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Possibilities of Using Unmanned Aerial Vehicle in Geospatial Support in the Czech Army

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Abstract

The importance of digital geographic data has been growing very rapidly in recent decades. It is hard to imagine a current military operation in which there is no need to plan, model, or visualize the environment using digital geographic data. The creation and distribution of this data is one of the basic tasks of geographical support in most armies. Most of these data models are created using photogrammetric methods from image data or aerial laser scan ning technology. The creation of data using these traditional procedures makes it possible to create robust geodatabases from a large area, but it is often lengthy and does not allow responding to current changes in the area of interest and the needs of the troops for accurate and especially up-to-date geographic data. A faster alternative for creating current geographical data or updating existing geodatabases is the use of unmanned aerial vehicle (UAV). Evaluation of the possibilities of using the AgEagle eBeeX UAV for selected tasks of data collection and creation of data models is the main goal of this article. The article will describe and evaluate selected tasks suitable for the use of this UAV.

KEY WORDS: *UAV, mapping, geospatial support, DEM, multispectral data, engineering survey, soil moisture*

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1. Introduction

The importance of digital geographic data has been growing very rapidly in recent decades. It is hard to imagine a current military operation without the need to plan, model, or visualize the environment using digital geographic data. The creation and distribution of this data is one of the basic tasks of geospatial support in most world armies. Most of these data models are created using imagery and photogrammetric methods or airborne laser scanning technology. The creation of data using these now common procedures allows for the creation of robust geodatabase covering a large area, but it is often lengthy and does not allow responding to current changes in the area of interest and to the needs of the troops for accurate and especially up-to-date geospatial data. A faster alternative for creating current geospatial data or updating existing geodatabases is the use of unmanned aerial vehicles [1].

Unmanned aerial vehicles (UAVs), also known as drones, are vehicles not having a human crew on board. They are controlled remotely or using an automated system. The use of UAVs is very extensive today. In military applications, UAVs are primarily used for the following tasks [2], [3], [4]:

- reconnaissance, surveillance of enemy positions, information collection and border monitoring;
- targeted attacks, carrying missiles or bombing.

However, UAVs are widely used in a number of civilian applications, some of which can also be used in the security and defense domain [4], [5], [6], [7]:

- reconnaissance of inaccessible or dangerous areas, e.g. inspecting oil pipelines or power lines
- monitoring arable land, monitoring crop growth, detecting diseases and optimizing fertilization
- forest mapping, tree condition monitoring and forest fire detection
- delivering of parcels, monitoring of the traffic situation and inspection of the transport infrastructure
- environmental monitoring
- data collection in geology, meteorology, biology and archaeology

• terrain mapping etc.

This text evaluates the possibilities of using the AgEagle eBeeX UAV for selected tasks of data collection and creation of data models for the needs of geospatial support. The article describes and evaluates selected tasks suitable for the use of this UAV.

2. UAV for Geospatial Support

The use of UAVs for the needs of geospatial support is focused mainly on its use as a quick replacement for large photogrammetric aircraft. The main task of the UAV in the geospatial support system is primarily data collection in the form of panchromatic, multispectral or thermal imagery; laser and radar data. Such data collection is done by both propeller-driven and fixed-wing aircraft, both of which are capable of collecting data with various types of cameras [8], [9], [10], [11].

This text focuses on data collection using a fixed-wing UAV equipped with a panchromatic and multispectral imaging camera. A specific representative of this type of UAV is the fixed-wing AgEagle eBeeX. Technical characteristic of the drone is shown in Table 1.

Table 1.
Main technical characteristics of the UAV AgEagle eBeeX [12]

Drone specifications		**Flight performance**	
Wingspan	45,7 in/116 cm	Cruise speed	11-30 m/s or 25-68 mph (40-110 km/h)
Material	Expanded Polypropylene (EPP)	Max. wind resistance	Up to 12,8 m/s or 28,6 mph (46km/h)
Underbody skin	Curv® Polypropylene thermoplastic composite	Landing type	Automatic linear landing (16,4 ft / 5 m accuracy in 35°angle cone)
Max. take-off weight	3,5 lbs / 1,6 kg	Service temperature	5°to 104°F (-15°to 40°C)
Backpack dimension	75x50x29 cm / 30x20x11 in	Humidity	Light rain resistance
Motor	Low-noise, brushless, electric	Ground avoidance	Yes – LiDAR (range 394 ft / 120 m)
Detachable wing	Yes	Ground resolution	Down to 0,6 in / 1,5 cm
Radio link range	1,9 mi (up to 5 mi) 3 km nominal (up to 8 km)	Max. flight time	90 minutes
Frequency	2,400 – 2,4835 GHz	Coverage at 400 ft / 120 m	543 ac to 1,235 ac / 2,2 km^2 to 5 km^2 / 220 ha to 500 ha
Data storage	SD cart	Linear coverage	Up to 17,2 mi / 27,7 km out and back

