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Monitoring Rice Crop and Paddy Field Condition Using UAV RGB Imagery

Mohd Yazid Abu Sari [a], Yana Mazwin Mohmad Hassim [b,*], Rahmat Hidayat [c], Asmala Ahmad [d]

[a] *Anjung Technology Sdn Bhd, 75450 Ayer Keroh, Melaka, Malaysia*

[b] *Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat, Johor, Malaysia*

[c] *Department of Information Technology, Politeknik Negeri Padang, West Sumatera, Indonesia*

[d] *Faculty of Communication and Informations Technology, Universiti Teknikal Malaysia Melaka (UTeM), Durian Tunggal, Melaka, Malaysia*

Corresponding author: [*]yana@uthm.edu.my

***Abstract*—An effective crop management practice is very important to the sustenance of crop production. With the emergence of Industrial Revolution 4.0 (IR 4.0), precision farming has become the key element in modern agriculture to help farmers in maintaining the sustainability of crop production. Unmanned aerial vehicle (UAV) also known as drone was widely used in agriculture as one of the potential technologies to collect the data and monitor the crop condition. Managing and monitoring the paddy field especially at the bigger scale is one of the biggest challenges for farmers. Traditionally, the paddy field and crop condition are only monitored and observed manually by the farmers which may sometimes lead to inaccurate observation of the plot due the large area. Therefore, this study proposes the application of unmanned aerial vehicles and RGB imagery for monitoring rice crop development and paddy field condition. The integration of UAV with RGB digital camera were used to collect the data in the paddy field. Result shows that the early monitoring of rice crops is important to identify the crop condition. Therefore, with the use of aerial imagery analysis from UAV, it can help to improve rice crop management and eventually is expected to increase rice crop production.**

***Keywords*— Precision farming; unmanned aerial vehicle; crop management; aerial imagery.**

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I. INTRODUCTION

An effective crop management practice is very important to the sustenance of crop production. With the emergence of Industrial Revolution 4.0 (IR 4.0), precision farming has become the key element in modern agriculture to help farmers in maintaining the sustainability of crop production. Precision farming or precision agriculture is an approach of farm management to ensure that the crops are at optimum productivity [1], [2], [3]. The application of modern information technologies in precision agriculture allow farmers to collect different data of the crops and land so that they can identify temporal and spatial variations in the production resources to facilitate them to take the necessary actions or treatments for managing their crops [4], [5], [6]. Several recent technologies used in precision farming are Remote Sensing, Geographic Information Systems (GIS), and Global Positioning Systems (GPS) [4], [7], [8].

Malaysia and most of the countries in the world, mainly in South Asia, consume Rice (Oryza sativa L) as the main staple food [9]. In Peninsular Malaysia, there are about 300,500 hectares of paddy fields and there are more than 100,000 farmers depending on rice production for their livelihoods [10], [11]. Therefore, the sustainable production of rice is critical for ensuring food security for the country. In Asia, food security has become a growing concern and an effort to maintain and increase the production of rice is widely discussed and investigated[12], [13],[14], [15].

In recent years, researchers have tried to develop many applications and conduct research such as planting, pest and disease, irrigation, fertilizer, and precision agriculture in rice production to sustain the crop production[16], [17, 18]. One of the most promising research is using the technology of remote sensing (RS), which allows farmers to monitor the growing condition of crops, to timely acquire the information on crop production[19],[20],[21]. Thus, the usage of the remote sensing technology will be helpful since it can produce the temporal and high spatial imagery to monitor the crop condition [22]. Many applications have been implemented by using remote sensing technology such as crop condition identification, yield estimation, weed detection, soil condition and plant life cycle analysis.

This study proposes the application of unmanned aerial vehicle (UAV) and RGB imagery (UAV RGB imagery) for monitoring rice crop development and paddy field condition. Unmanned aerial vehicle (UAV) is one of the remote sensing platforms that can be used to collect the high resolution in an effective way compared to satellite imagery [23]. This technology has been used in many applications such as land suitability, flood monitoring, environment and agricultural field at global stage [24], [25], [26], [27], [28], [29]. Managing and monitoring the paddy field especially at the bigger scale is one of the biggest challenges for farmers [30]. Poor management may disturb productivity and also may lead to huge loss [31].

