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Integrating Drone Technology Into Smart Farming: Identifying Key Competences For Agricultural Experts And Drone Operators

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Short abstract

The integration of drone technology into agriculture is transforming how sustainability, productivity, and resource efficiency are addressed. Precision agriculture, enabled by unmanned aerial vehicles (UAVs), supports data-informed decision-making and optimised resource allocation. This study investigates the skills and competencies required for effective UAV deployment by agricultural professionals and drone operators. Through surveys, interviews, and focus groups with 20 experts across three countries, the study identified the emerging roles, training needs, and digital skill gaps in smart farming. Findings emphasise the importance of technical, digital, and socio-environmental skills, alongside transversal competences such as collaboration, digital literacy, and problemsolving. Domain-specific knowledge in agronomy and UAV operations—such as data interpretation, flight planning, and regulatory compliance—was found to be essential. These insights were mapped against the DigComp and ESCO frameworks to ensure consistency with EU policy standards. The study informed the development of a career eGuide and self-assessment tool, supporting targeted upskilling and vocational training. By aligning education and advisory services with technological advancements, the project contributes to workforce readiness in precision agriculture. It offers a structured framework for educators, policymakers, and stakeholders to promote the effective and sustainable integration of drone technologies in agricultural practice.

1. Purpose

1.1 Introduction

The increasing deployment of UAVs in agricultural contexts reflects a broader trend toward digitalisation and datadriven decision-making in the agri-food sector. Precision agriculture, facilitated by drone technologies, offers substantial potential for improving sustainability, productivity, and efficiency in resource use. However, the widespread integration of UAVs into standard agricultural practices is hindered by a lack of structured training pathways and

formally defined competence profiles that align technical UAV expertise with agronomic practice, expertise and needs. This skills gap is particularly pressing in light of ongoing ecological and economic challenges, including climate change, labour shortages, and the imperative to meet European Union targets related to the green and digital transitions. Without a workforce adequately trained to operate at the intersection of agriculture and emerging drone technologies, the transformative potential of UAVs may remain underutilised. This study aims to identify the key skills and competences required for effective UAV integration in agriculture. Using a multi-method approach and aligning with DigComp and ESCO frameworks, it develops validated occupational profiles and informs the creation of a career e-Guide and MOOC to support targeted upskilling across the sector.

1.2 Literature Review

Integration of drone technology into agriculture has emerged as a transformative force, addressing challenges in sustainability, productivity, and resource management. Precision agriculture, enabled by advancements in UAVs, empowers farmers with data-driven insights to optimise resource allocation and enhance crop yields [1], [2]. As agriculture becomes increasingly data-centric, the sector requires digitally skilled professionals capable of leveraging drone technologies to improve decision-making and operational efficiency [3]. However, the full potential of drone technology in agriculture remains underutilised due to persistent gaps in technical know-how, regulatory awareness, and the integration of drone operations into standard agricultural practices [4], [5]. This study explores the critical skills and competences required by agricultural experts and drone operators to successfully implement UAV-based solutions in agriculture. It presents key findings from the AgroPro project, which aims to address skill gapsin the agricultural sector by developing a comprehensive career e-Guide. The central focus is the identification of new occupational profiles for professionals using drones in agriculture. These roles show potential to improve crop yields and reduce costs related to labour, fertilisers, and other inputs. Based on an analysis of tasks and responsibilities, the study provides a clear overview of the required skills, using recognised frameworks such as European Digital Competence Framework (DigComp) and ESCO to ensure alignment with EU training standards. Two main profiles are defined—Drone-Oriented and Agriculture-Oriented—each outlining the essential knowledge, tasks, and competences. The e-Guide developed around these profiles supported the creation of a Massive Open Online Course (MOOC), aimed at delivering targeted training and promoting the use of drones in sustainable agriculture.

2. Methodology

The research adopted a multi-method qualitative approach, structured in three sequential phases to develop a targeted training framework and occupational profiling for agricultural drone professionals.



Figure 1: Methodology

2.1 Survey Design and Implementation

An initial online survey was conducted to identify the skills, knowledge gaps, and training needs of professionals involved in agriculture and drone deployment. Respondents

represented a diverse range of sectors including industry, academia, research institutions, and unemployed professionals. The survey instrument was designed in alignment with the DigComp to ensure comprehensive coverage of the digital skills necessary for UAV operations in agriculture. Questions were structured into four thematic blocks:

- Professional background,
- Drone familiarisation,
- Future agricultural tasks,
- Personal demographics.

The third block, which formed the core of the skill assessment, consisted of questions beginning with "Future agriculture professionals will need to be able to…", and was directly mapped to the five DigComp competence areas. This allowed for an evidence-based analysis of the technological, operational, and regulatory competences necessary for UAV integration in agriculture.

2.2 Storyboard and Interviews

Following the survey, a storyboard technique was employed through individual semi-structured interviews with 20 experienced agricultural and drone professionals. These interviews aimed to identify and describe the real-life tasks, responsibilities, and contextual challenges of drone usage in the sector. The interviews were guided by the ESCO classification system, ensuring standardisation in capturing occupational information and facilitating the translation of practice-based insights into structured profiles. This phase resulted in the initial formulation of two occupational profiles: Drone-Oriented and Agriculture-Oriented professionals.

