Study of field capacity and variables of UAV operation time during spraying hormone fertilizer in sugarcane field

Peace Koondee¹, Khwantri Saengprachathanarug¹,²,*, Jetsada Posom¹,², Cumnueng Watyotha¹, and Mahisorn Wongphati³

¹Curriculum of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, Thailand
²Applied Engineering for Important Crops of the North East Research Group, Khon Kaen University, Khon Kaen, Thailand
³HG Robotics Company Limited, Bangkok, Thailand

E-mail: khwantri@kku.ac.th

Abstract. Spraying fertilizer to improve sugar content using Unmanned Aerial Vehicle (UAV) is receiving lot of interest by farmers since the field conditions are almost inaccessible by ground at the appropriate period of application. However, operators have to decide based on theirs experiences to choose the applicable and profitable field for UAV sprayer as the operation time and cost. This study aims to investigate UAV field capacity and time consumed by all steps during operation. The spraying experiments were conducted in fields located in Chaiyaphom and Khon Kaen province with the area of 0.16-0.64 ha/field. The field capacities were evaluated and time consuming activities of flight planning, fertilizer filling, active and passive working were studied. The results showed the average field capacity is 3.36 ha/hr. Most of time consumption was for flight planning step, followed by fertilizer filling, and passive working such as take-off time, landing time and turning time. Time consumed in flight planning was caused by the attempt to avoid the trees around field. However, it takes a long time only for first flight and then previously generated flight plan can be re-used for next flight. Moreover, non-rectangular shape and small size of fields affected passive working time directly.

1. Introduction
Nowadays, criteria of payment in sugarcane trade considers both weight and sugar content (Commercial Cane Sugar or CCS) [1]. Spraying hormone fertilizer on sugarcane canopy can help to increase CCS, however, the suitable age of sugarcane for applying this hormone is up to 8 months old when sugarcane field is almost inaccessible as sugarcane stalks are about 3 meters in height. Hence, it is very difficult for spray to reach canopy. Currently, UAV has been studied and used as a platform for applying fertilizer, pesticide and herbicide due to its flexibility in various field conditions and consideration of health safety of workers [2]. For instance, investigation has been conducted about effects of airflow in field, droplet properties, and positions of nozzle-target on droplets distribution by UAV spraying in control wind tunnel [3]. Moreover, studies about total time of operation per rai for applying organic fertilizer on kale, onion, celery, rice and sugarcane fields have also been conducted [4]. However, there is still no detailed study about time utilization in all steps of preparation and operation.
Hence, this study aims to investigate time consumption distribution and all related aspects that effect field capacity of UAV when spraying fertilizer in various conditions of sugarcane fields. The outcomes of this study will become fundamental data for further developing of UAV for spraying applications.

2. Materials and Methods

2.1. Instrument

The tiger drone sprayer shown in Figure 1 is used in this study. The specification of this UAV is listed in Table 1.

![Figure 1. The drone sprayer (Tiger Drone, HG Robotic Thailand).](image)

| Type                  | Specification                          |
|-----------------------|----------------------------------------|
| Size                  | 1055x1055x800 mm                       |
| Battery               | 2 battery, 13,000 amp                  |
| Spray Boom Length     | 1780 mm                                |
| Rotor                 | 22 in. 8 Rotor                         |
| Payload               | 13 kg                                  |
| Nozzle                | Flat fan, 2 Nozzle, angle 110°, Pressure 1 bar |
| Pump                  | Brushless motor, 4 bars                |
| Tank Capacity         | 10 L                                   |
| Spraying Speed        | 1 l/min                                |
| Flight Speed          | 3-6 m/s                                |
| Flight Time           | 10-15 min                              |

2.2. Experiment all procedure

In this study, 6 fields with varying size in Konsan district, Chaiyaphom province and Nam-Phong distic Khon Kaen province were selected, in which two field had area of 0.64 ha, one field had area of 0.48 ha and other three fields had area of 0.16 ha. All fields were planted with KK3 sugarcane. Flight mission of each field was done for 1 time.

