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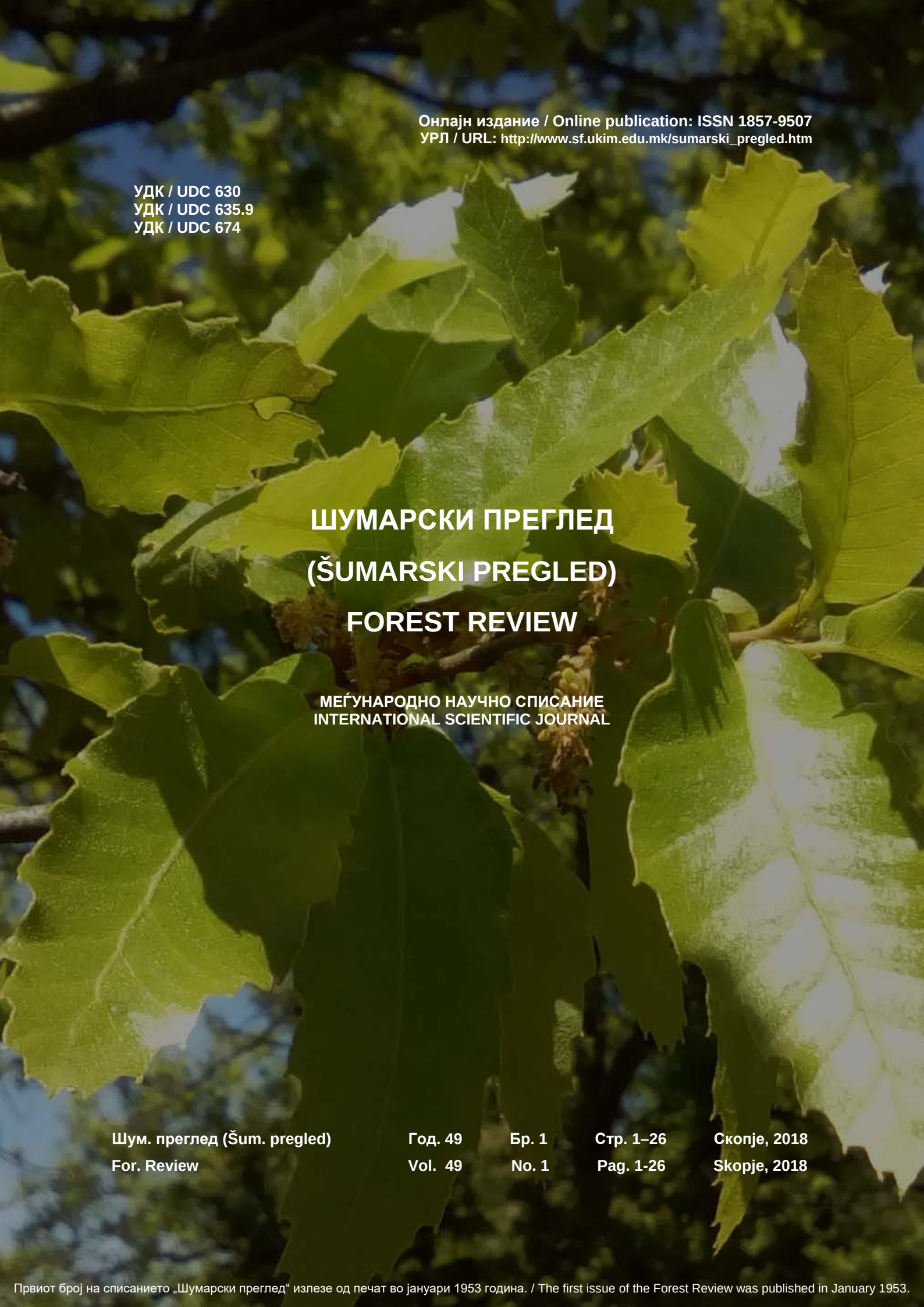

