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# HUNGARIAN AGRICULTURAL RESEARCH

Spring 2023

Environmental management, land use, biodiversity

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# APPLICATION OF PESTICIDES BY DRONES FROM THE POINT OF AUTHORITIES

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## ABSTRACT

Agricultural precision farming has gone through a huge development recently, which applies to plant protection as well. It can be said that it is no longer just a strong interest in using drones as plant protection machines, but the use of these machines in agriculture has actually begun. As though drone spraying has been granted social legitimacy. In our research, the regulatory instruments currently in force have been examined. However, for the time being, the exercise of the activity constitutes an infringement that the authorities – following the existing legal requirements – may only consider as fine to be imposed on the person carrying out the activity. It has been declared that, as a result of a growing interest coming from the farmers, a more extensive use of drones in activities of pest protection will be made available when creating the related regulations.

**keywords: sustainable agricultural, crop protection, drone technology, legislation**

## INTRODUCTION

Agricultural production has undergone a vast technical development during the past decades. (Rodroques 2009). As a result of development, our yields in terms of cultivated plants have increased in such a way that in the meanwhile a much higher emphasis was put on environment protection as well as nature conservation (Lav R. et al. 2012). As a consequence of technological development, less and less dosage of both fertilising products and pesticides has to be used (Gebbers és Adamchuk 2010). A growing demand towards plant protection treatments with the use of drones has also occurred lately.
I analysed how –as part of precision agriculture – farmers are increasingly encouraging the use of drones as plant protection machines, in particular for the application of plant protection products, however, the domestic legal environment of this activity is still being developed and the exercise of this activity is therefore still illegal. Meaning by this that plant protection treatments with a drone should be sanctioned by the imposition of plant protection penalty. The legislative process has not progressed by the time this study was written. The use of pesticides by drones continues to be illegal activity. Meanwhile, not only has the interest in drone plant protection increased, but the plant protection authority had been informally aware from the beginning of 2020 that drone treatments were becoming more common. In the end, it was inevitable that by the end of August 2020 a drone treatment is officially on the authority's radar and an official administrative procedure is therefore initiated for the imposition of a fine.  The study seeks to demonstrate how the authority interprets existing legislation, and in the light of that how legally assesses the plant protection activity with a drone and what sanction it applies.
The authority carried out its procedure for the application of pesticides by drone on the basis of the legislative provisions referred to below (Figure 1.).
1. In accordance with Paragraph 1. (4) of the Act No CLXV of 2013 on Complaints and Public Interest Disclosures:

**Figure 1: Drones with precision sprayers (insert) apply agrochemicals only where they are needed**
***(Source: Anthony 2017)***

*„Any person may lodge a complaint and public interest notification with the body entitled to take action in the matter relating to the complaint or to the public interest notification (hereinafter: competent body). The public interest notification made orally shall be recorded in writing by the competent body and shall be provided in a duplicate to the public interest notifier."*.

According to Paragraph (1). 2. of Act on Complaints:

*„The complaint and the notification in the public interest must be dealt with within 30 days of receipt of the complaint by the competent body, unless provided otherwise by law."*.

According to point d) Paragraph (1) 3. of Act on Complaints:

*„In the light of the complaint or the public interest notification - if it proves to be valid – provision should be made for the initiation of Liability where appropriate."*.

2. According to Paragraph 99. of the Act CL of 2016 on the Code of General Administrative Procedure (hereinafter: GAP.):

*„The authority shall – within its powers – verify compliance with the provision of law, and compliance with the enforceable decision."*.

According to point a) of Paragraph (1) of 101. GAP:

*„If the authority finds an infringement during an official inspection, it shall initiate proceedings,"*.

According to Point a) in Paragraph (1) of 104. GAP:

*„The authority initiates the procedure ex officio in its area of competence if it becomes aware of the circumstance giving rise to the initiation of proceedings,"*.

3. According to the Decree 43 of 2010 of the Ministry of Agriculture and Rural Development on the rules of plant protection 5. Paragraph (1)-(2):

*„5. § (1) Plant protection products shall only be used as authorised in full compliance with occupational health and chemical safety rules."*

*„(2) Plant protection products shall be used in accordance with the requirements of the marketing and use authorisation (hereinafter: licence), in compliance with its labelling requirements for the prevention of risk to man and the environment and in accordance with its instructions for its use and plant protection technology. "*

According to Paragraphs (1), (2) of 32 and Paragraph (1) of 34 of the Decree 43/2010:

*„32. § (1) Plant protection machines with tanks bigger than 5 dm3 – except plant protection machines for research, testing, experimenting or exhibition purposes - shall be subjected to the type-approval procedure in accordance with Annex 3 for droplet formation and spraying technology before marketing.*

*(2) Plant protection machines that have legally binding international quality assurance certification documents may be approved administratively. The producer, or the distributor must declare to the Institute of Agricultural Engineering National Agricultural Research and Innovation Centre (hereinafter: the Institute) that the plant protection machinery meet the marketing requirements specified in this regulation.*

*34. § (1) If, as a result of the type-rating procedure a plant protection machinery does not comply with the requirements set out in Paragraph (1) 32. § (1), the Institute shall not grant the marketing authorisation, or withdraw the authorisation already granted.*

4. According to Paragraph (1) 17/B of Act XLVI of 2008 on the food chain and the official supervision thereof (hereinafter: Act on Food Chain):

*„Plant protection machinery shall be subject to type rating before marketing and periodic technical inspection (hereinafter: technical inspection) during use in accordance with the legislation issued for the implementation of this Act."*

According to Paragraph (1) 56 of Act on Food Chain:

*"In case of infringement of this Act, or the legislation issued for the implementation of this Act, as well as the infringement of the Act of the European Union which is directly applicable, and in the event of infringement of the provisions of an official decision the Food Chain Inspection Body may take action, impose a fine or give a warning to the legal person subject to the proceedings, an organization or natural person without legal personality ( hereinafter in this chapter: the person subject to proceedings."*

According to Point d) of Paragraph (1) of Act on food Chain 60:

*„A plant protection fine shall be imposed on persons who market, advertise, offer to the public or use a product that is subject to prior authorisation without authorisation, by way other than authorisation, without registration or by way of derogation of registration, or without the qualification or certification for the activity;"*

According to Point i) of Paragraph (1) of Act on Food Chain 60:

*„A plant protection fine shall be imposed on persons who do not have marketing authorisation (type rating), in addition did not participate in a periodic inspection, or marketed, operated or used non-compliant plant protection machinery;"*

5. The section entitled "Plant Protection Fine" and Annex I. of the Government Decree of 194/2008. (31.VII.) concerning the method of calculation and the scale of penalties in relation with food chain control set out the rules under which the authority determines the amount of the fine to be imposed.

## MATERIAL AND METHODS

After reviewing the existing legislation, the procedural acts that the authority has taken to clarify the facts will be described as well as what facts had to be assessed.

On 31 of August 2020 a notification has been submitted to the plant protection authority. According to the notifier, the iceberg lettuce grown by the notifier was damaged due to the dessication of the neighbouring sunflowers by drone. It needs to be clarified that the authority's notification procedure was a broader one that investigated the illegal drift during pesticide application, and this included the legal assessment of the plant protection treatment with the drone.

The authority examined the notification with regard to the provisions of the Complaint Act. In the course of the investigation, it carried out an official inspection according to the Code of General Administrative Procedure., as a part of which an on-the-spot check was carried out on the 2nd of September 2020. During the visit the user of the sunflower area presented and verified with an invoice that the dessication of the sunflowers was carried out in the evening of 26 August 2020 using the product Reglone Air in the dosage of 2,0 l/ha with a total spray volume of 8 l/ha by drone application by a service provider. During its procedure the authority concluded that the operator did not have a pilot authorisation for plant protection treatment with the drone.

Although it is no longer necessary to prove unlawful use of drones, it is interesting to devote a few sentences to the experience of the field check that demonstrate the drift of the plant protection product. During the on-site visit it was found that the sunflower is dried due to desiccation, as was the weed it contained in it. Cultures on the East, South and West sides of the plate show no symptoms. However, beyond the 18 metres wide stubble field of oil radishes, on the iceberg and maize at the depth of 168 metres and some of the weeds contained therein had necrosis spots in the leaves, and in more severe cases, leaching of the leaves. The effects of the spray reaching into the cornfield were also observed in lower weeds inside the stock. A significant part of the declared iceberg lettuce culture has been damaged to such an extent that it has become unmarketable. Phytotoxic symptoms on vegetation indicate scorching herbicide, which includes diquat-dibromide, the active substance of Reglone Air. So there is a causal link between the desiccation of the sunflower and the damage to adjacent cultures.

The authority found an infringement on the basis of the experience of the site visit, customer statements, documentary evidence and laboratory examination records, and, of its own motion, initiated an official procedure against a customer carrying out plant protection treatment with a drone.

