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THE FLOOD THREAT MAPPING OF THE KOLUBARA RIVER BASIN USING THE LEICA ALS80HP LASER SCANNER

Abstract:

Every year, floods cause great damage in the Republic of Serbia. The lack of solutions for flood risk management and prevention during their escalation causes great financial deficit. One of the solutions for achieving stability in this sphere is creating a map of flood threats and risk according to the European Flood Directive. The task of the IPA2014 action is the creation of those maps using the latest technology in laser scanning of terrain, or LiDAR sensors. Scanning the terrain from air using the aforementioned technology gathers data which by later processing results in very precise digital models of terrain which are used as the foundation for mapmaking.

Key words *:Flood, Map of flood threats, LiDAR, IPA2014, Hazard maps*

КАРТИРАЊЕ УГРОЖЕНОСТИ ОД ПОПЛАВА СЛИВА РЕКЕ КОЛУБАРЕ ПРИМЕНОМ ЛАСЕРСКОГ СКЕНЕРА LEICA ALS80HP

Сажетак:

Поплаве сваке године нанесу велике штете у Републици Србији. Недостатак решења за управљање ризицима и превенцију од поплава приликом њихове ескалације изазивају велике буџетске дефиците. Једно од решења за постизање стабилности у овој сфери јесте израда карата угрожености и ризика од поплава сходно Европској директиви о поплавама. Задатак пројекта ИПА2014 јесте израда тих карата применом најсавременије технологије у области ласерског скенирања терена односно LiDAR сензора. Снимањем терена из ваздуха користећи поменуту технологију прикупљају се подаци који у каснијој обради резултују врло прецизним дигиталним моделима терена који служе као основа за израду карата.

Кључне ријечи: поплава, карта угрожености од поплава, LiDAR, ИПА2014, карте хазарда

1. INTRODUCTION

Flooding is the most catastrophic natural phenomena causing extensive damage to human life, environment, and infrastructure. Although it cannot be prevented, it is possible to reduce the risk of true flood modeling. The constant problem with flooding activity in the Republic of Serbia, particularly the flooding that happened in May 2014, lead to the conclusion that the process of risk management and especially flood prevention must be taken very seriously at the national level, as well as raising awareness of the issue.

Flood modeling techniques are mostly based on the Digital Terrain Model (DTM) and projected water level [1, 2], therefore the reliability and accuracy of flood risk maps are highly dependent on the accuracy and resolution of DTM model. Remote sensing, covering a large geographical area at the different spatial, spectral and temporal resolution, provides a large amount of data that has been extensively used for flood management.

Airborne light detection and ranging (LiDAR) have become a widely-used remote sensing method that provides a rapid collection of high-resolution topographical datasets. LiDAR has become one of the most used data sources in flood modeling [3, 4]. However, all those applications are built around the generation of DTM using a raw point cloud. The point cloud is represented as a set of 3D points where each point Pi is a vector of its coordinates (Xi, Yi, Zi). The raw LiDAR point cloud contains the ground and non-ground points. The DTM refers to a bare earth surface created by interpolation of ground points therefore the classification of point cloud need to be performed. The classification methods can be divided into filtering algorithms [5] (mostly based on geometrical features of 3D ground points) and deep learning algorithms [6].

Flood prevention in the Kolubara river basin is just one small piece of the puzzle of comprehensive flood prevention in the Republic of Serbia. Therefore, the IPA2014 action which is executed by many state institutions from different areas is a great chance to approach the problem of flooding more seriously.

The main aim of this paper is to present in detail the process of creating a flood threat map using descriptive metodology, based on a local territorial framework, the Kolubara river basin. The whole process is viewed from a general perspective, due to the technological impossibility to view the details of the process from a local level. On the other hand, the whole process of making a flood threat map of the Kolubara river basin within the IPA2014 action is still ongoing, so at the time of writing a map of flood threat of the Kolubara river basin does not exist. Therefore, analisys of the maps quality and accuracy itself cannot be done. It should be noted that some period of time after the publication of this map will be possible to analyze their engagement and usage.

Cartographic idea for a flood threat map at a local level of the Kolubara for the wider area of the city of Valjevo is enclosed.

2. GEOGRAPHICAL STUDY OF THE KOLUBARA RIVER BASIN

The Kolubara river basin lies in the northwest part of Serbia. „The shape of the basin is roughly rectangular and is lined with low or middling mountains of the Valjevo and Sumadija region. On the fourth side, northward, the gently rolling hills spread out into the Pannonian plain. Kolubara is the last tributary of the river Sava, flowing into it 27km upstream from Belgrade. The mouth of Kolubara lies at 76m above sea level, while the highest point of the south river divide is Povlen, located at 1346m above sea level" [7]. On the territory of the Kolubara river basin are the parts or whole territories of the following municipalities: Obrenovac, Barajevo, Sopot, Lazarevac, Koceljeva, Vladimirci, Šabac, Osečina, Ub, Lajkovac, Mionica, Ljig, Aranđelovac, Gornji Milanovac and Kosjerić, as well as the city of Valjevo with a population of 335.000 people [7] (Figure 1).

