International Cartographic Association
Association Cartographique Internationale

The rising role of drones in the training of cartographers at Eötvös Loránd University (ELTE)

Fanni Vörös [a,*], Béla Kovács [a], László Zentai [a]

[a] *ELTE Eötvös Loránd University, Inst. of Cartography and Geoinformatics, Budapest, Hungary – vorosfanni@map.elte.hu, climbela@map.elte.hu, laszlo.zentai@elte.hu*

* Corresponding author

Abstract: The achievements of the technical boom of the recent past will inevitably appear in the world of cartography and geoinformatics. One of these relatively new and increasingly popular technologies is drones (UAVs). This article serves a dual purpose: first, it presents the courses offering practical training at ELTE Eötvös Loránd University, Budapest (Hungary) for several decades and lists the tools used in them; second, it shows how information about drone recording can be integrated into which courses. The article also discusses how difficult it is to implement this in university education in Hungary under the current legal conditions, and what obstacles teachers encounter.

Keywords: GIS, training, UAV in education, drones

1. Introduction

Together with 48 European countries, Hungary participates in the Bologna process, in which the member countries voluntarily undertook to coordinate their higher education systems. Because of the independent intergovernmental process launched in 1999, the higher education systems of individual countries have become (or are becoming) part of a large European system, the European Higher Education Area. In 2006, the Hungarian higher education system switched to multi-cycle education, in which a higher education system based on bachelor's, master's and doctoral education was created (Zentai, 2011a).

The pre-Bologna system was called 'dual system' – see more in Zentai, 2009. Of course, in the first few years of the transition, the old five-year training and the basic training of the new Bologna system ran parallel. Due to the differences between the two systems and the available data, we only examine the time of the Bologna system.

The authors present the used tools/equipment and their necessary development on the example of a specific unit, a department (later institute) – mainly focusing on the technical innovations of the last few years.

At other universities in Hungary, there are courses in which drones play a significant role, but they mainly appear in research projects and work with the products they have created - the theoretical material is in the foreground. Since there are special (paid) courses of external companies in which the applicant can obtain a drone "driving license", flying drones in university courses is not common.

It is important to note that in the case of ELTE, we are only talking about civil mapping. Geodesy and military mapping are not part of our MSc programme. The surveying part belongs to BME (Budapest University of Technology and Economics).

That is why the thoughts and investigation expressed in the paper approaches the subject from a purely cartographic, not from a technical point of view (or not from agricultural users).

2. Levels of Hungarian higher education

The Hungarian higher education system consists of three interdependent training cycles: bachelor's, master's and doctoral training

a) Basic level: for those who have a school-leaving certificate and want a degree, the first step is to complete a bachelor's degree. The bachelor's degree (BA: Bachelor of Arts; BSc: Bachelor of Sciences, depending on the discipline), which lasts 6–8 semesters, provides a higher education qualification and a professional qualification in the relevant field.
b) Undivided training: some degree programmes offer 10–12 semesters of training to obtain a Master's degree (e.g. lawyer, medical doctor).
c) Master's degree: the Master's programme (MA: Master of Arts, MSc: Master of Sciences) offers a Master's degree and a professional qualification. To be admitted to a Master's programme, you must have at least a bachelor's degree or a bachelor's degree from a college/university under the former system of education.
d) Doctoral level: those planning a research or more theoretical career can apply for an accredited doctorate (PhD) and a Master of Arts (DLA) after completing the Master's degree.

Proceedings of the International Cartographic Association, 5, 23, 2023.
31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa. This contribution underwent single-blind peer review based on submitted abstracts. https://doi.org/10.5194/ica-proc-5-23-2023 |

2.1 Cartographer training at ELTE

The authors of the present paper belong to the same organizational unit: the Institute of Cartography and Geoinformatics at the Faculty of Informatics of ELTE Eötvös Loránd University. Students studying cartography and geoinformatics can complete the training as follows:

After secondary school, the student can apply for the 6-semester BSc course in Earth Sciences of the Faculty of Sciences at ELTE. At the end of the first semester, cartography is one of the six optional specializations, which students can choose themselves. After obtaining the diploma, the student will be transferred to the Faculty of Informatics: either the cartographer or the geoinformatics master's course, which are 4 semesters long (Zentai, 2011c).