The authority has notified the client of the initiation of the procedure. The client did not make use of his right to make a statement within the deadline, so the authority issued a decision imposing a plant protection fine on the basis of the evidence at its disposal.

## RESULTS

In this section, an overview is given of how the authority applied the legal provisions cited in relation to the use of pesticides by the drone. In other words, how the authority has established that the application of pesticides by a drone by the customer is illegal and, in view of this, what penalties were applied and to what extent.

Decree 43 of 2010 of the Ministry of Agriculture and Rural Development on the rules of plant protection Paragraph 5. Article (1), (2) provide that plant protection products may be used only in the authorised manner and in accordance with the specifications and instructions of the marketing and use authorisations and labels. The authority considers that the customer by the application of the product Reglone Air subject to licence with an agricultural drone, in the amount of 8 litres per hectare has performed a use and application different than set out in the licence, as the emergency licence of NÉBIH 6300/234-1/2020 states that *"Reglone Air may be used in autumn colza and sunflower crops for the production of good, furthermore in sunflower seed production for pre-harvest stock drying in the dosage of 1,5-2,0 l/ha by land-based machinery (hydra-tractor) spraying 300-400 l/ha… The preparation may be used by air applications in sunflower and autumn colza in at least 10 ha contiguous areas with an obligatory addition of a drop heavy additive in the amount of 50 to 60 litres/ha spray mixture."* Even the emergency licence does not approve the spraying in the volume of 8 l/ha by the use of agricultural drone.

The Act of 17/B. § (1) on the food chain and the official supervision thereof and 32. § (1), (2) and 34. § (1) state that plant protection machinery shall be subject to a type-approval procedure as a precondition for the granting of a marketing authorization. The authority concluded that the client had carried out plant protection services activities with drone equipment without Type Rating. The client attempted to interpret the activity as pilot application, however no experimental authorization has been granted by the competent authority for that area.

As a result of the official control carried out during the investigation of the complaint received on the 31st of August 2020 – on the basis of the on-site inspection, customer statements and documents obtained – the authority concluded that by using the plant protection product subject to authorisation in a different way, and using plant protection machinery without marketing authorisation (type rating) the client has committed an infringement.

In the light of the infringement established, the authority has decided to initiate proceedings on its own motion against the client for the imposition of a plant protection fine in accordance with point a) Paragraph (1) of 101 in the Code of General Administrative Procedure.

In the following, the basis and extent of the imposition of the fine will be examined. In case of infringement of the

Table 1: Basic fines to be applied in determining the amount of the plant protection penalty shown in table B) in thousand HUF

| Infringement of Table B) | Persons subject to proceedings that are not subject to the Accounting Act | Subject to the Accounting Act not exceeding HUF 500 million net annual turnover | Subject to the Accounting Act exceeding HUF 500 million net annual turnover |
|---|---|---|---|
| d) point 3. | 100 | 300 | 500 |

provisions laid down in the Act on the food chain and the official supervision thereof 56. Paragraph (1) or in the legislation issued for its implementation, the authority may impose a fine. In the present case, the grounds for imposing a fine are laid down in Article 60 of the Act on the food chain and the official supervision thereof Paragraph 1, points d) and i), according to which a plant protection fine shall be imposed on a person using a product subject to authorisation in a manner other than set out in the authorisation; using plant protection machinery without marketing authorisation (type rating).

As the authority found, as above, the infringements committed by the customer, thus imposed the two fines.

The amount of the fine is primarily determined by the rules of the Government Decree. At this point, it must be borne in mind that the authority also assessed the fact of the drift in the original proceedings when imposing the fines. Thus, instead of describing the specific fine amount, only the rules of the calculation are derived. In accordance with Point i) 2 of Annex No 1 of the Government Decree, the amount of the plant protection fine set out for the use of plant protection machinery without marketing authorisation (type rating) is HUF 50.000 per machinery. In accordance with Point 3., Paragraph d) in Table B) of Annex No1 of the Government Decree plant protection penalty rate for the use of a product subject to authorisation in a manner other than permitted is up to HUF 150 million, depending on the risk arising from use. Paragraph (1) of the Government Decree 5. provides that plant protection fines for infringements listed in Table B) of Annex No 1.shall not be less than the minimum specified in Table C) of Annex No1 for the given facts (Table 1.).

In the procedure described, the client was a company with an annual net turnover not exceeding HUF 500 million.

In view of the above, the minimum amount of the fine to be imposed is HUF 350.000. In other words, no lower amount may be set by the authority. The upper limit is HUF 150 million. The amount of the fine to be imposed under the fines shall be determined by the authority, taking into account the circumstances of the case, in which it may not disregard the principle of graduality. Thus, in the case of a first infringement, the amount of the fine clearly tends towards the lower limit.

## DISCUSSION

It can be said that it is no longer just a strong interest in using drones as plant protection machines, but the use of these machines in agriculture has actually begun. As though drone spraying has been granted social legitimacy. However, for the time being, the exercise of the activity constitutes an infringement that the authorities – following the existing legal requirements – may only consider as fine to be imposed on the person carrying out the activity.

## CONCLUSIONS

It can be said that it is no longer just a strong interest in using drones as plant protection machines, but the use of these machines in agriculture has actually begun. As though drone spraying has been granted social legitimacy. However, for the time being, the exercise of the activity constitutes an infringement that the authorities – following the existing legal requirements – may only consider as fine to be imposed on the person carrying out the activity.

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7. Act XLVI of 2008 on food chain and the official supervision thereof;
8. Government Decree No.194 of 2008 concerning the method of calculation and the scale of penalties in relation with food chain control;
9. Decree 43 of 2010 of the Ministry of Agriculture and Rural Development on the rules of plant protection;

# DEVELOPING A NATIONAL REQUIREMENTS FRAMEWORK FOR SPRAYING DRONES

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## ABSTRACT

The Hungarian University of Agriculture and Life Sciences (MATE) is designated by FVM Decree 43/2010 (IV. 23.) to determine the order and requirements of the type approval procedure for plant protection machines. International publications, experiences and methods have been studied to develop the criteria for spraying drones, attracting increasing interest. Field tests were conducted to determine the risks involved regarding the environment and the operator's workload. The measurements provided an opportunity to optimise the operational settings for better-quality treatments. Based on the literature and our tests, we developed a system of requirements for spray drones relevant to plant protection and identified further research purposes.

**keywords: drone technology, legislation, plant protection machines, sprayer testing, sustainable agricultural**

## INTRODUCTION

Nearly 30 years ago, spraying systems mounted mainly on unmanned aerial vehicles (UAVs), commonly known as drones, appeared in Asian countries. Over the past decade, drone technology has exploded thanks to its wide range of potential applications. However, it is no longer only used for military, law enforcement and disaster management tasks but has significant commercial and private uses. In agricultural applications, remote sensing was primarily used for quick and cost-effective soil and cultivated crop assessment. With the rise of precision agriculture, in addition to drones equipped with various cameras providing input data and systems that process, analyse and support farming with large amounts of data, devices developed for the drone platform are increasingly appearing for use in the production process. Firstly, they offer an alternative to technologies based on traditional machines in plant protection. Spraying drones is currently the only solution for plant protection work that requires quick detection and intervention, often in extreme weather conditions, considering economic, work quality, and environmental protection aspects.

Unmanned aerial spraying systems (UASS) are licensed in approximately 20 countries. However, the growing demand for the introduction of the technology is prompting legislators to consider amending the legislative environment. The global agricultural drone market is estimated at $3,807 million in 2023. According to some research, this revenue will reach $14,237 million by 2033 (Future Farming, 2023). Within the European Union, aerial plant protection is considered environmentally risky, and its use is prohibited or only allowed under strict supervision and conditions. Directive 2009/128/EC proposes a prohibition on aerial spraying of pesticides, allowing derogations in cases where they have a clear advantage in terms of reducing impacts on human health and the environment compared to other spraying methods where no other alternative is justified, provided that the best available technology is used to reduce drift. In the European Union, two regulations control the use of drones. The first is Regulation 2019/945 on unmanned aircraft systems, and the second is Implementing Regulation 2019/947 on the regulation of operations with drones. Besides the directly applicable regulations, the Hungarian national regulatory environment provisions also apply to unmanned aerial vehicle operations. National regulations applicable to plant protection activities: the definition of the pilot's competence and the special regulations of the operation are included in the 44/2005. (V. 6.) FVM-GKM-KvVM joint decree. FVM Decree No 43/2010 (23.IV.) contains the specifications for plant protection machines. This decree assigned the MATE to inspect plant protection machines from drip formation and spraying technology aspects.