"The Kolubara river basin has a very unfavorable water regime, created by the hydro-meteorological, topographic, geological, and hydraulic conditions in the basin. Unfavorable temporal and spatial distribution of precipitation and great drop of its tributaries with an unfavorable distribution of hydrographical flow network, regularly cause fast and concentrated confluence of waters on a proportionally short section of Kolubara's central valley. The hydrographical network is such that it enables large quantities of waters from the tributaries to coincide in the central part of the Kolubara valley, with spilling of floodwaters on the spacious plain. The unfavorable condition of sudden water inflow is amplified by the insufficient permeable power of the Kolubara river bed in the plain to be able to take such a vast concentrated flow into the main recipient – the river Sava, which causes frequent flooding in the valley" [7].

Figure 1. *Kolubara river basin [7]*

The floods in the Kolubara river basin have always been an ongoing issue. The most extreme examples are the floods from 2014 and a flood that caused similar damage in 1926. Besides those, numerous examples tell us that Kolubara and its tributaries tend to flood multiple times per decade.

3. THE METHODOLOGY OF CREATING A FLOOD THREAT MAP AND A FLOOD RISK MAP

The methodology of creating a threat map and a flood risk map was defined by regulation from 2017 ("Regulation on determining the methodology for the creation of a threat map and flood risk map") which defines the basic rules of its creation. The methodology defines some concepts which concern this paper, which should be highlighted [8]:

- *flood*–temporary water coverage of ground that is usually not covered by water, and includes flooding by outer waters and floods by inner waters;
- *flood area* – area at risk of flooding;
- *significant flood area* – flood area where significant flood risks are present or can appear;
- *flood threat map* – cartographic display of flood area borders, water depth and, if needed, speed of water in certain flood scenarios, and
- *geographic information system (GIS)* – computer system meant for collection (integration), processing, managing, analysis, display and maintaining spatial information.

A map of flood threat by inner waters for a specific scenario must show [8]:

- flood area border,
- water depth, in four classes (depths <0,5 m; 0,5 – 1,5 m; 1,5 – 4 m; и >4 m), and
- existing facilities for protection against flooding by outer waters.

The flood area border is defined by transferring the computational level of water to the GIS environment. It is a vector (polygon), obtained by a cross-section of the water mirror plain with a digital terrain model. Flood area borders and water depth, in case of internal water flooding, are determined by using the available meteorological, topographical and other data depending on the requirements of the models applied to the calculation. Water depth in a certain flood scenario is the difference between the water level and the digital terrain model. „It is recommended that the risks within the border of the realistic area are displayed with polygons/lines/dots/marks in different colors, while risks in the potential flood area are marked in the same way, in lighter shades of the same colors" [8].

These maps should be available to the public administration body which is in charge of spatial planning to consider different scenarios and make decisions.

After the catastrophic floods that hit the Republic of Serbia in 2014, which have caused the most damage in the Kolubara basin, the Republic of Serbia quickly started developing active measures of flood prevention. The Republic of Serbia saw a chance for establishing the technological framework by using the pre-accession funds of the European Union (IPA funds). In the wake of those efforts and with the support of the European Union (EU) the IPA2014 action was started (IPA – Instrument for Pre-Accession Assistance).

The IPA2014 action represents the initiative of the Republic of Serbia and EU in the rehabilitation of the damage made by the catastrophic flooding that impacted the western part of Serbia due to heavy rainfall in the third week of May 2014 and prevention of further potential flooding in the future. That help is reflected in the items of the action document which the European Commission set to the Government of the Republic of Serbia which states that the EU will donate 62 million euros and provide guidelines for project implementation. During the May 2014 floods 200 mm of rain fell in the area of west Serbia in just a week, which equals three months of continued rainfall under regular circumstances. Along with rainfall in the rest of Serbia, that impacted the rise of water levels of the rivers Sava, Tamnava, Kolubara, Jadar, West Morava, Great Morava, Mlava and Pek. During the flood, around 32.000 people were evacuated from their homes, and around 1,6 million people were directly or indirectly involved in providing various kinds of aid towards rehabilitation and prevention of further consequences, both privately and within relevant institutions [9]. The European Directive on flood risk assessment and management together with the Directive 2000/60/EC practically reduces activities regarding flood risk into three-element procedures: *preliminary flood risk assessment, risks assessment within which threat maps and flood risk maps are made, and plans for flood risk management* [10, 11]. In accordance with that, one part of the obligation is the creation of the mentioned maps. This paper concerns the creation of flood threat charts and not flood risk charts, and its contents are oriented accordingly.

The carriers of the project are also the Ministry of Agriculture, Forestry and Water Economy, Republic Water Directorate, Republic Geodetic Authority, Ministry of Defense - Military Geographical Institute (MGI) and Air Force capacities and air defense of the Serbian Armed Forces, Republic Hydro-meteorological Service of Serbia, public water management companies „Srbijavode" and „Vode Vojvodine" [12].