The master's course in geoinformatics is very recent: the first year started in the fall of 2022. In Hungary, the master's course in cartography is launched only by our Institute, while geoinformatics by several institutions. (As the amendments of the new National Higher Education Act make it easier and easier to start new courses, expansions may occur in the future.) Applying for these courses from other programmes or universities is also possible by fulfilling certain requirements (Figure 1). After the master's degree, it is possible to apply for a doctoral degree.

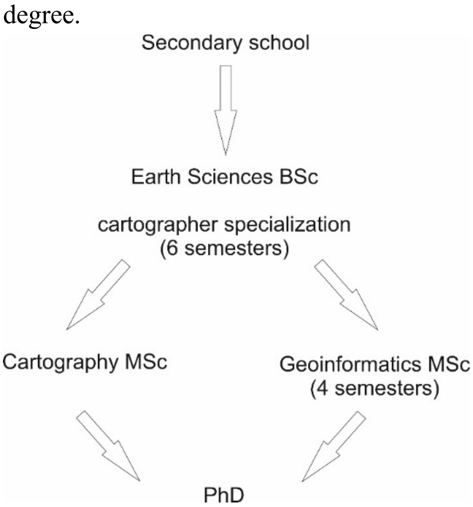

Figure 1. Trainings with the involvement of the Institute of Cartography and Geoinformatics.

3. Courses with instruments at our institute

In addition to theoretical courses, the appropriate amount and quality of practical classes is also important. It is very common for students to solve calculation tasks in the practical classes. Within the framework of earth sciences, some practical lessons are often held on the terrain. In these classes, the understanding and use of technical tools and equipment is essential.

Even before the transition to the Bologna system, there were practical and theoretical classes in which students learned how to use various instruments. As the courses have become much easier to follow and organize in the new system, only those courses are presented below that were introduced since then.

a) **Measurements and observations.** The very first lesson where the cartographer teacher meets *all* the earth science students. This subject has existed since the appearance of the Bologna system: initially in the second semester, but in the first semester since 2017. This is a practical class: in the first half of the semester, the students receive theoretical instructions, and then in the second half they have practical lessons in the field. They have two cartography training sessions. The first time they do a "geocaching" task (they have to find pre-defined points), the second time they have to make a map of a designated area. In both cases, Garmin Map 60/62 GPS equipment is used (see later in Figure 6). Although the task could be completed with their own cell phones, but it is important to introduce students to other methods. The latter field devices (unlike phones) are more reliable, do not drain after a few hours of use, and they are waterproof and robust – which aspects can be important in the field.

b) **(GPS) Fieldtrip**. This was a class for first-year earth science BSc students, but not for the entire class: the cartographer's field is an optional field exercise. It lasted from the introduction of the Bologna system until 2016. The course ran for five days: the first day included a briefing at the university on how to use the GPS devices followed by four days on terrain. At the beginning, a part of Budapest had to be surveyed, and then the following days were spent on the terrain. Each day, the groups had to survey a designated area and see if anything had changed in recent years. These measurements were made with 60 and 62 Garmin GPS. At the end of the survey, a renewed map had to be prepared for each area.

c) **Satellite positioning (**formerly **GPS course)**. This course is already meant for cartography students, who study it in their second year. Since 2007, there have been lectures and practical classes every year. In the theoretical part, the students get a comprehensive overview of the evolution (Figure 5) and use of satellite positioning. In the practical part, the students have to survey a part of a selected settlement with Garmin 62 GPS units. All objects and attractions must be measured, and then the data should be processed and presented in the Trackmaker software (at that time, the students had not yet learned to use any other drawing software).

d) **GPS fieldtrip (orientation, map knowledge)**. At the end of the second year of the BSc, there is a 5-day field practice. Initially in the Mátra Mountains (Hungary), though it has always been elsewhere in the last few years. The students, in groups of two, use Garmin Map 60/62 to update one designated area and then redraw the map.

