^2).

The LiDAR flight was conducted with the scanner RIEGL Q780 mounted on a plane type DA42 MPP. The aerial photography was made using digital cameras UltraCam Eagle Mark 2 and UltraCam Lp, mounted on a gyrostabilisator platform.

Current stage of the project LAKI II - the contractor handed over to the National Center of Cartography (CNC) reception committee the following deliverables**:**

- LiDAR flight;
- DTM and DSM;
- Aerial photography and aerotriangulation;
- Orthophotomaps.

3. LiDAR applications using data from LAKI II

- **Analysis of natural disaster risks using LiDAR technology**

The **Crisuri** river basin is located in the NW part of Romania with an area of 14.860 km^2. The main feature of the river basin is the existence of four main rivers: Barcău, Crişul Repede, Crişul Negru and Crişul Alb. The Crişul Negru springs from the northern slope of Curcubata top, at an altitude of 1.440 m. One of the area with significant potential flood risks identified within Crişuri Basin Water Administration is Valea Roşie river, an affluent of the Crişul Negru river.

Fig. 7. Location of areas with significant potential risk - Valea Roșie river

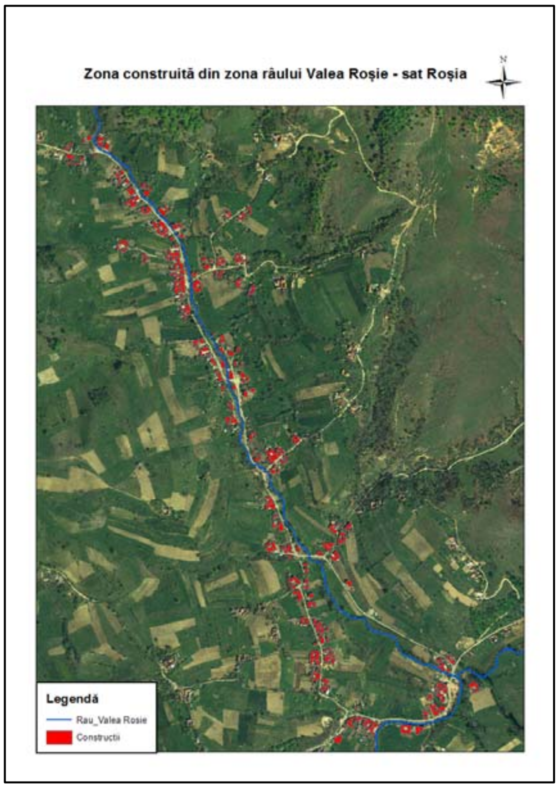
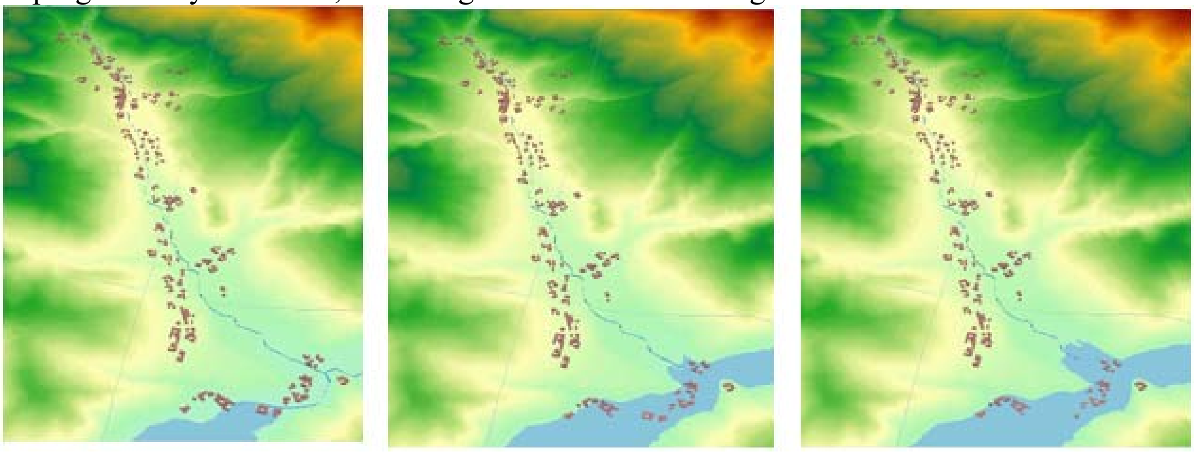


Fig. 8. Built area used for the flood simulation (257 constructions)

The area of interest is the residence village of the administrative-territorial unit Roşia with a population of 1979 inhabitants and 630 households, according to the 2011 Population and Housing Census.

