

## APPLIED RESEARCH

# A Drone Technology Implementation Approach to Conventional Paddy Fields Application

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**ABSTRACT** This paper proposes an approach to implementing modern technology farming, namely agricultural drones, to help farmers enhance crop spraying efficiency, with a case study on conventional paddy fields in West Kalimantan province, Indonesia. Traditional spraying operations in paddy fields are dangerous as operators must deal with prolonged and frequent exposure to toxic chemicals. In the field experiment, an agricultural drone sprayed fertilizer and pesticides in the 1.5 ha paddy field in Parit Keladi Village, Kubu Raya Regency, West Kalimantan, Indonesia. For fertilizer and pesticide spraying, the impact on the paddy was measured periodically, involving leaves length and tiller number, randomly in the same field. Implementation in the area shows that the ground area coverage by the spraying drone was 6-7.5 m when it had an altitude is 4 m, with four nozzles and a 1.6 l/m spraying flow rate. This study implemented drone technology in the conventional paddy field, one of the famous agricultural commodities in Indonesia and other Asian countries. With this agricultural drone technology approach, we believe that semi-modernization or even modernization of conventional paddy fields can be achieved and accepted by the farmer community to increase the efficiency of farming activities and pave the way for smart farming.

**INDEX TERMS** Smart farming, precision farming, agricultural drones, drone control, spraying drone, rice fields, paddy fields.

## I. INTRODUCTION

The concept of precision agriculture is currently developing to improve efficiency and agricultural yields with all problems related to labor and the performance of the farming process that will be directly related to agricultural production. This concept intends to carry out an optimal farming process. Developing countries have started using unmanned aerial vehicles (UAVs) for precision agriculture [1], [2]. Yamaha first developed the UAV model for agriculture for pest control and crop monitoring [3], but the company discontinued its production in 2007. Previous researchers carried out an

analysis of the use of UAVs in agriculture to see their application capabilities. Some examples include crop monitoring [4], plant height estimation [5], pesticide spraying [6], and soil and land analysis [7]. However, implementing these UAVs in agriculture is still very dependent and limited on many factors, such as UAV weight, flight distance, load limitation, configuration, and cost. Some researchers investigated UAVs regarding technology, methods, systems, and constraints [8]. More than 250 models were analyzed and summarized in [9] to select a suitable UAV for agriculture applications. Techniques and components such as integrating hardware and software systems, autonomous flight control, and aerodynamic modeling are essential to consider building a mini-UAV, as described in [10].

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Some people have tried image-taking technology on agricultural land in the last few decades to increase agricultural production. Technology from NASA with a heavyweight system with solar energy serves to become a platform for image collection of 3,500 ha coffee plantations in Hawaii [11], [12]. VIPTero [7], a low-cost UAV for site-specific vineyard site-specific management, has taken 63 multi-spectral images within a 10-minute flight and MK-Okto [4] for multi-spectral and thermal image acquisition. Laser power beaming technology has increased the flying time of the UAV [13]. Some researchers have performed the phase domain aerodynamics, tuning, and trimming of the UAV on a PID basis [14], [15], [16]. Then the images are examined based on NDVI. The results explain the condition of the plant plainly. Combining instruments and a vision system also increases UAV's capability [17]. Other crop monitoring techniques using drones and satellite data are also presented in [18] and [19].

A UAV must install a spraying system for spraying crops. UAV integration with the system is beneficial and accurate for large fields. For this purpose, large spraying areas need UAVs with large payloads [20], [21]. PWM controllers increased the effectiveness of the spraying equipment attached to the UAV [6], [22] in pesticide applications. A UAV with a Yamaha RMAX gasoline engine has also been developed for spraying pesticides on paddy fields in Asia [3]. Compared to conventional sprayers, the pesticide deposition of the UAV is practically similar. RMAX is a sprayer for high-value yield environments. A UAV prototype developed in [23] tended to increase droplet size with an average volume diameter of up to 300µm [23]. Nowadays, the use of UAVs in spraying processes is rising due to their quickness and precision. However, several issues decrease crop value, such as some areas of the crop field not being adequately covered when spraying on overlapping crop fields and the outside edges. To overcome these problems, the team in [24] used a swarm of UAVs in the algorithm loop for agricultural operations, where the UAV was responsible for pesticide spraying. Spraying pesticides on plants was regulated by feedback from WSN used in the field [25]. Communication between UAVs was carried out based on control loops to adjust the route of the UAV with changes in wind speed and the number of messages exchanged between UAVs [26]. The MSP430 automatic UAV navigation spray system was developed in [27] to direct the UAV to the desired spray area.