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They are out in the field recording the observed changes of objects in the GPS and in the report. These changes are entered into the GIS software in the evening. In recent years, there has also been a drone demonstration.

e) **Navigation systems**. This MSc first year course is about GIS level (below sub-meter) precision field receivers/computers. Areas previously surveyed (with Garmin GPS's) are also surveyed with devices that are more accurate. They use Trimble GeoExplorer series field data loggers (Figure 7). They can also try real-time and post-processed high-precision units and tools. The measured data are processed and displayed using GIS software.

f) **Geodesy**. This course including practical and theoretical classes is for MSc students. Students become acquainted with basic geodetic concepts (projections, shape of the Earth, basic calculations) and with geodetic instruments and measurement in several classes. They get to know the instruments within the exercises, e.g. the theodolite (Figure 4 a)).

g) **Complex fieldtrip**. This course has been available since 2014 (previously under a different course name) for first-year master's students. Except for the last three years, this field exercise was always in Transylvania, Romania, usually for a week. The students are acquainted with the mapping of high mountain areas. Because of Covid, the field exercises have not taken place abroad, but somewhere in Hungary since 2020. In the beginning, the surveys were carried out only with Garmin Map 60/62, but in the last three years drone flights were added. The domestic exercises were all next to Lake Tisza (which is an artificially created water reservoir on the Tisza river): the students mapped the settlements along the lake while riding on bicycles. The result of the surveys was a map of Lake Tisza, which is constantly updated (Kulcsár, 2021).

h) **Measurements, data collection**. This is a new course for geoinformatics MSc students. It is entirely about drone data collection techniques and data processing (see Chapter 6 d).

i) **High precision GNSS measurements**. This course can be taken as a PhD course. The backbone of the course is the use of RTK (Real Time Kinematic) GPS's (Figure 8) and the use and theoretical practice of the extremely accurate GNSS systems.

Some courses have been discontinued over the years:

a) **Survey field exercise**. Traditional equipment was used: analogue and digital theodolite, level (Figure 4). A survey of the areas of the ELTE campus had to be done at this time. Maps were made from the data generated during the survey in the context of other related courses.

b) **Modern survey methods.** The following instruments and survey methods were introduced: GIS level field data collectors, 3D terrestrial scanner, RTK GNSS and Total Station. Several instruments were included in university education within the framework of external ongoing projects (e.g. Gede et al. 2013).

In Figure 2, the statistics of the three selected courses can be seen depending on the number of participating students. The *Measurements and observations* course, showing the number of students per year, is for all the BSc students. It can be seen that the highest number of students (over 200) since the introduction of the Bologna system was recorded in 2009. However, the number has been slowly decreasing: only 60 students enrolled in the earth sciences basic course this year. The *Satellite positioning* course is for BSc students (specialising in cartography), but it is usually taken by students from other specialisations too. The downward trend can be seen here as well: the initial ~35 people now dropped only to 8 this year. The *Navigation systems* is for MSc students. While there were 13 students in the master's program in 2014, only two graduated this year.

Figure 2. Number of students of three selected courses (Measurements and observations, Satellite positioning and Navigation systems) since 2006.

Unfortunately, this is a general trend in earth science courses in Hungary: the number of students nationally decreases annually by approx. 10%. In Figure 3 the cumulative number of admitted natural sciences students in the four largest universities (ELTE, University of Szeged, Pécs and Debrecen) can be seen.

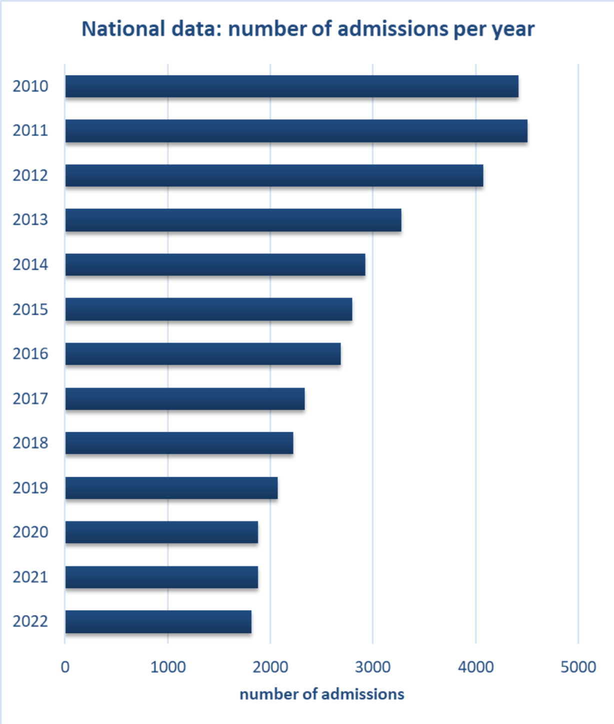

Figure 3. National data of number of admissions per year in the four largest universities in the field of natural sciences. Data source: felvi.hu.

