Original scientific paper
Journal of Central European Agriculture, 2024, 25(3), p.807-818
DOI: /10.5513/JCEA01/25.3.4278

Vegetation mapping based on visual data

Vizuális adatokra épülő vegetációtérképezés

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Received: February 19, 2024; accepted: May 12, 2024

ABSTRACT

This research aimed to present the database construction process using some plant species found in the sample area. In addition to aerial photography, the characteristic plant species were determined through fieldwork, and their coordinates were recorded with the iPoint software. In the course of the research, DJI Phantom 4 Pro and Mavic Mini drones were used to take aerial photographs of Zimányi-island in Kis-Balaton. Several photographs were taken of the individual plants for identification and assessment of association characteristics, thereby broadening the spectrum of processed data. The aerial photos obtained during the recordings were initially processed with Agisoft PhotoScan 1.4.3 (Metashape after version 1.5), then for comparison with Agisoft Metashape 2.0.3 and Agisoft Cloud software. By combining the aerial photos, a high-resolution TIFF orthophoto was obtained for the entire area. After that, the visual data sets required for the 3D model-based vegetation map were created, pre-processed and processed. The integration of visual and non-visual data sets were integrated into the GIS system. In the research area, non-image data were also collected, which were entered into Microsoft Office Excel tables. QGIS software was used to insert these tables into the database. The completed project shows the coordinates of the 27 plant species recorded in 2019 and the 28 plant species recorded in 2020. The process of querying the developed database was also presented. Finally, a comparative analysis of two different versions of the software was presented and used for matching in the past period. The method can be widely used in precision agriculture as well, such as weed detection, which is pivotal to increasing crop yields.

Keywords: GIS, remote sensing, drone, environmental protection

ÖSSZEFOGLALÁS

A munkánk célja az adatbázis építés folyamatának bemutatása volt néhány, a mintaterületen található növényfaj bevonása által. A légifelvételezés mellett terepi munka során meghatároztuk a jellemző növényfajokat, valamint felvettük azok koordinátáit iPoint szoftverrel. Vizsgálatunk során DJI Phantom 4 Pro és Mavic Mini típusú drónokkal készítettünk légifelvételeket a Kis-Balaton Zimányi-szigetéről. A növényekről beazonosítás, valamint társulástani jellemzők felmérésére céljából fényképeket készítettünk, ezzel is szélesítve a feldolgozható adatok spektrumát. A felvételezések során kapott légifotókat kezdetben Agisoft PhotoScan 1.4.3 (az 1.5 verzió után Metashape), majd az összehasonlításhoz Agisoft Metashape 2.0.3 és Agisoft Cloud szoftverrel dolgoztuk fel. A drónfelvételeket összeillesztve egy nagyfelbontású TIFF ortofotót kaptunk, mely az egész területet lefedte. Ezt követően a 3D modell alapú vegetációtérképhez szükséges vizuális adatsorok létrehozása, előfeldolgozása és feldolgozása történt meg, valamint a vizuális és nem vizuális adatsorok térinformatikai rendszerbe történő integrálását is megvalósítottuk. A terepen gyűjtött nem képi információkat Microsoft Office Excel táblázatokba rendeztük, ezek adatbázisba történő illesztéséhez QGIS szoftvert alkalmaztunk. Az elkészült projektben a 2019-ben felvett 27, valamint a 2020-ban felvett 28 növényfaj koordinátái láthatók. Bemutattuk a kifejlesztett adatbázison történő lekérdezés folyamatát és az eltelt időszakban az illesztéshez használt szoftver két eltérő verziójának összehasonlító elemzését. A módszer széles körben alkalmazható a precíziós mezőgazdaságban is, például a gyomfelderítésben, amely kulcsfontosságú a terméshozam növelésében.

Kulcsszavak: térinformatika, távérzékelés, drón, környezetvédelem

INTRODUCTION

Nowadays, remote sensing test tools and methods are increasingly coming to the fore, which contribute to the protection of natural communities and help to protect the still-existing flora, fauna and biodiversity. Biodiversity and survivability are closely related. The greater the biodiversity in an ecosystem, the greater the adaptability and survivability of the system (Gazdag, 2018). One of the tools for this purpose is unmanned aerial vehicles. Unmanned aerial vehicles, also known as drones, are playing an increasingly important role in all areas of life, they can be considered one of the most dynamically developing sectors.

Kis-Balaton is a wetland connected to Lake Balaton, which formed a unit with Lake Balaton until the 19th century and essentially functioned as a separate basin of today's Lake Balaton. Its area is largely connected to the estuary of the Zala River, which has always been a marshy, semi-static, and occasionally static area. Its significant role has always been its' natural filter function. Currently, Kis-Balaton represents a unique natural value in Europe as a wetland, it is home to nearly 250 species of birds, as well as many species of animals and plants that are now rare. In addition to domestic protection, the area also has international protection as part of the Balaton Upland National Park and, to a greater extent, as a highly protected area. The nearly 15,000-hectare Kis-Balaton is included in the list of "wild waters of international importance" under the scope of the Ramsar Convention (Nagy, 2013).