The quadcopter aerial automated pesticide sprayer was built for pesticides based on GPS in lower altitude environments [28]. To deal with this, Freyr drone users were created and controlled by an application based on the Android operating system [29]. Some parameters were analyzed in liquid discharge and pressure level, spray uniformity and fluid loss, droplet density, and size of the hexacopter mounted on the sprayer [30]. An electrostatic sprayer was introduced and designed on UAV [31]. The particle image velocimetry method has been used to measure the liquid droplets' movement and the deposition on plants at different rotational speeds [32]. In addition, filter and water-sensitive paper [33]

were used to study spray deposition and droplet coverage over land in multiple spraying plots [34], [35]. Given these facts, the monitoring and spraying of crops with pesticides developed with the UAV consists of an automated drone system and a sprinkling system with multi-spectral cameras. The sprinkling system was attached to the bottom area of the UAV, which had a nozzle under the pesticide tank to splash pesticides downstream. A multi-spectral camera carries out the first monitoring. The camera took images of the entire crop field to produce a spatial map. This map reveals the crop condition, and the farmer assesses the type of pesticide/fertilizer that should be applied to the crop. Examples of drone crop monitoring techniques for further disease control can be seen in [36] and [37]. Furthermore, some of the results of the drone use survey can be seen in [38] and [39].

In previous studies, the performance and cost of using drones for agriculture is still a challenge, so it is still an obstacle to implementation in Indonesia, especially in West Kalimantan, which has primarily conventional crop environments, such as paddy fields. Therefore, this paper presents an approach to implementing drones on traditional paddy fields and analyzes the drone's performance and the drone-based spraying impacts. The remaining sections will be in the following structure: the description of the hexacopter agricultural drone that was used for spraying, a case study, an analysis and discussion of the results, and finally, the conclusion.

## II. MATERIALS AND METHODS

In this study, we assembled and used the hexacopter agricultural drone. The frame of a hexacopter drone mainly consisted of fiber carbon materials. There are two main parts: the body, where all the primary electronic circuits are placed, and the six arms that connect the body to rotors. Fiber carbon with a tube shape made the arm. We can fold the six arms to increase mobility during transport. The rotors consisted of motors, where each is attached to one propeller. The motor was a type of brushless dc (BLDC) with the specification of one motor: 100 kV, working voltage of 44.4 Volt, and maximum thrust of 13.6 Kg. In this research, we have used six BLDC motors. BLDC motor has several benefits: high efficiency, high velocity and torque, high dynamic reaction, long working life, and noise-free operation. A BLDC motor is a synchronous motor that the magnetic field generated by the stator and rotor have the same frequency.

The rotor (the rotating part of the motor) in a BLDC consists of permanent magnets, while the stator consists of coils. To control the speed of the BLDC motor, the electronic speed control (ESC) was used as the driver connected to the flight controller. In this research, we used 80-Ampere ESC. Furthermore, each propeller has a dimension: of 10-inch diameter and 4.5-inch pitch. Two rotation directions have the same thrust direction: clockwise (CW) and counterclockwise (CCW). This direction of rotation determines the rolling moment produced by the propeller. In a hexacopter, a pair of CW and CCW propellers are essential so that the rolling moment can cancel each other out.

Moreover, a remote control (RC) helps to control flight movement. It consists of a Transmitter (Tx) as a signal sender and a Receiver (Rx) as a signal receiver. RC comes in a variety of different bandwidths and channels. For the hexacopter, the RC as Tx has at least four channels to control the four basic movements of the hexacopter, namely pitch, roll, throttle, and yaw. In this research, the RC used has the following specification: Model T12, working Voltage 3.7 V, current 170 mA, FHSS system, frequency 2.40-2.48 GHz, Dimension 225 × 123 × 35 mm, 12 channels, 560 g weight, battery capacity 4 A, and transfer data port.