Additionally to these specifications, other obligations of the unmanned aircraft system operator include compul-

sory liability insurance, UASS and operator's official registration, meeting competence requirements, determining the operational category and fulfilling the relevant regulations, and obtaining the special permits required to use Hungarian airspace. The Hungarian Drone Coalition attempted to resolve the complexity of the legal environment when it prepared the barrier map, outlining the system anomalies and making proposals to simplify the regulation while keeping in mind the interests of all parties involved and the social risks.
MATE is legally obliged to publish the requirements for the type approval procedure for spraying drones on its website. Due to the rapid development of drone technology, no generally accepted standards or international specifications and test methods were available. Our goal is to present the development and description of the drone technology requirements from a spray technology viewpoint.

## MATERIAL AND METHOD

To comply with our legal obligations and conduct a well-established official procedure, we had to consider the impact of drones on human health, the environment, and efficiency views. The following terminology was followed in setting up the requirements and the methodology: scientific publications on the relevance of the usability of spray drones were collected and analysed. We studied the certification system for spraying drones pioneered in Europe by Switzerland, where drones are widely allowed to apply chemicals.
Before developing the requirements, we carried out preliminary experiments with plant protection drones. Penetration, work quality features and working widths were investigated on the soil surface and the foliage of plants under different application parameters. Water-sensitive papers are laid out perpendicular to the direction of flight at 25 cm from the ground on special holders for fixing the pieces. The distance between each paper was equal

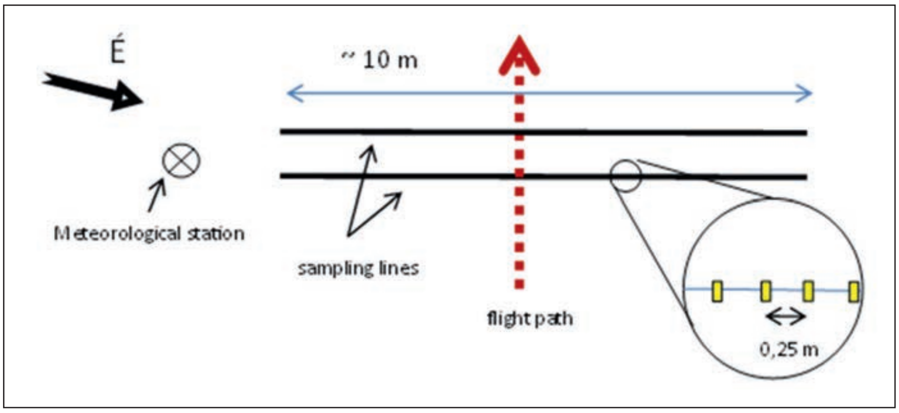


Figure 1: Test arrangement

Figure 2: Sampling site on the plant

| Table 1: Flight parameters and environmental characteristics | | | | | | | |
|---|---|---|---|---|---|---|---|
| **dose (dm³/ha)** | **flight altitude (m)** | **flight speed (m/s)** | **temperature (°C)** | **RH (%)** | **wind speed (m/s)** | **wind direction (°)** | **working width (m)** |
| 60,0 | 2,0 | 1,6 | 19,8 | 35,7 | 1,9 | 180 | - |
| 20,0 | 2,0 | 4,1 | 20,4 | 34,4 | 1,5 | 110 | - |
| 10,0 | 2,0 | 5,3 | 20,8 | 32,2 | 0,7 | 150 | - |
| 5,0 | 2,0 | 6,3 | 21,5 | 32,5 | 1,5 | 320 | - |

(25 cm) along the line for 10 m (Figure 1). In the experiments on the crops (sunflower, corn), water-sensitive papers were placed on the leaf surface at three different height levels, as shown in Figure 2. The parameters and environmental characteristics of the experiments are given in Table 1. The test was performed with a DJI AGRAS T20 UAV. Environmental features were recorded using a meteorological data collection station. After spraying, dried samples were collected, digitised, and relative coverage and specific droplet number were determined using National Instruments LabVIEW vision image processing software.

## RESULTS

Our literature research found a small number of usable, relevant literature. Based on reliability, robustness, and comparability, only a few publications (approx. 20 pieces) can be considered and are reliable from a legislative point of view. Since the spread of spraying drones is the largest in Asia, most publications also come from there, but the operational and legal environment is different. The study prepared by the Working Party on Pesticides (WPP) working group of the Organization for Economic Co-operation and Development (OECD) assists researchers, legislators, and drone manufacturers in further development and suggests research directions. We also considered the cited study's guidelines and experiences during our work. The publications emphasise that the efficiency of spraying drones is affected by other factors, such as turbulence, speed, and nozzle location, compared to conventional technology, under the same application settings. Considering these conditions, overall lower coverage and poorer coefficient of variation (CV %) are achieved compared to conventional technology. Most studies conducted tests between 1.5-3 m flight height, while flight speed was typically between 3-4 m/s. In European publications, air volumes of 30-100 l/ha were mostly tested. Alternatively, a dose of 10 l/ha would be preferable for UAVs to achieve greater economic efficiency, but this may cause problems in achieving adequate coverage. Similar experiences were observed during our field tests. Without a defined quality standard, coverage quality is not defined because it depends on the number of droplets, the quantitative value of coverage, and the type of pesticide. Based on the measurement results, it can be concluded that at the dose settings of 60, 20, and 10 dm³/ha (Figure 3), a specific droplet number of at least 20-30 pieces/cm² is provided, as accepted in literature sources.