The AgEagle eBeeX with an optional RTK/PPK module allows to achieve the absolute accuracy up to 3 cm (1.2 in) without ground control points (GCP). However, the image collection described in this article used the AgEagle eBeeX UAV without RTK/PPK GNSS measurement, which achieves lower accuracy.

According to the technical documentation, this type of UAV is capable of creating images of an area of 300 - 500 hectares in one flight, which is up to 5 square kilometers. However, these values can only be achieved under ideal conditions. The shortening of the flight length is mainly caused by the strength of the wind and the ruggedness of the terrain. Practical experience from using the AgEagle eBeeX wing shows that the optimal area for one flight is approx. 2 square kilometers. If it is possible to use multiple batteries or recharge them directly in the field, it is feasible to cover about 10-15 square kilometers in one day. [12]

The UAV AgEagle eBeeX is compatible with a wide range of interchangeable cameras that are suitable for a wide range of mapping work (3D, thermal, multispectral, …):

• SenseFly Duet T - a two-channel thermal mapping kit that can be used to quickly and easily create thermal maps and digital surface models;
• S.O.D.A. - a camera designed specifically for professional photogrammetry using drones;
• MicaSense RedEdge-MX - a professional multispectral sensor working in the red, green, blue, near-infrared and red edge parts of the electromagnetic spectrum;
• S.O.D.A. 3D - a professional photogrammetric camera capable of changing orientation during flight and capturing three images at a time (two oblique and one in nadir).

The use of MicaSense RedEdge-MX and S.O.D.A. 3D cameras for the following tasks is described as part of the testing of tasks for geospatial support needs.

The first task is the rapid collection of data for the needs of updating existing geodatabases. The need for this solution stems from a relatively long period of updating geodatabases and map products, which are still an irreplaceable geographic basis for decision support. On the territory of the Czech Republic, a regular aerial scanning campaigns takes place every two years [13] and map products can thus be replaced by relatively up-to-date orthophotos. This is not the case everywhere, moreover, in military operations there can be significantly faster changes in the landscape, which need to be captured and transferred to geodatabases. For this reason, the temporal and spatial aspects were tested for the acquisition of current images and subsequent updating of existing vector geodatabases. On the territory of the Czech Republic, regular photogrammetric imaging is carried out every two years. The principle is that one half of the territory is photographed every year. In the case of dynamic phenomena, such as natural disasters or military activity, this period is insufficient. Therefore, it is necessary to look for new alternatives for the needs of geographic security, which could be the use of UAVs.

The second task tested is the creation of an up-to-date digital elevation model for the planning of engineering structures or for the needs of restoring existing structures after their destruction by military, as well as non-military, activities. To solve these tasks, an existing elevation model is usually used as a primary source (DMR5 in the Czech Republic [14]), but it may not be sufficiently accurate or up-to-date for some tasks. Therefore, in the case of a request for an accurate elevation model, the geodetic survey of the given territory is used and the creation of a detailed current elevation model processed in time corresponding to the design activities. UAV means offer a new technology for creating these elevation models, which is faster than terrestrial geodetic measurement. At the same time, the non-contact method enables the creation of a height model even in places that are inaccessible, mainly due to the conduct of military operations.

As the UAV eBeeX also enables data acquisition with a multispectral camera that provides data in five spectral bands (three visible, IR and RedEdge), testing of the use of the UAV for the purpose of detecting the distribution of soil moisture was also carried out in order to refine the soil passability modeling procedures. The goal was to find at least partial dependencies between the measurement of soil moisture by a moisture meter in the area of interest with any of the selected combinations of individual multispectral bands.

3. Rapid Geodatabase Updating

The first task tested was the rapid collection of data for the needs of updating existing geodatabases. As part of this task, temporal and spatial aspects were tested for the acquisition of current images usable for subsequent updating of existing vector geodatabases.

