OPERATIONAL STUDY OF DRONE SPRAYING APPLICATION OF PHYTOSANITARY PRODUCTS IN VINEYARDS

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ABSTRACT:

The use of drones in topics related to precision agriculture to improve the efficiency in the application of phytosanitary products to vineyards increases every day. Drones are especially productive in difficult orographic terrains, where other mechanical systems such as tractors cannot be used.

This study shows the development and implementation of a methodology to determine key parameters to decide the suitability of a drone to a spraying task (i.e. spraying time for a certain parcel, number or tank refills required), taking into account the technical specifications of a certain commercial model. For the validation, the data of a vineyard belonging to the Rías Baixas appellation of origin (NW Spain) and the technical specifications of drones from three different manufacturers (i.e. DJI, Hylio and Yamaha) are used. Results show that the Hylio AD122 with a phytosanitary tank of 22 L provides the best performance, with a productivity around 6 minutes per hectare.

Keywords: drone spraying; vineyard; precision agriculture; aerial works

RESUMEN:

La utilización de drones en tareas relacionadas con la agricultura de precisión para mejorar la eficiencia en la aplicación de productos fitosanitarios en viñedos es cada vez mayor. Los drones son especialmente eficientes en terrenos con orografía difícil, donde no se pueden emplear otros sistemas mecánicos como tractores.

Este estudio muestra el desarrollo e implementación de una metodología para determinar parámetros clave que decidan la adecuación de un drone determinado a una tarea de fumigación (por ejemplo, el tiempo de fumigación para una cierta parcela o el número de tanques requeridos para dicha fumigación), teniendo en cuenta las especificaciones técnicas de un determinado modelo comercial. Para la validación de la metodología, se han utilizado los datos de un viñedo que pertenece a la denominación de origen Rías Baixas (Noroeste de Espala) y las características técnicas de tres fabricantes diferentes de drones (DJI, Hylio y Yamaha). Los resultados obtenidos muestran como el Hylio AD122 con un tanque de fitosanitario de 22 L provee el mejor rendimiento, con una productividad de aproximadamente 6 minutos por hectárea.

Keywords: fumigación con drones; viñedo; agricultura de precisión; trabajos aéreos

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1. - INTRODUCTION

Galicia is one of the Spanish regions with greatest tradition in winemaking, especially in the zones around the Miño and Sil rivers. These zones are less humid than the rest of the region, with sunnier and drier summers [1]. There is historical evidence that Galicia, already during the IX century, exported wines to other European cities. Galician wine production is structured in five appellations of origin: Rías Baixas, in the Atlantic Area of the Pontevedra Province, Ribeiro, Valdeorras and Monterrei, in the Province of Ourense, and Ribera Sacra, along the Sil river, sharing the provinces of Ourense and Lugo. The five appellations of origin sum an area larger than 9,000 ha, with more than 400 wineries that commercialize more than 0.5 million hectoliters [2-6].

The development of the wine sector in Galicia presents two structural limitations. On the one hand, there is the low size of its vineyards, with an average area of 0.14 ha, compared to 1.8 ha on average in the whole Spain. This results in a significant imbalance. The Galician community represents 3.5% of the area dedicated to vineyards in the state, but instead has 200,000 parcels, 40% of the total Spanish parcels [7]. Another aspect to consider regarding the peculiarities of viticulture in Galicia, is that of its complex orography. In many areas, viticulture is developed on the valleys of the rivers, with very steep slopes. In fact, this type of viticulture is traditionally called heroic viticulture [8].

The specific described characteristics of Galician vineyards make it very complex to mechanize the main agricultural tasks (i.e the application of phytosanitary treatments against pests such as mildew, odium or botrytis) [9] with traditional solutions such as tractors. This opens the interest to explore other technologies that replace human work, such as drones. They have been widely used in recent years in agricultural and forestry applications, mainly from the point of view of acquiring geospatial data with LiDAR systems, photogrammetry or multispectral cameras. Chandel et al. showed the interest of multispectral and thermal infrared imagery for the geospatial mapping of crops [10]. Panday et al. depicted a review on drone-based data solution for crop mapping to combat food insecurity caused due to the pandemic, zoonotic diseases, and other food shocks [11]. Nuijten et al. used unmanned aerial systems and object-based image analysis for measuring plant-soil feedback effects on crop productivity [12]. Borra-Serrano et al. used high resolution time series from unmanned aerial systems for soybean growth analysis, providing objective data from field trials [13]. In spite of the great amount of the remote sensing application from drones, there are other less explored applications, such as those focused on the drone spraying capacity.