For higher dose rate sprays, this is 5.5-7 m, for the lower

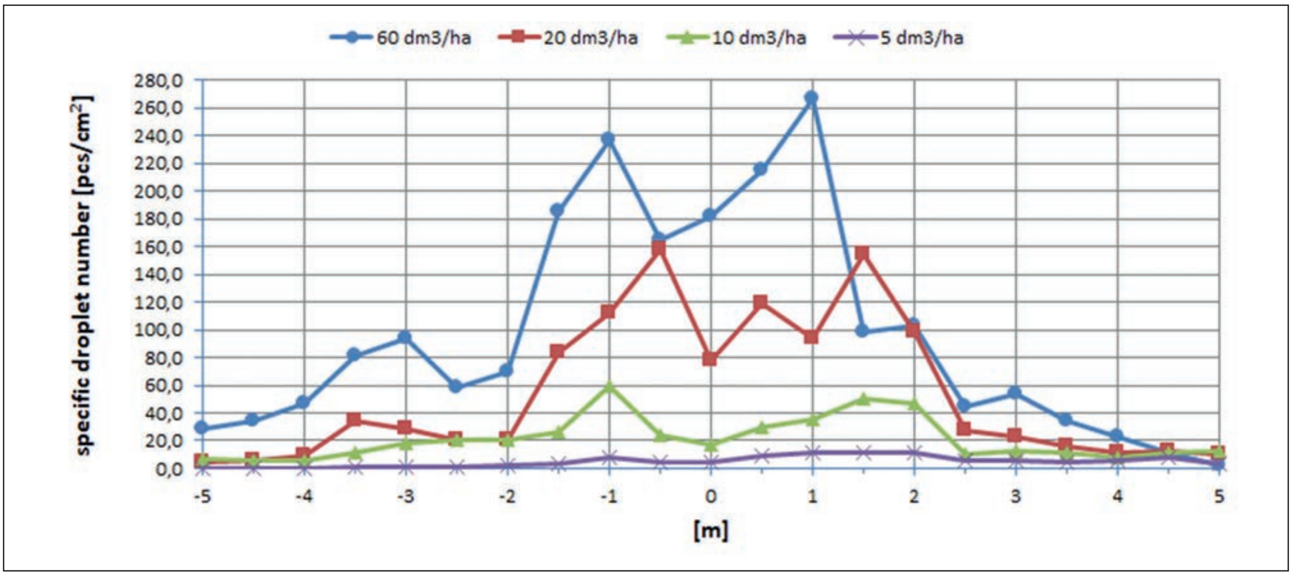


**Figure 3: Specific droplet number at different application rates**

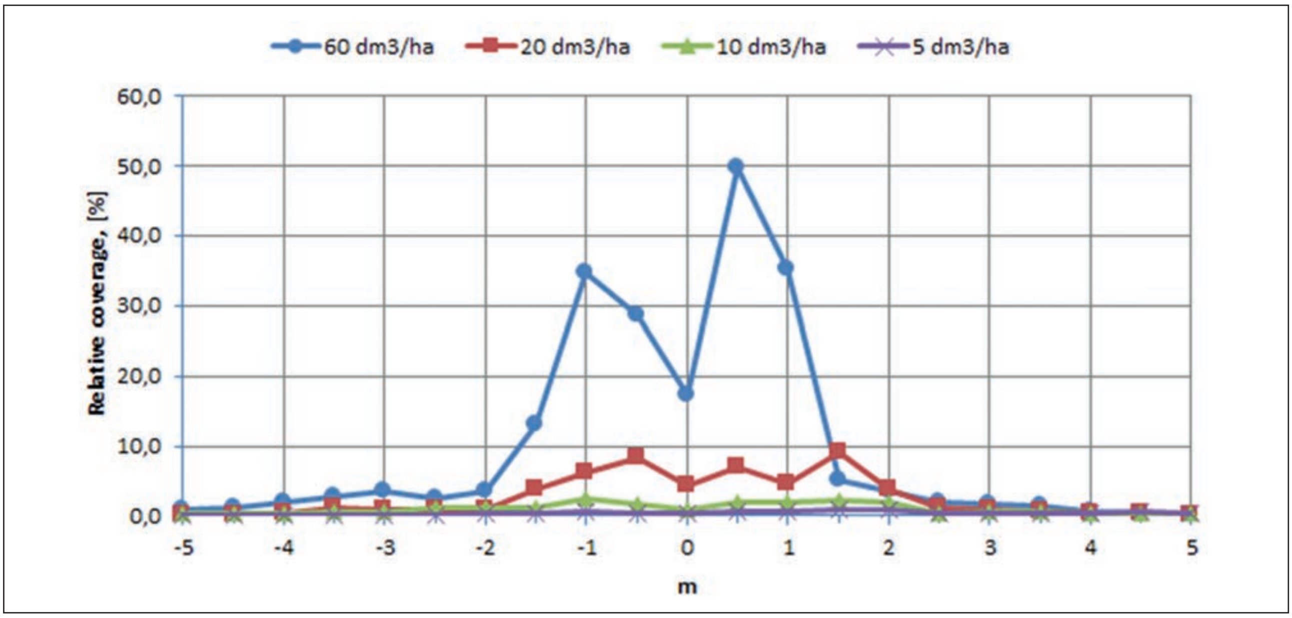


Figure 4: Relative coverage at 20 dm³/ha application rates

10 dm³/ha setting, this is only achievable at a working width of 3.5-4 m. When spraying with a dose of 5 dm³/ha, the desired spray coverage was not detectable on the target surface. The minimum specific droplet rate of 50 pieces/cm² accepted for fungicides can only be achieved at doses of 20, 60 dm³/ha up to working widths of 5.5 to 7.0 m. The relative coverage values for the above-mentioned working widths are 1.5-50% for the dose of 60 dm³/ha and 1.5-8% for the setting of 20 dm³/ha (Figure 4). In the treatment with a dose of 10 dm³/ha, the relative coverage value changes in the range of 0.7-3%, while in the case of a dose of 5 dm³/ha, it does not reach the value of 1%. The results show that the transverse distribution uniformity is less favourable than is usual for conventional spraying technologies but significantly better than aerial (rotary and fixed-wing application technology).

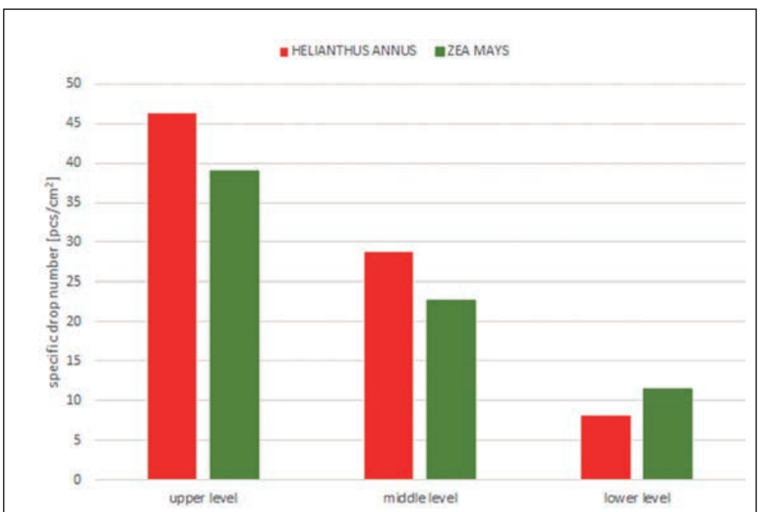


Figure 5: Specific droplet number at different height

Penetration was tested at three altitude levels in different crops (Figure 5), at a dose of 20 dm³/ha, 2 m flight height and 4 m/s flight speed. In summary, a satisfactory quality of treatment can be achieved (at least 20 specific droplet numbers per cm²) both in the upper and middle levels of the sunflower and corn stocks.

Two countries in Europe have authorised the use of drones for plant protection. In Germany, the use of UASS is allowed in terraced vineyards. According to the announcement of the Julius Kühn-Institut, the operation of 6 types is currently permitted. Applications of pesticides authorised by the Federal Office of Consumer Protection and Food Safety (BVL) can usually be applied with a water consumption of 75 or 150 dm³/ha (Bundesamt für Verbaucherschust und Lebensmittelsicherheit: Liste der Pflanzenschutzmittel, die für die Anwendung mit unbemannten Luftfahrzeugen (Drohnen) genehmigt sind, Stand: März 2023).

In Switzerland, all plant protection work carried out by UASS requires authorisation by the Federal Civil Aviation Office (OFAC). This authorisation can only be granted to equipment that has met the requirements specified in the type approval procedure carried out by the Swiss Agricultural Research Agroscope and the Federal Environmental Protection Office (OFEV). Moreover, for visual inspection and functional testing, the classification system developed by Anken, T. et al. also requires two essential parameters: measuring the horizontal uniformity of application on a test bench and determining the potential drift.

According to the results of literature reviews and the experience of the Swiss and German models, we have developed a set of requirements and a test method for the type approval procedure. In contrast to the Swiss model, the transverse distribution uniformity is not defined in a groove because it assumes floating, which does not consider the travel speed's effect on the distribution pattern. Instead, we measured the coverage on water-sensitive papers placed at a height of 80 cm. Our requirements included work safety, health and environmental aspects, droplet formation and spraying techniques, and plant protection flight safety requirements, detailed on the MATE website. In Hungary, 17 types are currently authorised for plant protection activities.

## CONCLUSIONS

Based on the results of the tests and the literature data, it can be concluded that unmanned aerial spraying systems with well-chosen settings can be used for spot treatments in precision farming and in difficult-to-access inland water areas. Application with a low air volume significantly increases the risk of environmental pollution caused by higher concentrations of pesticides. Further drift studies are needed to assess and manage the risks, particularly regarding human health and environmental impact. In order to use the UASS technology, it is necessary to have plant protection products approved for aerial application. Similar to traditional technology, uniform, internationally accepted standardized methods and requirements would also be required for drones. The ISO 23117-1 standard on environmental protection requirements is expected to publish this year.

## ACKNOWLEDGEMENTS

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# EXAMINATION OF PROPELLER GAINED DISTRACTING AIR MOTION IN THE CASE OF REMOTE SENSING LAKES AND FISHING PONDS WITH C1 TYPE UAVS

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## ABSTRACT

UAVs are gaining popularity in remote sensing and environmental monitoring every year. The point of remote sensing is to observe without disturbing the environment, but this study reveals potential disturbances. In this study two potential confounding UAV generated factors were examined, and their potential impact on the accuracy on related measurements. The first examined factor is the propeller generated air motion caused waving on water surface. The waves may result unwanted excess reflection to sensors on measuring, and it may affect the accuracy of the recorded data. The second factor is the altitude limitation, the possibility of the sensor may sense differ at high altitude according to the less resolution per water surface. While the first potential factor is confirmed, as the generated waves can cause deviation with maximum 4,2% value depending on maneuver height, the second potential factor has been denied, there was no correlation found on sensing still water surfaces from 10 meters to 120 meters. However, there is detectable air motion on 5 meters altitude and below, no air motion generated waving impact was detected on 5 meters high, or above.

**keywords: UAV, remote sensing, air motion, water quality**

## INTRODUCTION

UAVs (unmanned aerial vehicles) or UASs (unmanned aircraft systems) commonly known as drones are aircrafts without crew, pilot or passengers on board. After left military application behind these aircrafts gained massive popularity in several fields on professional level; sport and hobby, art (photography and filming), and remote sensing. As remote sensing it is has been widely used in military defense (Orfanus et al., 2016), surveying and mapping management (Joan-Cristian et al., 2019), and disaster and emergency response and management (Erdelj et al., 2017). Although satellite remote sensing has high efficiency and wide range of data acquisition, it will be affected by the atmosphere and appear some ambiguous states, reducing the accuracy of remote sensing (Osco et al, 2021). But great advantages to UAVs are low cost, high efficiency and low threshold, this low-altitude remote sensing technology has been widely used in the acquisition of some small-range images (Hardin et al, 2011; Feng et al, 2015). Clearly, when a UAV is equipped with basically any kind of sensors with remote sensing capabilities, it has the opportunity to gather information for pointed targets, under remote human control. Also, the UAV monitoring approach overcomes the shortcomings of traditional satellite remote sensing recognition, such as long distance and poor real-time performance (Iglhaut et al., 2019, Singh et al., 2022). Many UAVs are prepared for industrial applications, and their boarded cameras are fit for those applications; like multi-or hyperspectral sensors, but this study focuses on high quality consumer cameras, and their imaging.

