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UAV PHOTOGRAMMETRY IMPLEMENTATION TO ENHANCE LAND SURVEYING IN CADASTER

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Abstract

The use of Unmanned Aerial Vehicles (UAVs) for surveying is now widespread and operational for several applications – quarry monitoring, archeological site surveys, forest management and 3D modeling for buildings, for instance. UAV is increasingly usedby land surveyors especially for kinds of projects. It is still ambiguous whether UAV can be applicable for smaller sites and property division. Therefore, the objective of this project is to extract an orthophotomap, which can be used later by the land surveyor engineer in the field of cadaster, to vectorize correctly a topographic plan of the studied area. In order to achieve the correct result, the orthophotomap was created using a UAV, and more specific TRIMBLE UX5 HP. The flight schedule was prepared in the office with "Aerial imaging Desktop" software, and for the processing of the resulted photos was used "TBC - Trimble Business Center" software. Both of the softwares are provided by Trimble, the manufacturer of the UAV. The main problems associated with using a UAV are the level of precision and the visualization of the whole area. The results indicated that the precision is quite satisfactory with a maximum error of 5.33 cm for the rest of the model.

Keywords*: Cadaster, Land Survey, Orthophotomap, TRIMBLE, Unmanned Aerial Vehicles (UAV).*

INTRODUCTION

Innovation in topography and land surveying is to aim to acquire more data with higher accuracy. Computer developments were a key change in that regard. Nowadays, utilizing UAVs could lead to another quantum leap in the surveying profession. Topographic plans are widely used in a variety of applications and at various sites. These plans involve several levels of accuracy depending on the client's needs.

Digital photogrammetry is the science of using computers to obtain the dimensions of photographed objects. It involves the analysis of one or more existing photograms / photograms with specialized photogrammetry programs to determine spatial relationships.

Planimetric photogrammetry was born with the discovery of photography in France with the first terrestrial photogrammetric elevations. It was followed by the analog collection method, then the analytical method (which is still used with accurate results) and the digital method. The digital method revolutionized photogrammetry (Preoțescu and Nedea, 2017). Digital photogrammetric stations completely solve the problem of collecting and processing the digital data needed in any areas.As a ground-based field science, photogrammetry serves to draw up maps and topographical plans, but is widely used in other spheres of activity such as architecture, cadaster, police investigations, or even medicine (plastic surgery) (Vîlceanu, 2013). Also, if used in the background of intelligent cadastral vector data, can improve the details of thematic maps as well as action plan maps (Moscovici et al., 2015). It also helps to monitor land cover changes (Herbei et al., 2016). All methods based on both UAV and satellite techniques are very often used in the analysis and characterization of the terrain and the vegetal cover (Gitelson 2004, Thenkabail et al., 2007, Sala, 2011).

Usually, projects that require crucial safety conditioning for construction, such as high-speed railways, landing strips, investigating building deformations or tunnel inspections, require plans with high accuracy, where just a few millimeters (mm) of deformation are highly significant. For many topographical surveys, the data are acquired with a total station. A total station is surveying equipment that consists of an electromagnetic measuring instrument and electronic theodolite. It is also integrated with a microprocessor, electronic data collector and storage system. The instrument can be used to measure horizontal and vertical angles as well as the slope distance from the object to the instrument. The redundant measures with total stations allow accuracy to within millimetres to be achieved. Furthermore, their automatic operation enables more data to be acquired in a limited period of time. Over one day a land surveyor can acquire up to 2,000 points. Since the process is repetitive it can easily involve errors. The survey then has to be georeferenced using different techniques based on the nature of the terrain and the available instruments. Usually, the most efficient technique used is a global navigation satellite system (GNSS) receiver with areal-time kinematic (RTK) network. This allows control points to be obtained with a high precision. Once the field survey is completed, the data are transferred to CAD software to generate the plan. Eventhough codification in the field enables automatic drawing, it usually involves some errors, and the post-treatment process usually takes several hours to obtain the final product.