In the last two decades, it has been recognized that invasions by exotic plants play a significant role in the reduction of biological diversity. In addition, there are also good examples of invasive species that harm human health and wealth (Vitousek et al., 1997). In addition to being components of global change, biological invasions also interact with other elements (Huenneke, 1996). In the European Union, the fight against invasive species is considered one of the main objectives of the 2020 biodiversity strategy (Geert and Leonie, 2017). *Solidago gigantea* is the most significant of the stands of invasive species in the area. The giant goldenrod is a species from North America, which originally arrived as an ornamental plant, and has become wild throughout Europe. It often forms dense, monospecific stands (Pysek et al., 2012). In its original habitat, it occurs in wetter regions, in wetlands, riverbanks, in the lower part of fields and in deeper areas that are wetter than their surroundings. The drier areas near them are often occupied by other *Solidago species*, such as *Solidago altissima* or *Solaidago canadensis*. A comparison of North American and European populations showed distinct differences in both plant and population characteristics. According to research by Jakobs et al. (2004), *Solidago gigantea* has a larger range in Europe and has been found in both wet and dry habitats. In addition, in the case of European plants, an increase in size and reproductive characteristics were observed. Previous study results suggest that this is likely the result of post-invasive genetic changes. In our country, it now occurs in large numbers and has become a defining component of various plant associations (forests and bogs, floodplains).

Drones are mostly classified as unmanned aircrafts, as they can fly completely independently from take-off to landing. However, if we take this definition as a basis, then a significant part of the quadcopters available on the market today cannot be considered drones, but rather remote-controlled machines. These devices, although autonomous to a certain degree, are not capable of fully autonomous flight tasks from automatic take-off after flying over specified points to autonomous landing. A significant proportion of the drones used in the army are also remotely controlled aircraft because they are controlled by technical staff (Elliott, 2016). Drones are generally considered safer for the user than piloted aircrafts, as there is no pilot to be injured in a possible accident (Rango et al., 2012). In the event of an accident, they are also considered safer for people on the ground, because their size is generally much smaller, so they cause less damage in a crash than larger aircraft (Jones et al., 2012).

On the other hand, since the control staff is not on the plane itself, the consequences of possible signal disturbances and problems caused by weather disturbances are more difficult to correct, which makes these devices more vulnerable (Lee et al., 2013).

Unmanned vehicles can collect a large amount of raster data from the area they fly into, from forests and fields with full surface coverage. The type of data is diverse and depends on the sensors and cameras mounted on the drone. The countless possibilities enable a wide range of usability. This helps the user in recognizing and dealing with situations and problems that could not be solved before or could only be solved much more slowly (Bálint, 2019). Due to their affordability, flexibility, and safety, it is important to further encourage their use in the field of ecological research (Anderson and Gaston, 2013).

Using remote sensing, two- or three-dimensional objects can be examined in such a way that the sensing devices are not in direct contact with the subject of the examination. Although microscopic image processing also meets this definition, but talking about remote sensing, satellite and aerial photographs are usually meant (Berke et al., 1999). The equipment used in remote sensing can measure the electromagnetic radiation coming from the earth's surface and landmarks. The energy arriving at the sensor, which is extremely complex, includes, among other things energy waves of solar radiation that pass through the atmosphere twice; which have already been partially changed by atmospheric effects, the reflected energy after being absorbed by the terrain surface, and the energy emitted by the earth's surface and landmarks to varying degrees. Different parts of the total energy and wavelength range can be detected and recorded depending on the type of remote sensing equipment (Balázsik, 2010).

Traditionally, the mapping of species requires intensive fieldwork. In addition to being labor-intensive, it is also expensive and time-consuming in most cases, and sometimes inapplicable due to poor accessibility. Overall, it can be concluded that the method is a practical solution only in relatively small areas. On the other hand, remote sensing is a practical and economical solution for examining the species of individual habitats and is also more accurate and efficient in most cases. Repeated recording helps to detect changes over time, and the generated digital data can be easily integrated into the Geographical Information System (GIS) for further processing (Shaikh et al., 2001). However, we can find differences between the applicability of individual images. Working in northern Australia, Harvey and Hill (2001) compared the accuracy and applicability of aerial photographs, SPOT XS and Landsat TM image data for spectrally distinguishing each vegetation type. Their research showed that aerial photography produces better results than SPOT XS and Landsat TM images when the goal is to map vegetation communities in detail. Jurišić et al. (2021) found that remote sensing methods have proven to be superior in the detection and monitoring of drought compared to conventional methods of observation from meteorological stations.

In the case of image processing operations, Agisoft's products were chosen because it is one of the best-known photogrammetry software series on the market. Its distribution started in 2010, then still under the name of Agisoft Photoscan. It is currently available as Agisoft Metashape. Agisoft Cloud is an online platform integrated with cloud processing for the Metashape Professional license owners. The parameterization options of Agisoft software provide the user with many setting options, although this also increases the number of mistakes that can be made. In the case of weaker hardware, we can use so-called chunking, during which we process the images of the workspace in smaller units and then combine them afterwards. The software provides the possibility to use various camera calibration data. We can also process multispectral recordings, assigning a unique color to each spectrum. The program's point cloud classification algorithm is one of the most advanced on the market (Lehoczky and Siki, 2020).