Beside digital terrain model – from LAKI II, for the flood study, elements from TopRo5 database (Digital Topographic Reference Plan of Romania, corresponding to 1: 5.000 scale is a digital product of CNC) were used. Based on the TopRo5 building feature class, in ArcMap environment, a 3D polygon shapefile was created. The Height attribute of these features was added, using the pixel value from DTM. Using ArcScene, these constructions were extruded to a value of 5 meters above ground level.

Starting from the information above, the simulation began from a water level of 230 m and progressively increased, following the effects of flooding on the area of interest.



a) 245 meters b) 249 meters c) 250 meters

Fig. 9. Flood simulation for different flood height values

Tabel 1. Simulation results on the constructions

Height (m)	**Number of flooded constructions**
245	3
246	11
247	14
248	30
249	33
250	35

The most affected area due to possible floods will be the southern part of Roşia village.

- **Fusion of data from different sensors for Oradea and Arad Fortresses**

In this case study, LiDAR data and orthophomaps for the Bihor and Arad counties were used. The orthophotomaps were made with a ground resolution of 0.2 meters

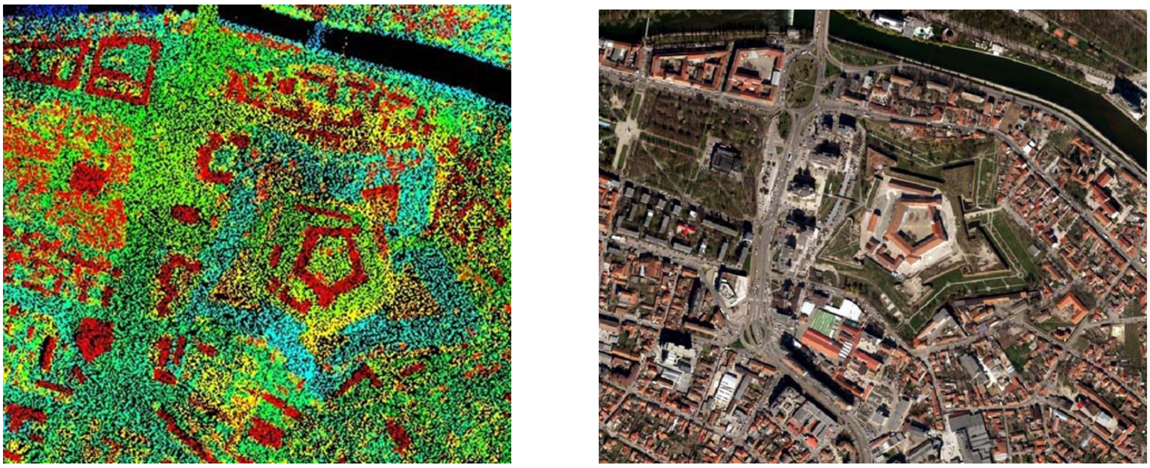


Fig. 10. Data used from the LAKI II - point cloud and orthophotomaps for Oradea

With Erdas IMAGINE software, each LiDAR point was assigned the RGB code from the corresponding pixel in the orthofotomap.