According to (Colomina and Molina, 2014), UAV photogrammetry has witnessed rapid development in the past few years. This can be attributed to the accessibility of drones and a major development of Structure from Motion software. Before UAVs, aerial photogrammetry involved planes or helicopters and metric cameras. It encompassed complex and various processes due to the heights to which the aircraft soared and the expensive cost of metric cameras and flight hours. It now offers an affordable access to precise aerial mapping (Fraser, 2015). According to (Küng, 2011), the developments of UAVs in recent years along with the improvements in Structure from Motion (SFM) software and computer vision enhanced the production of photogrammetry. They made it accessible with centimetric-al precision even with bad positioning systems on-board the aircraft. This precision is approximately within the same range as the existing technologies for most land surveying purposes. Application requiring millimetric precision is still out of the range of possibilities for UAVs. UAVs are becoming more and more affordable, and the ultra-light and user-grade cameras on-board also offer very good resolution for low-altitude photogrammetric work. Moreover, UAVs are becoming easier to use with automated flight planners and automatic obstacle detection.

MATERIAL AND METHOD

The principle of data acquisition using the photogrammetric method aims to obtain physical and environmental information about the physical objects and the environment remotely without physical contact with them by recording, measuring and interpreting metric photographic images called photograms. The obtaining of a photogram is done by photogrammetric cameras either located on the ground (ground photogrammetry) or placed on board airborne platforms (Vîlceanu, 2013).

Photogrammetry is suitable for the following functions:

- ensuring orthoimages;
- both in local systems and in regional systems
- creating digital models of height (allowances) of the land;
- creating 3D models of objects;
- direction and inclination of geological strata;
- determining the position of the points. (Vîlceanu, 2013)

The development of an orthophotomap begins with the planning of the flight plan for the area of interest. For this stage, we need to know the scale of the desired orthophotomap in order to calculate the flight height, as well as the longitudinal and lateral overlap of the images. In parallel with the aerial image acquisition operation, control points for calibration of the final image could be determined. This is mandatory with the UAVs which do not have integrated a GPS system (Herbei, 2015).

The main advantage in using unmanned flight equipment (drones, UAV), represents the availability and flexibility of the execution of a project, whom are clearly superior to the use of

classic flight equipment (airplane, helicopter). The surfaces that can be covered with such equipment are in the range of tens of up to hundreds of hectares.
Aerial photography is useful both for regular monitoring of an area of interest (landslides, reservoirs, ponds, etc.), as well as for supporting topographic and cadastral works on extended surfaces (general cadastre, agricultural and systematic cadastre etc.).

- **UAV system – Trimble UX5 HP**

The drone or the unmanned aerial vehicle (UAV) is a generally small unmanned aircraft that is remote-controlled: based on a predefined flight plan/route or with a remote control.
This kind of gear is equipped with different type of sensors, GPS (is not a mandatory feature) and has a high-resolution or infrared camera with the help of which it records a large number of photographs. The resulted photographs can be georeferenced using ground control points, ultimately obtaining a high-resolution orthophotomap. Also, with the help of specialized software, the digital model of the ground or a “cloud of points” can be obtained, later to be used in deferent field analysis, or even to obtain a 3D model of the studied area.
In the current study, the UAV used is a TRIMBLE UX5 HP (Figure 1) .

Figure 1. UAV TRIMBLE UX5 HP

The Trimble UX5 HP hardware features are listed in Table 1.

Table 1. Hardware specifications

Type	Fixed wings
Weight	2.9 kg
Wingspan	1m
Wing surface area	34 dm²
Size	100cm X 65cm X 10.5cm
Battery	14,8 V; 6600mAh
Camera	36MP
GNSS Receiver	L1/L2 GNSS
Controller	Trimble Tablet Rugged PC

- **High precision mapping and surveying solution**

The Trimble® UX5 HP Unmanned Aircraft System (UAS) is an easy to use, fully automated, high precision system capable of capturing aerial photography with resolutions down to 1 cm. Featuring Trimble Access™ Aerial Imaging field software and Trimble Business Center office software, this complete system provides an intuitive workflow that allows you to quickly create the highest quality orthomosaics and 3D models for applications such as survey grade mapping, power line monitoring, field leveling, site and route planning, progress monitoring and asset mapping.