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Original scientific article

Use of modern geomatic techniques for creating and updating a green cadastre of urban trees and shrubs: a case study of Kumanovo city river bank

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ABSTRACT: The goal of this paper is to implement modern, up-to-date, geomatics technique and technologies in the environment. The base is made in GIS software, a GPS device is used to record detailed points on the field and for recording and preparing a new orthophoto was used a modern sophisticated drone DJI Mavic Pro. QGIS (Quantum Geographic Information System), as a key software, was used for computer data processing and recordings obtained from the field research, and other utility programs were used to perform the tasks. The subject of the article is the Kumanovo city promenade in Macedonia, which is a convenient place to try to implement this data processing method. The results obtained give us a map of the entire urban dendroflora on the river bank in the city of Kumanovo. In fact, an inventory of all trees and shrubs was carried out, 4 projections were prepared with the help of modern applications, and as the ultimate goal, and a web digital map of the riverbank was prepared. This method can be applied in forestry, agriculture, water management, geodesy, space planning, sustainable development and environmental protection.
Keywords: QGIS and GPS, drone, urban dendroflora inventory, geomatic techniques, remote sensing, Kumanovo

1 INTRODUCTION

The good appearance and preservation of nature is a wealth that needs to be passed on from generation to generation. The care for the environment and the overall natural environment becomes a moral responsibility of the whole community. With the great advances in the technologies in all spheres, as well as in forestry and urban areas, new transparent databases are created that will make it easier, more effective and safer to manage the environment [1]. In Finland, the City of Helsinki's Street and Park Division maintains a digital tree register (approximately 40,000 trees) that includes trees that are situated at road sides and some of the trees in the parks. The tree-register data includes information on the species, height, diameter-at-breast height (DBH), and geo-location. The tree-register data are used in urban and environmental planning, in locating old trees that are hazardous (for citizens), and in biodiversity monitoring [11]. A GNSS (GPS) or global navigation satellite systems is a very precise way to display the desired location. The accuracy dependents on the device itself, or data available on the base station, and of course the number of available satellites in the sky when the data is collected [2]. In recent decades, remote sensing (RS) techniques applied in forestry have been given an increased attention, which leads to the ability of extracting important information for forest planning and sustainable management [7]. There is also a method of collecting data on the exact location of the trees with the so-called Total Station. Today it is an indispensable instrument for geodesists, in fact, this instrument uses infrared rays to measure distance and automatically record and store it in its base. After the collecting of data is completed with this device it can be directly downloaded into a computer and entered into geographic information system (GIS). GIS gradually but surely becomes a valuable tool for demonstrating how natural and human-produced components communicate with one another. In many countries, GIS software is used as the main tool in many departments and sectors, in particular in (urban) forestry.

2 MATERIALS AND METHODS

2.1 Investigation area

The riverbank is located 1 km from Kumanovo city centre. This specific location is the subject of investigation because it is a great place with quite dense vegetation, and unique green space for implementation some new methodologies of work in urban areas. It extends over an area of 45,000 square meters and represents a new city infrastructure built in 2007 (Figure 1) with coordinates North 42.13573, 21.72777 and 42.13579, 21.72853. On the South, the coordinates are 42.12597, 21.73119 and 42.12616, 21.73225.

Figure 1: Satellite image of the Kumanovo city river bank (Google Maps, 2018)

2.2 Methods

This study started in August 2018, and the entire geo data base was developed in GIS software. GPS device was used to record detailed points on the ground, as well as for recording and for making a new orthophoto image from DJI Mavic Pro drone. First, the collection of field data using a GPS device as well as a collection of

attributes (species, diameter, height, canopy, damage, leaning) as detailed points, in this case, trees, was done. The collected data was processed into Excel table and used in QGIS software. Drone was used to record the entire space occupying the river bank in a pre-made map, using DroneDeploy© application (Figure 2). With the help of the drone, 2D and 3D models were made, as well as DEM (Digital Elevation Model) and health condition of trees and shrubs. Special layers displayed in GIS format were created and processed. As previously mentioned, drone is an unmanned aircraft that is driven from the ground. Controlling and using of the drone can be manual or automatically with a pre-made flight plan, or with the help of various applications that give the opportunity to create a map or route for the drone to fly. First step for using this application is to install it into a device (smartphone) that will be connected later with the drone controller. Creation of profile on DroneDeploy© gives the opportunity at any time to plan and edit new or old maps and flight plans [9].