A flight controller is used and mounted on the body of the drone. It uses Pixhawk 2.1 cube, which has some features: 1) isolated inertial measurement unit (IMU), which can reduce interference to sensors, 2) Foam pads filter high-frequency vibrations to IMU, 3) triple redundant IMU with various gyroscopes, barometers, accelerometers, and magnetometers, 4) modular flight controller - all inputs/outputs in one DF17 connector, 5) Built-in IMU heating system allows flight at temperatures below freezing, 6) Improved drop and shock resistance, and 7) actual time command to RC plane via a ground station. A homing function, namely return-to-launch (RTL), where the RC plane can return to its starting place if there is a communication interruption between the RC plane and the ground station. Furthermore, the LSM303D sensor integrated with the system is a system-in-package that can be used as the sensor of 3D digital linear acceleration dan 3D digital magneto. These sensors are compasses, position detectors, free fall detectors, and pedometers. The drone can calculate and know the movements and their position with those sensors. Those are closely related to the trajectory in getting to the point on the desired trajectory mission because these sensors help us determine the drone's position. Another used sensor is L3GD20, a 3-axis angular velocity sensor with a standard output I<sup>2</sup>C/SPI digital serial interface. It tracks a device's rotation based on motion. It will determine the movement, so the drone moves according to the trajectory planning direction.

MPU9250 is a sensor that calculates the acceleration and orientation of the direction of movement of the hexacopter using a combination of accelerator and gyroscope sensors. With the MPU9250, the hexacopter can calculate and know its movements, so it can help to find the position and trajectory in its path without using GPS (e.g., when it cannot get a GPS signal). The accelerometer, combined with the gyroscope, will determine which direction is being taken by the hexacopter when it accelerates. Recording and mixing all these calculations will obtain a new position of the moving hexacopter and its movement path. By knowing the latest status of the hexacopter, the flight controller can determine whether the drone is at the trajectory planning point. Finally, the MS5611 Barometer sensor is an instrument used to measure air pressure. This research used the barometer to determine the height of the hexacopter, using the principle of different air pressure at different altitudes. This sensor is significant for drone movement, for instance, when landing.

We used a software named Mission Planner to plan the trajectory mission. The software's personal computer or mobile phone will send the trajectory mission to the drone. The drone will follow the trajectory as accurately as possible when the GPS fly mode is selected. For this purpose, we must calibrate the drone previously.

Furthermore, we have investigated the dynamic movement of the drone's body. Finite Element Analysis (FEA) was employed to examine the drone's capability under flight conditions. The FEA simulation utilized Autodesk Fusion 360. Two primary materials for the drone structure are Carbon Fiber Reinforced Plastic (CFRP) and Stainless Steel. We used the CFRP material for the main frame of the controller and rod arm for the motor driver with a modulus of elasticity of 133 GPa and Yield Strength of 300 MPa. Meanwhile, we considered stainless steel for the rest of the structure material with a modulus of elasticity of 193 GPa and Yield Strength of 250 MPa.

For the simulation constraint, we applied structural constraints at each servo. The 1 kg electrical controller circuit was placed as a structural load on the main frame. At the same time, the water tank and battery were imitated by the remote force of the drone shank. There were two batteries with a mass of about 5 kg. Meanwhile, the water tank had rough dimensions of 450 x 405 x 150 mm with a maximum volume capacity of 16 Liters.

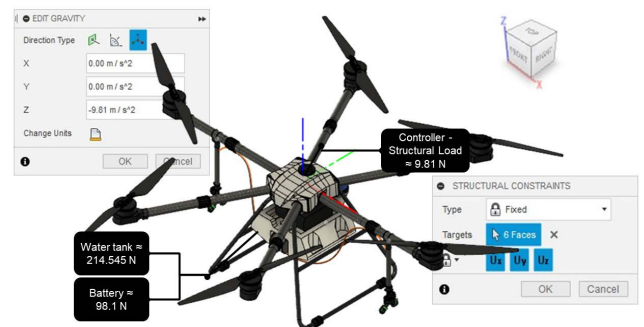


FIGURE 1. Loads and constraints for simulation of motion.