![Figure 2. Flow chart of UAV spraying operation.](image)
Every field was tested in the same pattern as shown in the flow chart in Figure 2. The work procedure started with; preparing instrument, flight planning, arranging hormone fertilizer, UAV flight mission, and cleaning and keep equipment, as described below:

2.1.1. Flight planning. In the first step, Condition surrounding test field was surveyed and total area for spraying operation was determined and then spraying option for sugarcane was selected in software. After determining spraying area, software calculated amount of fertilizer that was needed for operation, speed of flight, width of flight path. The height of flight was set to 5 meters from ground. However, speed of flight, height from ground and width of flight plant can be adjusted as desired.

2.1.2. Chemical fertilizer and equipment preparation. In this step, the drones and battery were prepared for the entire flight and fertilizer and water were mixed according to recommend rate per ha. Then mixed fertilizer was filled in the tank according to the amount calculated by software and the condition of spraying nozzles was checked as a final step.

2.1.3. Flight Mission. Flight mission was set to start automatically, but if there is any unexpected obstacle during flight, UAV will be set to manual control.

2.1.4. After Flight Mission. Fertilizer tank and nozzle and keep equipment were cleaned.

Time consumed by every step as recorded and we can divide those processes as 4 groups as follows:
- Group 1: Time for Flight planning.
- Group 2: Time for fertilizer filling and battery changing.
- Group 3: Passive working time: Time for taking off and landing, turning during flight.
- Group 4: Active working time.

Time consumed by these 4 groups was used for analysis to determine field capacity of UAV and identification of factors that cause and increase passive working time.

![Image 1](image1.png)
![Image 2](image2.png)
![Image 3](image3.png)

Figure 3. Flight planning for all 6 fields.

2.3. Criteria of field capacity evaluation

Determination of Drone field capacity (ha/hr) require knowing the field area and total time of UAV in field [5]. This determination of UAV field capacity show in equation 1 given below.

\[ C = \frac{\text{Field (ha)}}{\text{time (hr)}} \] (1)
3. Result and discussion

3.1. Field capacity

The field capacity in all 6 experimental fields are shown in table 2.

Table 2. Working capacity

| Field No. | Area (ha) | Field capacity (ha/hr) |
|-----------|-----------|------------------------|
| 1         | 0.64      | 4.48                   |
| 2         | 0.16      | 1.92                   |
| 3         | 0.16      | 2.88                   |
| 4         | 0.16      | 4.48                   |
| 5         | 0.64      | 3.04                   |
| 6         | 0.48      | 3.52                   |
| Avg.      |           | 3.36                   |
| S.D.      |           | 0.99                   |

According to table 2, field number 1 (0.64 ha) and field number 4 (0.16 ha) have the same field capacity despite of differences in size of these fields. The similarity of these two fields is having long length which help to reduce number of turns and make it possible for UAV to fly in full speed longer during operation when compared to short length field number 5. Hence, we can conclude that the size of area does not affect field capacity, but the length of field does.

3.2. Total time consumptions in spraying operation

The results demonstrate that flight planning process takes the longest time because workers need to survey condition surrounding fields to avoid accidents caused by crashing with trees or shrubs around the fields. Distribution of time consumptions of 6 fields is shown in Figure 4.

According to time spent on flight planning, we can category condition of field into 4 group as presented in table 3 below:

Figure 4. All procedures and time of operation (In this study, there is no changing battery incident).
Table 3. Surrounding the field and time to flight planning.

| Trees around the field | The height of cane | The average time to flight planning | Area (ha) |
|------------------------|--------------------|------------------------------------|-----------|
|                        | No.                | (min/field)                        |           |
| No trees /Less uniform | 5, 6               | 17:48                              | 0.64, 0.48|
| nonuniform              | 1, 2               | 09:18                              | 0.64, 0.16|
| Have many trees         | uniform            |                                    |           |
| nonuniform              | 3, 4               | 30:46                              | 0.16, 0.16|

Table 3 illustrates that field group number 4 require the longest time for creating flight planning because there are many trees around field and the height of sugarcane in field is uniform.

Time spent on flight planning is required only for the first flight mission, and then for next flight mission in the same field, we can reuse the previous plan. Hence, total time of operation will be reduced as shown in Figure 5.

Figure 5. All procedures and time of operation in the same field (In this study, there is no changing battery incident).

According Figure 5, even after excluding time of flight planning, total time of operation in field number 1, 5, and 6 are still long because these three fields (0.64, 0.64, and 0.48 ha, respectively) when compared with the rest fields. However, if we consider time spent for filling fertilizer for spraying 1 ha area, all 6 fields have similar time consumption rate as shown in table 4.