- **Superior Image Acquisition and Accuracy**

The UX5 HP delivers precise data by integrating a high-performance Trimble GNSS receiver and a superior camera. Post-Processed Kinematic (PPK) GNSS technology is used to establish very accurate image locations in absolute coordinate systems, eliminating the need for ground control. As a result, less time is spent in the field and high precision results can be achieved even in the most inaccessible areas. With PPK, georeferencing aerial data is more robust and accurate than RTK, providing a superior level of reliability and accuracy. Use either your own base station or work with data from reference stations to georeference your deliverables with the highest accuracy possible.
The Trimble UX5 HP features an industry-leading 36 MP full-frame sensor camera

capable of capturing sharp, high resolution images. The camera achieves a leading level of image resolution - orthomosaics down to 1 cm GSD and point clouds up to several thousands points per square meter.

- **Configure for the Job**

No one project is ever the same, that is why you can select a camera and lens combination that match your project needs. You have the flexibility to choose between a near infrared or RGB sensor system, and a selection of lenses. The lenses include a 35mm lens for high accuracy, a 15mm wide angle lens for increased flight coverage or a 25mm lens delivering both accuracy and increased flight coverage.

- **Trusted Performance**

The Trimble UX5 HP is an extremely safe and durable system, made from impact resistant foam, that can withstand extreme temperatures, winds up to 65 km, and light rain—making it ideal for use in conditions that most unmanned aircrafts struggle to operate in.

- **Intuitive Workflows with Trimble Access**

The Trimble Access Aerial Imaging application loaded onto the Trimble Tablet Rugged PC operates the UX5 HP and is a single software tool for planning your aerial missions, performing pre-flight checks and monitoring your flights. Now you can map corridors, cover disconnected areas in a single flight, import multiple map layers, fly irregular shaped areas and heights, plan or change multiple takeoff and landing locations during flight, and perform flight simulations to confirm the plan. The export functionality gathers all required data into a single file that can be imported into Trimble Business Center.

- **Valuable Photogrammetry Deliverables**

Optimized to process data from the Trimble UX5 HP, the Trimble Business Center Photogrammetry Module creates impressive deliverables. With a single drag-and-drop, imported GNSS information, base station or reference station data, and onboard images are processed in Trimble Business Center to produce a scaled orthoimage, point clouds, Triangulated Irregular Network (TIN) models and contour maps of the area flown. These can then be used in planning a project, calculating volumes, excavation planning, drainage planning and many other functions. Alternatively, Inpho UASMaster provides the power user or photogrammetrist with the right set of tools to use the full potential of aerial data. With feature based seamline-finding, terrain editing capabilities, state-of-the-art DTM generation, classification and filtering, even the most challenging projects can be processed.

- **Performance specifications – Trimble UX5 HP system:**
  - maximized image footprint without compromising resolution, obtained with a custom wide-angle lens and APSC-type sensor.
  - maximized coverage per flight and per hour due to large image footprint, sharp turning capability and high cruise speed.
  - reversed thrust technology for a short and steep landing circuit.
  - powerful propulsion system for steep climbs and high altitude flights.
  - high airframe service life due to wing robustness and maintainability.
  - short setup time with automated procedures in Trimble Access field software.
  - self-check and failsafe procedures for safe operation.
  - one-button export to Trimble Business Center to create deliverables.
  - optimized data accuracy when processed with Trimble Business Center or Trimble Inpho UASMaster.
  - high Precision GNSS receiver to georeference deliverables accurately and easily.

- **Software description-** Trimble Access Aerial Imaging application

Allows:
  - project management
  - mission planning with option for multiple flights
  - automated pre-flight checks

- automatic take off, flight and landing
- autonomous camera triggering
- automated fail-safe routines
- user-controlled fail-safe commands
- automated data consistency checks
- export to Trimble Business Center, Trimble UASMaster and a generic format for image processing

RESULTS AND DISCUSSIONS

The study area is located in the town of Birchis, Arad County (Figure 2) and is part of the of the territorial administrative unit Birchis.

Figure 2. Study area

This project has been divided into 3 stages:

- **Part 1, in the office, with the following objectives:**

1. Identification of the area of interest
2. Flight preparation: The area of interest, after identification on Google Earth, was divided in flight sectors (each of maximum 20-21 minutes, including take-off and landing) (Figure 3 and Figure 4). For each flight sector, the desired altitude and the precision of the orthophotomap were set (Figure5), and after checking the battery charging status, control tablet battery charging status, GPS battery charging status, the UAV is prepared for takeoff.