The first test of an agriculture aircraft occurs in August 1921, at Ohio, USA, to spread lead arsenate to kill catalpa sphinx caterpillars on a crop farm. The test was successful and first commercial operations of agriculture aircraft began at 1924 also in the USA. These types of applications spread all over the world, but in recent decades certain countries have opted for the use of unmanned aerial vehicles [14 – 16]. This phenomenon started in Japan and South Korea in the 1990s, where the complex orography (mountainous terrain) and relatively small family-owned farms required lower costs than those of manned aircraft, and higher precision in spraying. The first drone system used for these operations was the Yamaha R-Max, although nowadays there are other options on the market as the DJI Agras or the Hylio. Drone regulation in Europe [17] include three different categories: open, specific and certified, depending on the maximum take-off weight of the system and the risk of the operation. In this case, drone-spraying operations could be framed inside the specific one. This category includes the requirement of a Specific Operations Risk Assessment (SORA) to maintain operational safety.

The aim of this work is to develop an operational study about the possibility of using different drone sprayers for the application of phytosanitary products in vineyards. The study does not go into the type of phytosanitary product to be used or its comparison with other pest control methods. The operational study includes a methodology developed in MatLAB to obtain the main parameters related to the operation, such as time to change batteries, time to refill the phytosanitary tank, and spraying time per hectare. The paper is organized as follows: Section 2 shows the material and methods part, where drone characteristics are presented, as well as the study area and drone operational model used. Section 3 depicts the results and discussion. Section 4 exhibits the conclusions.

2. - MATERIAL & METHODS

Figure 1 shows the different drones and helicopter used for this study and Table 1 their technical specifications. Three different manufacturers were selected, Yamaha, DJI and Hylio. Liquid tanks capacity for phytosanitary varies from 10 L up to 22 L. Flight endurance changes from the 9 min of the DJI MG-1P (brushless DC electric) up to the 60 min of the Yamaha R-Max (gasoline/oil mix). Maximum take-off weight starts in 24.8 kg of the DJI MG-1P and finishes with the 94 kg of the Yamaha R-Max. Maximum operating speed ranges between 7 m/s (DJI MG-1P) and the 9.7 m/s (Hylio systems). Maximum spray flow is achieved by the Hylio AG122 with 8.5 L/min and minimum by the Yamaha R-Max with 2.5 L/min. Spray width also changes with different models. The maximum width is achieved by the DJI Agras T20 with 7 m and the minimum one by the DJI Agras MG-1P with 4.5 m.

A testing vineyard from Condes de Albarei was selected in the neighborhood of Pazo Baión (Figure 2) [18]. It belongs to the region of Galicia (NW Spain) and the appellation of origin Rías Baixas. The total area of the parcel is 33.6 hectares.