„The Ministry of Defense is recognized as the carrier of the implementation of the project, while the Military Geographical Institute is recognized due to its achievements in the field of cartography as the national cartography institution capable of performing the necessary measurements in their capacity, as well as collecting and initially processing the terrain data required for the creation of flood threat chart. For that purpose, and according to the specification of the Republic Geodetic Authority and Military Geographical, the EU has approved the acquisition of equipment for realization of the necessary aero photogrammetry and LiDAR scans, and the realization of fieldwork and further processing of the measured/collected field data" [9].

This paper deals with the entire process of collecting and processing the data for the needs of creating a flood threat map, which can be described in the following phases:

- Defining the area of the survey in accordance with the Preliminary flood risk assessment for the territory of the Republic of Serbia.
- Flight planning to scan the area of interest using the LiDAR system.
- Scanning the area of interest using the LiDAR system.
- Orientation, calibration and other operations of initial processing the collected data
- Point cloud classification.
- Generating digital terrain models.
- Generating hydrographic and hydrological models.
- Map creation process.
- Integration into the Water information system (WIS).

In all those phases, the integration of the data from local government, relevant and authorized institutions and field works should be gained. The ultimate contribution of these maps and hydrological and hydrographic models within digital terrain models (on which the map rests) is to create conditions for an improved early warning and flood forecasting system as well as to advance the development of flood risk management plans through implementation in the WIS.

4. THE TECHNOLOGY OF CREATION OF A THREAT MAP OF THE KOLUBARA RIVER BASIN

4.1. The technological base for measuring and collecting data

„Laser scanning of the terrain is a modern technology for acquiring spatial data in the form of coordinate points in space. In regards to the type of scanning, laser scanning can be terrestrial and aerophotogrammetrial. In both cases, collected data can be used for the construction of digital, two-dimensional sketches or 3D models, whether it is a digital terrain model or a model of a separate object. The ultimate advantage of this method is high accuracy and speed. When it comes to laser scanning of terrain from air, it is done from an aerial platform which can be a helicopter, airplane, or an unmanned aerial vehicle. The significance of spatial data and their application is increasing. This especially applies to the creation of 3D city models, various engineering projects, collecting DTM data for the needs of ortophotoreproduction and creation of geodetic bases of large and middle-size” [9].

“Laser scanning is not a replacement for the existing techniques of geodetic survey but is an alternative which can be used is most geodetic operations. The scanning is done by the already familiar method of registering the distance and angle of a certain point in the study area. The result of laser scanning is a group of three-dimensional XYZ points which is called a point could. The spatial distance between adjacent recorded points within a point cloud depends on the proximity of the recorded object and the technical specifications of the instrument itself ” [13]. Along with spatial data a point cloud can also contain the intensity of the color reflected from the surveyed surface. The color data are determined based on the intensity of the reflected beam and the records of the camera which is an integral part of the laser scanner [13].

LiDAR is a synonym for the laser method of terrain survey. The name LiDAR is an acronym made form „Light Detection And Ranging” which would describe the method of distance detection aimed at examining the Earth’s surface [14]. With this method, the distance is measured based on light, or laser impulse. In combination with data from the aerial platform system and orientation, we generate precise three-dimensional data about the topology of the Earth's surface and their characteristics, which is what forms the digital terrain model – DTM [9, 14]. The basic components of the LiDAR system are a laser scanning unit, GPS receptors on a platform and at a ground station, a unit of the inertial navigational system with the inertial measurement unit (IMU) and a data storage and processing unit [15, 16].

The ALS80HP, in the name of the laser scanner used for the IPA2014 action Leica, stands for „Airborne Laser Scanner” which is a laser scanner meant for recording from an airborne platform, while the HP defines a model for general-purpose recording meant for altitudes up to 3.500 m above ground [16].

4.2. Laser SCANNING USING THE LEICA ALS80HP SYSTEM

When speaking about aero photogrammetry and LiDAR technology recording, we are speaking about sensors that are mounted on aerial platforms. Those platforms can be airplanes, helicopters, satellites, unmanned or any other aerial vehicles.

4.2.1. Flight plan concept and distance exploration method

As the LiDAR survey, projected within the IPA2014 action, need to be done using an airplane, the explanation of the flight planning concept will be made for that example. To conduct an aero photo survey and scanning of terrain by airplane it is necessary to determine numerous parameters that will ensure that the procedure is as efficient as possible, and the product of recording as precise and relevant as possible [17]. For the needs of the IPA2014 action for laser scanning of around 9.4km^2 the following instructions are given [18]:

- Point density must be greater than or equal to 5 points per meter square for plains areas and greater or equal to 8 points per meter square for hilly areas.
- The ratio of mean point distance in the direction of flight line (dx, Along-track mean spacing) and mean point distance relative to the direction of flight (dy, Cross-track mean spacing) must not be greater than 2 to 3 to ensure the homogeny of the collected data.
- Laser scanning should be done with a projected 30% cross overlap of scanning lines. Deviation from the realized scanning lines cross overlap must not be greater than a third of the cross overlap.

