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The use of unmanned aerial vehicles for the assessment of land boundaries accuracy

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Abstract

The Land and Property Register (LPR) also called the Cadastre by the legislator should function in accordance with regulations in force, meet expectations of the public and provide universal access to Register data for its users. Beyond any doubt, credibility and usefulness of data in this public register are affected by the manner it is kept, which generally includes active and passive approach. If the LPR is kept in an active manner and constantly up to date, its data is very useful. The qualitative aspect of the land and buildings database's records establishes the calculation accuracy of the owners' land parcels evidenced in the Land and Mortgage Registers, which protect the ownership right to the property. In order to ensure that the plot of land is unequivocally and correctly measured, it is necessary to establish breakpoints of the parcels' boundaries in the presence of the interested parties.

Research conducted on the possibility of using the unmanned aerial vehicle (UAV) for measuring purposes indicates immense probability where this technology may be used for the selected details of group I (most accurately located) in modernization of land and buildings registers.

Key words: *cadastre, modernization of land and building records, photogrammetry, unmanned aerial vehicle (UAV)*

INTRODUCTION

Data collected in the land register, from the economic and country management point of view, play very specific and important role [WÓJCIK-LEŃ, SOBOLEWSKA-MIKULSKA 2017; LEŃ 2017]. Pursuant to the said law, the surveying and cartographic regulations [Ustawa PGiK… 1989] provide the basis of economic and country planning, refer to tax and benefit issues, official statistics, land property and farm records as well as to land register indication. It is thus vital that the data submitted was accurate and reliable.

Regional Development and Construction Minister's Order, §80 of 29th of March 2001 on the register of lands and buildings [Rozporządzenie MRRiB... 2001] states that the deadline for setting up and launching computer databases is set, and in order to create basic reports showing registration data, included in §22 of the abovementioned regulation, December 31st, 2005 for urban areas, and December 31st, 2010 for rural areas is binding. Subsequently, Minister of Administration and Digitization (the competence resulted from Article 6 § 1 point 4a of the amended Act on government administration departments, in Regulation of November 29th, 2013, on land and building register [Rozporządzenie MAiC… 2013], postponed these dates by setting December 31st, 2014 for urban areas, and December 31st, 2016 for rural areas. In order to facilitate the registration of land and buildings, often without providing adequate financing for this costly and extremely responsible task to local and regional authorities, the provisions of §82 of the Regulation [Rozporządzenie MAiC... 2013] were allowed, stating that in case of no limit points determined on the basis of geodetic measurements with average errors not exceeding 0.30 m in relation to the 1st class network (§ 61 1 of the above-mentioned regulation), adoption of border points of which location was determined on the basis of data existing in the Head Office of Geodesy and Cartography with errors average not exceeding 3.00 m for parcels located in rural areas outside dense buildings, and 0.60 m for registered plots located in cities and areas of compact rural development, was possible. The low quality of source materials, like resources of the District Geodetic and Cartographic Documentation Centers, especially in the rural areas of the former Austrian and Russian partitions, prevents adapting the register operation without