In the case of the need for a quick update of geodatabases, it can be assumed that entry to the area of interest will not be allowed and therefore it will not be possible to create the GCPs. For this reason, a procedure without GCPs was used to verify the accuracy of the created orthophoto and the possibility of using it for updating databases. The test area was located southeast of the village of Slavonice. The size of the territory was 0.25 square kilometers. Using the S.O.D.A. 3D camera, 337 images were taken with 60 percent overlap, both forward and lateral. The orthophoto was processed in the Pix4D program without the use of GCPs, then to verify the accuracy of the created orthophoto, the positions of the geodetic surveyed GCPs were compared with the values determined from the orthophoto. The GCPs were surveyed by the Trimble Geo XR GNSS receiver using the STOP and GO method in real time using the VRS Now corrections. The GCPs were regularly distributed in the corners of the test area. The results can be seen in the Table 2.

Table 2.

Positional accuracy of the created orthophoto

	Geodetic		Ortho			
	E_G	N_G	E_O	N_O	E_O - E_G	N_O - N_G
	m	m	m	m	m	m
Slavonice_1	526935,55	5426440,14	526936,25	5426441,27	0,70	1,13
Slavonice_2	527175,64	5426247,56	527176,37	5426248,48	0,73	0,92
Slavonice_3	526353,47	5426131,35	526353,93	5426132,28	0,46	0,93
Slavonice_4	526260,89	5426299,67	526261,48	5426300,82	0,59	1,15
				Mean Square	0,63	1,04
				Horizontal ERROR		**1,21**

The results show that the root mean square deviation on the GCP is 0.63 meters for the E coordinate and 1.04 meters for the N coordinate, and the positional error is 1.21 meters. These values are slightly worse than the accuracy of the data in the ZABAGED database [15], which is the basis for the creation of the basic military database VMÚ. The achieved accuracy, however, fully corresponds to the accuracy required for updating databases as part of the renewal of medium-scale map products, which is also VMÚ.

In addition to verifying the accuracy of the resulting orthophoto, attention was also focused on verifying the time necessary to process the orthophoto. The Pix4D program was used to process the Slavonice location, allowing to create an orthophoto without operator intervention. The operator uploads images, sets the parameters for the orthophoto and starts the creation process.

The calculation was tested on a computer with the following parameters: processor – Intel Xeon CPU E5-2620 2.10GHz; RAM memory – 16GB; operating system – Windows 10.

For testing purposes, the resulting orthophoto pixel size was chosen: 1 cm, 5 cm, 15 cm, 50 cm, and 100 cm. The results representing the time required for processing are presented in table 2. The value shown in bold corresponds to the resolution value of full-area orthophotos, which are used for updating military or civil geodatabases in the Czech Republic [13].

Table 3.
Orthophoto processing time according to different resolutions

Resolution of the result	1cm	5cm	15cm	50cm	100cm
Processing time	31 hours	65 minutes	56 minutes	19 minutes	19 minutes

The results in the table (see Table 3) show that with a suitably chosen resolution of the resulting orthophoto, the time required for processing is not a limiting factor in the use of UAVs for rapid updating of geodatabases.

From all the above facts, it follows that the use of UAVs for updating databases represents a suitable technology providing a sufficiently accurate orthophoto, and the time required to obtain it is negligible compared to the use of an aircraft. The main limiting factor is the size of the area of interest. Based on the experience gained during the processing of testing areas on the territory of the Czech Republic, it appears that the suitable territory for the use of this type of UAV is up to 100 square kilometers.

4. Generating Surface Models for Construction Planning

Design and implementation of construction works is one of the important tasks of engineering support. The main tasks of engineers are the following: mobility support, counter-mobility support, survivability support, general engineer support. It allocates special column to perform rescue and liquidation work during crisis as a part of the Integrated Rescue System (IRS) to fulfill humanitarian tasks. The spectrum of these tasks is very broad and the requirements for geospatial data vary both in terms of content and accuracy.

In this text, attention is focused on tasks for which geodetic support is currently used. These tasks usually require the calculation of the volume of earthworks, or the complete processing of the project of special military constructions. These are, for example, the following tasks [16], [17]:

- construction of military bridges and maintenance of permanent bridges
- design, construction, repair and renovation of command posts
- design, construction, repair and modification of the airport in the area of deployment
- design, construction, repair and maintenance of field temporary camps and bases, including related facilities and equipment

These constructions are almost always associated with the design of earthworks. Currently, modern object applications are used for design with an overlap into design with the use of BIM (Building Information Modeling). The input data for these modern applications are current elevation data from the construction area. This data may have varying levels of accuracy. The requirements for the accuracy of these data vary according to the type of building, the area of implementation and its scope. When determining the requirements for the accuracy of the geodetic survey, an important factor is also the requirement of the construction contractor, who can determine its level based on his requirements.