UAVs are often used as a monitoring device in precision farming, or even in vegetation health status monitoring (Bao et al, 2023), forest resource development, and crop monitoring development (Pajares, 2015; Zhang et al, 2021). Ado et al. (2017) present a significant review on hyperspectral imaging acquired by UAV-based sensors for agriculture and forestry. Ishengoma et al. (2022) accelerated the detection of corn plants infected by armyworm by using UAV visible light images. Vegetation is the most important element of the terrestrial ecosystem, and it plays an important role in maintaining the balance of the ecosystem, the protection of water, and the protection of soil and water. The use of remote sensing technology to

monitor vegetation related information is the main purpose of remote sensing (Xu et al, 2023). The vegetation remote sensing could monitor, leaf area index, vegetation coverage, biomass. These data and photosynthetic effective radiation can effectively reflect the vegetation's very own dynamic (Lawley et al, 2016). Li et al. (2018) used UAV images to estimate the coverage of corn crops in farmland. Yuan et al. (2021) collected multispectral images of rice fields using UAVs and accurately estimated rice yields. Zhang et al. (2019) employed a UAV equipped with a hyperspectral image sensor to obtain an image of winter wheat yellow rust and realized its effective detection. However, in the practical application of UAVs at home and abroad, taking into account the difficulty and cost of sensor acquisition, generally only UAV images including the visible light band are acquired and used. Therefore, it is very necessary to use the vegetation index in the visible light band to design a vegetation information extraction suitable for UAV remote sensing images (Moranduzzo, and Melgani, 2014; Xu et al, 2023).
But till the recent years, only a few studies are published about the UAV remote sensing and natural water status monitoring. Jinchen et al (2021) apllied UAV remote sensing for bathmetry mapping for tufa lakes, according their transparency. Kai et al (2021) improved the resolution of UAV data of water quality of Lake Hachiroko. This study focuses on the potential distracing factors during an UAV based remote sensing on natural or artificial waters.

## METHODS

To define all UAV generated contributing factors of distracting the focus was on color accuracy (of the recorded images), and to test multiple C1 aircrafts to have overall image of their performance of gained air motion.
To control color accuracy, previously a test was performed to the boarded recording system of the main UAV in contrast of a color measuring device, named NIX COLOR PRO (Canada) in 13 different scenarios. After those measuring mathematical equation was set up on CieLAB color coding, after white balance (WB) correction of the recorded images (no data shown here).

Then measuring were performed to the generated air motion with the main UAV; via an installed an air motion sensor in an artificial pool, to learn the altitude limit, when UAV generated air motion appears, and measure its quantity. Three general maneuvers were operated: hovering, ascending, and descending, because changing the altitude of the UAV requires various performance of the propellers, and their motion rotors. These measuring were repeated with other two types of C1 UAVs, to gain an overall data of hi-end consumer drones.

The main UAV included in the measurement was the DJI Air S2 drone. This type has a range of up to 18.5 km and a flight altitude of up to 5 km above sea level, but according to local and EU law, these devices can climb up to top 120 metres in order to avoid any risk to air traffic. The minimum flight/hover altitude is 0.5 metres (measured by the lower range finder sensors), during which the aircraft will automatically initiate a landing manoeuvre. It can stay airborne for 25-30 minutes on a single battery, depending on the wind. The UAV has a top speed of 70km/h and the stabilisation system can maintain altitude and heading up to a gust of 10.7 m/s.
The LiPo 3S battery has a power of 3500 mAh and a consumption of 42.42 Wh. The aircraft weighs 595g (battery included), 180mm x 253mm x 77mm when ready to fly.
The camera is mounted on a three-axis gimbal stabilizer, tiltable between 90 and -24 degrees, with a vibration excursion of less than 0.01°. The 1" CMOS sensor captures 20MP (5472×3648; for 3:2 aspect ratio) still images at 2.4μm pixel size in jpeg or RAW (*.DNG) format, during the measuring RAW format was used. The lens is 88° (wide-angle, full-frame equivalent 22mm), with a fixed aperture of f/2.8. It has a 10-bit colour depth of field, so colours are accurate and dynamic separation is facile. In burst mode, 2-3 *.DNG images per second is captured.
The first of the other aircrafts used as a control measuring is the DJI Mini 2 unmanned aerial vehicle. It has a total weight of 249g, can accelerate to 58 km/h and has a maximum altitude of 4,000 metres. It has a maximum climb rate of 5m/s and a maximum descent rate of 3.5m/s. Airborne endurance 27-31 minutes. I did not take any pictures with this aircraft.
The second was the DJI Mavick Pro. This type of aircraft weighs 734g, can accelerate up to 65km/h, and can climb up to a maximum altitude of 5000m. Its time in the air is 21-24 minutes. Maximum climb speed 5m/s, maximum descent speed 3m/s. I did not take any pictures with this type of aircraft.
It is important to note, that all repeated measurings were applied by pre-programmed flying, so no difference could occur on altitude and location.

Adobe Photoshop (PS) was used for image processing, or Adobe Lightroom (LR) in case of multiple repetitive images.
After importing the images, processing the images took place by the following; white balance (WB) adjustment and correction of exposure values of the images based on the shooting histogram was applied here.
The images were then exported, keeping the original uncompressed format of the images: *.DNG or *.Tiff.
Depending on the test, the previously exported images were re-imported in PS, not per separate file, but per layer, so that averaging could be performed much easier, using a PS-Script, averaging could be applied to all image layers in the file.

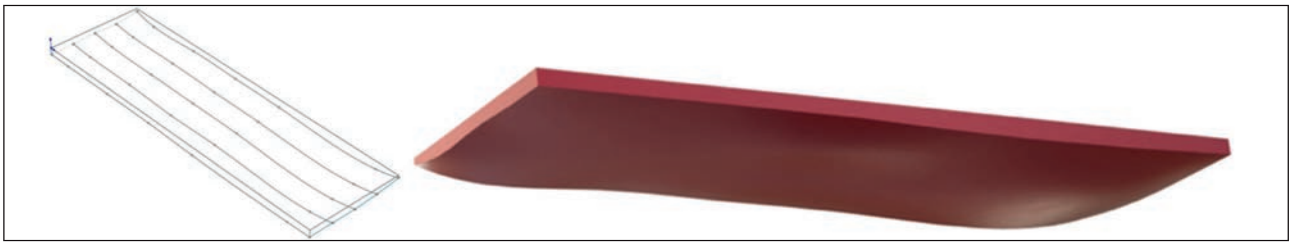

Figure 1: 3D modell of the breeding pond No.4. near by Isaszeg.

Figure 2: The breeding pond No.4. near by Isaszeg, and its environment

When averaging, polygons were used to cover the target area, zooming in on the images for the most accurate selection possible. Pixel-based averaging was applied to the polygonally selected area; this script analyses all pixels in the selected area, averages them by channel (R, G, B) and displays the resulting colour.

Microsoft Excel was used to record the measurement results.

The most significantly used functions were averaging "=AVG()", moving average, expanding average, standard deviation "=SWARCH()" and correlation search "=CORREL()".

For RGB visualization and analysis, most often bar charts or dot plots were applied, the CieLAB visualizations were presented in dot plot coordinate system.

Also in Excel trendline fitting was performed, after selecting linear trendline, also wrote out the formula of the trendline and the value of the $R^2$.

Rounding was also applied in Excel, because in RGB coding natural numbers can appear (0-255), in CIELAB coding the L value (0-100) and the A-B values (-128-+128) can take a fraction up to two decimal places. These values are dimensionless values and have no unit of measurement.

The measuring campaign was performed on two locations. The air motion measurements were performed at the Environmental Technology laboratories of MATE (Magyar Agrár- és Élettudományi Egyetem – Hungarian University of Agriculture and Lifscience) in Gödöllő (Hungary, EU). That applied artificial pool has dimensions 140 cm x

75 cm, with a 1,05m$^2$ water surface. The bottom-ceiling distance is 50 cm, but the technological water height is 35cm, so the technological capacity is 0,3675 m$^3$.
The second location is the breeding pond No.4. near by Isaszeg (Hungary, EU), operated by Aranyponty Ltd. The lake dimensions are 50 m x 15 m, east-west oriented, with average depth of 120 cm, and 900m$^3$ of operative water volume. The volumetric flow is 15m$^3$/h, therefore the total water refreshment takes circa three days. On the Figure 1, the 3D model of the lake is demonstrated, and on the Figure 2 the lake and its environment is demonstrated.