Traditionally, the paddy field and crop condition are only monitored manually by the farmers and sometimes they could miss some of the plot due the large area and difficulties to get access to that point of areas. The use of unmanned aerial vehicles (UAV) could help farmers in monitoring their paddy field and rice crop condition in an effective way. Hence, this research is focusing on monitoring the crop condition by using UAV and low-cost camera (RGB digital camera). The RGB digital camera was used in this experiment as it is more cost effective for farmers as compared to the use of multispectral imagery.

II. Material and Method

Materials and methods involved in this study include the study site of paddy field, the use of multirotor UAV and RGB digital camera for image acquisition in phase 1 and the use of Agisoft PhotoScan software for image processing for phase 2. Figure 1 shows the phases involved in the methodology.

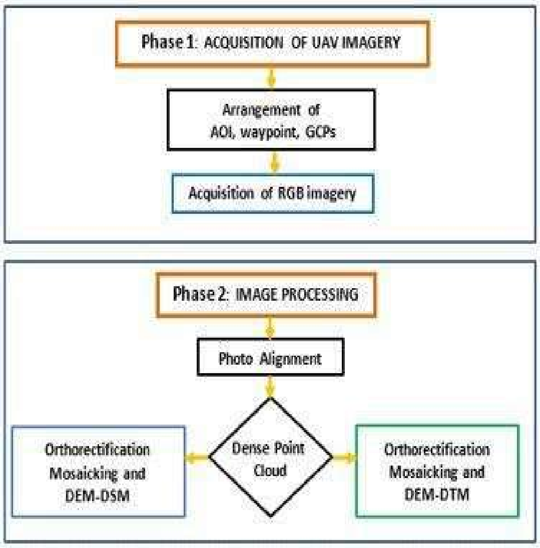


Fig. 1 Phases in the Methodology

A. Study Site

The project was conducted in Sawah Sagil, Kampung Parit Sagil Ayer Hitam Batu Pahat, Johor. The area of the paddy field is 175 acres equivalent to 70 hectares. Figure 2 shows the location of the study site.

Fig. 2 The Location of the Study site

B. Acquisition of UAV Imagery

This study implemented the use of multirotor UAV and RGB digital camera. For the purpose of imagery acquisition, we use DJI Ground Station Pro (https://www.dji.com/downloads/products/ground-station-pro) to design the UAV flight plan. The altitude for data acquisition of RGB images was 58.0 m equivalent to 1.4 cm/px spatial resolution. The data collection was conducted on the 15th day after planting (DAP) [32]. For consistency in capturing images the camera needs to be adjusted according to the light conditions. We also made sure that the camera was set to a fixed exposure for each flight.

A crucial step to ensure the successfulness of the aerial imagery acquisition mission was to ensure the correct mapping of the UAV waypoint. With the correct waypoint mapping, this will improve the mission routine and reduce the post-processing computation load. In this study, DJI Ground Station Pro was used which has good mapping tools. It supports various auto-waypoint generation tools. Six sorties waypoint distance-travelled from takeoff point to landing point has to be in the range of UAV airtime limitation. Figure 3 shows the waypoint mapping of a six sorties flight prepared for surveying Sawah Sagil site area.

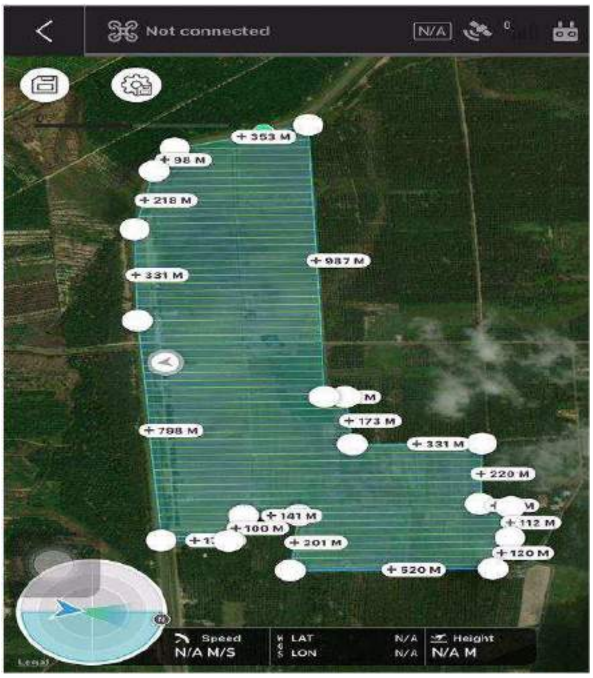


Fig. 3 Waypoint planned by using DJI GS Pro software for 175 acres

The estimated number of aerial images expected from this flight plan were 2045 images where the front overlap ration was set to 69% and side overlap ration was set to 64%. The waypoint configuration is shown as in figure 4.