In general, the most accurate data is important for the construction of military bridges, military roads, airports, and the design of military bases. For designing these types of military constructions, it is advisable to work with data with centimeter accuracy [18].

At present, geodetic data from the construction area, or point clouds acquired by laser scanning are mainly used for these projects. The cloud of points in the national data models correspond to their content at the time of the survey, and the terrain very often undergoes significant changes since then, and the national data models cannot therefore be used. For the needs of engineering support, point clouds can be obtained by acquiring imagery and its subsequent processing.

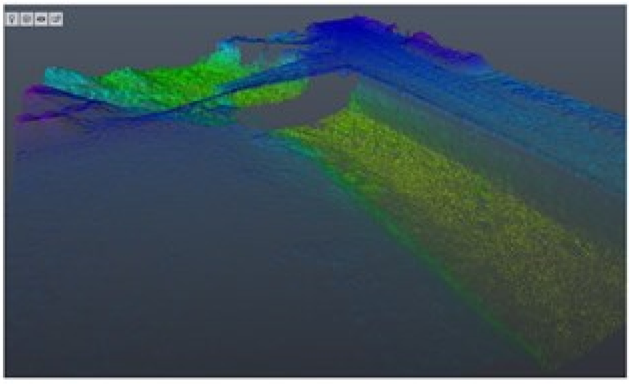
As an example of the use of the point cloud from AgEagle eBeeX, the processing of temporary bridge projects within the framework of humanitarian aid during the floods in Slovenia in 2023. In August 2023, Slovenia was hit by devastating floods that affected up to two thirds of its territory. The Czech Republic provided a total of 108 meters of heavy bridge sets (TMS) for three locations (Črna na Krkoškom, Mežica and Ljubno ob Savinji).

On the basis of the results of the engineering survey of individual locations, the geodetic surveying was carried out. The Trimble S7 total station, Trimble R12i GNSS receiver and AgEagle eBeeX UAV were used to survey the sites. The survey resulted in very precise orthophoto images of the locations of interest, a geodetic survey scheme and point clouds acquired by the AgEagle eBeeX drone in *.las format (see Fig. 1).

(a)

(b)

(c)



(d)

Fig.1. Cloud of points acquired by the AgEagle eBeeX drone (location Crna na Koroško): (a) north view; (b) south view; (c) south view after radiometry adjustment; (d) colored point of cloud.

The point cloud was processed in the ReCap2024 application, in which the data was prepared for further use in the creation of a digital terrain model (classification of points, modification of the area of interest). The data was further exported to a format usable in the AutoCAD Civil 3D software suite. This software is used for creating a digital terrain model and its subsequent modification. By default, the terrain is created in the format of a triangular irregular network (TIN). The digital terrain model in TIN generated in AutoCAD Civil 3D is presented in Fig. 2.

