[F] PhD Extended Abstract Form

ASSESSMENT OF DRIFT AND DEPOSITION FROM UAV SPRAYERS IN SUPER-HIGH-DENSITY OLIVE ORCHARDS AND AGROFORESTRY CROPS

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Extended Abstract

1. General Introduction and Literature Review

Global agriculture faces a dual challenge: feeding a population projected to exceed 9 billion by 2050 while transitioning toward more sustainable practices. Meeting future demand requires increasing production by approximately 70%, yet the tools historically relied upon carry significant environmental costs. Global PPP consumption has more than doubled since 1990, reaching 3.7 million tonnes annually, while losses to pests and diseases still account for 20 - 40% of global crop yields. In Europe, the Farm to Fork strategy aims to a 50% reduction in PPP use by 2030, placing precision application technologies at the center of this transition.

Unmanned Aerial Spraying Systems (UASS) have emerged as a promising precision agriculture tool capable of targeted PPP application in demanding scenarios, including steep slopes and hedgerow crops. However, widespread adoption remains constrained by two major barriers: a strict EU regulatory framework that classifies UASS as conventional aerial sprayers and a critical knowledge gap: no validated UASS-specific drift models existed for the European regulatory context at the start of this research. This thesis was motivated by that gap.

2. Objectives

The primary objective was to investigate UASS spray drift, soil depositions, and crop depositions in comparison with conventional ground orchard sprayers, and to assess their potential to reduce environmental and human exposure to PPPs. Three specific hypotheses were formulated: (1) UASS generate less spray drift than conventional terrestrial orchard sprayers; (2) UASS achieve soil deposition levels comparable to those of conventional sprayers; and (3) UASS perform consistently across different crop systems and agroforestry scenarios. These were tested through a compendium of three peer-reviewed publications across representative Spanish agroforestry scenarios.

3. Publication 1: Drift Reduction in Orchards Through the Use of an Autonomous UAV System

Computers and Electronics in Agriculture, 2023 ; DOI: 10.1016/j.compag.2023.107981

The first study compared sedimented spray drift generated by a UASS and a conventional tractor-mounted mist blower in a commercial super-high-density olive orchard in Southern Spain. ISO-standardized drift methodology (ISO 22866, ISO 22522) was applied, utilizing tartrazine as a tracer and spectrophotometric analysis of filter paper collectors placed up to 40 m downwind of the sprayed area. Exponential functions were fitted to mean drift data from each sprayer, yielding R^2 values above 0.95.

The UASS produced significantly less sedimented drift than the mist blower across all distances. Buffer distances required for 90%, 95%, and 99% drift sedimentation were reduced by factors of 2.54, 2.66, and 2.81, respectively. This was the first direct comparison of UASS and terrestrial mist blower drift in super-high-density olive orchards under Mediterranean conditions.

4. Publication 2: Reducing Environmental Exposure to PPPs in Super-High-Density Olive Orchards Using UAV Sprayers

Frontiers in Plant Science, 2024 ; DOI: 10.3389/fpls.2023.1272372

The second study expanded the analysis by simultaneously assessing airborne drift, soil deposition, and crop deposition. Airborne collectors were positioned at 5 and 10 m downwind at heights up to 6 m; soil collectors at intra-row and inter-row positions within the sprayed area; and crop collectors at 1, 2, and 3 m canopy heights.

UASS generated significantly less airborne drift than the tractor-mounted mist blower at all heights and distances ($p < 0.05$). Total soil depositions were not significantly different between the two sprayers overall, though UASS exhibited higher spatial variability, partly attributable to a swath width (2.25 m) exceeding the average hedgerow width (1.66 m). Intra-row soil depositions were significantly higher for the mist blower. Crop depositions were significantly lower with UASS at all sampled heights, with maximum deposition concentrated at the canopy top (3 m), while downwash airflow promoted penetration into lower canopy layers.