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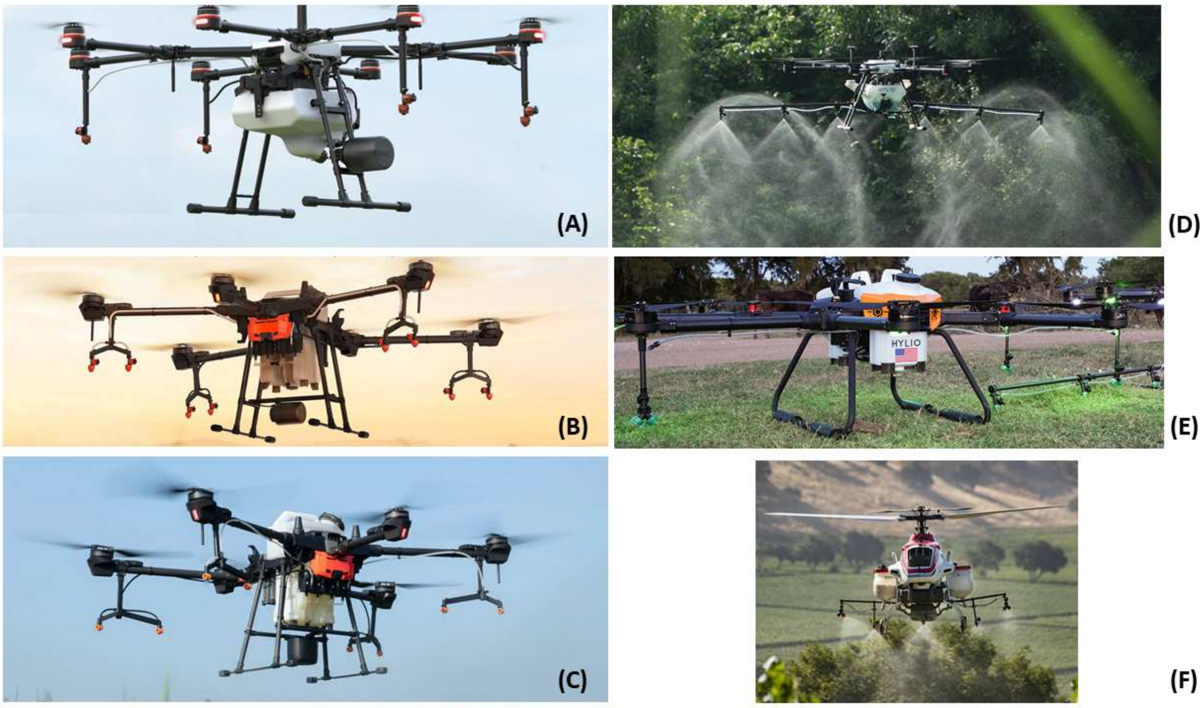

Figure 1. Drones and helicopter under study. (A) DJI Agras MG-1P, (B) DJI Agras T16, (C) DJI Agras T20, (D) Hylio AG116, (E) Hylio AG122, (F) Yamaha R-Max.

Drone	Type of engine	MTOW (kg)	Tank volume (L)	Flight endurance (min)	Maximum operating speed (m/s)	Spray flow (L/min)	Spray height (m)	Spray width (m)
DJI Agras MG-1P	Brushless DC electric	24.8	10	9	7	2.2	1.5 - 3	4.5
DJI Agras T16	Brushless DC electric	42	16	10	7	4.8	1.5 - 3	6.5
DJI Agras T20	Brushless DC electric	47.5	20	10	7	6	1.5 - 3	7
Hylio AG116	Brushless DC electric	59.6	16	14	9.7	4.3	1.5 - 3	6
Hylio AG122	Brushless DC electric	79.5	22	14	9.7	4.3	1.5 – 3	6
Yamaha Rmax	Gasoline/oil mix	94	16	60	8	2.5	3	5

Table 1. Spraying drones and helicopter main specifications. MTOW indicates the maximum take-off weight.

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Figure 2. Testing vineyard area Condes de Albarei from appellation of origin Rías Baixas (red parcel).

To evaluate the operational performance of the different drones under study, a software tool based on MATLAB was developed [19]. The tool follows the workflow diagram shown in Figure 3. The code begins with the reading of different flight performance parameters, given by the technical specifications from the drone manufacturer (spraying width, autonomy, flying speed, tank volume and spraying flow), and the perimeter of the vineyard, obtained from a kmz geometry on Google Earth.