- The GNSS station network „AGROS" of the Republic Geodetic Authority needs to be used. The distance between the aircraft and the permanent (or virtual) GNSS station at all scanning points (including the turnaround of the aircraft) must not be greater than 30km. To conduct laser scanning at least two permanent (or virtual) GNSS stations are to be used.
- The tilt of the aircraft during turnaround for next row scanning must not be greater than 25^{o,} to avoid an unfavorable satellite constellation.
- During data collection, the „8" flight procedure must be applied before and after the completion of LiDAR scanning.

To fulfil these requirements, it is necessary to plan the flight path the airplane will be taking, at what speed and altitude, and that explain the essentiality of the flight plan. An indispensable component required for flight planning is the base – the DTM. It is recommended to always use the most accurate available DTM of the recorded area. If we do not have one or it does not exist, we can use the global DTM – Shuttle Radar Topography Mission (SRTM). The accuracy of the SRTM is significantly lesser than digital terrain models at national or local levels, but it can still provide support during flight planning [17].

4.2.2. The realisation of terrain scanning using the LEICA ALS80HP system

Flight realization and terrain survey is done in accordance with separating the recorded territory into polygon „strips" (Figure 2). That is the actual shape defined by a point from the project task set by the IPA2014 action regarding the ratio of mean point distance in the direction of flight and relative to the flight line. In the middle of each strip, we can define a flight line that is used to graphically representation of every flight plan. The survey is done in order, by flight lines, so that the airplane does a turnaround after every recorded line to record the next line in the opposite direction. The surveyed territory on two adjacent flight lines has a cross overlap of 30% because it is necessary to ensure the comprehensiveness of the recorded content during recordings on all flight lines [17].

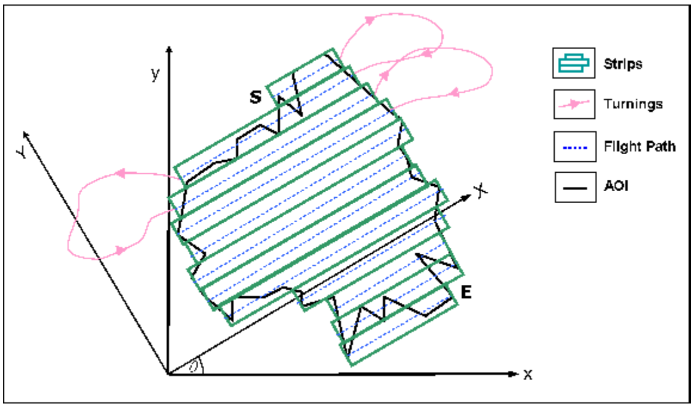

Figure 2. *Graphic display of flight plan with recording range marks by flight lines [17]*

Flight planning requires the optimal relation between the laser scanner, the aircraft, the navigation subsystem, terrain characteristics, and other components. Also, the flight plan defines the manner of turning to the next flight line, the angle of airplane rotation while turning as well as the process of initiating the systems for starting and finishing the recording. As stated above, the tilt while turning to scan the next strip must not be greater than 25^{o} to avoid an unfavorable satellite constellation [16, 17]. The flight path trajectory during one recording is shown in Figure 3. A red rectangle on the image marks the parts of the flight path to which the "8" procedure refers to the project task. It represents a mandatory procedure during flight, before and after completion of LiDAR scanning which initiates and stops the IMU laser scanner subsystem during recording [16, 17]. Underlined in red are the permanent stations of the AGROS network, which must not be at more than 30 km distance at any point of recording (including the aircraft turnaround), whether they are permanent or virtual [16]. The Active Geodetic Reference Network of Serbia (AGROS) is a network developed on the territory of the Republic of Serbia as support for performing precise positioning. It consists of 30 permanent GNSS stations which are used for continuous GNSS observation, positioned at an approximate distance of around 70 km, which are mostly placed on local cadastre buildings. The network was created in 2005 by the Republic Geodetic Authority in cooperation with the Faculty of Technical Sciences from Novi Sad. The path which the airplane took to reach the area of recording can be seen in Figure 2. That path is particularly curved due to the density of air traffic, another factor that is taken into account for recording planning. There is another important detail when it comes to initial turnings and permanent stations, and it is that the distance between the initial turnings and permanent stations must not be greater than 20 km which is recommended by the manufacturer, and the maximum distance between the final point of the recorded area and the station is 30 km for the needs of the project [17].

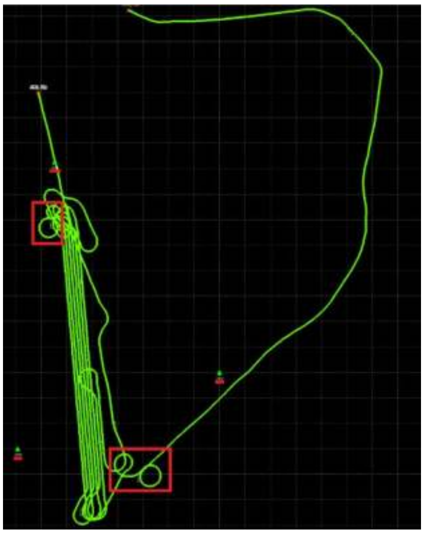

Figure 3. *Flight trajectory display during recording with marks for initial turns and permanent stations [17]*

The Kolubara river basin area meant for recording is large and demanding. Many tributaries that figure into the basin and Kolubara's meander influenced the recording so that it has to be done partially by areas. It is required that the Kolubara be recorded in 7 parts, as well as recording some of its tributaries separately [17]. Figure 4 shows the areas of recording the Kolubara basin by polygons.