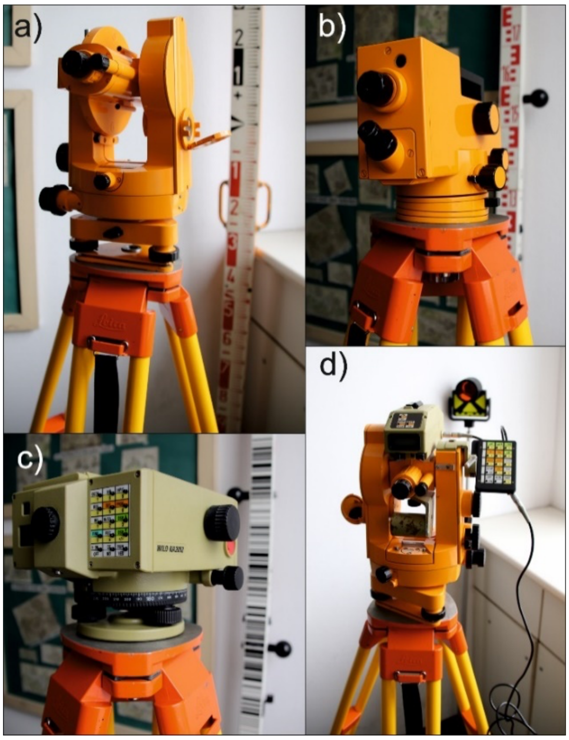

Figure 4. Traditional surveying tools.

4. Used equipment

In the following, we present what tools are available at our institute. The students learn to use the tools during the courses (see Chapter 3), which they can also use later in projects and tasks related to the university.

4.1 Traditional tools

Figure 4 a) shows a Leica tripod with a Carl Zeiss Dahlta 010A self-reducing tacheometer from 1979 (a measuring pole/tacheometric staff in the background). Basically, it is for distance measurements based on optical, parallactic triangle with a variable angle and a base on a vertical staff. The precision is 10–20 cm per 100 m for distances and 5 to 10 cm per 100 m for height differences. Range is up to 300 meters. b) is a Carl Zeiss NI 020A (1982) compensator level with connecting pole. c) is a Leica Wild NA2002 digital optical automatic level with a connecting barcoded staff. The accuracy of distance-measurement is 1–5 cm in the range of 100-meter distance. d) is a Distomat Wild DI1001 integrated on a Carl Zeiss Theo 010A (a GPH1A single-prism reflector in the background). Under excellent conditions, distance measurement of 6 km is possible with a precision of centimetre level.

4.2 Satellite-based field tools

The base of the satellite-based positioning and measuring technics were introduced with a base, hobby level GPS gadgets. From the early "GPS times" we have a contract with providers to test their equipment, so we were enabled to test the small, new handheld devices.

In Figure 5, various small GPS receivers can be seen. In Hungary, the top sold Garmin and Magellan GPS equipment simplicity and precision were enough to present easily the base of the satellite positioning technics for students. Most of this equipment has 3–12 channels that can simultaneously track up to 12 GPS satellites. The display can show only the coordinates, though there was a map window too on some equipment. The precision is "below +/–30 m on the 95% of the all-time". This precision can be enough to practice the technics and technology for ordinary mapping and map corrections (again: *not* for precise mapping and surveying).

The Garmin geko (Figure 5 a)) was the cheapest equipment that we tested, while the etrex series GPS (Figure 5 b)) was the top sold equipment in that time. They can store not only 500 POIs (Point of Interest), but up to 10,000 tracklog positions as well.

The Magellan produced equipment (Figure 5 c)) has the availability to enter manually the Helmert transformation parameters – necessary to present the Hungarian coordinate systems coordinates directly.

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Figure 5. Hand tool GPS's.

Figure 6 shows the equipment used nowadays. The Garmin 60-series (Figure 6 a)) was the most robust case-based equipment that we used: most of them still work today. The new standard was the Garmin 62 series (Figure 6 b)), with a new higher resolution display, preloaded maps (and possibility to show/enter the self-created maps too), nearly unlimited field collected waypoints and tracklog points, fast data transfer, and long working time with standard AA batteries – this was the strongness of this GPS. The new series can track the GLONASS or even all satellite-based global systems signals (Figure 6 c)). The various handheld computers/PDA's we also used for training, but the working time (typically less than 2–4 hours), the vulnerability, and the price was the contraindication for everyday usage.