Perimeter is obtained in WG84 geographic coordinates. However, UTM (Universal Transverse Mercator) projection is preferred to the calculations required in this work, since length is easier to handle than latitude and longitude angles [20]. The projection is codified in MATLAB. Take-off and landing point area are automatically calculated as the average of X and Y UTM coordinates from the perimeter points. If required, this point could be manually selected by the user. The point for spraying beginning was also automatically selected as the Southwest corner point from the vineyard perimeter data. The starting point does not seem to be an important variable for operation efficiency and any other point from the perimeter of the vineyard could be used. The spraying route begins at this point and continues in North direction up to the limit of the parcel. Once the limit achieved, the aircraft flies East a distance equal to the spraying width and spraying operation continues to South direction. Once South limit is achieved, the aircraft is again displaced the spraying width to the East and spraying continues along North direction. This pattern continues until the entire parcel is sprayed. Flight speed as input in the simulations is the maximum value presented in Table 1. Flight height is estimated as 3 m during all the flight segments. All the simulations are done using ideal conditions equally for all drones without considering weather conditions as wind speed. The current simulations are performed in horizontal vineyards. The current implementation has been made to ensure that all area of the vineyard are treated with phytosanitary and that no spraying trajectories are repeated.

Based on the expertise of the authors, it is estimated that the drone must return to the base station with at least 25 % of battery charge or fuel to prevent an accident. Flight endurance was estimated in agreement with information of Table 2. In addition, each battery change, refuel and phytosanitary re-fill is estimated as a duration of 5 min, based on the expertise of the authors. Output parameters include the total spraying distance, total spraying volume, number of battery changes, number of phytosanitary refills, parcel area, tank emptying time, flying time and mission time. Mission time includes the sum of the flying time, the battery change or re-fuel time, and the phytosanitary tank re-fill.

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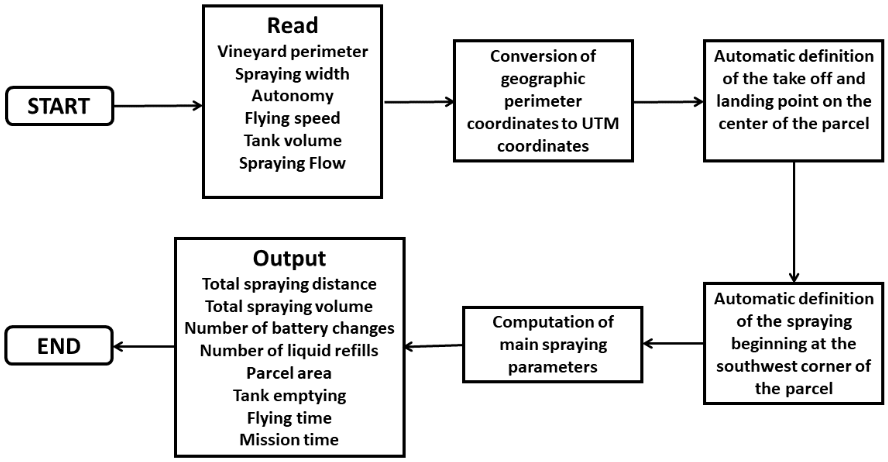

Figure 3. Workflow of the operational simulation.

3. – RESULTS

Figure 4 shows the results of spraying planning for the DJI Agras T20. Take-off and landing areas are situated on the center of the parcel (red cross). However, this point could be placed at any desired location on the vineyard. Parcel limits are delimitated by a blue perimeter. Spraying starts at the blue cross (West side of the parcel) and finishes at the other blue cross (East side of the parcel). Spraying path is drawn with a green line and the points to refill phytosanitary liquid area marked with a red circle. Phytosanitary refill is performed on the takeoff / landing area. Battery change or refuel is also done to optimize this operation.

The spraying planning algorithm is executed using the technical specifications of all the drones under study (Table 1). Figure 5A exhibits the time required to complete all the spraying mission and Figure 5B depicts the mission time per hectare. The Hylio AG122 is the drone that shows less time to perform the mission. It even improves the results of the Yamaha RMax, with a combustion engine and larger flight endurance. In this case the key aspect is the tank capacity. The Hylio AG122 presents a volume of 22 L, the largest one under study. In addition, the productivity of the Hylio AG122 is the best one of the tested vehicles (Figure 5B), with around 6 minutes per hectare.

Figure 5C shows spraying area accomplished with one phytosanitary tank. In agreement with the results exhibited on Figures 5A and 5B, the Hylio AG122 show the best results. It can cover almost 1.8 hectares with a single tank. This fact reduces the number of phytosanitary tank refills and the global mission time, since fewer flights to the take-off / landing point are required. As it can be seen, the emptying time of the phytosanitary tank is shorter than the flight endurance in all drones, which makes it the determining parameter to define the efficiency of the system.