- **Part 2, "In situ", with the following objectives:**

3. Travelling to the area of interest
4. Establishment in the area of interest of the take-off and landing site (Figure 5) (take-off requires a free area of approximately 3 m in width and 25 m in length, and for landing a free area of approximately 25 m width and 50 m long isnecessary, as flat as possible and without any objects or obstacles that could damage the drone's body in case of contact)
5. Half an hour before the actual take-off, the Survol Service is notified by phone in order to register the flight and the UAV used and the operator.
6. A flight point is established in the flight area, in which, using the GPS, measurements are conducted with the static method throughout the flight (measurements necessary to increase the accuracy in orthophotograph processing).
7. Introducing the points, take-off and landing directions, and wind direction in the field in the tablet's flight software (Aerial Imaging).
8. Once the drone is ready (charged batteries inserted, take-off and landing points set), the PreFlight Check List is initiated (a series of steps to be taken for safe take-off)
9. After the launch of the drone, the actual flight is automatically performed by the Aerial Imaging flight program of the tablet connected to the UAV, and the operator constantly checks the drone's status displayed on the screen of the control tablet (altitude, battery level, recorded pictures, minutes flown, flight minutes left, speed and direction of the wind, and his assistant constantly observes the movement of the drone and the possible obstacles in the air to warn the drone operator (helicopters, light aircraft, other drones, hot air balloons, etc.)
10. Once the air corridors are finished, the UAV automatically announces the operator through the tablet thatit prepares to land, and the operator and his assistant ensure that the landing area is free of obstacles and confirm the landing.
11. Once it has reached the ground, the UAV prepares the download (the flight path file is downloaded), the recorded pictures and the static measurement from the GPS (if they were measured)
12. The flight termination is announced at the Survol Service and the equipment is gathered.