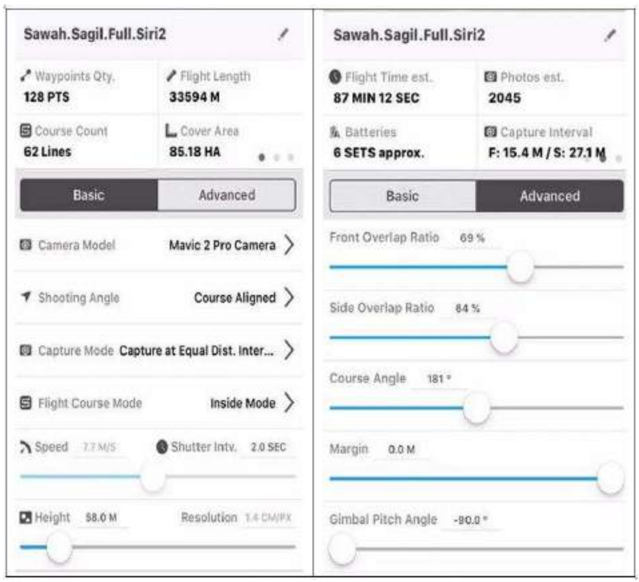


Fig. 4 Waypoint configuration for image aquisition

The specification of multirotor UAV is shown as in Table 1. The same multirotor UAV has been used by [5], [6] for ground surveying due to the ability to fly at low altitude. The advantage of using this multirotor UAV is that it can acquire high spatial resolution imagery at the specific area.

TABLE I
SPECIFICATION OF MULTIROTOR UAV

Criteria	Specification
Main rotor blade length	700 mm
Length	289 mm
Width	289 mm
Height	200 mm
Brushless motor	Wk-ws-28-008a
Brushless esc	Wst-15a (g/r)
Receiver	Rx703
Main controller	Devo-m
Flight time	35 minutes

The aerial images taken for this study were produced with an RGB digital camera which has an effective pixel of 20 megapixels and one inch of CMOS sensor size. Figure 5 shows the RGB camera used for aerial images acquisition in this study and Table 2 shows the details of the specifications for the RGB digital camera.

Fig. 5 The RGB camera used for aerial images acquisition

TABLE II
SPECIFICATIONS DIGITAL CAMERA

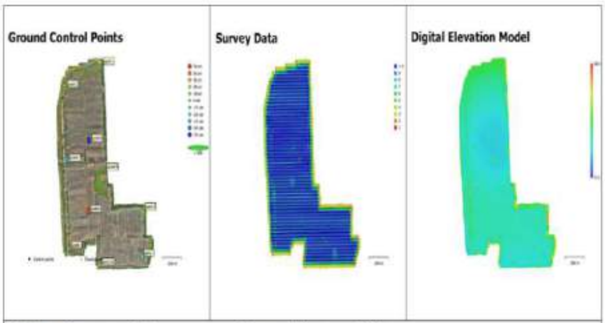
Criteria	Lens
Sensor	1” CMOS 20 megapixels
Lens	FOV: about 77º 35 mm – 28 mm Aperture: f/2.8-f/11 Shooting Range: 1m - ∞
Shutter Speed	e-Shutter: 8-1/8000s
Still Image Size	5472 x 3648
Still Photography Modes	Single shot Burst shooting: 3/5 frames Auto Exposure Bracketing (AEB): 3/5 bracketed Frames at 0.7 EV Bias Interval (JPEG: 2/3/5/7/10/15/20/30/60s RAW: 5/7/10/15/20/30/60s
Photo Format	JPEG / DNG (RAW)

All mapping flight missions were executed and controlled using autonomous waypoint flights command. Ground control station (GCS) laptop and radio control transmitter (RC Tx.) were used for monitoring and stand-by manual intervention purposes only. The real mission execution lasted for 87 minutes for six sorties with six sets of batteries with flight length of 33,594 m flight travel distance.