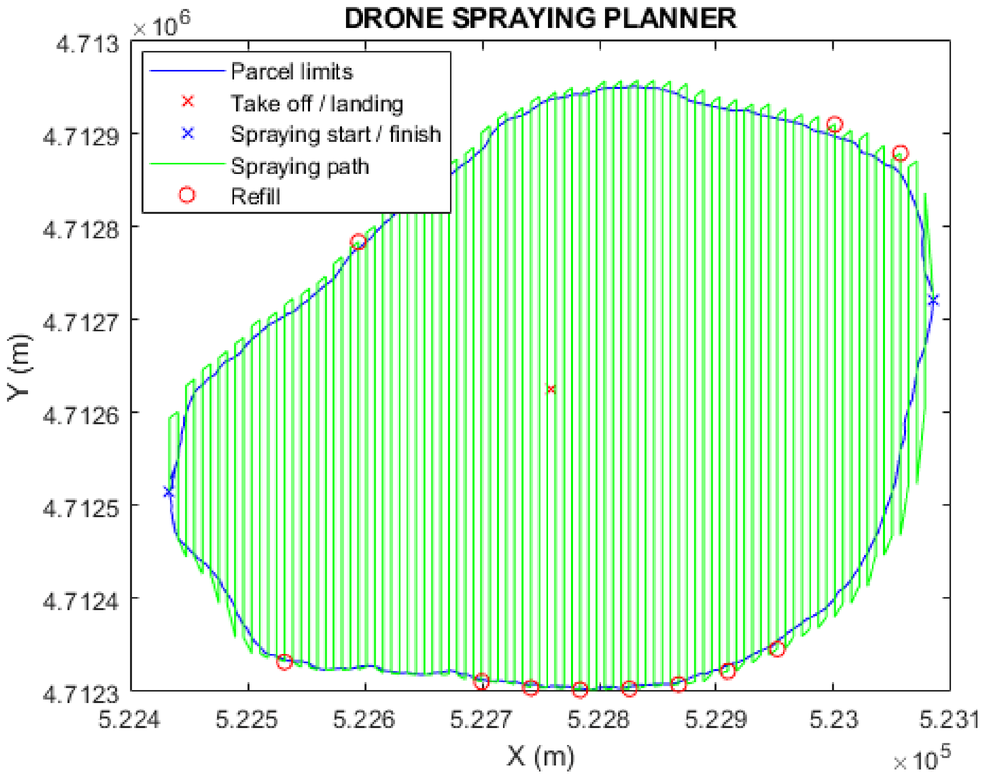

Figure 4. Workflow of the operational simulation (DJI Agras T20).