In this simulation, 80% of the tank space was liquid. While the drone was in a rolling and pitching motion, the drone initiates water to move, and the center of gravity (CoG) shifts. The shifting of the CoG can be seen in Fig. 2. It was simplified to assume that water movement was stable and the shape was maintained. The redefined CoG was calculated using the equation (1)-(3).

$$x' = \frac{\sum Vx}{\sum V} \tag{1}$$

$$y' = \frac{\sum Vy}{\sum V} \tag{2}$$

$$z' = \frac{\sum Vz}{\sum V} \tag{3}$$

It can be seen in Fig. 2 that when the drone makes a pitch or roll motion while flying, the CoG of the water in the tank

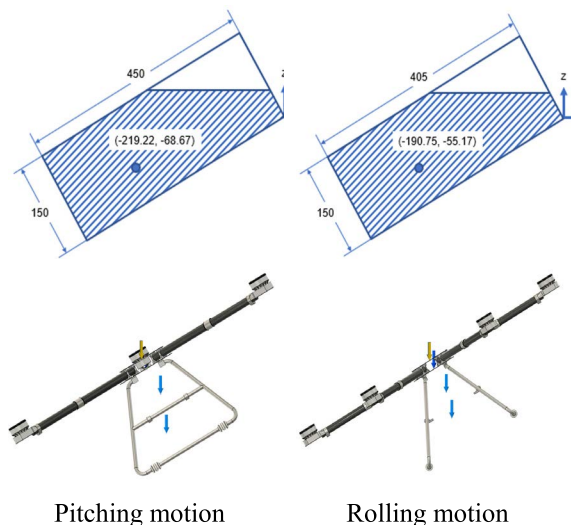


FIGURE 2. Motion analysis.

moves further down. This results in a change in the location of the loading, which will also be affected.

We chose the hexacopter type for agricultural drones because it has good stability to carry heavy loads. The drone's movement is affected by an angular rotational motion called the attitude. The body frame orientation determines attitude compared to the earth frame. It embodies rotation regarding the  $x$ ,  $y$ , and  $z$  axes. The right-hand rule involves roll, pitch, and yaw movements. Attitude is controlled by adjusting the rotor angular velocity. For this purpose, the rotors are numbered clockwise, with rotor number 1, or the first rotor is the right front rotor of the hexacopter drone.

### III. IMPLEMENTATION OF THE HEXACOPTER DRONE TO THE PADDY FIELDS (A CASE STUDY)

#### A. DRONE SETTINGS

The drone is powered by 16.000 mAh 30 C x 2 (12 cells) batteries. It is designed to have a payload capability of approximately 50 Kg. The weight of the BLDC motor is 3.87 Kg (645 g x 6), the ESCs 0.51 Kg (85 g x 6), the propeller is 1.08 Kg (180 g x 6), the frame weight is 5 Kg, the battery weight 3.816 Kg in total, tank 4.524 Kg, Spray nozzle 0,3 Kg, controller wiring 0.4 Kg. The total drone weight (without additional load) was about 19.5 Kg, where the maximum safe payload is 35 Kg. The drone's capability is designed for a total weight of 50 Kg. Fig. 3 shows the drone that has been assembled and used for spraying fertilizer and pesticides.

Furthermore, the Supply Voltage is 43 – 48 V. Once the voltage is 43 V, the drone must land soon and stop flying). Operating temperature: -20 – 65 °C. Spraying capability: 4 nozzles 1.8 liters/min (number of nozzles can vary depending on the demand). Maximum Liquid that can be carried (related to tank area): max. 16 liters. The battery life for Spraying 0.5 Ha is about 25 minutes (empty tank) and 14-16 minutes when the tank is filled with 16 liters of fertilizer).



FIGURE 3. Implemented hexacopter drone for spraying fertilizer and pesticides in paddy fields.

#### B. LOCATION OF THE IMPLEMENTATION

As a case study for the implementation location of conventional paddy fields, our assembled agricultural drone has been implemented in Kubu Raya reGENCY, West Kalimantan, Indonesia. The area map showing the implementation scenario can be seen in Fig. 4. In field 1a, the spraying drone was not implemented. In field 1b, the drone was used only for spraying fertilizer, not for pesticides. In fields 2-3, it sprayed both fertilizer and pesticide. In fields 4-5, it sprayed only pesticides and conventional fertilization without drones. The result among areas was compared and analyzed. The activity of drones during the spraying can be seen in Fig. 5 in the two above figures and harvesting activities at the bottom.

### IV. RESULT AND ANALYSIS

#### A. MOVEMENT ANALYSIS

The finite element method successfully simulated the drone with a different loading scheme. At first, the force scheme was applied at the hovering condition, where all the forces were directed downward. The simulation results can be seen in Fig. 6.

The results indicate there is concentrated stress on the drone leg. It suffers most from drone carriage. Therefore, further analysis focused on the drone leg's bending location. Fig. 7 below shows a detailed picture of the stress on the drone leg in hovering conditions.