Figure 6. Nowadays used equipment.

4.3 GIS data tools

From the early 1990s, the Trimble GeoExplorer II and following systems were used for teaching the field data collecting and positioning technics at our department. The precision of handheld data collectors – with built-in GPS receivers – were around 2–5 meters after the post-processing of field collected raw GPS signals. That was more precise than the non-GIS level handy GPS equipment (with +/–10–30 m precision). The early produced instruments were affected with the "GPS week number rollover" phenomenon, which made the data process more difficult.

The GIS precision level instruments (Figure 7) we used were the Trimble Scoutmaster, Trimble GeoExplorer II and Trimble GeoExplorer 3, a Trimble Geo2005 series equipment and later the Juno series GPS receivers/field data collectors. Nowadays the Trimble Juno series handheld was used mostly with GIS level (ESRI Arcpad) software installed on them.

Figure 7. Trimble tools.

4.4 High-precision survey tools

For the teaching of the high accurate positioning, we used mainly two poles mounted GNSS equipment. The Spectra Precision series Epoh 35 GNSS receiver (Figure 8 a)) with TDS Nomad series handheld field data collector is used for high-precision positioning and measuring. This equipment can track GPS and GLONASS satellite signals, and process RTK, networked RTK or standard PPK measurements. In places where the data (radio/mobile) signal coverage is weak or impossible, while the raw data collecting can be enabled, the post-processing is also an available option.

The Stonex S8III+ (Figure 8 b)) is the multiband GNSS receiver that can track and collect all known global satellite-based positioning systems signal. For data collecting also the handheld field computer (Stonex S4) is used with appropriate data collecting software.

On the roof of the University building, we have a Trimble NetR5 GNSS base station – with an appropriate sensitive antenna system –, which is a part of the non-governmental based Hungarian GNSS base stations network (GeotradeGNSS: http://www.geotrade.hu/index.php?lang=en).

Figure 8. High-precision RTK GPS's.

4.5 The new UAV and sensors

As a new, modern discipline, geoinformatics places great emphasis on the processing of spatial data and the production of data derived from them (Zentai, 2012). Drones, or UAVs, are one of the best and newest tools for producing these. The terms Unmanned Aerial Vehicle (UAV) and Unmanned Aerial Systems (UAS) are well known internationally and mostly include any device capable of taking off and landing without a pilot (Elliott 2017, Major et al. 2016, Restás 2017).

Our Institute has one UAV and two accompanying sensors. The DJI Matrice 210 RTK V2 UAV is a quadrocopter (Figure 9 a)). Several sensors and lights ensure flight safety and obstacle avoidance. In addition to these, a 608x448 px resolution FPV (first-person view) camera is located on the UAV, which can help with orientation in the case a higher resolution camera (in our case Zenmuse X5S) is mounted to pan the ground. Two D-RTK antennas are responsible for the most accurate detection of the correction data measured by the separate RTK station (Figure 9 b)) belonging to the drone. Two batteries are required to fly the device.

Two sensors can be connected at the same time. For our institute, two sensors are available. The Zenmuse X5S high-resolution RGB camera is used to capture the surface and other objects (image and video). The MicaSense Altum multispectral sensor (Figure 9 c)) has six different spectral bands: near infrared, red, blue, green, RedEdge and a low-resolution thermal (Pál et al. 2021). There are plans to purchase other sensors and devices (e.g. Lidar sensor).

Figure 9. a) DJI Matrice 210 RTK V2 UAV, b) the RTK Station, and c) the MicaSense Altum multispectral sensor.

5. Processing and theoretical courses

Although this paper specifically scrutinizes the practical classes, we present in a few words what happens "after" - that is, what happens to the data after data collection. These courses were also present before the arrival of the new UAV, so they are not directly related to our own device. Since we can record data ourselves, they are also used in these courses in some cases. The software used in the classes is adapted to the needs of the market.

a) **Remote sensing and photogrammetry.** It gives a general, theoretical knowledge of remote sensing and photogrammetry, e.g. different resolutions.

b) **Processing of remote sensed data.** It is a more general processing course. The main topic is the processing of satellite images and the calculation of different indexes (e.g. NDVI).

c) **Drones in field spectrometry.** As the name suggests, students work with drone images in this exercise. They learn how to read the exif data, how to create an orthophoto from separate images, classify data automatically and calculate indexes. Since the files are very large, the students work with smaller parts (and in lower resolution) in the course, so the process is faster. As homework, they must work with the entire data, so they can experience the processing time of up to several hours.