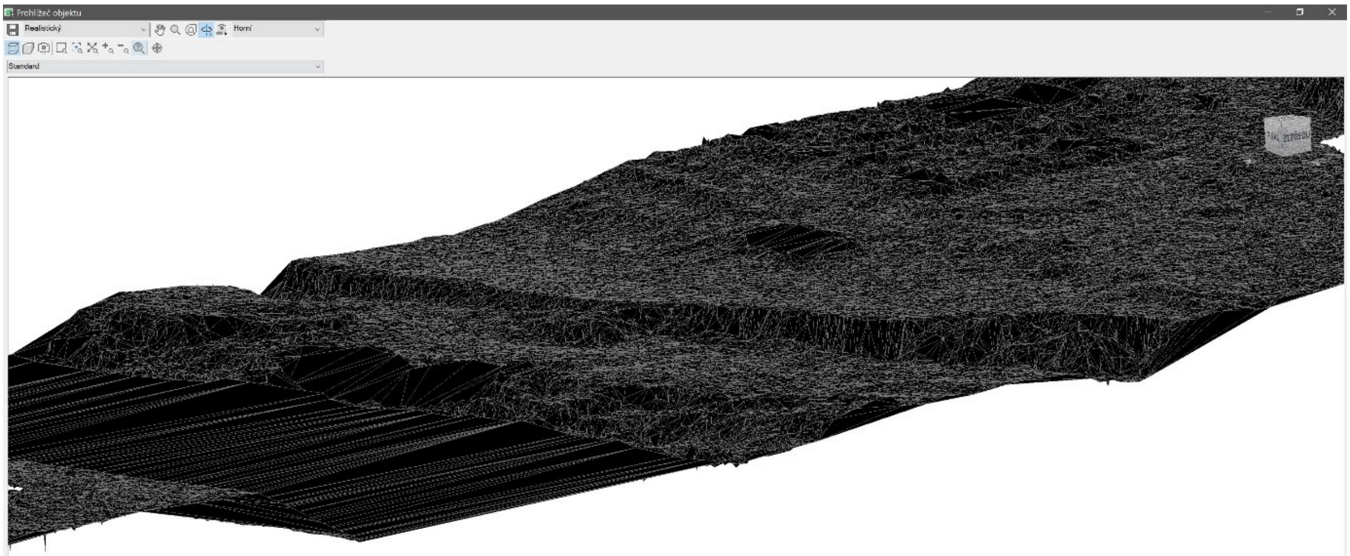


Fig.2. Digital terrain model in TIN generated in AutoCAD Civil 3D.

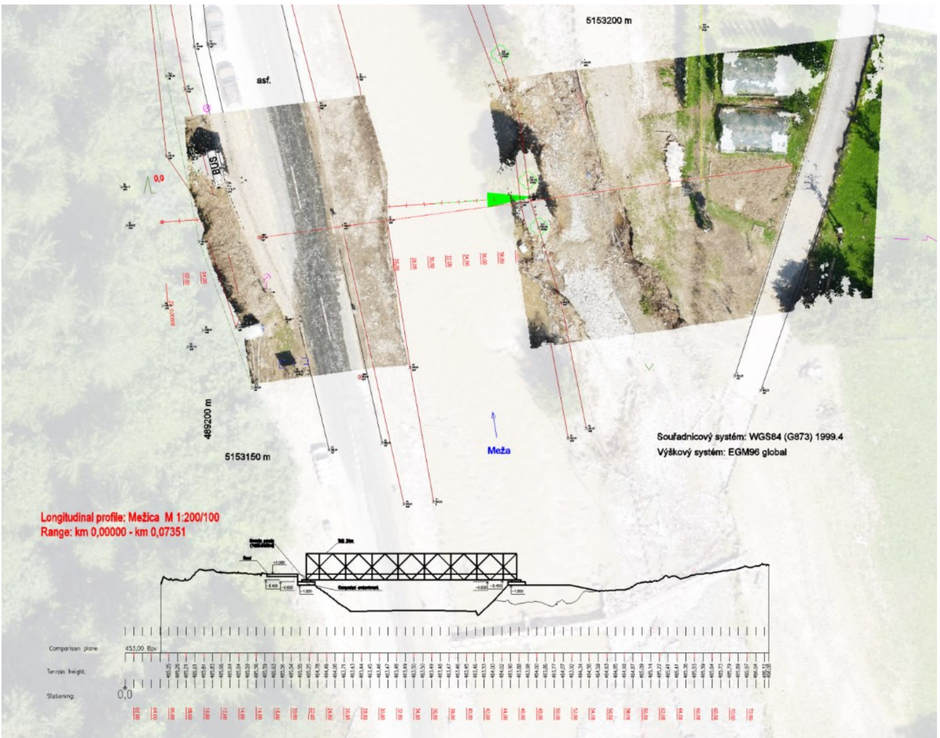


Fig.3. Longitudinal profile in the axis of the planned temporary bridge (Mežica).

For the temporary bridge designer, the starting point is the longitudinal profile in the axis of the planned bridge (Fig. 3). From this profile, information is obtained about the elevation conditions at the construction site and landscape modifications are proposed, which will need to be implemented before the construction of the temporary bridge (modification of the river bed, strengthening of the banks, preparation of places for storing the bridge etc.). For a good height adjustment of the bridge, it is necessary to have a data with centimeter accuracy. The model created using AgEagle eBeeX provided an equally accurate model for design and subsequent construction work as geodetic surveying of sites. The solution with the application of AgEagle eBeeX for design and construction work was also used in other tasks (construction of a training areas for wheeled vehicles, construction of command posts and others).