Objects on the surface can usually be separated better with images taken in several spectral bands than with those taken in a single band. Among other things, it is due to this that hyperspectral technology is widely spread as a research method. The technology is mainly used where high spectral resolution recordings are needed in many spectral bands to achieve the appropriate results (Kozma-Bognár, 2010; Soos et al., 2014). Bíró et al. (2024) examined the 37 most common RGB indices found in the literature using the objective similarity method. They proved that we can talk about 16 independent indices. It is important to emphasize that this does not mean that redundant indexes are unnecessary, but only that during image data processing, we can even use several indexes to answer a question, which will probably give a similar result. Images can be classified by using various classification algorithms. The classification algorithms can be compared with the confusion matrix, so we can find out which one is the most useful in our situation. Kevi et al. (2023) compared six algorithms in their experiment for *Solidago gigantea*, in which the best result was obtained by the Maximum Likelihood classification procedure.

MATERIALS AND METHODS

Zimányi-island was selected as the sample area, which is located in the area of Kis-Balaton Phase II. The purpose of the investigations was to better understand the composition of the plant population in the area and the changes during the growing season through aerial photographs. The investigated peninsula is located in Kis-Balaton, which can be classified as one of Europe's most sensitive areas, and together with Lake Balaton, it forms a unique ecosystem in the world. The investigated area is essentially a sand island, on which the vegetation is mostly thin sedge grass with weeds. On the edge, there are marsh plants, reeds, cattails, and further in, the giant golden (*Solidago gigantea*) appears as an invasive plant (Szabó et al., 1994). Grasses interspersed with weeds form the dominant vegetation in the center (Kozma-Bognár et al., 2016), and scattered smaller woody stands could also be found. Several researches were carried out in the sample area, which were mainly related to vegetation or a certain species within it. Vastag et al. (2019b) focused on *Solidago gigantea*, which is not native to the region. They found that high water levels (above 106 m) have a significant negative effect on the species at the beginning of the vegetation period. They also examined Zimányi-island by the Neural Network-based classification method with students who could have been demonstrators. They proved that within the Digital Image Processing, Remote Sensing, Geographic Information Systems and Info-communication courses, students can acquire knowledge about the full process of aerial photography, practical knowledge and experience, to solve real problems later in their work (Vastag et al., 2019a). Bíró et al. (2023) presented a lesser-known methodology during their investigation of the Kis-Balaton nature reserve. They established that the (multitemporal) recordings made by drones with a given time-frequency can be used not only to detect changes but also to refine the classification procedures during their processing. Based on their research, it can be stated that using multitemporal recordings, RGB sensors are also suitable for vegetation monitoring tests, namely, by evaluating the R band, appropriate accuracy can be achieved during classification. The research consisted of two main parts. The individual sub-processes were presented in chronological order. In the years 2019 and 2020, the main role was data collection, in which field plants in the investigated area were studied. As a part of this investigation, the recording of drone footage and the periodicity depended on the weather conditions. The necessary permits to use the drone were acquired. The flight height was 100 m, with flight speed between 3-5 m/s. During the growing season, we carried out aerial- and field surveys 1-2 times a month, to dynamically detect changes in the plant population. The number of these data collections was determined depending on current weather conditions and the phenological stage of the plant population. The purpose of the investigations is therefore to supplement the mainly botanical results obtained during traditional land surface surveys with visual data sets from aerial photographs to carry out a more precise condition assessment on Zimányi-island. The obtained data were then subjected to qualitative and quantitative evaluations and analysed with a statistical program. The data collection phase of the study period lasted from the beginning of the growing seasons of to the end, but recordings were also taken before and after that.

 DOI: /10.5513/JCEA01/25.3.4278

The position of each plant was determined with the iPoint program. With the help of the software, specific points and routes can be recorded using the A-GPS in the iPhone. Location data is stored in KML format. The high-quality images must also be assigned in PNG or JPEG format to the location data. In addition to the coordinates, the vertical and horizontal accuracy as well as recording time are also included. In addition, the names of the images assigned to the point are also indicated, making it easier to find them from the set. Three images were assigned to each point.

The aerial photographs taken with the Mavic Mini were processed with Agisoft PhotoScan 1.4.3 software. The quality of the uploaded images is extremely important for the alignment operation (Align Photos) because blurry photos can negatively affect alignment results. The alignment operation took more than 20 minutes for the machine even with this file containing 161 images. When the alignment is complete, the calculated camera position and a sparse point cloud are displayed. Then the alignment results can be checked and the misplaced photos should be removed. To view the matches between any two photos, the View Matches ... command from the Photos context menu can be used. After aligning the photos, the set of pasted images completely covers the examined area.

PhotoScan allows to create and visualize a dense point cloud model, which serves as the basis for further processing stages such as Mesh construction, DEM construction, and orthophoto creation. This operation took approximately 32 hours with a mediocre configuration (CPU: 2x3 GHz Quad-Core Intel Xeon, GPU: NVIDIA GeForce 7300 GT 256 MB, Memory: 16 GB 667 MHz DDR2 FB-DIMM). Based on the created point cloud information, Photo Scan can reconstruct the polygon mesh (Figure 1).