The distributed stress at the bottom of the bend indicates the load provided by the battery and water tank focused on the legs of the drone. The load is evenly distributed on both legs at the bend, with an average value of 12.92 MPa. Meanwhile, the stress in the leg frame is on the back for the drone pitching condition. The illustration of this condition can be seen in Fig. 8.

When a pitch movement occurs (see Fig. 8), which causes the drone to move forward, the CoG shifts 128.67 mm on the positive  $z$ -axis and 5.78 mm on the negative  $y$ -axis. So that the center of mass shifts and causes more significant stress on the frame's rear leg. Tension occurs 44.5% higher on the back compared to the forelegs. When the drone rolls, the load is generally supported by one leg. In contrast to conditions during the pitch, when rolling, the upper and lower parts of the bent position receive relatively the same load, around



FIGURE 4. Research location for implementing agricultural drone.

22.46 MPa. At the same time, the stress is relatively low in the other leg structure, at about 2.11 MPa, as shown in Fig. 9.

**B. AGRICULTURE PERFORMANCE**

This section shows the spraying results and their comparison with the conventional way. Paddy leaves length and paddy tillers were the parameters measured in five paddy fields (see Fig. 4), as shown in Fig. 10 and Fig. 11. Each paddy field was measured in ten locations to get ten samples. Then the average was used as the data at the paddy field for one measurement activity. Field 1a is the paddy field treated without the drone, while on Field 1b the fertilizer had been sprayed with a drone, but the pesticide had been sprayed manually. Field 2 and Field 3 were sprayed with a drone for fertilizer and pesticide. On Field 4 and Field 5, fertilizer was sprayed manually (without a drone) while the drone was used to spread the pesticide.

The growth in the number of leaves between those carried out by spraying with drones for fertilization and pesticides or both when compared to the manual method at the beginning of paddy plant growth was not different. However, after the 49th day, the effect of spraying with drones showed resulted in a tremendous increase in plant height. It can be seen in Fig. 10 that the growth of paddy plants without drone application for fertilization or pesticides yields lower results than others.

Spraying with a drone using a nozzle produces a small particle size so that the surface becomes wider. This right is thought to result in greater penetration of the leaf surface, fertilizers, and pesticides. The longer the spraying activities, the greater the growth acceleration, so that after 49 days, the growth leverage cannot be covered by conventional fertilization and pesticide spraying methods.

The traditional pesticides and fertilizer spraying techniques require more time and are less effective [40]. Spraying in a paddy field is the most harmful operation since the operator must deal with prolonged and frequent exposure to toxic chemicals. The drone provides an effective method for such operation by reducing the processing time to less than one-third time required by the conventional way [41].

According to Fig. 11, drone application for fertilizing with pesticides (Field 2 and 3) during 71 days of growth increased



FIGURE 5. Agricultural drone on spraying and harvesting activities in conventional paddy fields, Parit Keladi village, Kubu Raya reGENCY, west Kalimantan, Indonesia.

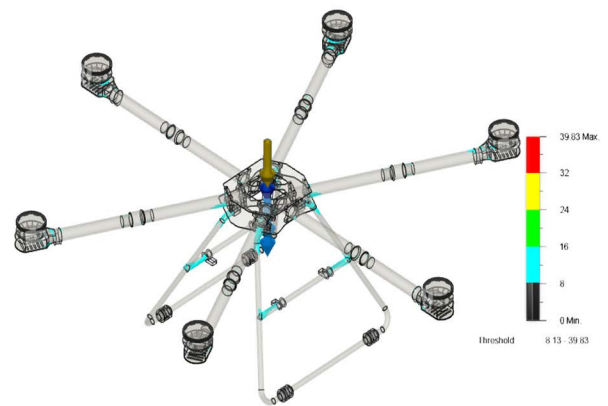


FIGURE 6. Simulation-based analysis results.

the number of tillers per clump. However, if the drone application is only for fertilization without pesticides (Field 1b) the development of the number of tillers stops after 58 days of paddy plant growth. It is presumably because the drone application causes the effectiveness of nutrient and pesticide uptake. The nozzle spraying with micro or nanoparticle size makes less liquid wasted into the paddy field puddle and slowly absorbed by the roots. Absorption of nutrients,