5. Using Multispectral Imagery for Assessing the Soil Moisture

The last application was focused on the use of a multispectral camera for the purpose of soil moisture detection. The soil moisture is a very important parameter for a number of areas of use that are related to the environment and have the potential to influence human society and its various activities. This means, for example, weather forecasting, drought monitoring, agricultural production management, water resource management, monitoring and management of natural disasters such as fires, landslides or floods, and others [19].

Knowledge of soil properties plays an irreplaceable role for some specific military applications, such as terrain passability. However, the effect of soil moisture on the modeling and prediction of terrain passability by military vehicles has not yet been sufficiently investigated and described, which can be considered a significant shortcoming.

A number of studies have been published for soil moisture estimation based on optical and thermal sensor data processing as well as from active and passive microwave sensor data [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31]. All these papers agree in stating that reliable relationships for the direct derivation of soil properties from spectral data are not yet available.

We performed tests of the possibility of remote detection of surface soil moisture using multispectral image data taken by various sensors located on UAVs.

As part of the testing, the following was performed:

- measurement of soil moisture using the traditional method directly in the field;
- acquisition of multispectral data from the UAV;
- searching and downloading corresponding imagery from selected satellite sensors;
- calculation of spectral indices;
- searching for a correlation between index values and actual soil moisture.

Before the actual measurements in the field, it was necessary to select suitable locations and plan the individual measurements in such a way that they could be repeated in as long a time series as possible. Two testing areas were chosen, which are located near Brno - Nížkovice and Silnična - where the soil type is chernozem. Due to the size of the area that had to be covered by the data, measurements were made at several tens of points that were evenly distributed throughout the area of interest, and the distance between each point was approximately 50 m. Several quantities were measured for each point. The measured quantities were soil moisture, shearing stress, penetrometric resistance. All quantities measured at a given point were located using GNSS measurements [32].

The NDVI (Normalized Difference Vegetation Index) spectral index was used to verify the possibility of using multispectral images. The NDVI is probably the best known and most used vegetation index for analyzing the health of vegetation, but it can also be used to evaluate soil properties, for example its moisture. In the subsequent data analysis, the search for correlation between the images and the soil moisture obtained from the field measurement was carried out. The NDVI was calculated from the image data taken by the UAV, which is calculated from the formula 1:

$$\text{NDVI} = \frac{NIR - Red}{NIR + Red} \qquad (1)$$

where NIR is the spectral band in the near-infrared region of the EMS (Electromagnetic Spectrum) and Red is the band in the red part of the visible region of the EMS.

Subsequently, a correlation dependence was sought between the calculated NDVI index and the measured values of soil moisture.

The statistical method for calculating the Pearson correlation coefficient was used. This coefficient is one of the characteristics of tightness of dependence and is used to determine the linear relationship between two elements. The coefficient can have values between 1 and -1. The closer its value is to 1 or -1, the stronger the correlation. The intermediate values in this interval then indicate the degree of dependence described as very weak, weak, medium, strong or very strong. In total, data from 211 points where repeated measurements took place between November 2020 and April 2021 were analyzed. In the case of UAV data, a weak and very weak positive relationship between the NDVI index and soil moisture was found with values around 0.20.

Most of the studies and articles describing the search for correlation between image or radar data and soil moisture state that the relationships for directly deriving this dependence are not yet available or are not yet robust enough. Admittedly, the results of our testing confirmed this finding.

In order to find reliable results, the involvement of radar data is needed, without them it really is not possible, but it is still a big alchemy and the search for clear relationships will probably take some time. However, the radar sensor is not part of the available sensors for the tested AgEagle eBeeX UAV.

Despite the fact that it was not possible to confirm the possibility of using a UAV with a multispectral camera for the needs of soil moisture assessing, the possibilities of using this tool for other tasks related to geospatial support will continue to be tested.

6. Conclusions

The possibilities of using wing-type UAVs, which have been described in the text, show that the use of unmanned vehicles in geospatial support is promising and will grow in importance. The main advantage of using these means is their operability and relatively low acquisition and operating costs. The quality of the obtained data is comparable to data from piloted aircraft or satellites. Their applicability is provable especially in the area of creation of up-to-date surface models, creation of orthophotos for the needs of visual interpretation and subsequent rapid updating of geodatabases. Unfortunately, it was not possible to find a dependence between soil moisture and multispectral images from the UAV and thereby extend the possibility of applications to the field of terrain passability or cross-country movement. Despite this, testing of the use of these resources will continue to be carried out for other tasks within the geospatial support.

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