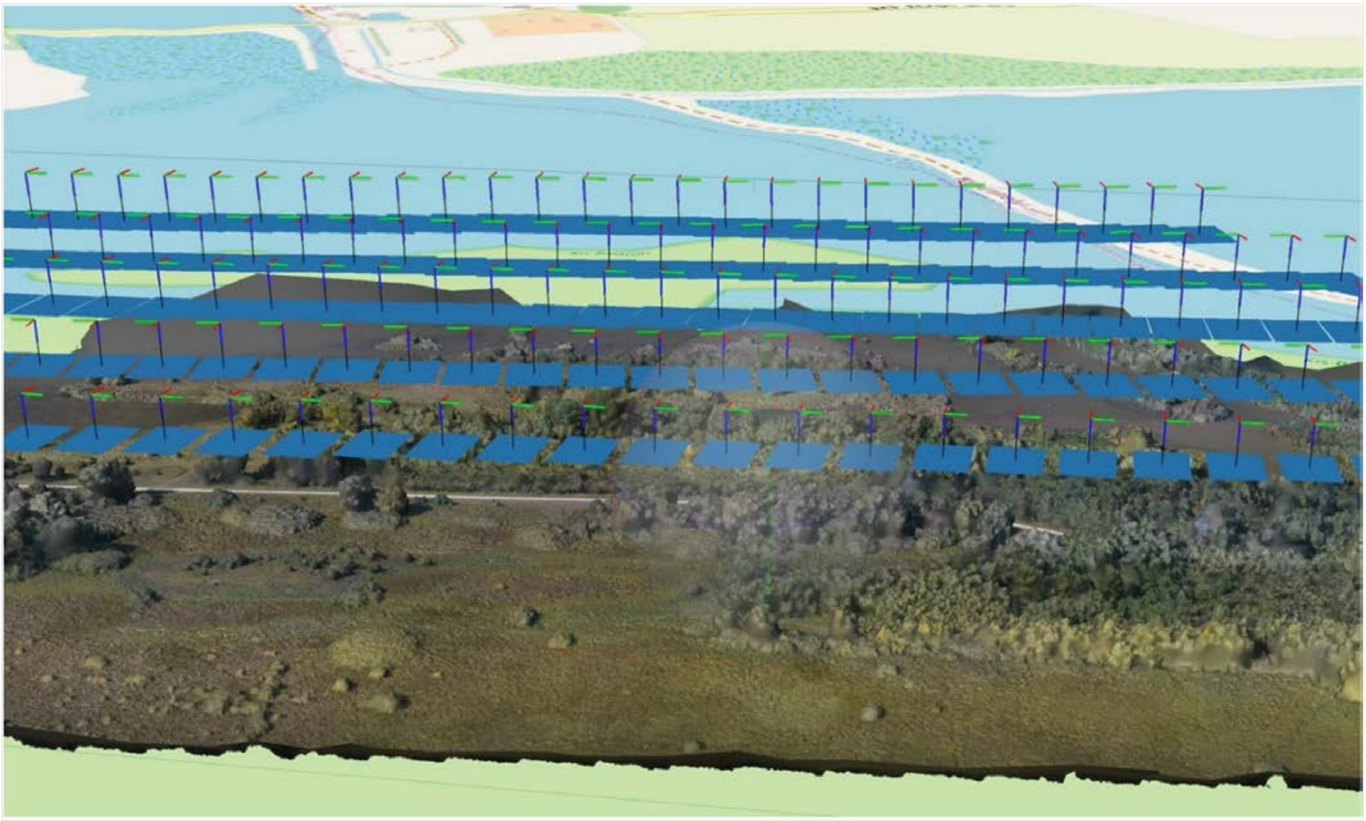

Figure 1. Side view of the complete polygon mesh

A model created from a dense point cloud results in a longer processing time, but the result will have much higher quality. The sphere in the middle of the work surface and the coordinate system in the lower right corner show the position in relation to the image. The image can be rotated as desired along the three axes so that the can be seen in different perspectives, which can provide the basis for correction.

The texture mapping mode determines how the object's texture is displayed in the texture atlas (Figure 2). With appropriate texture mapping settings, the optimal texture composition can be facilitated, as a result, it makes a better view and the quality of the final model will be better. The program enables the merging of low-frequency range components to ensure adequate overlap, thus avoiding seam line problems. The frequency component responsible for image details in the high-frequency range comes from a single image that shows the examined area in good resolution.

In the next step, the digital elevation model (DEM) was created (Figure 3). DEM is essentially the display of elevation values in different colors. The model can be created based on a dense point cloud or polygon mesh. The first option is generally preferred as it provides a more accurate result. Exporting orthomosaic is a common procedure for producing high-resolution images. The most common field of application is data processing obtained during aerial photography, but it can also be useful if the goal is to view a specific object in detail. The creation of orthomosaic based on DEM data is particularly effective for processing aerial survey data, consequently, this was the right choice.