Figure 2: Flight plan for drone created on DroneDeploy© application

In this case, the aerial image was taken on altitude of 100 meters with a pixel size of 3 cm, overlap of images of 70% and a maximum flight speed of 54.7 kilometres per hour. Recording of the imagery lasted 21 minutes and 241 photos were taken. In addition to the orthophoto, the application also offers a 3D projection of the marked space as well as elevation model and pictures showing the state of the urban dendroflora.

The processing of data collected from the field was carried out in the QGIS (Quantum Geographic Information System) platform version 2.18.25. Geo-referencing of footage, processing of collected GPS points (Waypoints), processing of excel tables; moving of GPS points was performed. Geo-referencing is most easily achieved with time-stamped GPS data recorded during the flight. It is typical uses of photogrammetry techniques to create a large and complete image [10].

Geo-referencing created orthophoto that is appropriately placed in the space, but since the footage uses a plain GPS system, the accuracy varies from 10 to 15 meters and the orthophoto recording is not absolutely precise and presented in the space. To correct this error, the orthophoto recording should be geo-referenced with a more accurate existing satellite image.

Excel spreadsheet processing is designed to simplify collection of data from the field. These are the attributes of woody species recognized with their scientific name, diameter in certain categories e.g. 0-5, 6-10, 11-20, 21-30 meter, etc. Category 'Damage' is created to obtain data on injuries, damages and other diseases, whether from the abiotic or biotic origin. There are four types defined: 'Trunk damage, 'Canopy damage', 'Fully damaged' and 'No damage'.

'Height' category coincides with the column 'Canopy' and here the parameters are taken in meters but in this table refer to the height of the tree itself. Prepared Excel file of inventory of our study is entered in the QGIS. Next step in QGIS software is moving GPS collected points of the field because each point make a certain "error" depending on the characteristics of the GPS device itself. The GPS device used to collect our data is with good positioning encounters of 2-meter error. With the processing of points, inserting them, as well as inserting a photo from the drone into the GIS software, the incomplete match of these two important elements has come to an end. Specifically, the GPS device for each point, in this case, the tree deviates for a certain distance. In order to complete this operation and processing, the GIS software offers the opportunity to move these points or move them to the desired position.

For woody plant identification species features and growth forms, certain literature for (urban) dendrology is used [14, 15, 16, 17, 18], and for recent nomenclature and taxonomy of the woody species, the plant database of World Flora Online [19] and The Plant List [20]. In addition, for the lower (hort.) taxa and the English common names the online Internet database of the Royal Horticulture Society [21] is consulted.

3 RESULTS AND DISCUSSION

3.1 Inventory of the urban dendroflora of the Kumanovo city river bank

With the inventory carried out in this area, 27 taxa of woody plants were identified, represented in 637 individuals. The list of the taxa and the number of individuals (where applicable) is presented in Table I, ordered alphabetically by species' scientific name.

