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REGULATORY CHALLENGES AND FRAMEWORKS FOR UAV-BASED CHEMICAL APPLICATIONS IN AGRICULTURE

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Abstract. Unmanned aerial vehicle (UAV) systems for chemical crop protection have experienced significant global growth. They offer precise, efficient, and targeted pesticide application as part of precision agriculture. However, the rapid technological advancement of UAV spraying systems has not been matched by equally fast regulatory development. This has resulted in fragmented frameworks, legal uncertainties, and barriers to widespread adoption. This paper reviews international and national regulations governing UAV-based spraying, with a particular focus on the United States, the European Union, Asia, and Serbia. Special attention is given to differences within the EU. For example, countries such as Hungary and Switzerland have introduced national authorizations for UAV spraying, while others remain limited by general pesticide-use rules. In Serbia, the absence of UAV-specific legislation and the lack of registered pesticides approved for use with UAVs represent critical constraints. This is occurring despite increasing farmer interest and positive field research results. The analysis highlights four key regulatory challenges: safety, environmental protection, equipment certification, and operator training. It also identifies the absence of UAV-specific pesticide registration as a major obstacle to adoption. The study concludes with recommendations to harmonize aviation and plant protection regulations, develop UAV-specific product registration pathways, and adopt international standards. These steps aim to ensure safe, sustainable, and legally secure integration of UAV systems in chemical crop protection.

Keywords: UAV SYSTEMS, PESTICIDES, STANDARDS, REGULATIONS, OPERATOR TRAINING

1. Introduction

Modern agriculture is working to achieve a delicate balance between two critical objectives: ensuring an adequate food supply while safeguarding the environment. A significant aspect of this challenge involves the responsible use of pesticides, ensuring

that each application is effective. In this regard, unmanned aerial vehicles (UAVs) have emerged as a valuable asset in precision agriculture [1]. These UAVs enable farmers to target only the areas of the field that require treatment, often resulting in reduced chemical usage without compromising effectiveness. Additionally, UAVs allow operators to maintain a safe distance from the spraying process [2]. They are particularly advantageous for rapid responses to pest or disease outbreaks and can access challenging terrains where traditional machinery may struggle, such as steep slopes, small plots, or regions near water bodies.

Asia has witnessed a significant surge in the commercial use of unmanned aerial vehicle (UAV) systems, with Japan pioneering their agricultural application as early as the 1990s [3]. China has since emerged as a leader, boasting both the largest fleet of UAVs and the most extensive area treated using this technology [4]. While the United States and the European Union have also adopted UAVs in agriculture, regulatory hurdles have somewhat restricted their widespread implementation [5, 6]. Serbia, too, is experiencing a growing interest in this field. Reports indicate that by the start of 2025, UAV usage is on the rise, accompanied by increasing [7]. This growth is often fueled by local distributors promoting advanced models such as the DJI Agras T50 and EAVision J100 [2].

The rapid advancement of UAV technology has left the laws governing it struggling to keep up. As unmanned aerial vehicles (UAVs) become more sophisticated, the rules and regulations surrounding their use are a patchwork of different approaches and often out of date [5]. Countries have their own specific rules about how high UAVs can fly, what kind of equipment they need to have, how pilots should be trained, and even how they can be used to spray pesticides [10]. This lack of consistency makes it harder to fully utilize the potential of this technology and creates legal confusion for both the companies that make UAVs and the people who use them. Beyond safety, environmental protection is a major concern. Any use of UAVs for spraying pesticides must follow strict rules to protect water, soil, and other living things [11]. Another hurdle is the need for standardized equipment and application methods. Although international groups like ISO and national standards organizations are working on guidelines for UAVs, these are not yet widely used in practice.

Serbia's agricultural use of UAVs for crop protection is just beginning. Current rules mostly lean on general aviation and pesticide guidelines, with little specific regulation for UAV chemical spraying. This situation calls for a deep dive into international standards and a comparison to find ways to safely and sustainably integrate UAV technology into Serbian farming.