2.3 Focus Groups for Validation

To refine and validate the preliminary occupational profiles, focus groups were organised across three countries (Portugal, Greece, and Cyprus), involving practitioners from various agricultural domains. Moderated by neutral facilitators, these sessions employed open-ended, thematically guided discussions to verify the identified competencies, explore training needs, and capture additional insights related to career development, regulatory awareness, and future outlooks. The open format also facilitated the identification of soft skills, collaborative capacities, and systemic thinking, often omitted in more structured assessments.

3. Findings

The study highlights the significance of technical, digital, and socio-environmental skills, along with transversal competencies such as collaboration, digital literacy, and problem-solving. Agriculture-specific expertise—including field observation, equipment management, and data analytics—must be complemented by drone-specific capabilities such as piloting, sensor data interpretation, and adherence to safety regulations [6], [7]. These competencies were mapped to the DigComp [8] and existing ESCO occupational profiles to align with EU standards. Furthermore, the findings contributed to the development of a career e-guide and a self-assessment tool, designed to guide professionals and trainees in acquiring the necessary skills.

3.1 Survey Insights

The survey, based on a 5-point Likert scale, revealed that Precision agriculture and mapping (avg. 4.0) and Environmental monitoring and assessment (avg. 3.8) are perceived as the domains where drones can offer the greatest added value. In contrast, the lowest perceived benefit was in cost reduction (avg. 2.8), reflecting concerns about affordability and return

on investment. The most valued skills among respondents were the ability to access and retrieve drone data and the ability to self-diagnose and update competences, both essential for maintaining relevance in a rapidly evolving digital environment. Least valued were tasks involving routine software instruction or basic maintenance, suggesting a preference for higher-level cognitive and interpretative tasks.

3.2 Skill Differentiation by Background

A comparison between professionals with drone and agricultural backgrounds revealed distinct skill priorities. Agriculture-oriented professionals rated traditional farming tasks (e.g., planting, machinery operation, pest control) highly, while drone professionals emphasised analytical skills, flight operations, and technical problem-solving. Both groups showed strong scores in transversal skills like collaboration, problem-solving, and willingness to learn, underlining the cross-sectoral nature of the emerging roles.

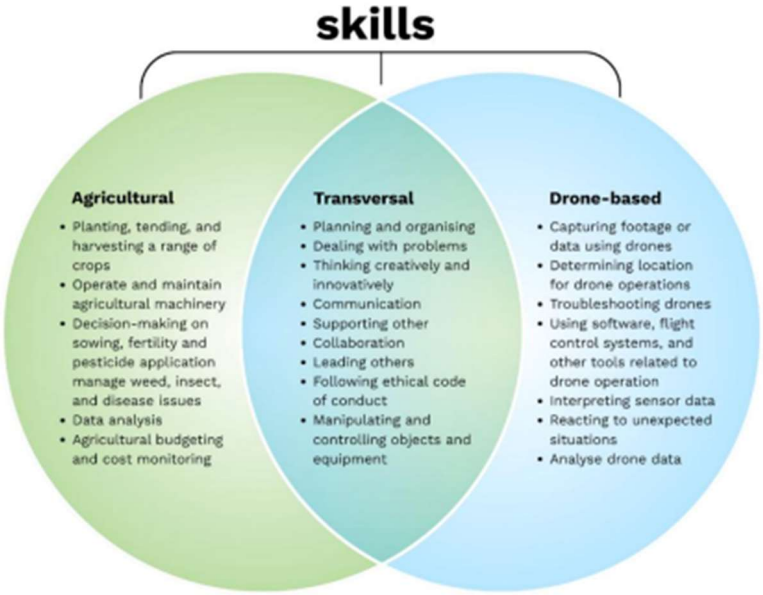


Figure 2: Skills Identified

3.3 Occupational Profiles

Development From the analysis of tasks and responsibilities, two main occupational profiles were defined, aligned with the ESCO framework:

• Drone-Oriented Professionals: Emphasise UAV operation, certification, flight safety, sensor calibration, data collection and analysis, software use, and regulatory compliance. Roles may include UAV pilots, drone technicians, and data analysts.

• Agriculture-Oriented Professionals: Focus on applying drone insights to optimise agricultural processes such as crop management, irrigation, pesticide application, and disease detection. Competencies include interpreting drone outputs, managing farm logistics, and integrating drone data with agronomic decision-making. The data also highlighted shared challenges, such as navigating regulatory landscapes, the need for formal certification, and the importance of practical training in both drone piloting and data interpretation.

3.4 Interview and Focus Group Results

Interviews and focus groups with experts further validated the profiles. Drone professionals emphasised the need for understanding sensor technologies, maintaining equipment, reacting to real-time challenges, and interpreting aerial imagery. Agricultural professionals

highlighted the relevance of drone-generated data for improving decision-making in crop treatment and planning, while also stressing the importance of traditional agronomic knowledge.