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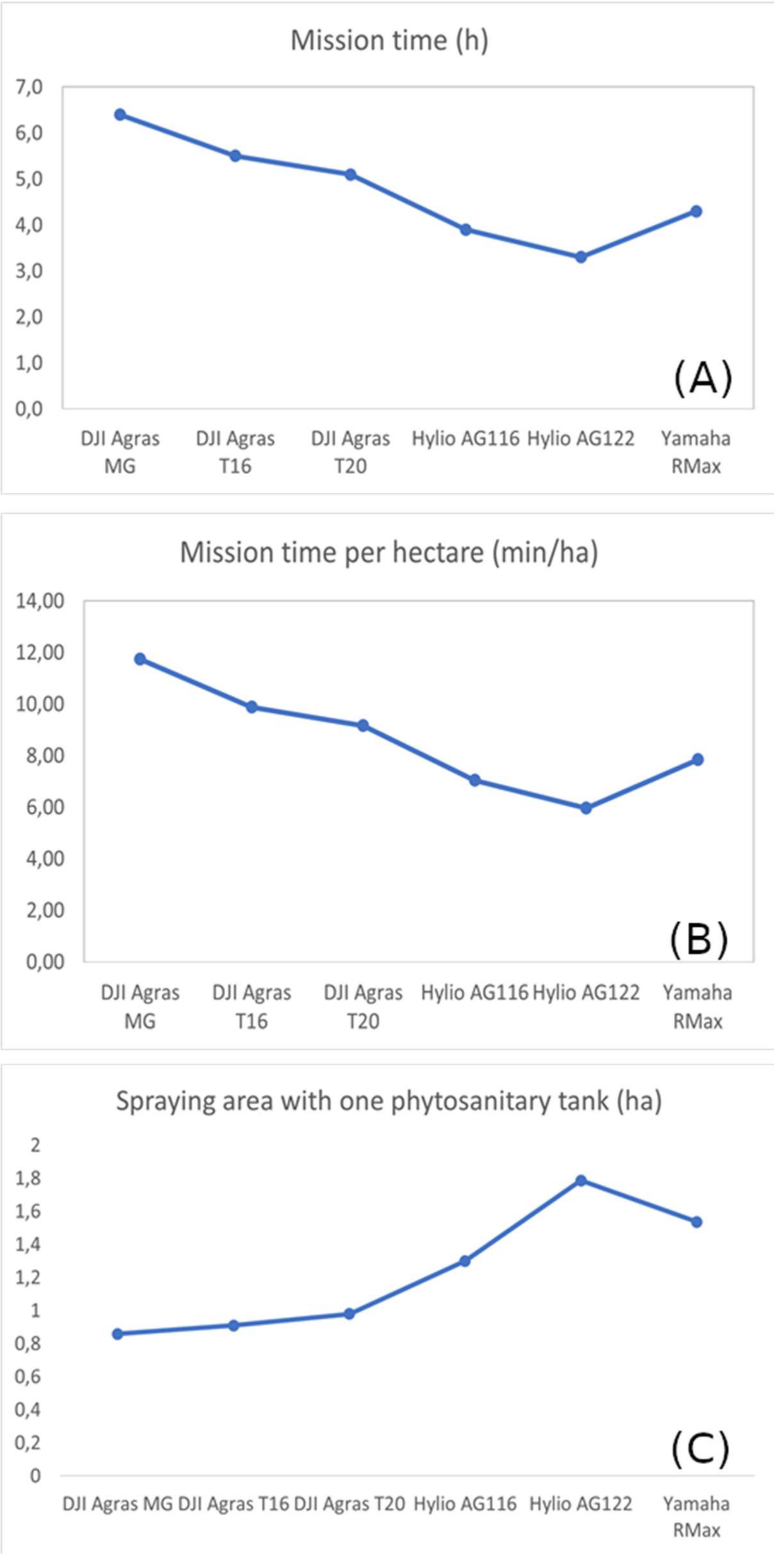

Figure 5. (A) Time required to complete the whole spraying mission. (B) Mission time per hectare. (C) Spraying area which could be covered by a single phytosanitary tank.

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4. – CONCLUSIONS

The application of drone spraying of phytosanitary products to vineyards is a hot topic that is expected to be increasingly present in the market in the coming years. Drones are especially interesting in zones with complex orography where other systems such as tractors are difficult to implement.

Methodology to evaluate the productivity of a drone spraying system in the application of phytosanitary products was developed, implemented and validated. Validation was performed using vineyard data from the appellation of origin Rías Baixas. The methodology included all the technical specifications of the drones (i.e flight endurance, phytosanitary tank volume, spray width, operating speed) to provide outputs as the total mission time, the mission time per hectare, the number of phytosanitary tank refills or the parcel area covered by a single phytosanitary tank.

Drones under study were the DJI Agras MG, DJI Agras T16, DJI Agras T20, Hylio AG116, Hylio AG122, and Yamaha RMax. The Hylio AD122 with the largest phytosanitary tank showed the best results, with a productivity around 6 minutes per hectare. DJI Agras system showed an improvement of productivity with the increase of the tank volume, from 10 L in the Agras MG to 20 L in the Agras T20. The capacity of the tank appears as the most limiting factor, more than the flight endurance limitations by the electric batteries. These results also correlate with the Yamaha RMax, which with the largest flight endurance does not show the best productivity.

Future research could include improvements as the modelling of the drone flight mechanics, the accurate calculation of battery consumption, the influence of wind or the orography, the comparison with traditional spraying technologies, the cost and robustness of the drones.

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