## RESULTS

In this study two potential confounding factors were examined. The first factor was the generated waves on water surface by the airmotion generated by propellers. The waves can cause unwanted excess reflection to sensors during recording, and it can distrace the recorded data. The second factor is the altitude limits, the possibility of the sensor may sense differ at high altitude according to the less resolution per water surface.
The first potentional confounding factor were measured by all three types of UAV-s, over a wind-velocity meter

**Table 1: Generated airmotion velocity averages**

| Altitude (m) | Hover minimum (m/s) | Hover maximum (m/s) | ASC minimum (m/s) | ASC maximum (m/s) | DESC minimum (m/s) | DESC maximum (m/s) |
|---|---|---|---|---|---|---|
| 0,5 | 2,4 | 12,3 | 4,2 | 15,2 | 1,3 | 3,7 |
| 1 | 1,8 | 8,7 | 2,8 | 10,4 | 1,1 | 3,2 |
| 2 | 1,5 | 3,2 | 2,2 | 4 | 0,6 | 1,1 |
| 3 | 1,4 | 2,6 | 1,9 | 3,1 | 0,3 | 0,8 |
| 4 | 0,3 | 1,6 | 1,5 | 2,6 | 0 | 0,3 |
| 5 | 0 | 1,3 | 0,4 | 1,7 | 0 | 0 |
| 6 | 0 | 0,3 | 0 | 0,5 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 3: Nadir image by the DJI AIR S2 UAV from the altitude of 2 metres, a wind speed sensor placed in the pool.**

**Table 2: Averaged color measuring on three different locations**

| Altitude (m) – 1.st measuring | R | G | B | R (fixed) | G (fixed) | B (fixed) |
|---|---|---|---|---|---|---|
| 0,5 | 66 | 74 | 65 | 64 | 71 | 63 |
| 1 | 66 | 73 | 65 | | | |
| 2 | 66 | 73 | 64 | | | |
| 3 | 65 | 72 | 64 | | | |
| 4 | 64 | 71 | 64 | | | |
| 5 | 64 | 71 | 63 | | | |
| 6 | 64 | 71 | 63 | | | |
| Altitude (m) – 2.nd measuring | | | | | | |
| 0,5 | 129 | 110 | 101 | 125 | 106 | 99 |
| 1 | 128 | 110 | 101 | | | |
| 2 | 128 | 109 | 101 | | | |
| 3 | 126 | 107 | 100 | | | |
| 4 | 124 | 106 | 99 | | | |
| 5 | 125 | 106 | 99 | | | |
| 6 | 125 | 106 | 99 | | | |
| Altitude (m) – 3.rd measuring | R | G | B | | | |
| 0,5 | 114 | 93 | 52 | 110 | 90 | 50 |
| 1 | 114 | 93 | 52 | | | |
| 2 | 113 | 92 | 51 | | | |
| 3 | 112 | 92 | 51 | | | |
| 4 | 111 | 90 | 50 | | | |
| 5 | 110 | 90 | 50 | | | |
| 6 | 110 | 90 | 50 | | | |

installed in an artificial pool, and the airmotion velocity was recorded here. In the Table 1 all the averaged results are demonstrated on the three main manuveurs: hover, descending, ascending.

As Table 1 demonstrates, there is still detectable motion on 6m altitude, but over 6 meters, there is detectable air motion. On the Figure 3 a camera recording demonstrates the measuring on two meters of altitude.

Next, the study went to understand the variance on the sensed water surface, caused by air motion. Obviously, there were no measurments were performed above 6 meters, while in the absence of air motion, we assumed that no waves are geerated.

The main drone (DJI AIR S2) was used for this measuring. First it was a fixed propeller-less, 2 meters altitude image recording, as a reference: no generated waves, it indicates the calm, still water status. Then with preprogrammed flying, measurings for applied from 0,5m-6m. Three different locations were used for the recording. Table 2 demonstrates the averaged measurings.

According to Table 2 there are detectable differences on the recorded color data in contrast of the reference data.

**Table 3: Measured varying on color channels on specified altitudes in percentages**

| Altitude (m) – 1.st measuring | R | G | B |
|---|---|---|---|
| 0,5 | 3,1250% | 4,2254% | 3,1746% |
| 1 | 3,1250% | 2,8169% | 3,1746% |
| 2 | 3,1250% | 2,8169% | 1,5873% |
| 3 | 1,5625% | 1,4085% | 1,5873% |
| 4 | 0,0000% | 0,0000% | 1,5873% |
| 5 | 0,0000% | 0,0000% | 0,0000% |
| 6 | 0,0000% | 0,0000% | 0,0000% |
| Altitude (m) – 2.nd measuring | | | |
| 0,5 | 3,2000% | 3,7736% | 2,0202% |
| 1 | 2,4000% | 3,7736% | 2,0202% |
| 2 | 2,4000% | 2,8302% | 2,0202% |
| 3 | 0,8000% | 0,9434% | 1,0101% |
| 4 | -0,8000% | 0,0000% | 0,0000% |
| 5 | 0,0000% | 0,0000% | 0,0000% |
| 6 | 0,0000% | 0,0000% | 0,0000% |
| Altitude (m) – 3.rd measuring | | | |
| 0,5 | 3,6364% | 3,3333% | 4,0000% |
| 1 | 3,6364% | 3,3333% | 4,0000% |
| 2 | 2,7273% | 2,2222% | 2,0000% |
| 3 | 1,8182% | 2,2222% | 2,0000% |
| 4 | 0,9091% | 0,0000% | 0,0000% |
| 5 | 0,0000% | 0,0000% | 0,0000% |
| 6 | 0,0000% | 0,0000% | 0,0000% |

**Table 4: The averaged altitude deviations in percentage.**

| Altitude (m) | R | G | B |
|---|---|---|---|
| 0,5 | 3,3205% | 3,7774% | 3,0649% |
| 1 | 3,0538% | 3,3079% | 3,0649% |
| 2 | 2,7508% | 2,6231% | 1,8692% |
| 3 | 1,3936% | 1,5247% | 1,5325% |
| 4 | 0,0364% | 0,0000% | 0,5291% |
| 5 | 0,0000% | 0,0000% | 0,0000% |
| 6 | 0,0000% | 0,0000% | 0,0000% |

In Table 3 the differences are demonstrated in percentage.

According to Table 2 and Table 3 no difference could be detected in contrast of the reference measuring on and above 5 meters altitude, despite according to Table 1 there are still detectable air motion on 5 meters altitude. Those deviations were averaged, and Table 4 demonstrates the compensation percentage on the measured altitudes, while Table 5 demonstrates the linear function equations and their $R^2$ values.

Table 5: Linear correlation per color channel and altitude, and their $R^2$ value

| | R_Y | G=Y | B=Y | R_ $R^2$ | G_ $R^2$ | B_ $R^2$ |
|---|---|---|---|---|---|---|
| 0,5 | y = 0,9658x + 0,1856 | y = 0,9728x - 0,8186 | y = x - 2 | $R^2$ = 0,9999 | $R^2$ = 0,9997 | $R^2$ = 1 |
| 1 | y = 0,9773x - 0,6696 | y = 0,9461x + 1,9621 | y = x - 2 | $R^2$ = 0,9995 | $R^2$ = 1 | $R^2$ = 1 |
| 2 | y = 0,9826x - 0,8899 | y = 0,9728x + 0,1542 | y = 0,9785x + 0,2179 | $R^2$ = 1 | $R^2$ = 0,9997 | $R^2$ = 1 |
| 3 | y = 0,9946x - 0,7893 | y = 0,9973x - 1,0892 | y = x - 1 | $R^2$ = 0,9997 | $R^2$ = 0,9989 | $R^2$ = 1 |
| 4 | y = 1,0065x - 0,6502 | y=x | y = 1,0055x - 0,7234 | $R^2$ = 0,9991 | $R^2$ = 1 | $R^2$ = 0,9995 |
| 5 | y=x | y=x | y=x | $R^2$ = 1 | $R^2$ = 1 | $R^2$ = 1 |
| 6 | y=x | y=x | y=x | $R^2$ = 1 | $R^2$ = 1 | $R^2$ = 1 |

Table 6: Averaged recorded data on A-B channels, and scattering

| Altitude (m) | A | B |
|---|---|---|
| 10 | -0,23 | 1,77 |
| 20 | -0,17 | 0,62 |
| 30 | -0,33 | 1,24 |
| 40 | -0,49 | 1,86 |
| 50 | -0,33 | 1,23 |
| 60 | -0,94 | 1,7 |
| 70 | -0,94 | 1,7 |
| 80 | -0,33 | 1,24 |
| 90 | -0,94 | 1,7 |
| 100 | -0,33 | 1,24 |
| 110 | -0,78 | 1,08 |
| 120 | -0,17 | 0,62 |
| Scattering | 0,1% | 0,2% |