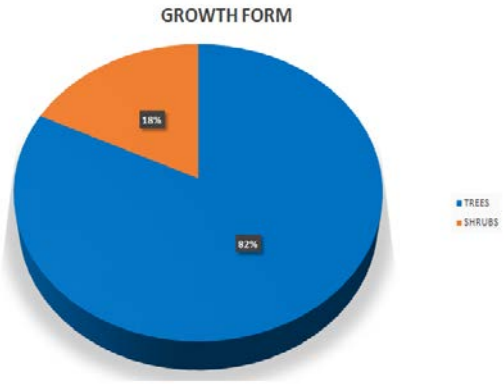

Figure 3: Growth form of the urban dendroflora of the Kumanovo city river bank

3.2 Analysis of the urban dendroflora of the Kumanovo city river bank

Analysing the Table I, there are 5 species that are dominant in this area. The most prevalent is *Fraxinus americana* L. (170 trees), which is distinctive for parks of this kind that require avenues near river. Also, a large percentage are willows: *Salix babylonica* L. (32), as well as *Salix babylonica* var. *pekinensis* 'Tortuosa' (f) (53),

which also form an avenue along the banks of the Kumanovka River. A good percentage of representation is found in the species *Catalpa bignonioides* Walter, *Platycladus orientalis* (L.) Franco, and *Cupressus arizonica* Greene. These quantitative and qualitative results are very important step in any inventory. In fact, that information or the inventory itself gives us the knowledge of what we actually have in the green area and what measures in the future should be implemented, in order to maintained urban green areas

Table I: Inventory of the urban dendroflora of the Kumanovo city river bank

Scientific name	Number of individuals
Acer negundo L.	1
Acer platanoides L.	7
Acer saccharinum L.	7
Catalpa bignonioides Walter	79
Cedrus atlantica (Endl.) Manetti ex Carrière	11
Cedrus deodara (Roxb. ex D.Don) G.Don	10
*Celtis australis*L.	5
Cupressus× *leylandii* A.B.Jacks. & Dallim.	22
Cupressus arizonica Greene	53
Cupressus sempervirens L.	1
Fraxinus americana L.	170
Juglans regia L.	1
Juniperus horizontalis Moench	1
Koelreuteria paniculata Laxm.	3
Morus alba L.	6
Picea abies (L.) H.Karst.	37
Picea pungens Engelm.	11
Pinus wallichiana A.B.Jacks.	5
Platycladus orientalis (L.) Franco	78
Prunus cerassifera 'Nigra'	7
*Quercus frainetto*Ten.	2
Salix babylonica L.	32
Salix babylonica var. *pekinensis*' Tortuosa'(f)	53
Thuja occidentalis 'Smaragd'	7
Thuja occidentalis L.	19
Thuja plicata Donn ex D.Don	3
Tilia tomentosa Moench	6
Total:	637

After realized collection of attributes and inventory phase, the next phase is processing the same input into the GIS software, as well as the production of statistical data that will give a detailed picture of what kind of green area is about. In few photos will be presented some statistical data obtained from the inventory.

On Figure 3 it is given the percentage of trees represented in comparison with the shrubs. Given the shape and surface area of investigated area as well as the obtained data from Table I, we can conclude that there is a large representation of trees, as much as 82%, comparing to shrubs with 18%. This is due to the observed two avenues, i.e., *Salix* species along the bank of the riverbed, as well as the avenue of *Fraxinus americana*, which follows Oktomvriska Revolucija Blvd. in length.

One of the important attributes of each inventory is the height of the species that are subjects of this type of work. In the investigated area, the results are shown on the Figure 4.

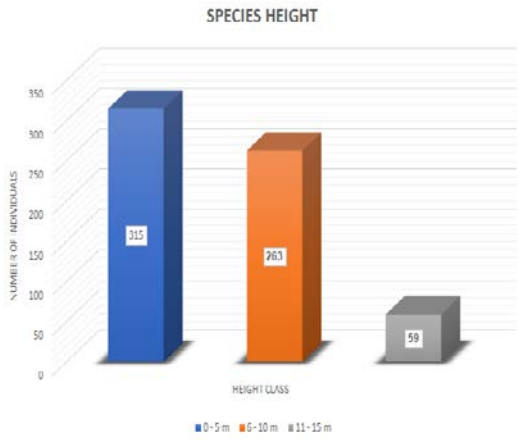

Figure 4: Species height of the urban dendroflora of the Kumanovo city river bank

As can be seen, this is a relatively new green area, i.e., 315 woody plants are at a height of 0-5 m, 263 individuals are at a height of 6-10 m, and 59 individuals are at a height of 11-15 m.