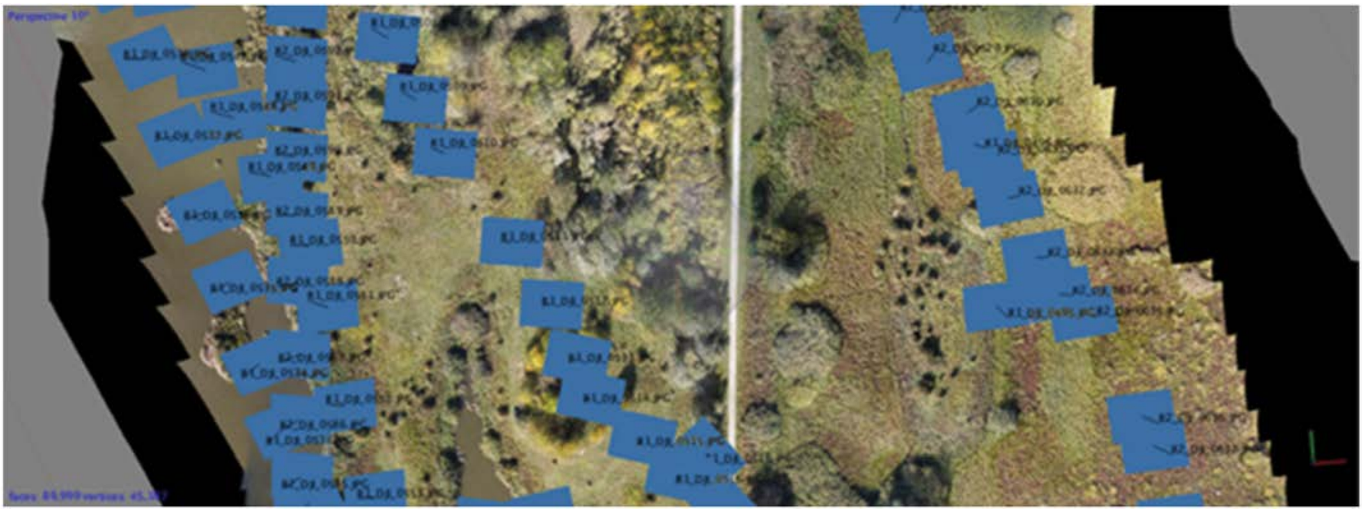

Figure 2. The resulting texture

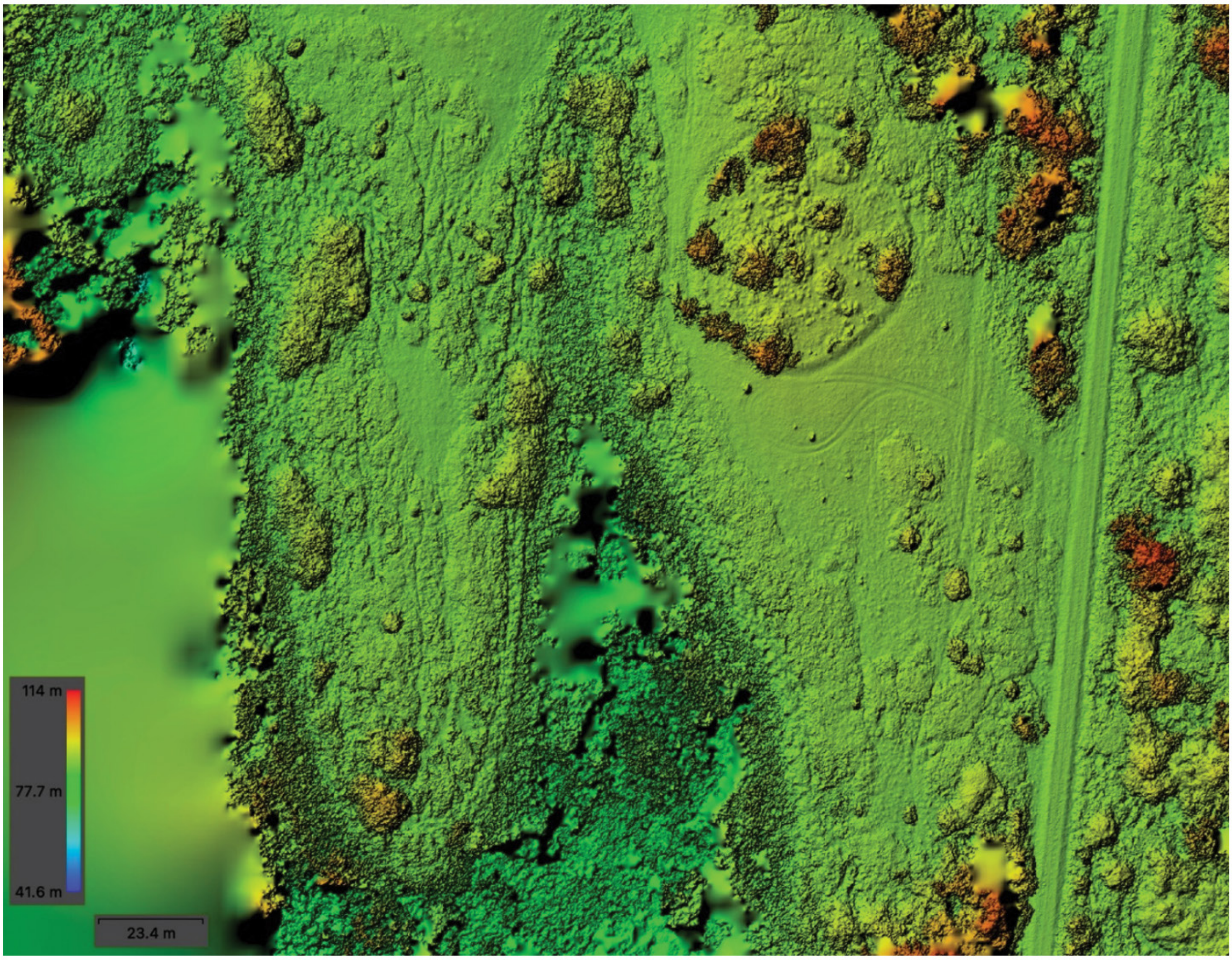

Figure 3. The digital elevation model

RESULTS AND DISCUSSION

After compiling the raw orthophotos, the QGIS 3.6 program was used to perform further work processes. The choice was important, because, among the most typical image file types (.jpg, .tif (GeoTiff), .img, etc.), the orthophoto is in .tif format (Figure 4), which can be opened with QGIS. Setting up the right projection system is extremely important for GIS files. In Hungary, the Unified National Projection System (EOV) is admitted. Each projection system has a specific EPSG code. 23700 for EOV and 4326 for WGS84 used by GPS.

During the work course, several photo sequences were taken on different days. The image sequences were all processed, and the layers were extracted from the created TIFF files. The user can switch between the added layers, and the added points with their corresponding data will later appear on them. The primary task was the inclusion of plants in the orthophoto. The fieldwork during the growing season helped with this. The pictures were taken of the more typical plants in the area in both years. That meant two, maybe three pictures. In the case of each plant, the coordinates were recorded with the iPoint software and then sent along with the images for processing.

In the end, the names of the plants were defined, such as their exact location, and some pictures that can be used to identify them. These had to be placed on the map in some way. The next step was the organization of the names of the plants, their coordinates, and the associated images using the Microsoft Office Excel spreadsheet, thus preparing them for use in QGIS. QGIS supports several formats, including Microsoft Office Excel's .csv format, so the spreadsheet was saved that way.

If the georeferenced image and recorded coordinates are correct, the points will appear in the actual location of the plants (Figure 5). More information is obtainable about the displayed points after selecting the Item identification menu. The data is displayed by moving the cursor to the point and clicking on the point with the left button (Figure 6).