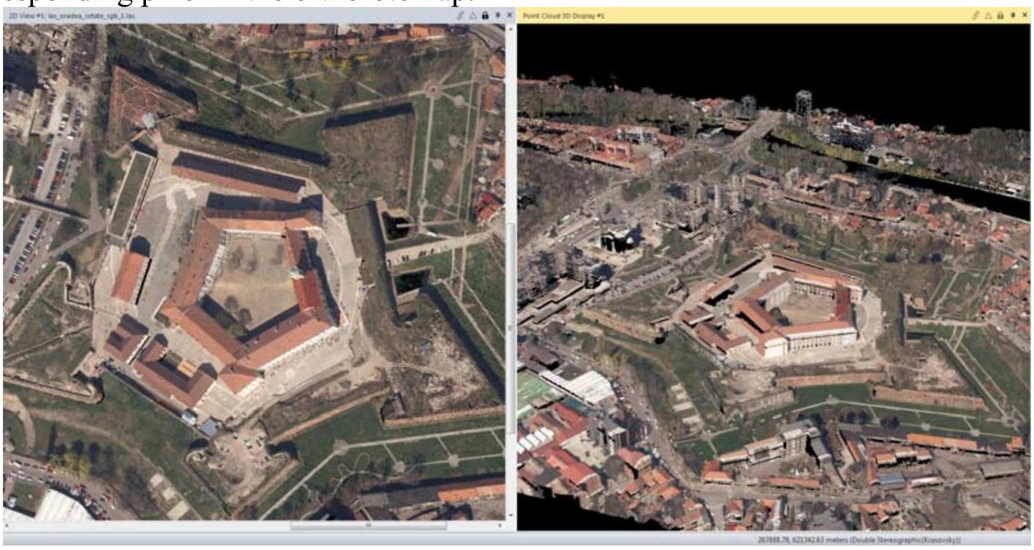


Fig. 11. RGB encoded point cloud for Oradea Fortress (2D and 3D view)

Fig. 12. RGB encoded point cloud for Arad Fortress (2D and 3D view)

After RGB encoding, building heights were measured to make a 3D model of the monuments.

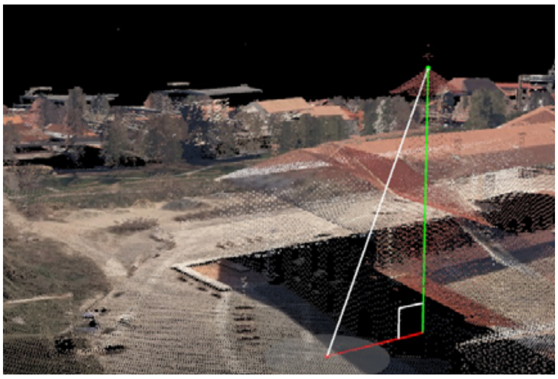


Fig. 13. 3D Building measurements

Fig. 14. 3D model of Oradea Fortress

Fig. 15. 3D model of Arad Fortress

- **Improving the final products of LAKI II for cities by generating higher resolution digital surface models**

According to the technical specifications of LAKI II project, digital terrain and surface models must be delivered with a resolution of 1x1 meters. After scanning the 10.000 km^2 area, the point cloud density from LiDAR was 60 pts/m^2, making it possible to generate digital models with higher resolution (10x10 centimeters).