C. Image processing

After the completion of the aerial photograph acquisition mission, all the digital photos acquired by the RGB digital camera were processed using Agisoft PhotoScan software (http://www.agisoft.com/). This software was used for the per-processing to combine or mosaic all the data into an orthophoto map. There are 2127 numbers of images processed by the software with resolution of 1.43 cm per pixels. Table 3 shows the map and information that was extracted from the Agisoft PhotoScan processing report. Camera location shows the position of the camera of the aerial imagery using UAV.

TABLE III
INFORMATION GENERATED FROM THE IMAGE PROCESSING REPORT



Number of images:	2,127	Camera stations:	2,127	Resolution:	5.72 cm/pix
Flying altitude:	65.7 m	Tie points:	6,395,944	Point density:	305 points/m²
Ground resolution:	1.43 cm/pix	Projections:	21,671,999		
Coverage area:	0.973 km²	Reprojection error:	1.09 pix		

Three images processing reports were produced which are based on Ground Control Points, Survey Data and Digital Elevation Model. The Ground Control Points, or GCPs, are the marked points on the ground that have a known geographic location. The survey data shows the points in the map based on the aerial imagery taken by the UAV. The digital elevation model (DEM) from this image processing report on the other hand represents the elevation of the paddy field area.

III. RESULT AND DISCUSSION

The imagery data produced from the image processing phase was analyzed by using Virtual Surveyor software (https://www.virtual-surveyor.com/). From the RGB image generated, the planted paddy field area can be sketched in the form of a polygon. Figure 6 presents the inflight imagery generated with paddy plot information. The left image shows the actual paddy field map while the right image shows the segmentation of the paddy fields signifying the paddy plot border.

Fig. 6 Image generated with paddy plot information

The report generated by Virtual surveyor software through statistics report for polygon attribute value in the figure 6 also shows that there are 188 paddy plot area, with the smallest paddy plot area is 0.0974 acres while the largest paddy plot area is 2.767 acres, and the total paddy field area is 148,7094 acres.

A. *Monitoring rice crop and paddy field condition*

Figure 7 below visualized the whole 0.973km2 of paddy field which displays the paddy field map derived from RGB imagery at 65.7 m altitude with the spatial resolution was 1.43 cm/px. The map generated from the aerial images visualized the whole plot area of the paddy field of the rice crop at 15th days after planting.

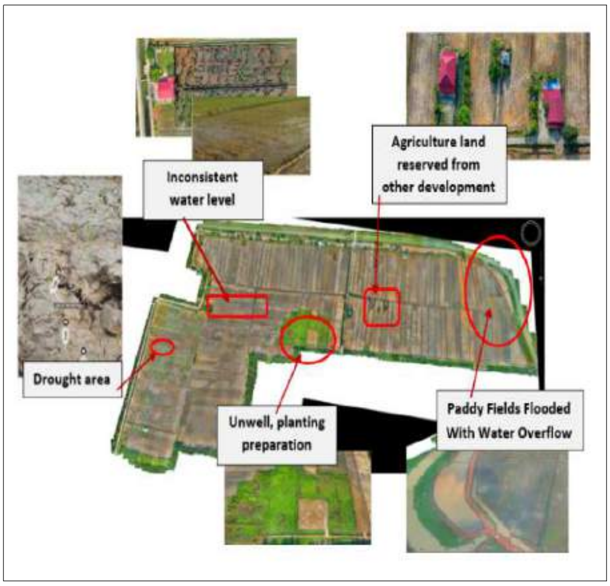


Fig. 7 Paddy field map of rice crop at 15th days after planting (DAP)

From the map, problem areas in the paddy field can be discovered immediately. Problems such as drought area, inconsistent water level, unwell paddy plants and flooded areas caused by overflowed water can be analyzed and identified instantly. This may help farmers to take proper immediate action to recover the affected problem area in the paddy field. This is very crucial in early monitoring of rice crops particularly at the stage of the 15th day after planting.

B. *Calculation of uneven zoning in the paddy plot*

Even ground leveling for paddy fields is very important to ensure proper water coverage in the paddy plot. Proper management of even areas in the paddy field may improve water use efficiency, increase grain yield, and improve grain quality. When the ground is uneven, consequently some of the part will have less water (the area will dry) and some of the part will flood. This condition will affect the production of the grain yield in that location and affect the quality of the grain yield.