6. Integrating the new equipment into the courses

In several of the courses listed in Chapter 3, the new UAV device was introduced.

a) **Measurements and observations**. The original two practical lessons and assignments have been preserved, though supplemented with an introduction to drones. Since we received one hour and half of an already existing course, only this interval is available, there is no possibility to fly in real terrain. That is why the demonstration can only be held around the university buildings; however, real flying is not possible due to legal restrictions (see later).

b) **GPS fieldtrip (orientation, map knowledge).** A drone demonstration was also introduced during this multi-day field exercise. Since the class is away from any settlement, in the field, it is possible to hold a real 'airshow'. In such cases, the students can try the device themselves and fly with it.

c) **Complex fieldtrip**. Due to the Covid, it has to be held in domestic territory: next to Lake Tisza. In addition to the traditional instruments, each student can fly the drone several times. Since there are fewer and fewer students, they can use it for more and more time: they even have the option of their own planned flight. The recordings made in this way are used not only for teaching, but also in research projects (Varga et al. 2022).

d) **Measurement, data collection**. As this class was held for the first time this year, its theme is entirely drone recording and processing. Students take combined (double) classes in a rural area. With one battery pair, one student can fly for approx. half an hour. At the beginning of the semester, they practice with manual flight, and later they plan a flight themselves and fly it. At the very end of the semester, they learn how to make an orthophoto from it. They will be tested as follows: they must take the simple, A1-A3 drone license test so that they can officially drive a drone under certain conditions at the end of the lesson.

Course	Equipment	
	traditional	UAV
Survey field exercise	✓	
GPS	✓	
Modern survey methods	✓	
(GPS) Fieldtrip	✓	
Measurements and observations	✓	✓
Satellite positioning	✓	
GPS fieldtrip (orientation, map knowledge)	✓	✓
Navigation systems	✓	
Geodesy	✓	
Complex fieldtrip	✓	✓
Measurement, data collection		✓
High precision GNSS measurements	✓	

Table 1. Instrumental courses since 2006 with the used equipment: discontinued courses are in gray.

31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa. This contribution underwent single-blind peer review based on submitted abstracts. https://doi.org/10.5194/ica-proc-5-23-2023

6.1 Legal background of drone flights

To fly a drone legally (even before the first flight) we need to do a lot of things, such as registering the drone, the pilot, taking several exams, and taking out insurance. EU Regulations 2019/947 and 2019/945 set the framework for the safe operation of civil drones in European skies. It defines three categories of operations: the ‘open’, ‘specific’ and the ‘certified’ category. For more, visit: https://www.easa.europa.eu/en/regulations/uas-unmanned-aircraft-systems. Hungarian regulations are stricter than the EU, e.g., regular flights within a populated area require a lot of permits. Such is the airspace permit, which must be requested at least 30 days before the planned flight and can be applied only for one week. If we are in an airport landing strip, we also need permission from the airport (the same is true for a hospital helipads), and in many cases we need many other permits, which are quite expensive. It is easier in rural areas, where you just need to use an app (MyDroneSpace). The problem with these is that they are located a long distance from the University buildings, where we have to get out. This is impossible to do in a one-and-a-half-hour course.

7. Summary

As in any evolving discipline, it is important to keep up with the latest tools and methods in GIS. One step towards this is the introduction of (drone) remote sensing into the curriculum. It would be important not only to teach the students the theoretical background, but also to provide them with the opportunity to try every step of a drone survey.

Under the current circumstances, it is practically impossible to fly within the framework of organized education, in the environment of the university, due to the following factors:

- airspace requests need to be submitted 30 days in advance;
- the possibly authorized airspace can only be used for 7 days, which is problematic due to the even less predictable weather;
- the request for a permit due to airports and other restricted airspaces is also a significant administrative task for each request;
- the lack of a legal background related to the use of drones for educational purposes is a huge disadvantage.

As described above, we can only currently drone away from urban environments. This requires a lot of time and extra costs (for petrol). It would be worthwhile to regulate drone flights for educational purposes separately, and to give concessions for them.

8. Acknowledgements

The research was supported by project no. TKP2021-NVA-29, which has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development, and Innovation Fund, financed under the TKP2021-NVA funding scheme.

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