Figure 4. *Sectioning the Kolubara river basin into recording areas [17]*

An image of the study area does not tell us much about the method of recording or approaching the area. In Figure 4 we have a display of sectioning the area of recording with flight lines figured for every territorial unit (Figure 5) [17]. The image displays the complexity of planning the recording of the entire territory, considering the variety of angles of flight lines for each territorial unit.

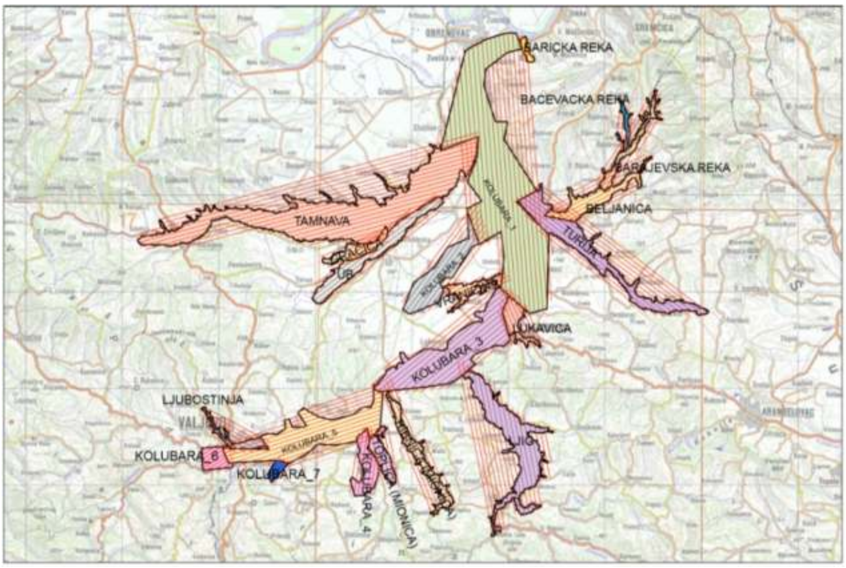

Figure 5. *Flight line display on worksites of Kolubara water basin [17]*

4.3. Processing the data collected by using the laser scanner leica als80hp

Immediately after executing the flight and laser scanning, it is required to conduct the preliminary data control of the GPS/INS systems, which includes checking for interruptions in data collection, controlling for data coverage of the area of interest, control of data collection interval and controlling the minimal number of satellites during the scanning. Obtained data is also controlled through checks of data coverage of the area, checks of completeness and accuracy of collected data and checking the density of the collected point cloud. Also, after the realization of the flight and scanning, the graphic part of the conducted flight plan is created and it contains the border of the scanned area, marked scan lines and executed flight directions and the absolute height of the realized flight for every scan line. The used geodata has the same characteristics as the one used for flight planning. If these preliminary checks find errors and omissions, it is necessary to conduct the scanning of those areas again. The goal of data processing is the creation of the DTM, which will be spoken of afterward [17].

Processing the data collected by using the laser scanner, is done in the software package of the company Leica with the programs MissionPro, FlightPro, NovAtel Inertial Explorer, CloudPro and also in the software package Terrasolid, which contains the programs TerraScan, TerraPhoto, TerraMatch and TerraModeler [16, 17].

4.3.1. Processing the recorded data

Trajectories of the flight provide us with information about the position and placement of the laser scanner for every point during the data collection in GPS and IMU. When we enter the trajectories and points it is necessary to connect every point with a precisely determined flight line. That way every point receives information regarding its creation and time [17].

The first step in data processing is the initial classification of points from the point cloud, which is automated to a certain extent. That means that the points are being sorted in accordance with their height into basic point categories. The classification results are preliminary, i.e. this classification is initial; however, it is important since represents a starting point for the final classification process in the later stages by classes like the ground point, low vegetation, middle vegetation, high vegetation, buildings, low points, very high points, water, and bridges [19].

As raw data, the point cloud was an undefined group of points without the ability to recognize the nature of objects present on the terrain as possible after the classification. Figure 6 shows the display of the point cloud after the classification from two perspectives was conducted.