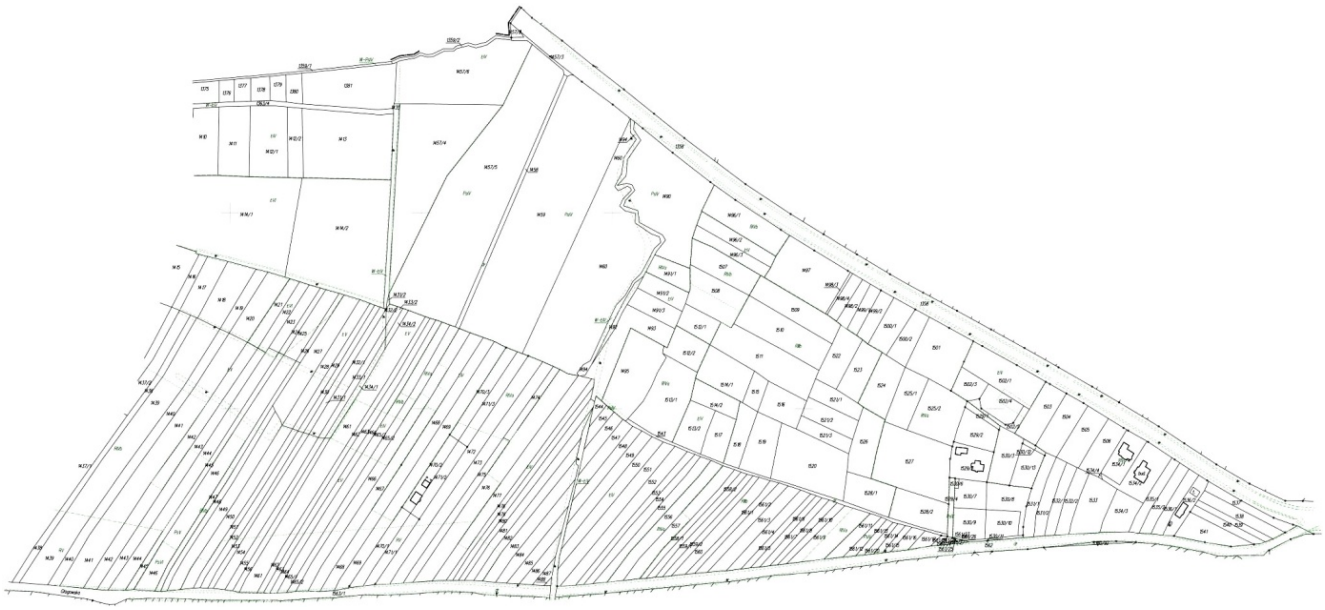

Fig. 1. Land and building register of the examined area; source: own elaboration

further investments and transparent regulations, especially in in the context of interoperability [MAŚLANKA 2015; Ustawa… 2010], harmonization [MAŚLANKA 2015; Rozporządzenie MRRiB... 2010] and the obligation imposed by the surveying and cartographic regulations [Rozporządzenie MRRiB... 2010] which apply also to the Principal Geodesist of Poland in terms of the integrated real estate information system, for whom the spatial data contained in the land and building register is of reference nature and affect the quality and credibility of the entire system.

The quality of the land and building register map determines the accuracy of determining the ownership of registered parcels boundary breakpoints lines. As soon as the land cadastre (real estate) is established in the written form, the accuracy of property ownership rights has a decisive impact on the value of the entire database. For precise data gathering, it is necessary to establish the boundaries of break-down points, in the presence of interested parties, regardless of the plot location. This is an indisputable requirement, resulting from the unique land feature, which is both a workshop and a way of production. This principle was in force when compiling maps of the former Austrian cadastre, which is still respected not only by property owners but also by lawyers dealing with property rights. Establishing the boundaries is based on determining to what point (place) the ownership of the neighbouring property is derived. This definition of a boundary line has a very important social, emotional and psychological content resulting from social coexistence and peaceful management, resulting also from legal and technical nature, especially in southern and south-eastern Poland, where there is a large land fragmentation registered. It should be remembered that the location accuracy is reflected in land records as a safety measure.

The aim of the work is to present the methodology carried out with the use of unmanned aerial vehicle (UAV) for the assessment of land boundaries accuracy. The scope of work covers an area of less than 50 ha, which is divided into 190 registered plots, located within the Sokołów Małopolski (Poland) as illustrated in map (Fig. 1). The area of the Sokołów Małopolski map in the geographical coordinate system is located between 22°00'–22°15' eastern longitude and 50°10'–50°20' northern latitude.