The aim of this paper is to provide an overview of international and national regulatory frameworks related to the use of UAV systems in chemical crop protection. Special emphasis is placed on regulations in the United States, the European Union, Asia, and Serbia. In addition to reviewing existing provisions, the paper identifies key challenges, safety, environmental protection, equipment certification, and operator training, and offers recommendations for improving legislation in order to foster broader and more responsible adoption of UAV systems in agriculture.

2. International Regulatory Frameworks for UAV-Based Applications

The integration of UAV-based spraying systems into agriculture has been addressed differently across global regions, reflecting variations in legislative maturity, institutional capacity, and adoption rates (Table 1) [2]. While Asia has pioneered the commercial use of UAVs in crop protection, the United States and the European Union have adopted more cautious and highly regulated approaches, often prioritizing airspace safety and environmental protection [12]. Overall, the regulatory framework for UAV systems for chemical crop protection remains highly fragmented. Although UAV spraying technologies have advanced rapidly and demonstrated clear agronomic benefits, legislation has lagged behind, creating legal uncertainties and barriers to broader adoption. Regulatory challenges generally concentrate on four pillars (Figure 1).

Figure 1. Main regulatory challenges related to UAV operations in crop protection.

Nevertheless, national frameworks differ considerably in their scope and enforcement, resulting in diverse implications for the practical deployment of UAV-based chemical application systems [7].

Asia

Asia represents the most dynamic region for UAV adoption in agriculture. Japan, as an early adopter, has deployed UAV spraying since the 1990s, with strong institutional support from the Ministry of Agriculture, Forestry and Fisheries (MAFF). The Yamaha RMAX model became one of the first certified UAV sprayers, marking a milestone in agricultural aviation regulation [4]. China, on the other hand, has rapidly scaled up UAV adoption, supported by subsidies, pilot training programs, and policies under the Ministry of Agriculture and Rural Affairs (MARA). China now leads globally in both UAV fleet size and treated farmland area [5]. Despite these successes, challenges remain regarding operator licensing, standardization of spraying techniques, and environmental safeguards.

United States

In the United States, UAV operations are governed by the Federal Aviation Administration (FAA), with the core regulatory framework outlined in Part 107 of the Federal Aviation Regulations [5]. This legislation establishes requirements for pilot certification, aircraft registration, and operational limitations such as altitude, line-of-sight operation, and flight over people. However, the agricultural use of UAVs for pesticide application requires additional approval under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and relevant state-level pesticide laws. Recent initiatives by the FAA and the Environmental Protection Agency (EPA) highlight the need for harmonization between aviation safety and environmental regulations [1,2]. Despite progress, fragmented jurisdiction and a lengthy exemption process remain key barriers to large-scale deployment.

European Union

The European Union has developed a harmonized regulatory framework through the European Union Aviation Safety Agency (EASA), which since 2021 enforces unified UAV regulations across member states [10]. These rules categorize UAV operations into open, specific, and certified categories, depending on risk level. Agricultural UAV spraying generally falls under the specific category, requiring operational risk assessments (SORA) and authorization from national aviation authorities [10].

In parallel, UAV pesticide use is subject to the Sustainable Use of Pesticides Directive (2009/128/EC), which regulates aerial spraying, establishes buffer zones, and prescribes operator training [13]. However, the lack of UAV-specific pesticide regulations creates interpretative gaps and delays in adoption across Member States [2].

Despite these limitations, some EU countries are moving faster in practice. Hungary has adopted detailed provisions under the FVM–GKM–KvVM regulations, explicitly allowing certain plant protection products to be applied by UAVs under strict technical conditions [14]. For instance, approved combinations such as Mospilan 20 SG (acetamiprid, 200 g/kg) + Combi-protec (protein-based attractant/adjuvant) for cherries and walnuts, Coragen 20 SC (chlorantraniliprole, 200 g/l) + DropMax (organosilicone-based adjuvant) for maize, and Amistar Sun 325 SC (azoxystrobin + difenoconazole) + Arrest (herbicide; active ingredient to be confirmed for the specific formulation) for sunflower are listed, each with mandatory operational requirements (spray volume, flight altitude, maximum wind speed, droplet size) [14]. This positions Hungary as one of the frontrunners in regulating UAV spraying at the national level.