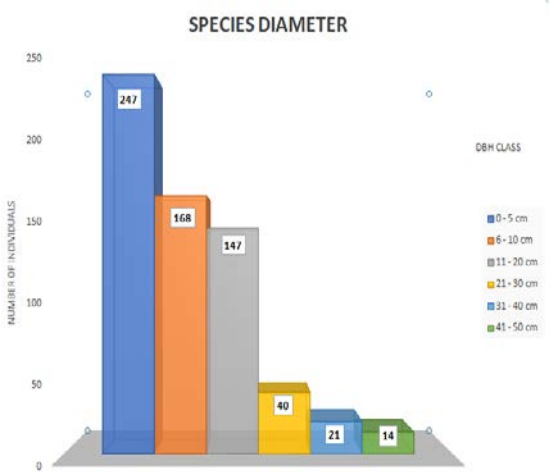

Figure 5: Species diameter of the urban dendroflora of the Kumanovo city riverbank

Along with height and diameter, we actually get a picture of what kind of individual is about So, Figure 5 presents the current state concerning the diameter of the identified woody plants in the investigated area. A good percentage of dendroflora has a diameter of 0-5 cm in 253 representatives, diameter of 6-10 cm in 168 representatives, and a diameter of 11-15 cm in 147 representatives.

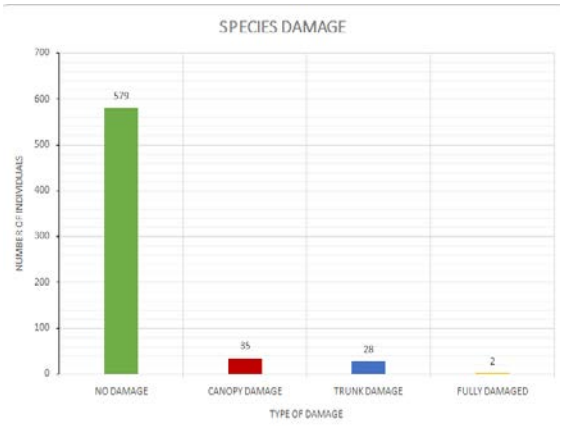

Figure 5: Species damage of the urban dendroflora of the Kumanovo city river bank

Significant importance for each plant is the state of health and vitality. By applying modern geomatics techniques and the use of modern devices to monitor the environment, we can fully discover the condition of all of them. On the Figure 6 it is observed that the whole area in large percentage is in healthy and good vital condition, in fact 88% of the total number of trees and shrubs on the investigated area. We have analysed a slight percentage of damage in damage of the canopy and damage of the main stem (trunk), and fully damaged are only 2 individuals (which are actually the consequence of anthropogenic factor).

Overall, main aspects and functions of the plant design [22] of the Kumanovo city riverbank are met.

3.3 Obtained projections in DroneDeploy© application

As previously stated, the filming of the investigated area lasted 21 minutes and 241 drone images were prepared. By processing them in the DroneDeploy© web platform and application, 4 projections were provided that represent a powerful tool and a preview image of the correct data for the objects investigated. First projection (Figure 7a) is orthophoto with excellent picture quality and resolution with 3cm pixels. In aerial photogrammetry the sensor is on a drone and is usually pointed vertically down toward the ground. When the sensor is pointed straight down it is referred to as vertical or nadir imagery. Multiple overlapping images are collected as the sensor flies along a flight path.

The second projection (Figure 7b) represents a projection that gives us accurate data on the height of the area concerned (Digital Elevation Model DEM). DEM represents a very important geospatial data type in the analysis and modelling of different hydrological and ecological phenomena, which are required in preserving our immediate environment. DEMs are typically used to represent terrain relief [10].