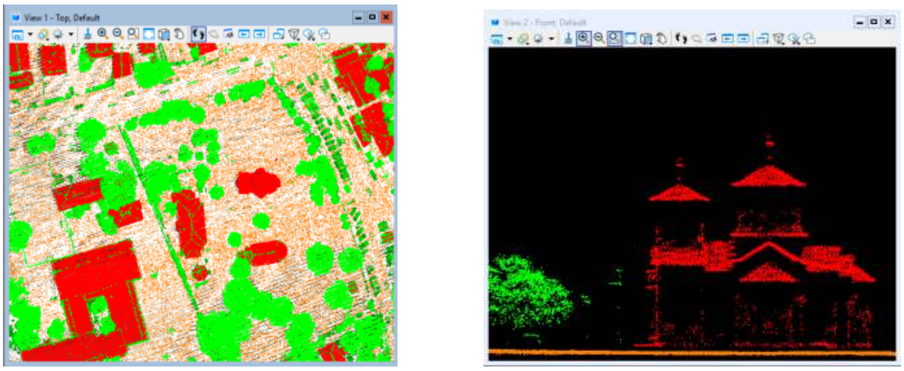

Figure 6. *The display after the classification from above (left) and from ground level (right) [19]*

After that, the relative orientation is conducted, which represents determining the position of the scanner during the survey in relation to the plane. It is performed by using data collected by the IMU during the flight, and concerns the movement of the plane across the three axes during the flight, explained in the part of the paper concerning the instruments. The next processing phase is HRPM correction which represents the correction of the factor of plane movement across the three axes during the flight (Heading-Yaw shift, Roll shift, Pitch shift) and the Mirror Scale parameter which represents the factor of the reflective mirror in the sensor [17].

During data processing calibration parameters are also introduced. According to the manufacturer's specification related to terrain calibration of the system, to achieve the highest accuracy of results, it is required to calibrate the system during one period of operational work. That means that after every change (conducting the scanning from the air by using other sensors, reinstallation of the system inside the aircraft...) the calibration needs to be done. Also, calibration must be executed in order to have a guarantee of the surveying consistency for the large projects. After that, absolute orientation is done, which creates the spatial reference and the referential frame for scanned points, in accordance with points scanned on the terrain. Absolute orientation is conducted according to the grid of Ground Control Points which are scanned on the terrain of the study area using GPS technology [17].

The elevation of points is expressed in ellipsoidal heights due to the nature of GPS technology. Because of that, the heights at the end of the process are reduced to geoid heights, for which global parameters of the RGA are used, and are universal for the entire territory of Serbia [17].

In order to make a recorded point cloud as suitable as possible, the classification of the points will create conditions for the most appropriate use of the data and creation of the DTM which represents the foundation of the flood threat map [18]. Point cloud classifications concerning the IPA2014 action is conducted by the Republic Geodetic Authority [18, 19].

Basic principles for DTM creation are stated in the Technical specifications for preparation of the DTM used for hydraulic modeling during the process of flood threat map creation, which is made for the needs of the IPA2014 action. The following requests for creation of the DTM were defined by the Technical specifications [18]:

- The spatial resolution of the DMT should be 1,0 x 1,0 meter (GRID);
- Absolute elevation accuracy of the final product (DTM) on open terrain, made of durable material (concrete, gravel, landscaped area, etc.) and tilted no more than 20% needs to be better or equal to 0.15 meters;
- Absolute elevation accuracy of the final product (DTM) on terrain covered with tall grass, crops, shrubbery, trees and other forms of dense vegetation, as well as on densely populated areas needs to be better or equal to 0,30 meters. In areas with distinctly dense vegetation, swamps and on terrain with extreme configuration, the absolute elevation accuracy can be lower;
- The horizontal accuracy of the final product (DTM) needs to be better or equal to 0,5 meters;
- DTM as a final product will be delivered in a resolution of 1 m and ESRI ASCII raster grid format and in ASCII (xyz) format;
- Structural lines of high-value objects are delivered in ESRI 3D shape format; and

- Data composed of a defined class of objects of importance is delivered in the shape of point clouds generated by automatic classification and in ASCII (xyz).

In addition to the data collected using laser scanning, for map creation, the updated topographic maps, results of hydro-meteorological observation and hydrographical surveys are needed.

In order to create a quality digital orthophoto for the needs of the IPA2014 a digital aerophotommetric camera, Leica ADS80 was used. The time between the data collection by using the laser and aerophotommetric systems cannot be larger then 15 days. A digital orthophoto is necessary during Point Cloud classification, as all ambivalences and doubts encountered during the processing of points are eliminated by evaluating the terrain using an orthophoto of identical terrain [18]. Data collected by using the aerophotommetric method for the needs of the digital orthophoto creation is conducted in accordance with the provisions of article 7 to article 81 of the Regulation of topographic measurements and topographic-cartographic creations [20].

4.4. Integration of data for creation of A flood threat map of kolubara river basin within the IPA2014 ACTION

The integration of data for the creation of the flood threat map in the Republic of Serbia within the IPA2014 action presents a very important process composed of hierarchically orientated activities through which the data is passed to finalize the project or more precisely the final result – the flood threat map (FTM). Besides the flood threat maps, this project also has a goal of creating flood risk maps (FRM). The process of their creation is regulated by the Agreement of cooperation on the realisation of activities from the Action document for flood consequences relief, within the Instrument for Pre-Accession Assistance of the EU – IPA2014. Cooperation is achieved within the following institutions: Public Investment Management Office (PIMO), Ministry of Agriculture, Forestry and Water Economy – Republic Water Directorate (RWD), Republic Geodetic Authority, Ministry of Defence (MOD), Republic Hydrometeorological Service of Serbia (RHMS), Public Water Management Companies „Srbijavode" and„Vode Vojvodine".