A cross-regional comparison reveals that while the United States emphasizes safety and airspace control, the European Union focuses on risk categorization and harmonization, and Asia promotes rapid adoption through policy incentives. The diversity of approaches underscores the absence of a universal framework and the need for international coordination, particularly in the fields of equipment certification, environmental protection, and operator training.

Table 1. Comparative overview of UAV spraying regulation.

Region / Country	Status of UAV spraying regulation	Key strengths	Key limitations
Asia (Japan, China)	Japan – regulated since 1990s; China – massive adoption with subsidies	Large-scale adoption, established operator training (Japan), rapid expansion (China)	Standardization of equipment and drift control remain challenges
United States	FAA Part 107 + Part 137 (dual compliance with EPA pesticide laws)	Clear aviation framework; Remote Pilot Certificate; LAANC system for airspace access	Complex, outdated pesticide rules; UAV spraying requires exemptions
European Union (general)	EASA framework (open/specific/certified categories) + SUD Directive on aerial spraying	Harmonized aviation safety rules; risk-based categories	Lack of UAV-specific pesticide registration at EU level; implementation varies by state
Hungary	National FVM–GKM–KvVM regulations allow UAV spraying; list of approved pesticide combinations	One of the first EU countries with official pesticide authorizations for UAV use	Strict technical conditions; limited range of approved products
Switzerland	National rules since 2019; UAV spraying permitted in steep vineyards under authorization	Homologation system for UAV sprayers; >440 ha treated (mainly vineyards) by 2023	Permitted only in specific crops/ conditions; high regulatory burden
Germany	Special permits issued for UAV spraying in certain regions	Early pilot projects; safety assessments in progress	Limited, case-by-case approvals; not yet mainstream
Serbia	No UAV-specific pesticide registration; UAV spraying not explicitly regulated	Growing farmer interest; market availability of UAV sprayers	No UAV-specific laws; no pesticides registered for UAV application; no training pathway

3. National Framework: Serbia

In Serbia, the use of UAV systems for chemical crop protection is still in its early stages and is shaped by a fragmented regulatory environment. The current framework is primarily derived from the Law on Air Traffic and general provisions on pesticide application. However, there are no UAV-specific laws that directly regulate chemical spraying operations, which creates significant legal uncertainty for both manufacturers and end users [15].

Aviation regulations

According to the Civil Aviation Directorate of the Republic of Serbia, UAVs fall under general aviation rules [16]. Operators must register their UAVs and, depending on weight and purpose, obtain special permits for flights beyond visual line of sight or in controlled airspace. These rules are designed for flight safety rather than agricultural use, which mean that UAV spraying currently lacks clear national authorization procedures.

Plant protection regulations

UAV pesticide application is indirectly regulated through the Law on Plant Protection Products and associated bylaws. While aerial application of pesticides is formally permitted under certain conditions, the law does not explicitly reference UAV systems. As a result, UAV operators must navigate requirements originally designed for manned aerial spraying, such as protective buffer zones, operator qualifications, and product authorization. This creates practical obstacles, since UAV sprayers cannot be directly equated with conventional aircraft.

Market adoption and practice

Despite regulatory gaps, the Serbian market for UAV sprayers has expanded in recent years. Local distributors have introduced advanced models such as the DJI Agras T50 and EAVision J100, while demonstrations and pilot projects have been reported in both orchards and field crops. Articles in the professional press emphasize the increasing farmer interest and document field trials of products like the XAG P100 Pro for herbicide application. The reports suggest that the practical adoption of UAV spraying is outpacing the regulatory process, mirroring trends in other developing markets [15]. The primary regulatory barriers in Serbia include:

- Lack of UAV-specific legal provisions for pesticide spraying.
- Certification gap: UAV sprayers and atomizers are not covered by national testing protocols (unlike conventional sprayers, which follow EN ISO standards).
- Absence of registered pesticides for UAV application: currently, no plant protection products in Serbia are officially approved for UAV spraying, which prevents legal large-scale deployment even when UAV equipment is available.
- Operator training: there is no recognized training or licensing pathway for UAV plant protection operators.