THE USAGE JUSTIFICATIONS OF THE UNMANNED AREA VEHICLE IN RESEARCH

In the conducted research, no classic photogrammetric methods of high accuracy and possibilities [KUKLICZ, KUŹNICKI 2015; KURCZYŃSKI 2006; KURCZYŃSKI 2016], were used, however due to the poor quality of maps made in the 1950s and 1960s, they were wrongly perceived as infamous [KUKLICZ, KUŹNICKI 2015; PYKA 2016]. Taking into account the economic aspects, it seems advisable to perform classic photogrammetric flights for larger areas than the commune one [KUKLICZ, KUŹNICKI 2015]. In addition, the time of establishing the breakdown points of land parcels would be too long and in a large part they would be exposed to destruction in the process of field work. For this reason, the use of unmanned aerial vehicle is justified, since the measuring may cover smaller areas within the register, dividing it into complexes. This approach allows for successive determination of break-down points of the boundaries of the registered plots. Research conducted on the possibility of using UAV for measuring purposes indicates with a very high probability that this technology can be used for the selected details of group I (most accurately located) in modernization of land and building registers [KĘDZIERSKI 2016]. However, the unresolved problem is the development of a uniform method of making measurements for the purposes of land registry, in such a way that the results of the work would be reliable, and accepted by the Poviat Centers.

LEGAL REGULATIONS REGARDING THE USE OF UNMANNED AERIAL VEHICLES FOR THE HEAD OFFICE OF GEODESY AND CARTOGRAPHY

The main legal act enabling and regulating the application of UAV on the territory of Poland is the Act of 3rd of July 2002 on Aviation Law, defining (Article 126) the basis for UAV use in the Polish airspace, whereas the implementing rule relating to Art. 94 § 8 and 9 and art. 104 § 1 of this Act [Ustawa... 2002], i.e. Order of the Minister of Transport, Construction and Maritime Economy of 3rd of June 2013 regarding qualifications certificates [Rozporządzenie RMTBiGM ... 2013], specifies the requirements for UAV operators performing flights for commercial purposes, for which geodetic works undoubtedly are. The use of UAV in geodesy is possible because of § 15 of the Regulation of the Minister of Internal Affairs and Administration of 9th of November 2011 on technical standards for surveying situational and altitude measurements as well as the development and the measurement transmission for the state geodetic and cartographic resources [Rozporządzenie MSWiA... 2011] that allows the use of geodetic measurement methods, technologies and techniques other than those provided for in the applicable regulations, which provide accuracy standards [Rozporządzenie MSWiA... 2011]. Also in photogrammetry Regulation of November 3rd, 2011 issued by the Ministry, regarding aerial and satellite imagery and orthophotomap and numerical terrain model [Rozporządzenie MSWiA... 2011], in § 19.6, it is possible to use other than the classical methods of data obtaining, as long as their technical parameters correspond to the applicable accuracy standards. The Regulation [Rozporządzenie MSWiA... 2011] on technical standards for situational and altitude surveying and state measurement transmission, defines in §2, a geodetic photogrammetric measurement as a situational or altitude measurement performed on a terrain model created from processed aerial photographs, and geodetic cartometric measurement is defined as a geodetic situational measurement performed on an analog map or its calibrated digital display as well as on an orthophotomap, it is of vital importance that the photogrammetric regulation [Rozporządzenie MSWiA... 2011] allows different from photogrammetric records performed in the classical approach, as long as they correspond with accuracy parameters, hence it seems legitimate to say that photogrammetric measurements, according to §35.2 of the Regulation of land and buildings [Rozporządzenie MRRiB... 2001] are the ones that can be performed using UAV. However, it should be remembered that the procedure of setting limits based on the provisions of §37 [MRRiB... 2001] can be used only in the absence of documents listed in §36, when the documentation is accepted by the Head Office of Geodesy and Cartography as a result of:

- demarcation proceedings,
- real estate division,
- land exchange and consolidation,
- real estate consolidation and division,
- court or administrative proceedings used to issue a final court decision or final administrative decision,
- establishing real estate cadastral on the basis of previously applicable regulations,
- defining the course of state borders by the Border Guards with accuracy appropriate for the record,
- geodetic situational measurement of existing, renewed or designated border points, or in the case of lack of credibility of the above-mentioned documents [FELCENLOBEN 2017], as indicated by Provincial Administrative Court in Krakow of 30 January 2015. III SA / Kr 1766/14 [Wyrok... 2015].

