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How Energy-Efficient UAVs Are Transforming Pesticide Spraying

> "The combination of geofencing and the CVRP model will reduce the contamination of non-target plants"

Unmanned Aerial Vehicle (UAV), often called "drones", is one of the modern technologies widely used in different fields such as real-time monitoring, remote sensing, disaster relief operations, delivery of goods, security and surveillance, precision agriculture, and civil infrastructure inspection.

In agriculture, UAVs are transforming the modern agricultural practices through enhanced efficiency, precision, and reduced labour intensity. Due to global population growth, global food demand increases therefore UAVs are becoming important tools in precision agriculture [1]. UAVs are integrated in farming operations and support a range of tasks including crop monitoring, pesticide and fertilizer spraying, seed sowing and growth evaluation. Equipped with high-resolution cameras and cutting-edge sensors, UAVs can gather real-time data on pest infestations, soil condition, and crop health. From those data about where and when apply inputs such as fertilizers or pesticides, and water ensuring better resource efficiency.

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UAV for pesticides spraying

Pesticide spraying is one of the key operations of agriculture helping to increase agricultural output by generating favourable conditions for crop growth. Traditionally, farmers spray pesticides and fertilizers using tractor-based methods or hand pumps. These conventional approaches widely employed; however, they have come with numerous challenges like high labour costs, time consumption, environmental pollution, and health hazards to farmers due to chemical exposure. Manual spraying often leads to excessive application, non-uniform application, and inefficient resource usage and potentially negatively impact the crop yield.

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A key concerning disadvantage of traditional spraying is the direct exposure of farmers to harmful agrochemicals. This is not only threatening their health but also contributing to destruction of environment. Manual methods make hazardous ergonomics by physical burden due to carrying heavy equipment, along with risks from inhalation and contact of skin with chemicals. Moreover, the pandemic of COVID-19 makes severe these challenges, make farmers difficult to monitor and manage the crop spraying using conventional methods.

In contrast, UAVs offer transformative methods to traditional pesticide application methods. UAVs can complete the spraying tasks significantly faster, with studies emphasized UAV spraying can be five times faster than traditional ways. Their smart spraying systems can save up to 30 – 40% pesticides and up to 90% water consumption [2]. The UAVs' spray rates ranging between 25 – 50 times lower than conventional methods and cover the area 10 – 15 times than conventional methods in the same time interval with significant savings of labour and time, ensuring efficient use of chemical and minimize the contamination of environment.

However, due to drift, the non-target plants got contaminated. As well as UAVs controlled remotely it's difficult to spray the target plants or field, if it's affected in various polygon shapes. To solve these problems, we did a routing-based simulation combining Geofencing technique and Capacitated Vehicle Routing Problem (CVRP).

Geofencing defines polygons where spraying is allowed; spray is disabled outside [3]. We must consider the payload capacity and flight endurance during the study hence CVRP is employed because it's considering the capacity of the vehicles while ensuring the route optimization [4]. A paddy field was chosen for this study, and diseased areas was marked hypothetically.

Two payload classes (30 kg and 50 kg) were simulated, and maximum flying distance is 10,000 m in 10 km radius. With these various combinations were simulated with fleets of 1–4 UAVs. The model indicated at least four UAVs were needed for full coverage in one wave and out of 14 mixes of UAVs, three combinations are fully covered in one wave. The UAV can reduce the energy consumption by minimizing flying distance.

Table 01 shows the combinations of UAVs which are achieved full covered. Among three configurations, three 50 kg and one 30 kg UAVs have emerged as the optimal combination due to minimum total distance travelled. This configuration is best fit to cover the target with minimum energy consumption. But to ensure the efficiency of configurations, three Key Performance Indicators (KPI) was measured and compared to evaluate. Table 02 consists of the measurement of KPI.

The energy consumption per hectare was calculated by the following formula [5]:

$$ECPH = \frac{P_s \times t_s + P_h \times t_t}{A}$$

ECPH – Energy consumption per hectare
P_s – Spraying power consumption
t_s - spraying time
P_h – hovering power consumption
t_t - transit time
A - total spraying area

Area covered per unit distance refers to the total spraying area covered per total distance travelled by the fleet. The optimum value is achieved when a large area is covered with minimum travelling distance. Spraying time per travelling time means that the spraying time should be high while the travelling time should be low.

However, this model is limited by real-world assumptions such as no wind turbulences, flat terrains, no battery ageing and a single depot. In the future, wind resistance and multi depots will be considered to improve the accuracy of the model. Also, try with real field trials to validate the model.

Table 1 UAV fleet mixes that achieved full coverage

UAV Combinations	Areas Covered (m^2)	Pesticide Usage (L)	Total Distance Travelled (m)
30 kg - 2, 50 kg - 2	43,417 m^2	144.72 L	4,746 m
30 kg - 1, 50 kg - 3	43,417 m^2	144.72 L	4,652 m
50 kg -4	43,417 m^2	144.72 L	4,652 m

Table 2 KPI Results

KPI	4*50kg	3*50kg, 1*30kg	2*50kg, 2*30kg
Energy consumption per hectare [kWh/ha]	0.845	0.840	0.849
Area covered per unit distance [m^2/m]	9.333	9.610	9.148
Spraying time per travelling time [s/s]	2.487	2.560	2.443

Optimal 3×50 kg + 1×30 kg mix cut total distance to 4.65 km while fully covering the diseased area

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