- Institutional coordination: multiple authorities (aviation, plant protection, environment) have overlapping responsibilities but no unified framework.

Recent academic studies underline that without harmonized rules, UAV spraying in Serbia will remain limited to experimental or small-scale applications [15]. However, the growing market demand, coupled with international regulatory developments, is likely to accelerate the introduction of UAV-specific legislation in the coming years. Incorporating standards from the EU (SUD Directive) and aligning with ISO requirements for UAV sprayers are key steps toward enabling safe and sustainable adoption.

A particularly critical limitation is the absence of plant protection products registered for UAV application. Current legislation does not recognize UAV spraying as a distinct application method, meaning that no pesticide label in Serbia specifies UAVs as an approved technology. This effectively prohibits legal large-scale use, even though UAV equipment is available on the market. Recent field-based research in Serbia has shown that UAVs can provide effective herbicide application in wheat when flight parameters are optimized, but also emphasized that regulatory gaps in product registration remain a major obstacle [15, 17]. Bridging this gap, by introducing UAV-specific registration procedures for pesticides, is therefore essential for enabling wider adoption and ensuring safe, efficient, and environmentally responsible UAV-based crop protection.

4. Conclusion

The rapid advancement of UAV technology for chemical crop protection has opened up considerable opportunities for enhancing the efficiency, safety, and sustainability of pesticide use. Nonetheless, the regulatory landscape varies significantly across different regions. Asia has taken the lead in large-scale implementation, bolstered by specific policies, whereas the United States and the European Union have adopted more stringent regulations, focusing on airspace safety and environmental conservation.

In Serbia, the use of UAVs for spraying is still in its early stages, hindered by the absence of legislation tailored to UAVs, the lack of certification processes for UAV equipment, and the unavailability of registered pesticides suitable for aerial application. These shortcomings collectively obstruct the legal and widespread implementation of this technology, even as farmers show increasing interest and research indicates the agricultural benefits of UAV spraying.

To tackle these challenges effectively, a dual regulatory approach is essential. Initially, Serbia needs to synchronize its aviation and plant protection regulations with global best practices by implementing specific rules for UAV operator training, equipment certification, and safe operational procedures. Additionally, the Ministry of Agriculture, in partnership with pertinent agencies, should create a clear pathway for pesticide registration that acknowledges UAV spraying as an accepted application method. Aligning with EU standards, incorporating ISO guidelines for UAV sprayers, and encouraging pilot projects can lay the groundwork for wider acceptance and use.

By closing these regulatory gaps, Serbia and other Western Balkan countries can

ensure that UAV-based spraying is not only technologically feasible but also legally secure, environmentally responsible, and aligned with the principles of sustainable agriculture.

References

[1] Kuster, C.J.; Kohler, M.; Hovinga, S.; Timmermann, C.; Hamacher, G.; Buerling, K.; Chen, L.; Hewitt, N.J.; Anft, T. Pesticide Exposure of Operators from Drone Application: A Field Study with Comparative Analysis to Handheld Data from Exposure Models. ACS Agric. Sci. Technol. 2023, 3, 12, 1125–1130. https://doi.org/10.1021/acsagscitech.3c00253

[2] Guebsi, R.; Mami, S.; Chokmani, K. Drones in Precision Agriculture: A Comprehensive Review of Applications, Technologies, and Challenges. Drones 2024, 8, 11, 686. https://doi.org/10.3390/drones8110686

[3] Huang, Y.; Thomson, S.J.; Hoffmann, W.C.; Lan, Y.; Fritz, B.K. Development and Prospect of Unmanned Aerial Vehicle Technologies for Agricultural Production Management. Int. J. Agric. Biol. Eng. 2013, 6, 1–10.