The Agreement of cooperation defines a consulting body in the form of a foreign company with experience in developing flood risk maps. After taking over the processed data, the consulting company would create maps and within a detailed methodology that is in harmony with the general methodology of the Regulation on determining the methodology for the creation of a threat map and flood risk map. Also, the consultant has an obligation to train staff of the homestate water companies in the field of flood thret mapping. In this way, local water utilities would be introduced into the process of mapping so that could be done indepentent in future projects.

The institution operating within the Ministry of Defence is the Military Geographical Institute as an establishment that deals with research and development and production work in the fields of geodesy, photogrammetry, cartography, geographic information systems, cartographic reproductions, metrology and other geodisciplines with the goal of creating topographic materials [12, 21].

5. CREATION OF THE FLOOD THREAT MAP OF THE TEST AREA OF A PART OF KOLUBARA RIVER BASIN

The flood threat maps provide information about flood area borders, appropriate depth and/or water velocity for floods that have a certain probability of occurrence. The creation of these maps is achieved by using different techniques, such as hydrological and hydraulic modeling, based on a precisely mapped river bed and the surrounding coastal area. The process of generating these maps is quite complex and requires a very long creation period, as well as significant funding [8, 21].

These maps are created in accordance with the requirements pertaining to areas with potentially significant risk of flooding, defined in the European directive on the assessment and management of flood risks 2007/60/EC. This directive mandates the following [11]:

- Flood threat maps will include geographic areas that may be flooded according to the following scenarios:
- Floods with low occurrence chance, that is an extreme event scenario,
- Floods with a medium occurrence chance (time-reversal period ≥100 years),
- Floods with a high occurrence chance, if required.
- The following elements will be displayed for every scenario from paragraph 3:
- Flood reach (Boundaries of the flooded area),

- Flood depth distribution (water level),
- As necessary, flow velocity or rate of flow.

Flood threat maps as a result of the IPA action should display the results of the analysis of at least three high water appearance scenarios – with time-reversal periods of 50, 100 and 1000 years and in that way include floods with high, medium and low occurrence chance. Estimates of floods with time-reversal periods of 50 and 100 years take into account already existing embankments and as a result show *realistic flood zones* (threat maps). In cases where there is a danger of embankment collapse, a separate, appropriate hydraulic calculation is allowed for, and as a result, *Potential Flood Zones* are derived from it. However, calculations of floods with a time-reversal period of 1000 years do not take into account the existence of embankments (it is considered that they are significantly damaged by flooding and no longer stop overspill from the original river bed). The flood zones defined in this manner show the area of *Potential Threat* from extremely high waters [22].

Flood threat maps are a great help when setting priorities in the implementation of active measures and their possible funding, taking into consideration all relevant factors (population, socio-economic factors, environmental protection, etc.). Based on this and suitable analyses it is possible to identify the best options and sets of measures for minimizing the risk of floods. The most important activities are spatial planning and development control, goods system management (flood prevention, retention areas, river systems, roads, etc.), preparations for flood occurrences (flood detection, forecast, planning for emergencies), flood incident management and response (Notifying and alarming the population about flooding, emergency services activities, activities of health services and и authorities in charge of flood risk management, public involvement (organizations for community support). Those goals, as well as the measures for their implementation, will, in general, ensure that the Plan for flood risk management enables assessment, evaluation and in the end the reduction of hazards and flood risks in the best possible way. Besides that, these maps are used as aids when planning the construction and development of villages and cities [21]. All in all, these maps will serve to illustrate the expected final results of the implementation of suggested optimal flood risk management system within the IPA2014 action.

In order to show the entire process of flood threat of the Kolubara river basin map creation, activities on a specific test area are presented in this paper. To achieve the most representative illustration of all principles contained in this very complex process, the choice of the test area will be the city of Valjevo.

5.1. Flood threat map for test area creation procedure

To better understand the concept of creation of a flood threat map, we must review how the creation of such a map appears from a cartography standpoint while respecting the institutional framework of European directive which poses certain standards for creation.

5.1.1. Cartographic review of flood threat map creation

The cartographic display on these maps will contain all the usual elements of the main content, the topographic surface of the area, as well as roads, railroads, objects, borders, river bed area. Also, they can contain protective infrastructure and markings for a water accumulation area in case of flooding. These maps are derived from previously created hydraulic 2D and 1D models, statistical analysis, observation, and all of that based on digital terrain models. Water depth is represented on the map according to time-reversal and is stated quantitatively [22, 23].