METHODS

The Topcon Unmanned Aerial Ship of the Sirius PRO type was used to measure the breakpoints of the boundaries of the registered plots. The Aerial Ship was equipped with a non-metric 16 Mpx RGB camera and a positioning system based on the L1 / L2 GPS receiver.

After research area establishing and before determining the boundaries of the parcels, UAV measurement was carried out, as a result of which an orthophotomap was created with a pixel value of 7 cm – Figure 2.

In this map, without signalling the breakpoints of the parcel boundaries, an attempt was made to determine, as a result of the photo interpretation, the location of the registered plots boundaries' bends. When measured, arable lands and construction sites boundary lines are clearly visible and "guarded" by the owners (users), it is possible to indicate the lines with good accuracy [KUKLICZ, KUŹNICKI 2015], but neighboring grassland and land on which agricultural production was stopped, the line indication is difficult, the measurement is often unreliable. The admissibility of the process on the terrain model (ortofotomap) does not create any doubts, because in the amended for the first time in 2013 regulation on land and building registry [Rozporządzenie MRRiB ... 2013] section 37 indicating the obligation to set ground boundaries was removed, however it can be questioned in §39.4 [Rozporządzenie MRRiB... 2001], stating the need to mark boundary points in a way that allows measurement.

Next the boundaries of the registered plots were determined in the presence of the interested parties. With the use of wooden pegs of 25×25×250 mm, 338 boundaries' bending points were marked (Photo 1).

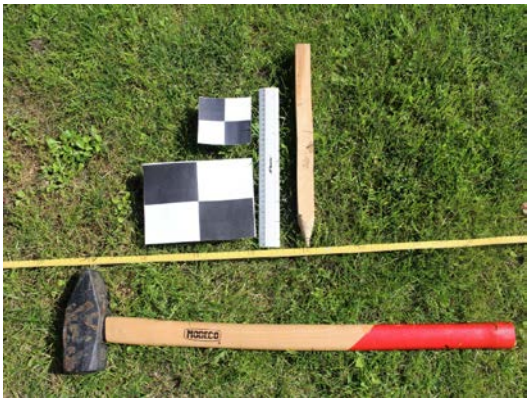

Photo 1. Tools for stabilizing border points (phot. *K. Ożóg*)

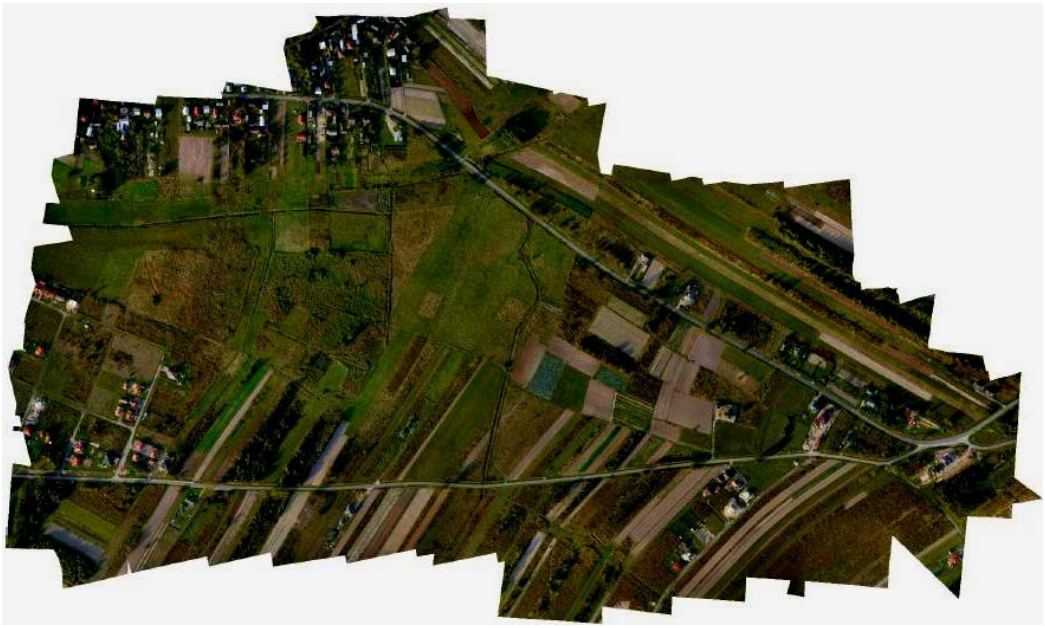

Fig. 2. Unmanned aerial vehicle measurement – a view with no scribe lines of the registered plots boundaries' bends; source: own elaboration