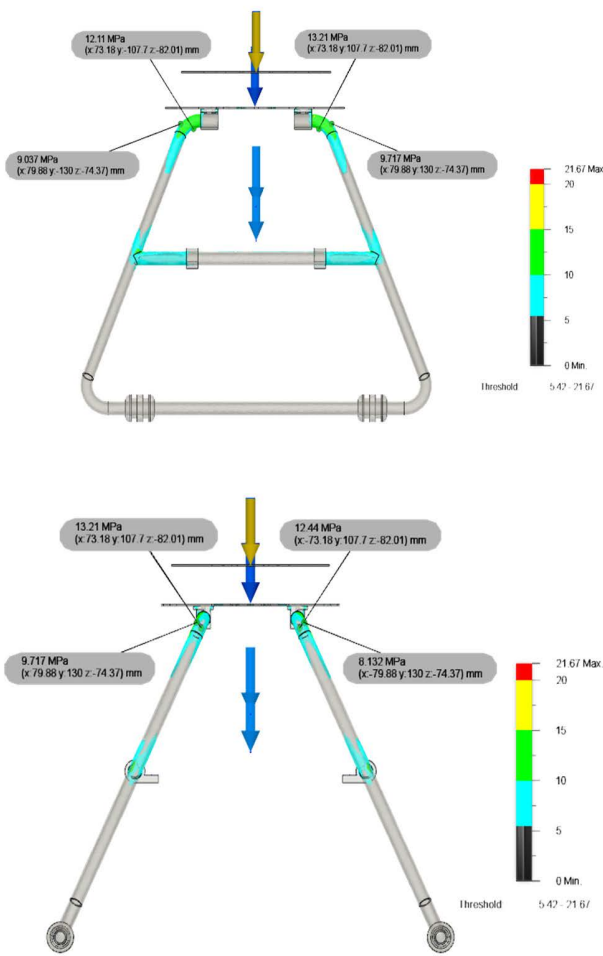


FIGURE 7. Drone hovering loading condition.

including nitrogen, will stimulate plant growth in addition to the development of new tillers.

The growth stages of paddy can be separated into vegetative, reproductive, and maturation. The vegetative growth stage includes seedling and tillering. In this stage, roots, stems, and leaves are predominantly grown. Therefore, the plants absorb water and nutrients, and at the same time, photosynthesis efficiency is increased, providing nutrients to roots, stems, and leaves. According to the on sites investigations in [42], the stage of paddy growth is as follows: seedling of the first crop (days 1–14), tillering (days 15–56), vegetation (days 57–77), and ripening (day 78–103). Furthermore, Investigation for the second crop was as follows: the seedling (days 1–7), the tillering (days 8–42), the vegetation (days 43–70), and the ripening (days 71–95). In this study, it was suspected that the growth in the number of tillers was higher in the paddy fields using drone applications for fertilization and pesticides, even though it had passed 58 days. This condition is beneficial because it is also followed by the growth of plant height so that the plant becomes more vital in hope that it can support paddy during the paddy grain ripening phase.

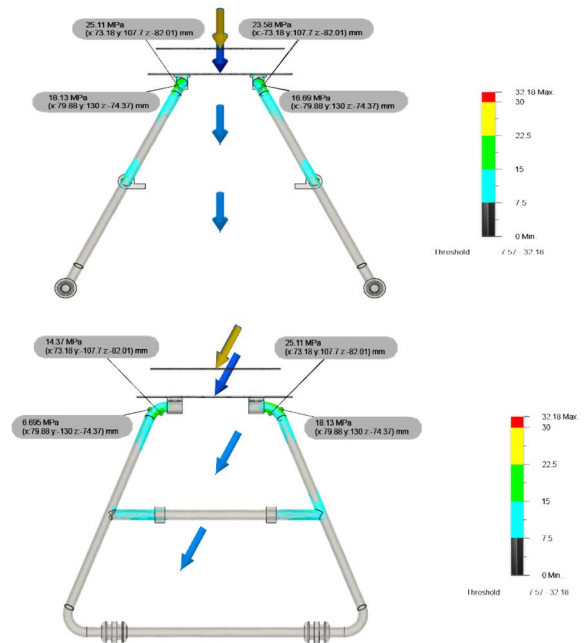


FIGURE 8. Drone pitch forward motion.