The third projection (Figure 7c) give us information on the state of the trees themselves, in particular, the state of the health of the urban dendroflora. 'Plant Health' is a tool specifically targeted towards agriculture. The main purpose of the 'Plant Health' projection is to allow you to explore your data even more deeply. You can adjust the contrast to highlight variability within any field.

Once you have identified the relevant plant health ranges, the thresholding tool lets you quantify damage and predict yields by showing the area within a specific range [8].

The last projection (Figure 7d) shows the three dimensional model of the entire research area. This demonstration of the desired area is one of the state-of-the-art projections in geomatics techniques in the last decade. For the complete picture of the entire area, you can check the link in the References chapter [13].

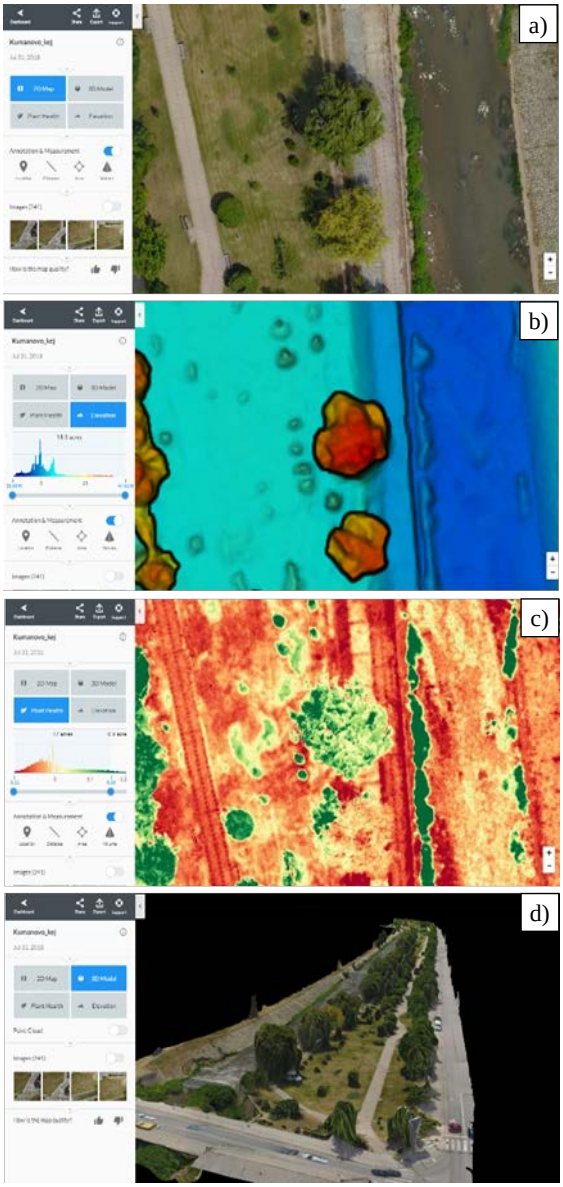

Figure 6: Projections of the urban dendroflora of the Kumanovo city river bank in the application DroneDeploy©

3.4 Uses of QGIS Cloud in GIS software

The use of GIS software in environmental management gives us numerous benefits and opportunities for easier and transparent work of the editors. QGIS Cloud plug-in that is found in the QGIS's software is a powerful tool for publishing pre-arranged data collected from the field. In fact, this plug-in gives us the opportunity to create a free webpage, in this case, creating a web-digital map of the Kumanovo city riverbank [5]. Figure 8 represents the GPS location of all points (marked yellow) and by clicking on it, a window on the right is opened, where all the attributes of the

identified woody species are given. The scientific name, height, diameter, canopy width, damage, and leaning are entered here, which were previously presented. The prepared database is attached to a free online domain that is automatically processed on a pre-created account. For the complete review of the study area, you can check the link in References chapter [5].