Figure 3. Flight Specification

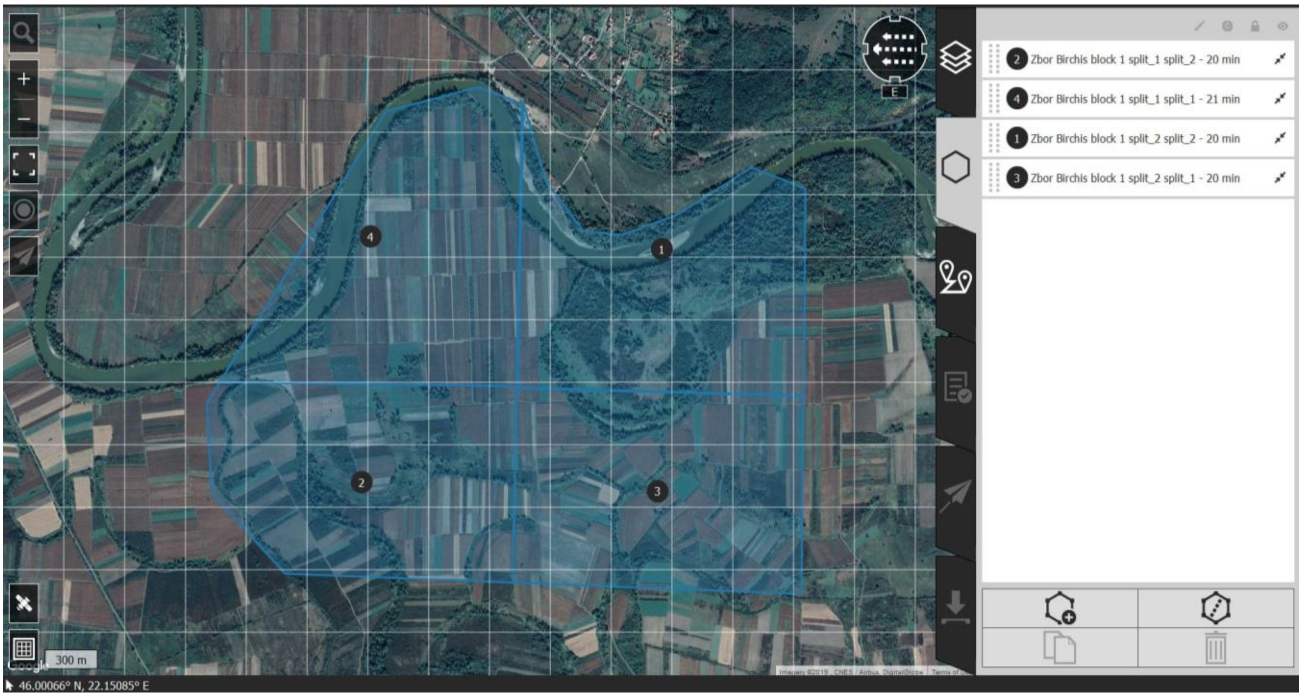

Figure 4. Flight area divided in flight sectors

Figure 5. Flight check-list for each sector

- **Part 3: of the Office, with the following objectives**

Using the TBC program (Trimble Business Center) the flight is processed. The processing is an automatic operation.The operator must only insert into the software the parameters of the flight performed, the flight file, the pictures and the static measurement (if it was necessary to be done). The final product (Figure 6) consists of 4 orthophotomaps which can be inserted into any CAD software program and used as support for the project for which the flight was thought.

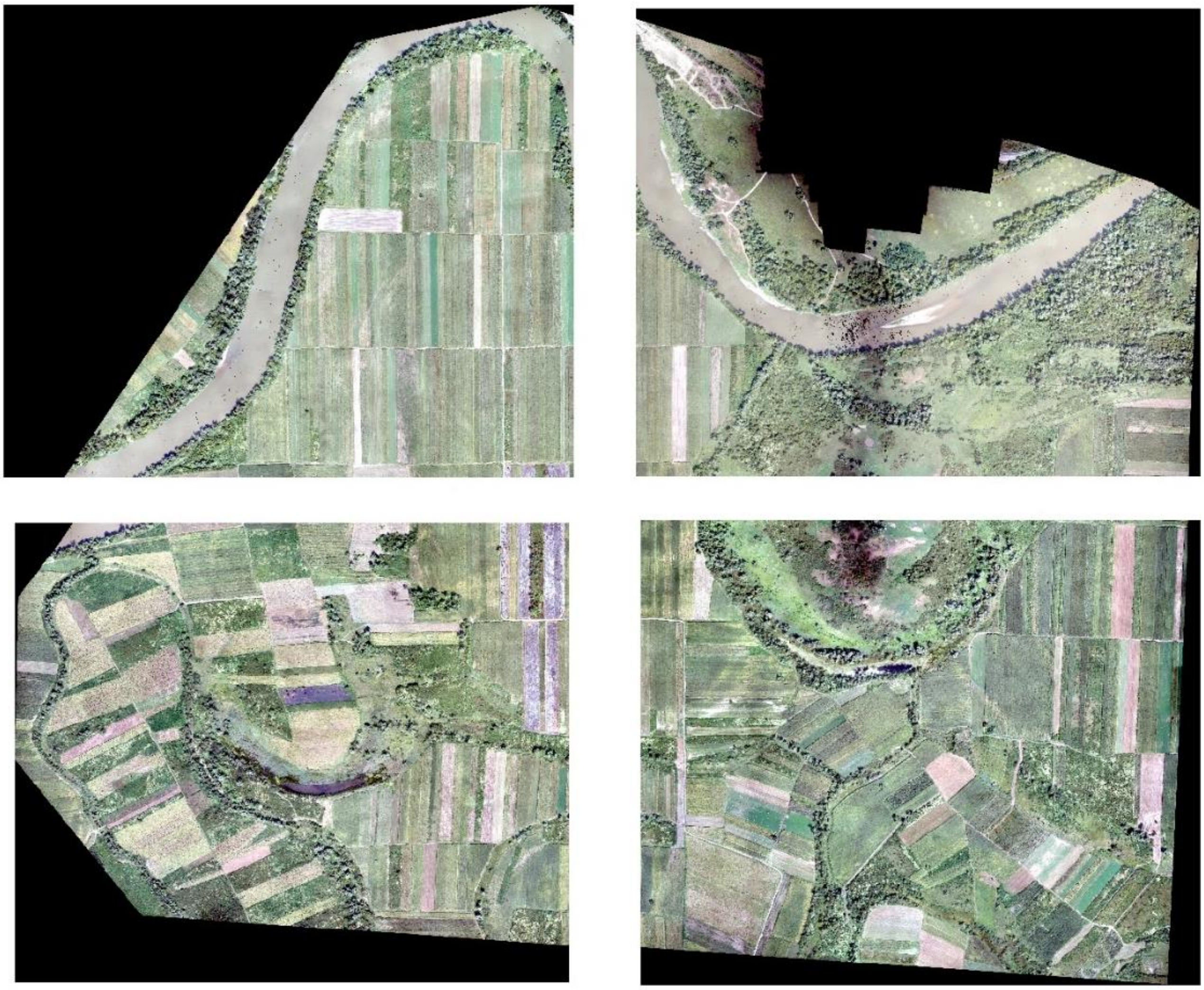

Figure 6. Final product (4 orthophotomap)