Table 4. Fertilizer filling time

| Field No. | Area, ha | Fertilizer filling time |
|-----------|----------|-------------------------|
|           |          | min/field | min/ha    |
| 1         | 0.64     | 07:10      | 11:11     |
| 2         | 0.16     | 01:40      | 10:25     |
| 3         | 0.16     | 01:19      | 8.13      |
| 4         | 0.16     | 01:57      | 12:11     |
| 5         | 0.64     | 05:57      | 9.17      |
| 6         | 0.48     | 04:32      | 9.26      |
| Avg.      |          | 10:07      |           |
| S.D.      |          | 0.06       |           |
Figure 5 shows that there are two types of time consuming tasks, which are active working time and passive working time.

### Table 5. Time of passive operation

| Field No. | W (m) | Turning during flight time | Take-off and landing time |
|-----------|-------|---------------------------|---------------------------|
|           |       | min/plot                  | min/(W=100 m)             | min/field |
| 1         | 52.0  | 01:17                     | 02:27                     | 01:27     |
| 2         | 30.6  | 00:23                     | 01:15                     | 01:18     |
| 3         | 47.3  | 00:41                     | 01:26                     | 02:00     |
| 4         | 26.1  | 00:24                     | 01:32                     | 01:41     |
| 5         | 98.0  | 01:28                     | 01:30                     | 01:01     |
| 6         | 40.0  | 00:31                     | 01:19                     | 01:53     |

*** Note: W is the width of fields test.

From the results shown in table 5, time consumed by turning dependent on the width field while number of turnings are relied to the shape of field. In addition, because field width of 6 fields are not equal, we calculated total time of turning in 100 m width of field for all fields, and the results demonstrated that field width factor doesn’t affect the total turning time, but shape of field does. Figure 6 shows an example of how shape of field affect turning times due to changes in number of turns that needs to be made. Time spent on taking off until starting operation can be reduced by setting the point of starting operation close to the point of taking off. On the other hand, for time spent on landing can be also reduced by setting the operation starting point close to the operation finishing point.

![Figure 6. The shape of field is a non-rectangle.](image)

Active working time in 6 fields are shown in table 6.

### Table 6. Active working time

| Field No. | W (m) | L (m) | Active working time (min/field) |
|-----------|-------|-------|---------------------------------|
| 1         | 52.0  | 163   | 06:31                           |
| 2         | 30.6  | 56    | 01:40                           |
| 3         | 47.3  | 48    | 02:50                           |
| 4         | 26.1  | 94    | 03:09                           |
| 5         | 98.0  | 84    | 08:13                           |
| 6         | 40.0  | 140   | 06:46                           |

*** Note: W and L is the width and length of fields test.

Table 6 shows that field number 5 has the most active working time, however it has low field capacity due to time lost in several turning operations.

### 4. Conclusions

The results of this study show that field capacity of UAV in spraying operation is in range of 1.92-4.48 ha/hr and average field capacity is 3.36 ha/hr. The factor that affect total time of operation and field
capacity is shape of field. If field has rectangular shape and long length, the field capacity is increased because UAV can fly in full speed for most of operation time with less turning times. Hence, user should pay special attention to the shape of operated fields to create flight planning that provide the best field capacity because those flight planning are only required at the first flight mission and then users can reuse those planning for subsequent flight missions in the same field.

References
[1] Naranong V 2013 Proposed Reforms in the Structure of Thailand’s Sugar and Cane Industry. *TDRI Q Rev.* 28 6–12
[2] Mogili U and Deepak B 2018 Review on Application of Drone Systems in Precision Agriculture. *Procedia Comput Sci.* 133 502–9
[3] Wang L, Chen D, Yao Z, Ni X and Wang S 2018 ScienceDirect Research on the prediction model and its influencing factors of droplet deposition based factors on UAV Research on based factors on UAV spraying Research on based on UAV spraying Chen environment. *IFAC-PapersOnLine.* 51 274–79
[4] Opanukul W 2017 Drone Research for Organic Agriculture. 18th TSAE Natl. Conf. TSAE 2017, 219–23.
[5] The Society for engineering in agricultural, food, and biological systems 2003 *Agricultural Machinery Management* (ASAE STANDARDS) (USA) pp 369

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