Figure 4. The completed PhotoScan 1.4.3 GeoTIFF

However, there are two exceptions between the points. In two cases, the recorded plants were located so close to each other that iPoint provided them with the same GPS coordinates. In such a case, the two points in the same place can be displayed separately by clicking on the point with the right button. The required point - to get more information about - can be selected from the drop-down window of the Plant coordinates layer.

In the project, after applying the layers, a GIS query was also performed. Within the framework of this, the goal was to display some data for viewing and reading purposes. In the process of the query, a recorded point can be found that contains a specific term, for example, the *Solidago gigantea*. This can be achieved by typing the following command:

select * from „Novenykoordinatak2019” where [Latin nevek] like „%Solidago gigantea%”

After executing the finished command, the program displayed all the lines where *Solidago gigantea* is mentioned in the “Latin nevek” column.

As a result of the investigations, information was obtained on the composition of the plant population of Zimányi-island in Kis-Balaton wetland. From the collection of the initial data and their processing to the construction of the database (including queries), the implemented tasks involving several fields of expertise, are based entirely on their own data, which are related to the vegetation mapping of Kis-Balaton. Vegetation mapping from remote sensing data has proven useful for monitoring ecosystems at local, regional and global scales (Gimenez et al., 2023). The finished project shows the coordinates of the 27 plants recorded in 2019 and the 28 plants recorded in 2020 with their associated information. Italian researchers (Tariku et al., 2023) have also successfully used UAV-collected RGB images for the accurate identification and classification of plant species in heterogeneous areas, plant mapping techniques, and transfer learning. They used ArcGIS instead of QGIS. They pointed out that although these tools offer free versions, it is important to recognize their potential limitations.