These results reveal a key operational trade-off: while UASS excel at reducing drift, their ultra-low-volume nature and downward spray trajectory limit canopy coverage, making them particularly suitable for systemic or bait formulations rather than contact-type PPPs requiring uniform coverage.

5. Publication 3: First UASS Drift Curves for Agroforestry Scenarios in Spain

Crop Protection, 2025 | DOI: 10.1016/j.cropro.2025.107164

The third study developed the first UASS-specific sedimenting drift curves in Spain across three agroforestry scenarios: grapevines (early and late phenological stages), super-high-density olive orchards, and pine plantations. Seven drift trials were conducted at four locations (Lleida, Cuenca, Sevilla, Aramaio) using three commercially available UASS models (DJI Agras MG1P, DJI Agras T10, and a prototype hexacopter AGX6) with different nozzle configurations. All trials followed ISO 22866 and ISO 22522 methodology.

The 90th percentile of drift data at each distance was modelled with power functions and compared to terrestrial reference models (Rautmann, 2001) and the aerial spraying reference model (Working Group on Surface Water Scenarios, 2001) used in European PPP risk assessment under Regulation (EC) No 1107/2009.

In super-high-density olive orchards, UASS generated significantly less sedimented drift than both terrestrial and aerial reference models ($R^2 > 0.98$), confirming and expanding the findings of Publications 1 and 2. In grapevines, however, UASS drift profiles closely resembled the aerial reference model: the UASS swath width exceeded the narrow vine row spacing, directing spray into interrow spaces and increasing off-target spraying. A swath displacement phenomenon was also identified, where the crosswind interaction with the autopilot system caused the effective spray swath to shift laterally from the intended flight line. In pine plantations, high spraying altitude above the 4 m canopy and the conical tree architecture produced variable deposition patterns from which no reliable drift curve could be established. These findings collectively demonstrate that UASS performance is strongly crop-specific and governed primarily by the match between swath width and canopy geometry.

6. General Results, Discussion and Future Research

Across the three studies, UASS demonstrated a reduction in drift in hedgerow systems, particularly in super-high-density olive orchards, where the continuous canopy geometry aligns with the characteristic UASS spraying and allows rotor downwash to be used effectively. Conversely, UASS showed limitations in narrow-row vineyards and were unsuitable for tall forestry crops under the current configuration.

The thesis identifies the main barriers to broader European adoption: payload limitations restricting applications to ultra-low volumes; limited and variable canopy coverage; absence of standardized spraying guidelines and authorized active ingredients; and a regulatory framework that does not differentiate UASS from conventional aerial sprayers.

Future research priorities include adaptive swath width control to dynamically match hedgerow geometry; optimized flight parameters per crop system; airborne drift modelling for UASS; and generating UASS-specific exposure data for EFSA to support regulatory revision under Regulation (EC) No 1107/2009.

7. Conclusions

UASS reduce sedimented and airborne drift compared to conventional mist blowers in super-high-density olive orchards, contributing to reduced environmental and human PPP exposure. Soil depositions are comparable between both sprayers, while lower crop depositions limit current suitability to systemic or bait treatments. In grapevines, UASS drift resembles conventional aerial spraying rather than terrestrial models, primarily due to swath width mismatch. In pine plantations, no robust drift model could be established. UASS suitability is strongly scenario-dependent; hedgerow systems offer the most favorable conditions.

Final remarks concerning benchmarks and strength points of the Pellizzi Prize 2026

This thesis produced the first validated UASS-specific spray drift models for multiple agroforestry scenarios in Europe, filling a critical regulatory and scientific gap. This work compared UASS against conventional spraying under EU regulatory frameworks and provided solid evidence for safer, more sustainable crop protection practices. All core publications appeared in Q1 journals. The work bridges precision agriculture, environmental risk assessment, and agricultural policy, positioning UASS as a viable tool for sustainable Mediterranean agriculture under favorable scenarios and an adequate configuration.