In the Birchis project, the flight altitude used was 400 m, the lens used were 35 mm, thus resulting in an accuracy of otofotoplan of 5.33 cm per pixel, because 400 m altidute respectively 6 cm per pixel provides the requirements of the conditions required in the specification (Table 2).

Tabel 2. Area coverage table

Hight	GSD	Area / Flight	GSD	Area / Flight	GSD	Area / Flight
	15 mm Lens		25 mm Lens		35 mm Lens	
75 m	2.4 cm	1.4 km²	1.5 cm	0.8 km²	1.0 cm	0.6 km²
100 m	3.3 cm	1.9 km²	1.9 cm	1.2 km²	1.4 cm	0.8 km²
120 m	3.9 cm	2.4 km²	2.3 cm	1.4 km²	1.7 cm	1.0 km²
150 m	4.9 cm	3.1 km²	2.9 cm	1.8 km²	2.1 cm	1.2 km²
300 m	9.8 cm	6.5 km²	5.8 cm	3.7 km²	4.2 cm	2.7 km²
750 m	25 cm	16.1 km²	14.6 cm	9.3 km²	10.5 cm	6.3 km²
For a 5:1 aspect ratio of a single rectangular flight block, at 80% lateral overlap, including 5 min of traveling time from take-off to the first waypoint and from the last waypoint to the landing.						

The final product, in this case a single orthomosaic (Figure 7) created from the 4 resulted orthophotomaps was realized with the TBC (Trimble Business Center) software. A mosaic is a combination or merge of two or more images (Herbei, 2018). In this project, alternative GPS measurements were not necessary, because how we have presented above, the Trimble UX5 HP system is manufactured with an integrated GPS, and thus the 4 resulted orthophotomaps do have the spatial reference, more exactly geographical coordinates.