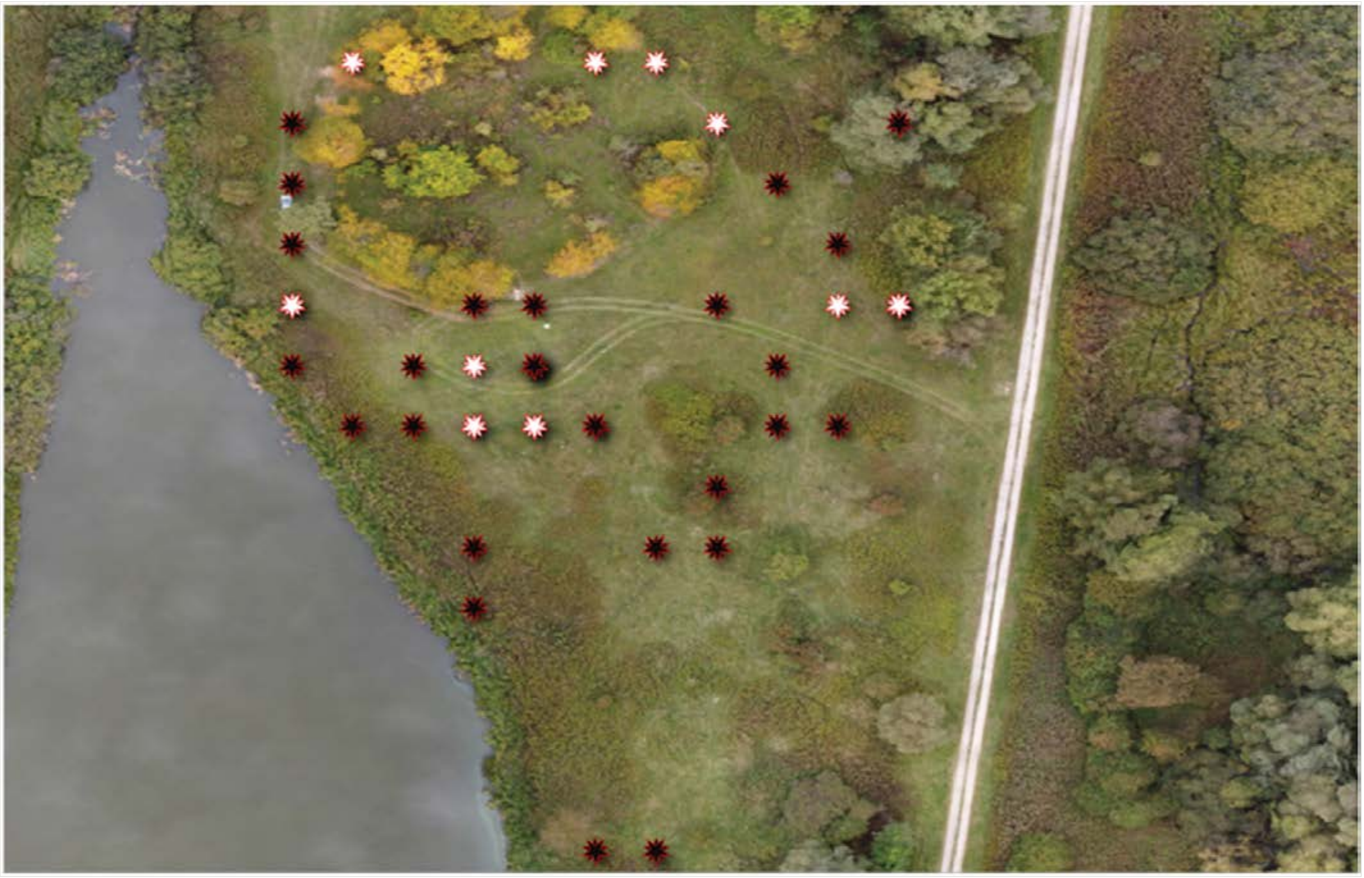

Figure 5. The displayed points

Some researchers do not use their own images as the basis of their work. Jain et al. (2022) concluded during their research, that the NDVI analysis can be used for monitoring vegetation coverage and different planning and management strategies. In this situation the multi-spectral data have been used to find out the spectral signature of various features, such as built-up, barren land, water, light vegetation, shrub or grassland and healthy vegetation, but they used Lansat-8 satellite data.

As a result of the research, a digital vegetation map was produced that contains interactive elements and can even form the basis of artificial intelligence-based developments. The development can also be used for the planning of fieldwork processes for environmental protection and water protection purposes as a supplement to the current central systems since the cm resolution of some data (DEM, orthophoto) significantly exceeds the resolution of 50 m - 0.5 cm, which is the resolution data of satellite and aerial photographs, common in water, or environmental protection systems.

Finally, a comparative analysis of processing by Agisoft PhotoScan 1.4.3, Agisoft Metashape 2.0.3 and Agisoft Cloud software was performed, and the results of which - with regard to the most important parameters - were presented in Table 1. A significant improvement can be found in the realistic production of the dense cloud between 1.4.3 and the new versions, which clearly supports that the orthophoto - as the most frequently used final product - should be produced based on the dense cloud.