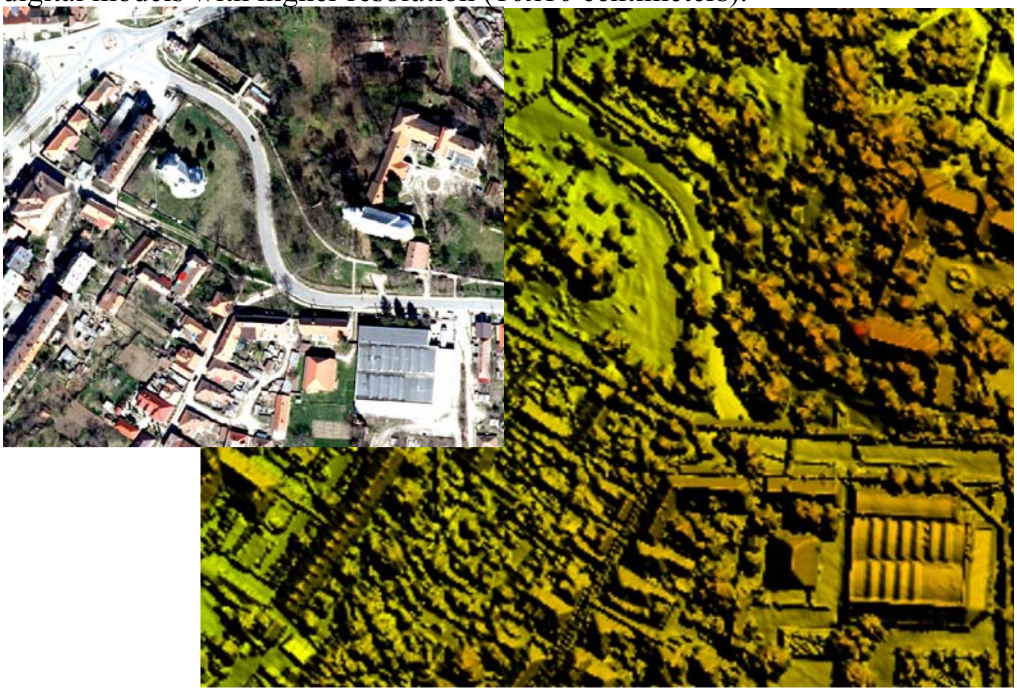


Fig. 16. Resolution of 1x1m - digital surface model for Săcuieni village, Bihor county

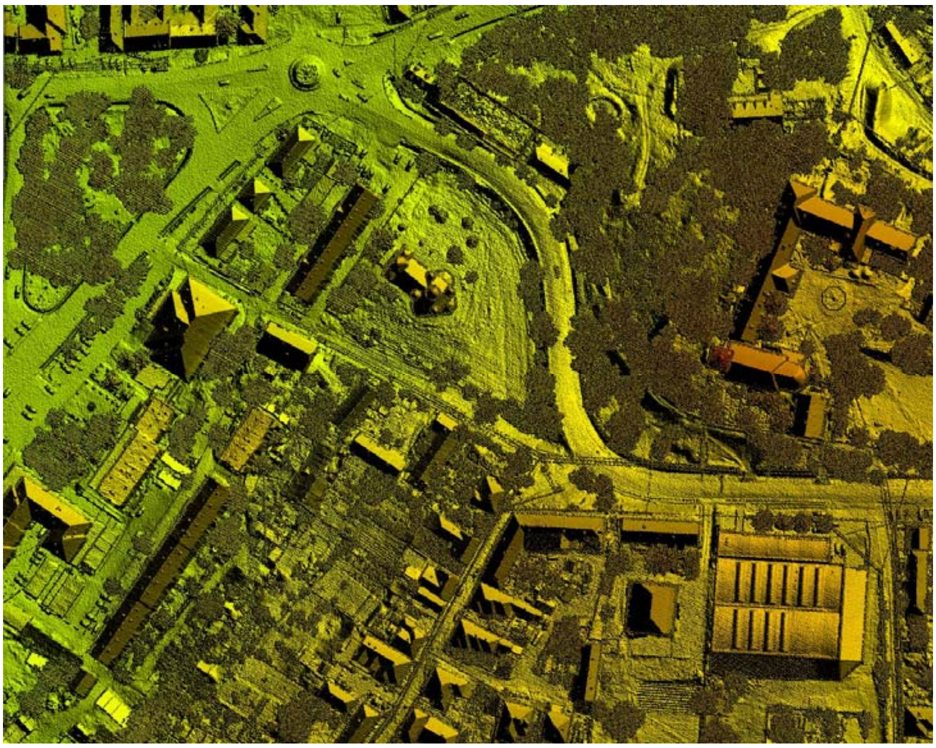


Fig. 17. Resolution of 10x10cm - digital surface model for Săcuieni village, Bihor county

4. Conclusions

The ability to process dense point clouds in an efficient and cost-effective manner has facilitated a multitude of 3D data acquisition applications in areas such as topography, environment, forest resource valuation, flood risk areas, etc.

World practice has shown that floods can not be avoided, but they can be managed and their effects can be reduced through a systematic process that leads to a number of measures and actions designed to help decrease the risk associated with these phenomena. Flooding studies and simulations are of utmost importance in preventive measures leading to the phenomenon as part of flood risk management.

Fusion of LiDAR data with orthophotomaps facilitates a better understanding of point clouds and more accurate 3D measurements.

Generating higher resolution digital surface models for cities improves the final products and future applications derived from them.

As future applications, CNC is considering the study of forest areas based on LiDAR data.

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