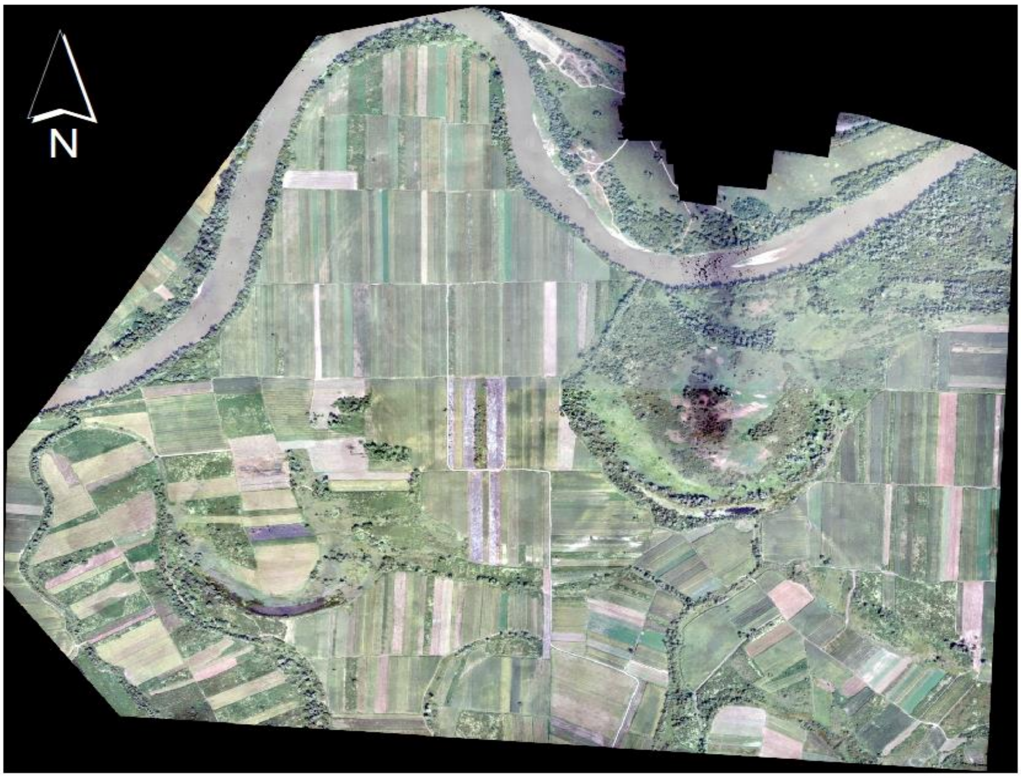

Figure 7. Orthomosaic of the studied area

CONCLUSIONS

The main object of this research was to determine whether UAVs can be operated at any type of site. But at the end, the results in terms of precision are acceptable, since the level of precision only depends on pixel size.
So, in order to create more accurate models, the challenge seems to be more the amount of data needed to manage and the acquisition speed of ground control points. Indeed, the level of precision reached can be achieved with a total station. However, this level cannot be reached using an RTK GNSS receiver. Actually, in certain conditions and with the latest developed technologies, a precision of about 1.0–2.0 cm may be reachable. Utilizing a total station, the model can be created with more precision.

The other innovation that may lead to facilitating this type of measurement isnormalizing the process for land surveyors and drone operators to work together. Such a process would allow the land surveyor to have easy access to safe flight and quality data. Actually, the land surveyor flying the drone will lead to depletion and loss of his time in planning the flight in considering several issues: weather conditions and administrative work, for instance, while the drone operator can plan all of these tasks while respecting the land surveyor’s requirements in terms of resolution and overlap.

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REFERENCES

Colomina I., Molina P., 2014. Unmanned aerial systems for photogrammetry and remote sensing: A review, ISPRS Journal of Photogrammetry and Remote Sensing Volume 92, p. 79–97.

Fraser, R. H., Olthof I., Maloley M., Fernandes R., Prevost C., Van der Sluijs J., 2015. UAV photogrammetry for mapping and monitoring of northern permafrost landscapes, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XL-1/W4, 361-361, doi:10.5194/isprsarchives-XL-1-W4-361-2015.

Gitelson A. A., 2004. Wide dynamic range vegetation index for remote quantification of crop biophysical characteristics. J. Plant Physiol 161(2), p. 165–173.

Herbei, M. V., Popescu, C. A., Bertici, R., Smuleac, A., Popescu, G, 2016. Processing and Use of Satellite Images in Order to Extract Useful Information in Precision Agriculture. Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca.Agriculture, 73(2).

Herbei, M. V., 2015. GIS si Modelare cartografica, Universitas, p.151-160, Petroşani.

Herbei, M.V., 2018. Cartografie digitala & Mobile GIS, Mirton, p. 117-167, Timişoara

Küng O., Strecha C., Beyeler A., Zufferey, J. C., Floreano D., Fua P., Gervaix F., 2011. The acuracy of automatic photogrammetric techniques on ultra-light UAV imagery. In UAV-g 2011-Unmanned Aerial Vehicle in Geomatics (No. EPFL-CONF-168806).

Moscovici A. M., Brebu F. M., Gridan M. R., David, V., 2015. Mathematical cartography based on georeferencing maps. In AIP Conference Proceedings (Vol. 1648, No. 1, p. 670007). AIP Publishing.

Preoţescu C. M., Nedea A. M., 2017. Traditional And Digital Photogrammetric Systems. Scientific Papers. Series "Journal Of Young Scientist", Vol. 5, Print Issn 2284-8030, p. 219-222.

Sala F., 2011. Agrochimie, Editura EUROBIT, Timisoara, p. 534.

Thenkabail P. S., GangadharaRao P., Biggs T. W., Krishna M., Turral H., 2007. Spectral matching techniques to determine historical land use/land cover (LULC) and irrigated areas using time-series AVHRR pathfinder datasets in the Krishna River Basin, India. PhotogrammEng Remote Sens 73(9), p. 1029-1040.

Vîlceanu C. B., 2013. Aplicatii practice in fotogrammetria digitala.

http://www.kmcgeo.com/Datasheets/UX5HP.pdf

https://ro.wikipedia.org/wiki/Birchi%C8%99,_Arad