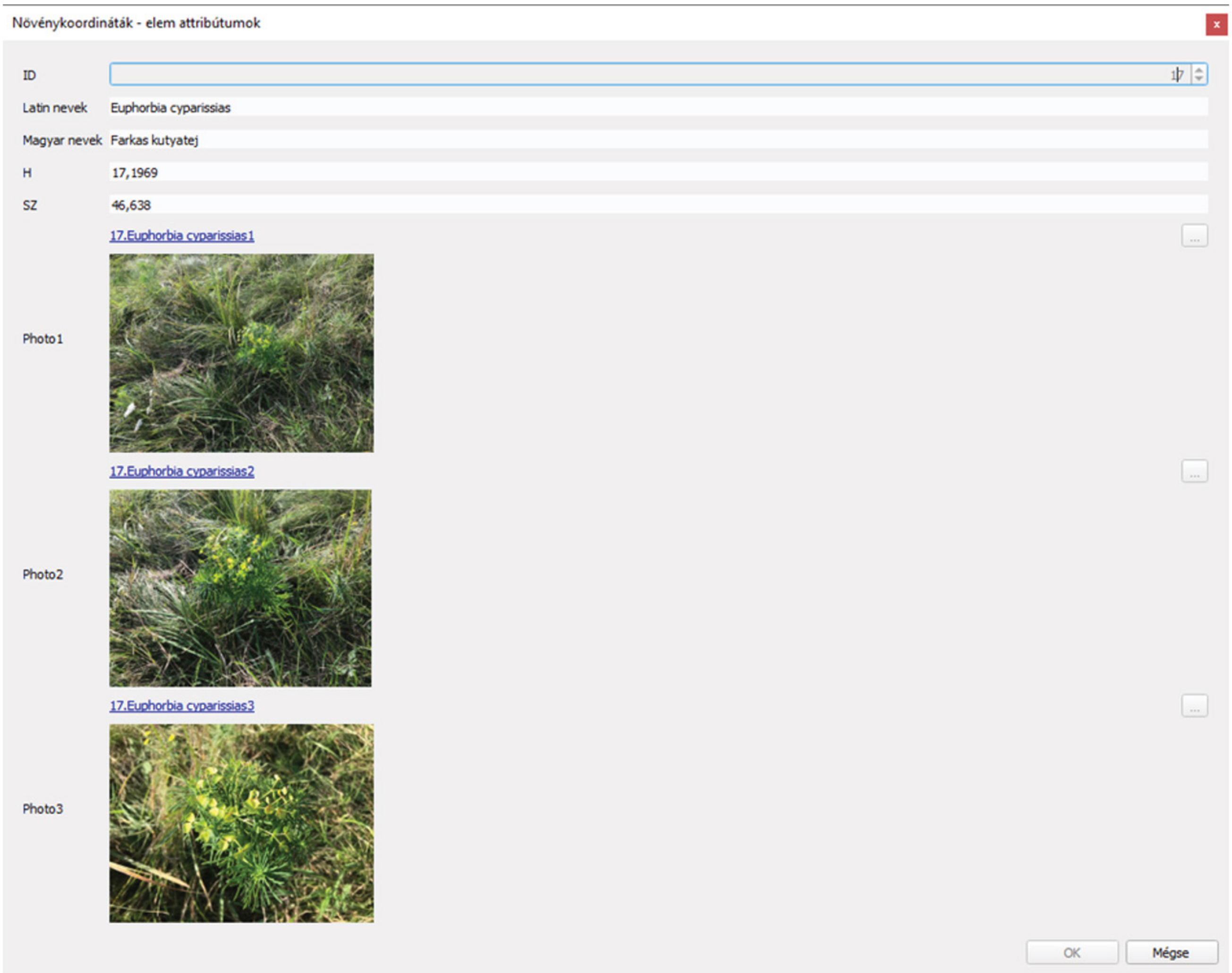

Figure 6. Displayed attributes of *Euphorbia cyparissias*

Table 1. Comparison of processing by Agisoft PhotoScan 1.4.3, Agisoft Metashape 2.0.3 and Agisoft Cloud software

	PhotoScan 1.4.3	Metashape 2.0.3	Agisoft Cloud NC 10/27/2023
All images used for fitting (DJI Phantom 4 Pro FC6310 RAW images)	201	201	201
The number of images matched	192	193	193
Coverage area (ha)	49.3	50.9	48.0
Camera locations total error (m)	3.60308	5.42929	5.34505
Number of tie points	212 308	248 400	248 534
RMS error of tie points	0.116531	0.159496	0.159244
Number of dense cloud elements	538 294 776	573 449 535	568 196 303
DEM size in pixels	33 579 x 48 198	24 631 x 40 403	23 587 x 38 541
DEM resolution (cm/pixel)	2.62	2.59	2.60
Orthophoto size in pixels	24 409 x 40 746	24 631 x 40 403	23 588 x 38 541

CONCLUSIONS

The research aimed to present the database construction process by including some plant species found in the sample area. This meant that plants and information about them were merely tools. The qualitative and quantitative properties of the plants were not examined, and the parameters of the individual years were not compared with each other. During the research, we performed the entire work process ourselves. That included the planning of the experiment and considering its expected course, the aerial surveys of the sample area, field sampling, data processing, database construction, and also the presentation of the evaluation and query process on the finished database. The fact that everything was done by one group from the beginning to the end, that each sub-process was carried out by a small team, is quite rare. The uniqueness of the work is further enhanced by the fact that the data was processed with three different software versions, and these were also compared with each other. In the article, it was presented why and how certain steps of the process were implemented. The result can serve as a guide for all those who want to perform a similar activity but do not know where to start, or get stuck somewhere and do not know how to proceed. The individual sub-processes can also be implemented in the case of agricultural areas, where one of the main goals is the visual separation of weeds and crops.

ACKNOWLEDGMENTS

Project no. TKP2021-NVA-05 has been implemented with the support provided by the Ministry of Innovation and Technology of Hungary from the National Research, Development and Innovation Fund, financed under the TKP 2021 funding scheme.

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