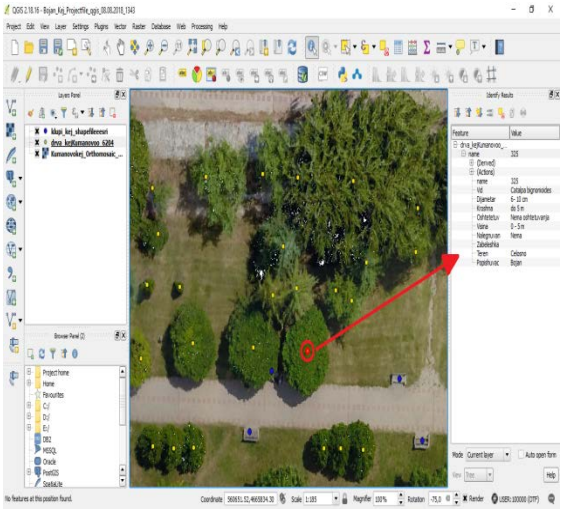

Figure 7: Fully processed data of the urban dendroflora of the Kumanovo city river bank in GIS-aided software

4 DISCUSSION

Unmanned aerial vehicle (UAV) can create many different types of maps such as geographically accurate orthorectify two-dimensional maps, elevation models, thermal maps, and 3D maps or models. Digital mapping and digital photogrammetry is a new practice, i.e., practitioners throughout the world are already intensively using these drones for a variety of mappings and for various purposes. The materials used in the methodology itself in this article greatly demonstrate the ability of these drones to be used in an urban environment, as well as mapping the urban dendroflora and urban city greenery. Although the performed inventory represents only one part of the overall operation, we must know that it is an important segment in creating a cadastre on green areas [12]. Advances in the fields of UAV technology and data processing have broadened the horizons of remote sensing in (urban) forestry, and made the acquisition of high-resolution imagery and 3D data more easily available and affordable. In fact, UAVs can be obtained at reasonable costs and can be perceived as a (urban) forester's eye in the sky, capable of performing (urban) forest inventory and analysis on a periodic basis. With the availability of a wide range of sensors, these UAVs allow the end users to define the spatial resolutions, thereby opening new opportunities to forest and urban green areas [4]. The collected data with the inventory as well as the collected data from drone processed in the software (in our case QGIS) gave us as a product digital map of the entire urban greenery of the study area. GIS is an invaluable tool for applying efficient practices to a large-scale environment. These spatial analyses and inventories provide current, comprehensive information vital to open-space decision-making and identify opportunities for a coordinated effort to guide urban development in a manner that will take advantage of all the social and ecological functions available from the urban forest [6]. The idea of the cadastre of urban greenery would not have the desired quality and usability if the data are not updated regularly and accurately. Only the updated data provides a permanent value for the green cadastre.

5 CONCLUSION

In this research, with the help of new geomatics techniques and the technology for remote management and monitoring itself, we made an inventory of the urban greenery that is located on the riverbank itself, as well as the creation of 5 maps, and at the same time a digital map of the whole river bank with all the attributes. The use of the drone in this investigation showed us all the good sides of this relatively new technology that in the last decade made a big step. One of the great advantages of this technology is the large 4K resolution (4096 × 2160) of the recordings made by the drone, in this case, it has reached 3 cm pixel, at a height of 100 meters. In brief, with a higher height you get a larger pixel, and vice-versa, the lower the height the smaller pixel it is and at the same time the better the quality of the photo recording and more details. Also, the advantage of this technology is that devices are not expensive, and it does not require special training for operating with the drones. It is visually very difficult to follow such areas covered with greenery and therefore the aspiration is aimed at spreading of various maps and digitizing them for the purpose of easier and more efficient management of public green areas. Publishing the thematic map, i.e., preparing a website on the collected attributes, is of great importance, primarily because this result is the final part of the research where the scientific community or the citizens will have an insight into the overall dendroflora that is located on the riverbank. Modern geomatics techniques and at the same time all the technology for remote monitoring and environmental management, whether big or small, can be introduced and applied in all areas of (urban) forestry.

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