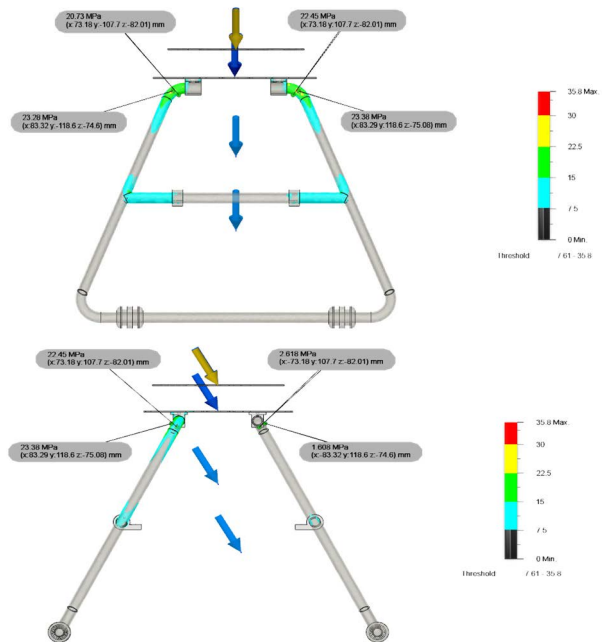
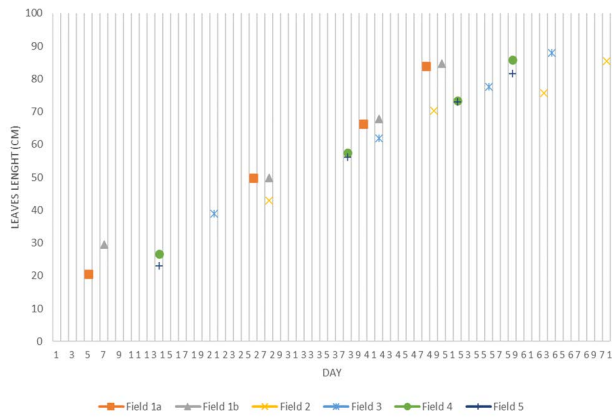


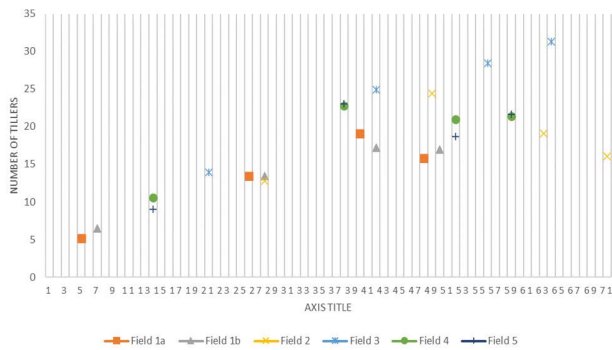
FIGURE 9. Drone rolling motion.

### C. POWER CONSUMPTION

Testing the power consumption on the drone is carried out by trying to fly the drone without carrying a load and when it has an additional load (i.e., liquid fertilizer). When doing this test, the drone flew for only one minute by trying all the forces that a typical drone usually does. At the time-of-flight testing, the pixhawk storage of the drone records the data. For testing load with additional load, the drone is set to work for 126 s, while the flying time is 75 s. This flight test set an altitude of 4 m with a flying speed of 2 m/s. Knowing the drone's power feature while flying is essential to estimate how much energy



**FIGURE 10.** Leaves length (cm) during 71 days of growth in various methods of drone application for paddy cultivation in Kubu Raya Regency Indonesia (x: the day; y: the leaves length).



**FIGURE 11.** Number of tillers per clump during the 71-day growth period on various drone application methods in Kubu Raya Regency Indonesia (x: the day; y: the number of paddy tillers in cm).

consumption the drone will need to carry out its flight mission at the desired distance.

In a no-additional load case (only drone weight 19.5 Kg), the mission planner software sets a height of 4 meters and a flight speed of 2 m/s. For a flight time of 123 seconds, the voltage and current were 43.79 V and 22 A, respectively. The voltage and current without an additional load will drop due to the noise reading of the sensor and the relatively low use of the motor. A stable voltage and current were when the drone was not flying even though already connected to the battery.

In the experiments with an additional load, the total full payload lifted by the drone when bringing 16 liters of fertilizer was about 35.5 Kg. For an altitude of 4 meters, a flight speed of 2 m/s, and a flight time of 70 seconds, the average voltage and current data were respectively 44.63 V and 50.56 A. When taking an additional load, the current flow to the drone’s electrical system increases significantly, and the supply voltage drops. The signal is stable when the drone is still not on a flight mission, although it was connected to the battery, like the no-additional load case.