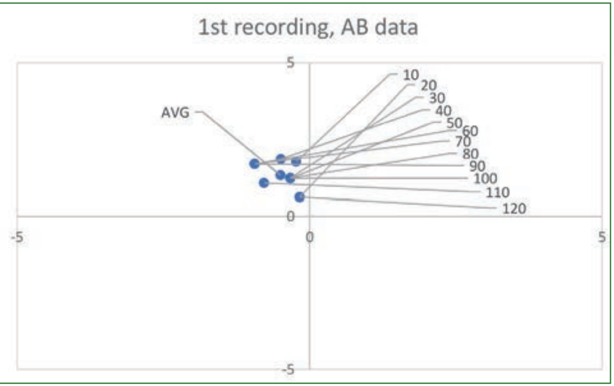

Figure 4: The first recorded data, altitudes and average

The second potential distracing factor was the opposite of the first factor; can the high altitude alter the sensing of the UAV's installed sensor or camera. These measurments were performed on 10-120 meter altitude with 10 meters step. In this measuring CieLAB coding was applied to fit the visualization into a coordinate system instead of bar charts. According to EXIF infos and histogram infos, lightness data were matched, so the only alternation should shown on the A-B channel. Only the main drone was used, six repetition happened on the same location.

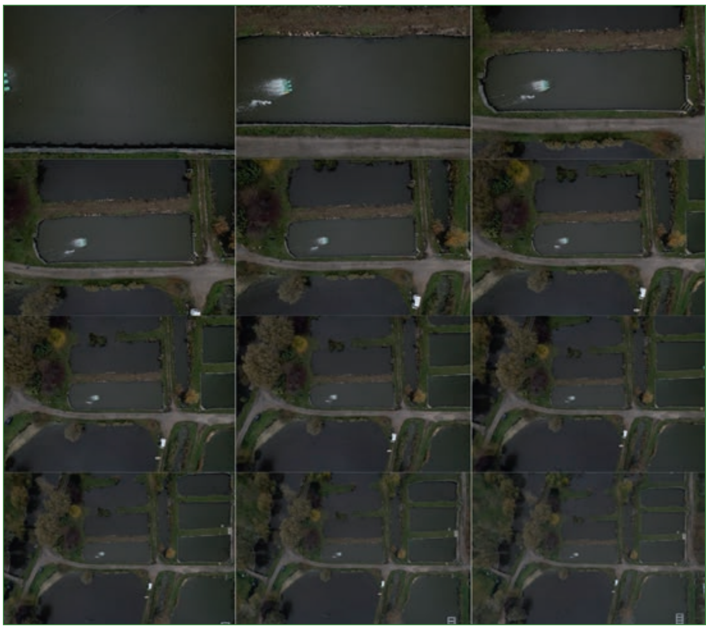
Figure 5: UAV recording from altitude 10meters to 120 meters.

Table 6 demonstrates the measured averaged data, and the scattering on both channels (AB).
As Table 6 demonstrates there is no significant varying on the altitudes, and those varyings are based on the inaccuracy of the manual polygon setting. On Figure 4, the first recordings are demonstrated. The figure was modified for better visuality, while AB scaling takes place between -128; 128. According to the Figure 4, the alteration is random, no mathematical equasion can describe it. On the Figure 5 we demonstrate the altitude varyings from 10m to 120 metres. this measuring.

## CONCLUSIONS

According to the measuring campaign, it can be stated, that UAV's propellers makes impact on the water surface under 5 meters, and those waves generated by air motion generates more reflection, that can distort the water condition assessment. However there is detectable air motion on 5 meters altitude, no impact was detected, and no impact was detected above. It can be also stated, that there is no significant difference on sensing still water surfaces from 10 meters to 120 meters, therefore only one UAV flight is capable to monitor and record huge amount of territories at once.

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# THE ROLE OF UAVS IN REMOTE SENSING AND INFORMATION DRIVEN AGRICULTURAL APPLICATIONS

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## ABSTRACT

Remote sensing is known as the most time- and cost-effective way of data collection. It plays decisive role in development of information based precision farming and environment protection. UAV or drone application is the latest technological implementation which integrates the capability of remote sensing and sight specific agricultural practice. Drone technology has high potential in many agricultural applications to save time and costs, to protect the environment and improve safety and ergonomics of sampling procedures, spraying and spreading.

**keywords: UAV, drone, remote sensing, spraying and spreading**

## INTRODUCTION

When talking about 'light' we usually associate it with 'visible light'. The phenomenon is understandable since looking back for a long time in history humanity only knew the range of light perceived by naked eye. The eye, the organ of vision developed during evolution to detect light, it performs remote sensing in the visible (380-750 [nm]) range of electromagnetic radiation. The visible range itself enables many analysis and classification procedures (Lágymányosi and Szabó, 2011; Felföldi et al., 2013). However, multi- and hyperspectral remote sensing devices make it possible to extend the visible range, thus displaying phenomena or information that are not visible to the human eye. Technology has created new horizons in the study of the environment (Kristóf, 2005). Remote sensing can be used successfully if supplemented with proper data processing methods (Lóki, 1996). Remote sensing is the science of recording and data processing, as well as the communication of data (Sabins, 1996).

## REMOTE SENSING

The finding that forms the basics of the method is attributed to a Russian mineralogist and meteorite researcher (Krinov, 1947). Remote sensing is considered as a scientific activity in which the electromagnetic radiation reflected from the examined object or geographical area is measured from various distances using sophisticated sensors. The measured signal is converted into valuable information using various mathematical and statistical procedures. In the fast-paced world of modern civilization, remote sensing has become an essential tool for examining the balance and functioning of various natural and artificial systems. It is an ability to read information based on different photophysical properties (Jung, 2005).

The basic condition of remote sensing is an energy source that illuminates the examined object or emitted from the object. Regardless of whether the energy source is natural (sunlight) or artificial (laboratory lighting) or emitted by the object itself we are talking about electromagnetic radiation. Talking about a point source of light - due to the Earth-Sun distance, the Sun is also a point source of light - the intensity of illumination is directly proportional to the power of the light source and inversely proportional to the square of the distance from the light source and it also depends on the angle of incidence.

Looking at the history and development of mankind, it can be established that the growth of the population and the technological achievements results in various rapidly emerging anthropogenic effects. By and large, until the end of the Stone Age - 10,000 years ago - the influence of civilization was minimal, in line with the ecosystem. Humanity is now drastically interfering with the Earth's ecological system, making rapid large-scale changes in its environment. These processes can no longer be followed by traditional field sampling. Remote sensing enables sampling of large areas, characteristics of surface processes, even time-series sampling and cost-effective data collection (Kardevan, 2009). It provides a number of methods and procedures for analysing various global and local processes. The huge amount of data is essential for studying global or local systems. Applications cover numerous agricultural, forestry, mining, urban and landscape planning, environmental protection, ecological, geological and hydrological applications, and is of particular importance in meteorological and climate change studies, as well as in military use. Remote sensing is based on the study of the interaction of material and light.

During remote sensing, we can analyse a specific surface area, object, or event by collecting information without physical contact, within the original environment by avoiding any destruction or interventions (Lillesand et. al., 2004). In the beginning of 2000's the equipment used for measurements is divided into three categories according to their location. We distinguish systems used on the ground, in space and at different heights in the atmosphere. Sensor operating heights were defined are followings: Ground level (1-8 [m]), hang glider (100-300 [m]), low height aircraft (300 [m] – 3 [km]), high height airplane (3-10 [km]), satellite (600-35786 [km]). The following figure shows an illustration of remote sensing applications as of the year of 2000 (Figure 1) (Yamazaki, 2000).

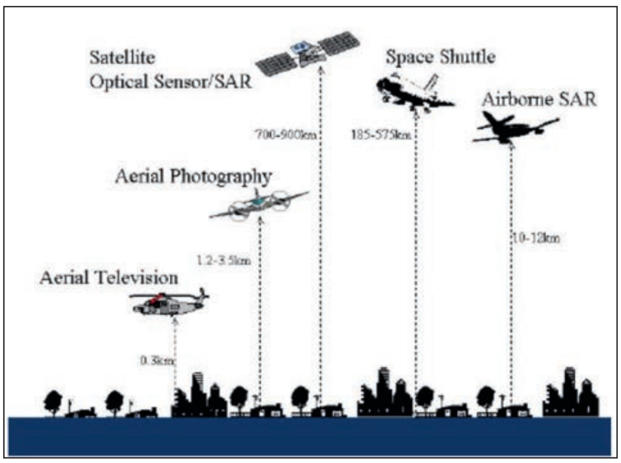


**Figure 1:** Remote sensing **applications (Yamazaki, 2000)**

### *The role of Unmanned Aerial Vehicles*

Together with the miniaturization of instrumentation and data systems the rapid development of UAVs as a remote sensing platform has resulted in an increasing uptake of this technology in the environmental and remote sensing science community (Busznyák, 2022a). Regulations across the globe still limit the broader use of UAVs (Busznyák, 2022b). Their use is precision agriculture, ecology, atmospheric research, disaster response bio-security, ecological and reef monitoring, forestry, fire monitoring, quick response measurements for emergency disaster, Earth science research, volcanic gas sampling, monitoring of gas pipelines, mining plumes, humanitarian observations and biological/chemosensing tasks, continues to increase (Figure 2) (Tsourdos, 2017).