Flood area borders are entered on the map – water level notch lines and terrain. The spatial distribution of the depth of flooding, shown in shades of blue, contains at least 3 classes, their borders defined according to criteria of traversability and the possibility of rescue. Depth display with 4 classes is the example with intervals 0,0 to 0,5 m; 0,5-1,5 m; 1,5-4,0 m, and > 4,0 m. In practice, a darker blue color is used to display floods of greater depth, while a lighter blue is used to display floods of lesser depth. This kind of display is clarified by the bathymetric scale in the legend so that the meaning of every shade is explained in accordance with the relevant cartographic rules [24, 26].

The European directive on the assessment and management of flood risks 2007/60/EC decrees that the ratio should be suitably adjusted and is not strictly defined, which gives the authors the freedom to decide on the best ratio [11].

5.1.2. Creation of the flood threat map ilustration process for a test area

The city of Valjevo is the optimal choice for a test area for a flood threat map for many reasons, and most of all because in the event of Kolubara flooding this area would sustain significant damage [8].

The tested area should encompass the entire territory of the city to better envision the comprehensive consequences of flooding in an urban and suburban area. When it comes to mapping creation for a tested area, it only represents the cartographic completion of the data collection and analysis process, which is done in segments for the whole Kolubara river basin. Taking into account only the data within the tested area, a representative sample was created – a flood threat map of the city of Valjevo. The map creation process was performed in the ArcGIS software package, which is an adequate choice considering the wide application it offers and the ability to integrate different types of data that are created during data collection and processing. A representative sample of a flood threat map of Valjevo on an orthophoto base with a spatial distribution of the depth of flooding displayed in different colors is included in the Addition. (Addition). The average elevation of Valjevo 185 meters above sea level.

5.2. Course of works and analysis of mapping resources

The World Bank has made a Grant Agreement with the Republic of Serbia, which defines that 3.689.750 euros should be allocated for this part of the project. Most of the technological acquisition was towards the Military Geographical Institute within the Ministry of Defence and Republic Geodetic Authority. These institutions represent the foundations when it comes to creating a flood threat map, considering that the project is based on LiDAR technology which rests upon the process of data collection and processing, which is conducted within activities of the Military Geographical Institute and the Republic Geodetic Authority [25].

The anticipated deadline for the completion of mapping the threat and risk of flood on the national level is the year 2020 so that the flood risk management plans could be implemented in 2021, to "catch up" with the 6-year cycle of map updating which is provided by the European directive on floods and Water Law of the Republic of Serbia [8, 21].

„Assessments reveal that the total consequences of the damage in the mentioned May 2014 floods amount to 1.525 billion euros, where 885 million euros (57%) of the total damage was too destroyed physical goods, and 640 million euros (43%) are losses in production or economy. Taking into account other areas which were indirectly impacted by the flooding, the number rises to 1.7 billion euros in damages" [21].

This quantitative illustration lets us put into perspective the ratio of invested financial resources against the potential damage which can be prevented or mitigated. Comparative analysis can confirm that all investment into flood prevention will return manifold [25].

6. CONCLUSION

Creation of the flood threat of the Kolubara river basin map, as well as maps of flood threats in general by using LiDAR technology required great dedication and work consistency as well as job training for data collection and processing. As a result of those activities, by processing the *point cloud* data, a DTM of very high accuracy is created (10 cm), serving as a quality base for the creation of flood threat maps [12, 18]. By integrating the data collected using other methods of geodetic survey and scanning (topographic and digital orthophoto bases, profiles of riverbeds, data from hydrographic and hydrological surveys), a quality base for the creation of hydrographic and hydrological models and flood threat maps is produced.

Application possibilities of the LiDAR technology and laser system Leica ALS80HP in the process of creation of these maps according to the requirements of the IPA2014 action are indisputable.

The main aim of this paper has also been achieved and in the practical part of the paper, the process for the creation of the flood threat for the local territorial framework (part of the Kolubara river basin) has been realized and described. The entire process of creation of the Kolubara river basin flood threat maps within the IPA2014 action is still on-going. For that reason, in the practical part of the paper, flood threat maps for the wider area of the city of Valjevo were created at the local level of the Kolubara river basin.

The role and importance of flood threat maps are indisputable. However, their creation represents just one phase in the entire process. Many other science and infrastructure activities are necessary for implementing flood risk management plans. Even though it is financially demanding, investing funds into the entire system of hydrographic and hydrological models, flood threat and flood risk maps, contributes to a proactive approach in flood prevention and protection. By using the Leica ALS80HP system, the process of high quality and accurate data collection is made significantly easier and notably faster, which brings to the end result – quality threat and flood risk maps. Comparative analysis can determine that the invested financial resources are justified in relation to potential flood damage. By implementing the IPA2014 action the potential damage can be prevented or mitigated, and the potential expenses of flood damage repair annulled or greatly reduced [21].

The Republic of Serbia needs to have professional staff capable of project implementation and tasks concerning management and flood risk prevention, and that is the great significance of the IPA2014 action, which would create a kind of initial national experience. Complete protection from floods does not exist, but with the correct approach and national strategy, it is possible to greatly reduce the consequences of the damage to their inevitable occurrence.

Due to still unfinished IPA2014 actions, the idea for further research is given with a focus on thorough methodological analisys of the project actions as well as analisys of completed flood threat maps.

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APPENDIX