To control the current injected into a BLDC motor, ESC is a crucial component. For safety reasons, the ESC must have a maximum current greater than the motor. The datasheet

**TABLE 1.** Total payload vs. maximum flying duration.

Total Payload (kg)	Maximum Flying Duration (minute)
35.5	15.2
34.5	15.73
33.5	16.3
32.5	17.0
31.5	17.6
30.5	18.3
29.5	19.2
28.5	20.1
27.5	21.0
26.5	22.1
25.5	23.3
24.5	24.6
23.5	26.1
22.5	27.8
21.5	29.7
20.5	31.9
19.5	34.4

shows that the maximum amperage of the motor at 100% throttle is 60.6 A. So, for safety, the ESC used has a size of 80 A because the minimum current ESC can handle equals 1.2 times the maximum current in the motor ( $1.2 \times 60.6 \text{ A} = 72.72 \text{ A}$ ).

Battery capacity is in milliampere hours (mAh). The greater the value, the greater the capacity of the battery. For example, a drone flying without liquid fertilizer uses a 16.000 mAh lipo-type battery, capable of carrying a current of 16 A for 1 hour. The total current strength = battery capacity  $\times C_{rate} = 16 \text{ Ah} \times 30 \text{ C} = 480 \text{ A}$ , meaning that the battery for the hexacopter drone can issue a current of 480 A continuously until the battery voltage reaches a safe lower limit to supply power to the rotor.

In this study, the batteries used were  $2 \times 6$  cells lipo batteries installed in series to achieve the required voltage to drive the rotor (BLDC motor) on the hexacopter. The maximum voltage of each cell is 4.2 V. When it is full, the total battery voltage is 50.4 V ( $12 \times 4.2 \text{ V}$ ). The constant voltage from the battery used to be 3.7 V per cell. During the flight, the drone has a battery voltage limit of 3.7 V per cell, or about 42 V in total. The flying operation of the drone must be stopped. Flying with voltage under the minimum voltage limit can make a drone fall.

From the field test results, if there is no additional load or an empty tank, the drone can fly for 34.04 minutes, but if it carries 16 liters of liquid fertilizer (full tank) or a total weight of 35.5 Kg, the flight time is about 15 minutes. The relationship of the entire payload (drone weight + an additional weight) with the current, voltage, and flight time of agricultural drones in this study is presented in Table 1. If the payload is constant, the maximum flying time is also constant. If it is dynamic, the allowed flying duration will vary depending on the current payload, especially in the spraying activities where the additional load (fertilizer) will be reduced when the extra load is reduced.

**D. TRAJECTORY**

An automatic flight experiment was done with a trajectory mission plan in Parit Keladi Village, Sungai Kakap District,

Kuburaya Regency Indonesia, with a drone altitude of 3 m, speed of 3 m/s, and additional load (liquid fertilizer) carrying 12 liters. Flight duration of 726 s obtained accuracy results in horizontal trajectory accuracy ( $H_{acc}$ ) and Horizontal delution of precision ( $H_{dop}$ ). The RMSE for  $H_{acc}$  and  $H_{dop}$  was 0.899651 m and 0.550855 m, respectively. The second experiment was done in another location in Pontianak, West Kalimantan, Indonesia, with an altitude of 3 m, speed of 3 m/s, additional load (liquid fertilizer) carrying 12 liters, and flight duration of 472 s. From the experiment, RSME for  $H_{acc}$  and  $H_{dop}$  was 0.52539 m and 0.523017 m.

## V. CONCLUSION

An approach to implementing drones for spraying fertilizer and pesticides has been discussed in this paper. It becomes essential since the agricultural drone is mainly used for modern farming. Some obstacles in conventional paddy fields involve trees, access to the location, and community understanding, especially about the liquid concentration that must be sprayed. This research shows those problems can be solved by providing the performance analysis of the drone for spraying activities. Regarding the movement, the agricultural drone presented in this paper can bring a maximum 16-liter load. The agricultural results show that drone applications can help the farmer to spray the crop. The drone application enhanced the effectiveness of nutrient and pesticide uptake. Furthermore, the energy consumption and the trajectory accuracy have also been analyzed.

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