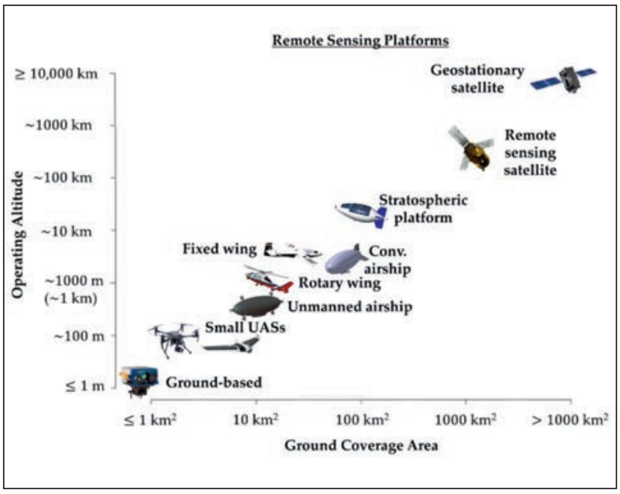


**Figure 2: A new horizon of remote sensing platforms (Tsourdos, 2017)**

Unmanned Aerial Vehicle – UAV popularly known as drone is an airborne system or an aircraft operated remotely by a human operator or autonomously by an onboard computer. There are two broad classes of UAVs – Fixed wing and Rotary based. When a UAV is equipped with sensors with remote sensing capabilities, it has the flexibility to gather information of various targets. Sensors for drones are increasingly being used for surveying, mapping, and inspections in several industries such as mining, construction, agriculture, environmental management, and waste management (NESAC, 2023). Fixed wing drones fly significantly longer, map larger areas, spend less time on-site, reduce labour costs, increase project capacity, simplify flight planning and operations and provide more flexibility with modular payloads. The major advantage of rotary-wing UAVs over fixed-wing UAVs is vertical take-off and landing. Rotary-wing UAVs are able to hover and change direction quickly. Lower speed, shorter range, and higher power consumption are considered as disadvantages.

Hyperspectral remote sensing has been an important technical means to obtain detailed information for the quantitative analysis of environmental processes. Hypersepctral images have long been bound to complex flight campaigns performed by conventional airframes or to relatively lower resolution and the limited repeat coverage of multispectral satellites. Through the introduction of UAVs the collection of hyperspectral information becomes available for a wider community (Boxiong et al., 2022). Finally, various UAV-based applications were introduced into the agricultural practice. Hyperspectral remote sensing and analysis of agricultural areas are considered as the most developed technique in data collection to support the information-driven agricultural practice. UAV hyperspectral imagery has advantages over colour photography and multispectral remote sensing, with higher level of spectral details which gives more sensitivity to physical-chemical properties.

Snapshot hyperspectral imaging is a method to capture hyperspectral images during a very short integration time of a detector array. No scanning is involved and detectors consist of high number of pixels. Snapshot devices in general offer larger light collection capacity. Another great advantage of snapshot systems is the simplicity of imaging. Since the entire data frame is received in one reading, there is no need to combine the recordings to generate the data frame. In addition, the snapshot cameras are able to create the recording in a short time, which is why they can create images with a better signal-to-noise ratio. Applications have proved the potential of the technique in soil spectroscopy (Jung et al., 2015) and vegetation sciences (Jung et al., 2019).
The most developed snapshot imaging hyperspectral camera to date is probably the ULTRIS X20 (Figure 3) which is a 20 Megapixel spectral video camera, is sensitive in the UV, visible and near infrared range. With a wavelength range of 350-1000 nm, the ULTRIS X20 is the first UV-VIS-NIR hyperspectral video camera. Snapshot imaging spectrometer that produces 3D data cubes in real-time. This technology provides hyperspectral images with a spatial pixel resolution of 410×410, resulting in 168,000 pixels per frame and 164 spectral bands. Weighing less than 350g, the camera is perfect for applications on small UAVs (Cubert, 2023).


**Figure 3: Ultrix 20 (Cubert, 2023)**

### *Spraying and granular spreading*

There has been a great progress in vegetation mapping with various technologies (RGB, CIR, multi- and hyperspectral and thermal images). The imaging technology is available to map agricultural fields. UAV platforms can support a fast and accurate field survey (Figure 4) to identify various plant stresses originating of pests, diseases, drought or nutrient deficit. Emerging weeds spots can also be detected. The heterogeneity of soil can be mapped. Following the survey UAV has gathered the relevant information to define a treatment strategy of a particular field sprayer or spreader drones (WohnderDrone, 2023; DJI, 2023) can perform pest and weed control, seeding and fertilizer broadcasting missions (Figure 5, Figure 6).

**Figure 4: DJI Matrice 300 RTK (DJI, 2023)**

**Figure 5: WohnderJet Agro H20 (WohnderDrone, 2023)**

**Figure 6: AGRAS T40 (DJI, 2023)**

The Matrice 300 RTK is a latest commercial drone platform with high reliability. It offers up to 55 minutes of flight time and advanced positioning. It has multiple payload configurations providing simultaneously up to 3 payload mountings with a maximum capacity of 2.7 kg (DJI, 2023).

The WohnderJet Agro H20 agricultural spraying system has been optimized for the Drone Volt Hercules 20 heavy-duty industrial drone with precise flight capabilities, with which it is possible to perform 6 hectares per hour spraying with an 8 litre per hectare dose (WohnderDrone, 2023). The AGRAS T40 is enabling it to carry a spray load of 40 kg and a spread load of 50 kg (volume - 70 l). It supports multiple missions from surveying, mapping, to spraying and spreading, depending on the configuration used. It promises a 21.3 hectare per hour field spraying and 1.5 tonnes of fertilizer spreading capacity per hour (DJI, 2023).

**Figure 7: Precision airborne plant protection with an Mi-2 helicopter (Axiál Ltd. and Forgószárny Ltd., 2022)**

Airborne plant protection (and nutrient supply) has a significant tradition in Hungary and other countries. Experience has been gathered over millions and millions of hectares over decades. Conventional airborne agriculture operation has been labelled as obsolete technique facing challenges to meet the latest demands on accuracy and precision. A rather promising recent development has proved that retrofitting of existing airframes with precision technologies can make a great difference. As a result of the development high-speed aerial applications could successfully transfer elements of precision farming to the air (Axiál Ltd. and Forgószárny Ltd., 2022). The Mi-2 (Figure 7) helicopter together with the unique developments made Forgószárny Ltd. provides a capacity to spread 9-11 tons of granules per hour which is one magnitude higher than existing UAVs are capable of. The helicopter frame offers enough space to potentially operate a remote sensing system which could perform an on-flight analysis of the field to support a variable spraying/spreading dose rate. Such a solution would create a new horizon to perform mapping and spraying/spreading in one overflight.

## CONCLUSIONS

Remote sensing is known as the most time- and cost-effective way of data collection. It has decisive role in development of information based precision farming. Precision farming can be considered as a useful instrument to mitigate global challenges. UAVs or so-called drones have been rapidly developing in the last decade integrating the capability of remote sensing and sight specific agricultural practice. Today these techniques are more affordable and easy-to-use tools to improve the sustainability of plant production. Various sensors like RGB, multi- and hyperspectral cameras, thermal or LIDAR technology can improve data collection and so the information-driven agricultural practice to increase yield and quality while minimizing environmental pollution, saving time and costs and improve safety and ergonomics of sampling procedures. The technical development of UAVs aims to increase payloads, flight time and to further improve spraying and spreading capacity. The continuous development of sensors and drones has greatly increased the amount of information which means more sophisticated data analysis methods are needed. There are visions of a future agricultural sector where UAVs have completely replaced field sprayers and conventional airframes, however, authors are proposing to take a complementary approach where available means of techniques are selected based on the local conditions and needs. UAVs have made available a wide range of remote sensing applications and should be considered as complementary tools to play their important role as a part of a complex system of tools in agricultural practice.

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