The scribe lines of the registered plots boundaries' bends were measured by the direct method in GPS-RTK technology with the Topcon GR-3 receiver. The next stage was to indicate on the wooden pegs the photopoints – black and white four-point chessboard (Photo 1), of 100×100 mm, and for 100 points located in a compact group of signals 148×210 mm. The use of signals with different dimensions was aimed at examining the readability characters for different pixel size and choosing the best optimal one.

RESULTS

Having marked the points in the studied area, the basic technical parameters of UAV was established before the air-raid, i.e.

a) the size of the unit pixel in relation to the terrain detail,
b) degree of longitudinal and transverse coverage in the series, which was respectively 60% and 40%.

Three raids were carried out with an UAV using the following three pixel sizes: 3 cm, 5 cm and 7 cm (Photo 2).

Photo 2. Test equipment used (phot. *K. Ożóg*)

Fig. 3. Legibility of pixelated points of interest: 3 cm, 5 cm and 7 cm; source: own elaboration

Photo 3. View from above of the building (phot. *K. Ożóg*)

With the increase in the unit pixel size (A»B), the time of the raid was shortened, the number of images taken by the camera decreased, together with the readability of the pictures. The possibility of interpreting the resulting material deteriorated (Fig. 3). After evaluating the readability of the pictures for further analysis, the pictures taken with a 5 cm pixel size were first selected.

It was also noticed that the assumed values of transverse and longitudinal coverage in the series affected the distortion of the geometry of spatial objects (Photo 3). The resulting imperfections are related to the applied algorithmic solutions in the software used to generate orthomosia. Experiments indicate that there are no such problems with 80% cross-and longitudinal coverage of photos. However, for the purpose of measuring the determined breakpoints of the parcels, the accepted coverage of the photographs seems to be sufficient.

DISCUSSION

The determination of the boundaries of the parcels was carried out in October due to the increased presence of farmers in the area caused by the end of the farming season. Then, the raid and measurement was carried out using UAV, which was based on 12 evenly spaced field points, directly measured. The square errors of the photopoints for X and Y coordinates were in the range 0.03–0.14 m, additionally after equalization the result was checked on 20 independent evenly distributed control points, obtaining differences not exceeding 0.10 m. Similar results were obtained by three points of the geodetic detailed network, what meets the legal parameters required by law. The regulation on technical standards for surveying situational and altitude measurements [Rozporządzenie MRRiB ... 2011] in §29.1 defines the accuracy of determination during the situational measurement of the break point of the registered parcel (group I) with an accuracy of not less than 0.10 m in relation to the nearest horizontal points of the geodetic control network and the measuring network. Bearing in mind that the measuring network is made up of a detailed network, and this, in turn, to the basic one, we get an absolute error of 0.17 meters [PYKA 2016].

CONCLUSIONS

In accordance with the applicable legal and technical regulations, in the process of modernization of land and building register, the undetermined or doubtful location of the breakpoints of the boundaries of registered plots, determined on the basis of documents accepted for the Head Office of Geodesy and Cartography, should be dealt with landlords, or persons who own these properties on the basis of self-possession. Determined breakpoints of the boundary lines should be marked in a way that allows their measurement. Indicating the border points of the registered plots by owners, or doing so in their presence, increases the credibility of the field measurements performed, and thus of the entire land and building register. Research indicates that points marked can be measured with good accuracy using UAV. Photogrammetric methods in agricultural works have been successfully used by the Swiss authorities for many years.

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