Figure 8 shows the generated map of a selected paddy plot and the details of the uneven ground zoning. The total area of the paddy plot was 30.99 m^2. The brown area on the map shows the uneven ground. The uneven ground will give a negative impact to this area and decrease the yield in the future. The uneven ground might be caused by the damage done by the tractor in the field. With this information, farmers can take appropriate action to make sure to level the paddy field before starting to plant for the next season.

Fig. 8 The value of the area and uneven ground in one plot paddy field

C. Volume calculation for each plot

The water needed for a rice crop is approximately 10mm of water per day. A rice crop that matures in 100 days will require approximately 1000mm of water while a rice crop that matures in 150 days will require 50% more. In order to manage the appropriate amount of water for the rice crop, farmers need to monitor the water level for their plot so that the plants will get sufficient water for their photosynthesis and growth development. From the map shown in figure 9, image acquired from the UAV imagery data, may help farmers to get the information regarding the calculation of volume of water for the paddy plot. The calculation of volume of water is very important to measure the water level so that the plot area has optimum water for the plants.

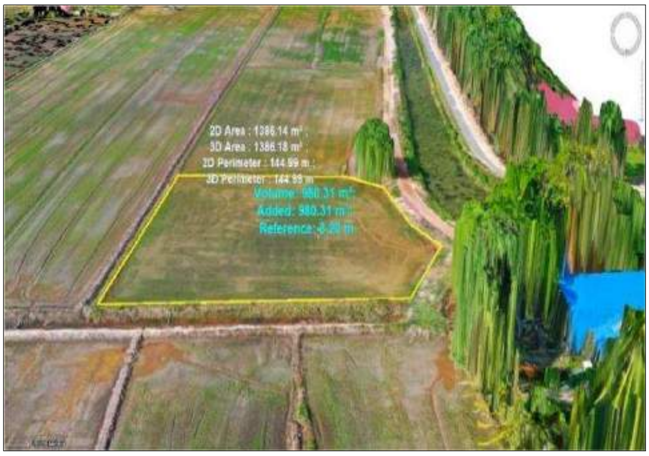


Fig. 9 The volume for the paddy plot

D. Detecting water movement

Figure 10 shows the water movement in a paddy plot from higher area to the lower area due the uneven ground. The uneven ground will lead to the inconsistent water level condition where the lower area will be flooded with more volume of water as compared to the higher surface. The yellow arrow from the map shows the water movement toward the lower area. Since the appropriate water level should not be more or less than 5 cm depth, the rice crop condition at the area will be affected because of the excess water volume which will result in the declining rice yields production during the harvest season.

Fig. 10 The water flow in the paddy plot (yellow arrows)

E. Profiling the paddy plot

The profiling of paddy plots is very important to make sure the paddy plot ground is even enough for the rice crop plantation (yellow line). Figure 11 shows the elevation of the cross section of the paddy plot. From figure 11, it appears that the elevation of the cross section is 0.12 m and slope is 0.09°. Paddy plot profiling is very important for rice crop management especially in precision farming as it gives the information of the paddy field conditions, water flow of the plot and the plants growth progress growth in the season.

Fig. 11 The cross section of paddy plot

IV. Conclusion

As a conclusion, UAV and RGB imagery was successful in monitoring the rice plot condition at an early stage. Farmers can monitor the crop condition as well as the field condition. The surface condition and the plot can be monitored at the early stage and farmers can plan their management and activity to increase the production and decrease the pest outbreak. The imagery was high spatial resolution and the user can analyze the spatial surface of the plot very clearly. The spatial resolution was 1.43 cm and suitable for rice monitoring since the plant was still small and at the young age. Results identify the uneven ground surface in the plot area. The poor irrigation system in the plot is also one of the factors contributing to the decreasing yield since at the beginning the management seems to be not well prepared. It will affect the plant condition and the rice production. It shows clearly that the water flow of the low surface. This will waste the input and some of the parts were not enough nutrient because of the high surface.

Therefore, the information was important to monitor the development of growth for the paddy field was in a good condition. All this information was beneficial for farmers in their management system. It can be a reference for the decision marker and action plan to improve the development growth of the rice plants. Thus, the preparation of the plot in the rice field needs to be prepared before the seeds are planted to make sure the condition of the soil is in a good condition. UAV helps a lot in monitoring the whole area at low cost and the data can be used for the further analysis and action plan for the future.

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