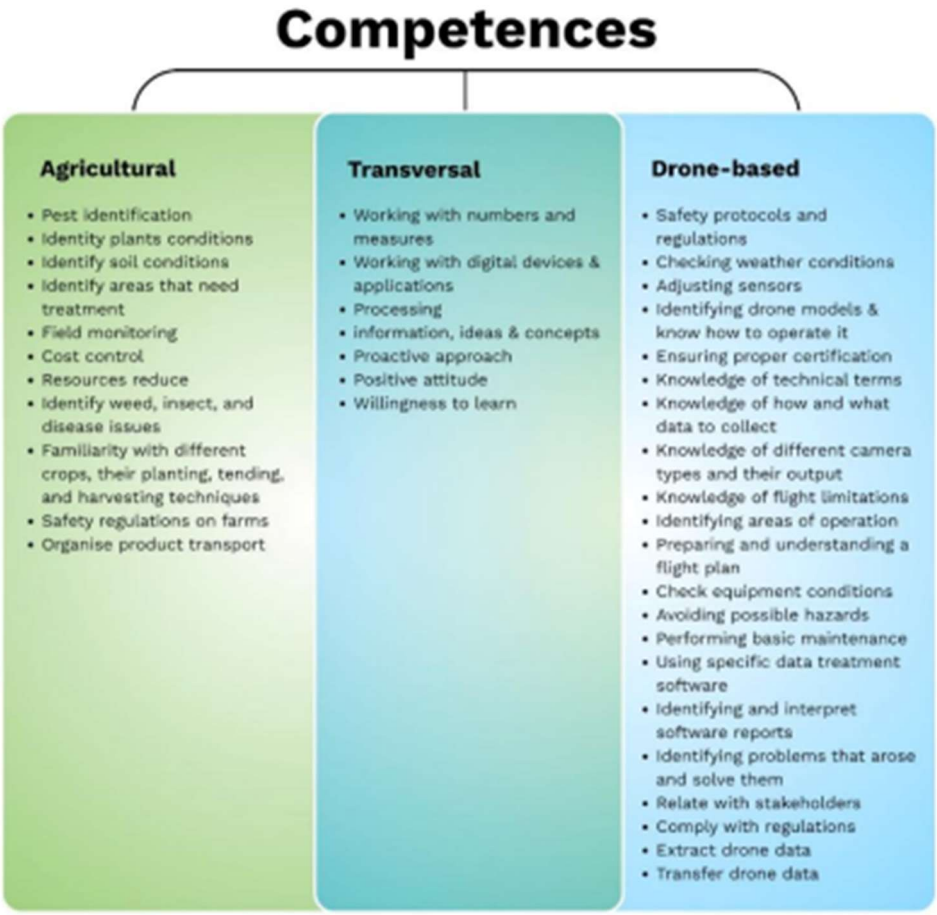


Figure 3: Competences Identified

4. Practical & Theoretical Implications

The study shows the importance of aligning vocational training, educational curricula, and advisory services with the technological advancements transforming modern agriculture. By identifying and addressing critical skill gaps in the use of UAVs, it contributes to the development of a digitally competent workforce equipped for the evolving demands of precision and smart farming. Practically, the findings support the design of modular, competence-based training programmes that are responsive to both technological developments and the operational realities of agricultural practice. The career e-Guide and associated MOOC developed through the AgroPro project serve as key instruments in this process. These tools offer structured learning pathways based on validated occupational profiles, enabling learners to acquire, assess, and certify essential digital and agricultural skills. Additionally, the study provides actionable guidance for policymakers and training providers by linking field-derived insights to established EU frameworks such as DigComp and ESCO. Theoretically, the research contributes to the discourse on digital transformation in agriculture by offering a dual-profile approach that bridges technological and agronomic domains. This model supports an interdisciplinary understanding of competence development and highlights the need for hybrid professionals capable of operating at the intersection of data, technology, and agricultural expertise. Furthermore, the study reinforces the value of participatory methods—surveys, interviews, and focus groups—in

grounding theoretical frameworks in the lived experiences of professionals. The approach is scalable and adaptable across EU contexts, and its integration of insights from initiatives such as the SmartVitiNet project strengthens its applicability. Ultimately, the study provides a replicable model for future skill development initiatives in agri-tech, promoting sustainable innovation and lifelong learning in the agricultural sector.

5. Conclusions

This study identified the core technical, digital, and transversal competences needed for integrating UAVs into smart agriculture and developed two validated occupational profiles aligned with EU frameworks. The findings informed the creation of a digital career e-Guide and MOOC, offering practical tools for upskilling professionals across the agri-tech sector. By linking field research with DigComp and ESCO standards, the project supports the development of a digitally capable workforce ready for the challenges of precision farming. The dual-profile approach demonstrates a replicable model for competence-based training in emerging technology domains. Future work will focus on pilot implementation and continued alignment with evolving EU digital and green transition strategies

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