[4] Hu, P.; Zhang, R.; Yang, J.; Chen, L. Development Status and Key Technologies of Plant Protection UAVs in China: A Review. Drones 2022, 6, 354.

[5] FAA. Certificated Remote Pilots including Commercial Operators (Part 107 Overview). 2025. Available online: https://www.faa.gov/uas/commercial_operators (accessed on 3 November 2025).

[6] EASA. Guidelines for UAS Operations in the Open and Specific Category. 2025. Available online: https://www.easa.europa.eu/en/downloads/139435/en (accessed on 3 November 2025).

[7] Oljača, M.; Pajić, M.; Gligorević, K.; Dražić, M.; et al. Design, Classification, Perspectives and Possible Applications: Drones in Agriculture of Serbia. Poljoprivredna Tehnika 2018, 43, 29–56. https://doi.org/10.5937/PoljTeh1804029O

[8] Ivezić, A.; Trudić, B.; Stamenković, Z.; Kuzmanović, B.; Perić, S.; Ivošević, B.; Buđen, M.; Petrović, K. Drone-Related Agrotechnologies for Precise Plant Protection in Western Balkans: Applications, Possibilities, and Legal Framework Limitations. Agronomy 2023, 13, 2615.

[9] Wang, L.; Zou, X.; Tang, X.; Luo, S.; Chen, M.; Li, Y.; Wang, C. Applications and Prospects of Agricultural Unmanned Aerial Vehicles. Sensors 2019, 19, 642.

[10] European Union Aviation Safety Agency (EASA). Easy Access Rules for Unmanned Aircraft Systems. EASA: Cologne, Germany, 2023. Available online: https://www.easa.europa.eu/en/document-library/easy-access-rules (accessed on 06 November 2025).

[11] European and Mediterranean Plant Protection Organization (EPPO). EPPO Standard PP 1/239: Efficacy Evaluation of Plant Protection Products. EPPO: Paris, France, 2023. Available online: https://www.eppo.int/ (accessed on 06 November 2025).

[12] Deng, Q.; Zhang, Y.; Lin, Z.; Gao, X.; Weng, Z. The Impact of Digital Technology Application on Agricultural Low-Carbon Transformation—A Case Study of the

Pesticide Reduction Effect of Plant Protection Unmanned Aerial Vehicles (UAVs). Sustainability 2024, 16, 24, 10920. https://doi.org/10.3390/su162410920

[13] European Commission. Directive 2009/128/EC Establishing a Framework for Community Action to Achieve the Sustainable Use of Pesticides. Official Journal of the European Union, L 309/71, 2009.

[14] Hungarian Ministry of Agriculture; National Food Chain Safety Office (NÉBIH). Hungarian UAV Spraying Decree and NÉBIH Guidelines on UAV Application of Plant Protection Products, 2024/2025. Available online: https://www.nebih.gov.hu (accessed on 06 November 2025).

[15] Boskovic, B.; Bozic, D.; Drazic, M.; Gligorevic, K.; Spalevic, V.; Kader, S.; Pajic, M. Impact of Unmanned Aerial Vehicle Flight Settings on Spray Quality and Weed Control in Wheat. Chilean J. Agric. Res. 2025, 85, 5, 705–719.

[16] Civil Aviation Directorate of the Republic of Serbia. Regulation on Unmanned Aircraft Systems. Official Gazette of the Republic of Serbia. Available online: https://cad.gov.rs/upload/propisi/2020/Pravilnik%20o%20bespilotnim%20vazduhoplovima.pdf (accessed on 06 November 2025).

[17] Bošković, B.; Božić, D.; Pajić, M.; Marina, I.; Buđen, M. Application of a Combination of Tritosulfuron and Florasulam by Unmanned Aerial Vehicle in Winter Wheat. Acta Herbologica 2023, 32, 1–8. https://doi.org/10.5937/32ah-47162