Mapping of Peat Soil Physical Properties by Using Drone-Based Multispectral Vegetation Imagery

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Abstract. Unmanned Aerial Vehicle (UAV), namely drone, is one of the aerial platforms, which used to monitor and mapping an agricultural sectors at large area. The platform equipped with some compact camera or sensors. This study aims to identify the peat soil physical properties, which correlated with the pineapple crops healthiness index. The index based on visible Red, Blue, Green (RGB) and Near Infrared (NIR) of spectral wavelength taken from multispectral camera mounted at the drone. The data captured with the drone validated with laboratory test result obtained from the soil samples at the site. The multispectral images of three plots of pineapple crops from the age of 4 months to 14 months was take to check their healthiness index. Soil moisture content and pH value were also test from 28 soil samples. The healthiness of the crops were analysed using both data and the results then compared and correlated. This contribution focuses at the study area of Morris pineapple crops that were cultivated on peat soil in Parit Nipah, Batu Pahat. It was found that the moisture content and pH value of the peat soil is linear with the index level of colour reflectance produced from the multispectral image. As a result, this study gives a proof that using of multispectral images technology from drone is able to correlate between the healthiness of pineapple crops with the soil physical properties.

1. Introduction
In 2050, food production is estimate to increase by at least 70% to support the continued population growth. On the other hand, the size of agricultural area in the whole world is still essentially unchanged. The demands of food production are increasing day by day. Consequently, the food resources and production should be increase. At the same time, any potential treat and problem deteriorate the food production in agricultural sector should be minimized. The development of productive, sustainable and resource-efficient primary production system should be at the front objective to food production. A more efficient way to use water, soil nutrients and chemical for crop protection can be one of the effective methods to improve production both in quality and quantity, and at the same time reducing the environmental impact [1].

Soil is one of the dominant factors contributing towards the growth of agricultural crop. Different types of soil, such as clay, soft, silt, sandy and loam soils, have their own physical properties which structuring the nature of the soil [2]. The physical properties of soil such as moisture content, pH, organic matter, colour, density, texture and pore space are different from each type of soil. Besides that, the physical properties of soil contribute to the crop healthiness covering the nutrients and water uptakes by the crops from the soil. Peat soil is classified as soft soil due to its high moisture content, high acidity,
high shear strength, high organic matter. This type of soil is only suitable for a certain types of crops such as palm oil crop and pineapple crop due to its high water content and acidity of the soil [3]. In Malaysia, pineapple crop is widely cultivated on peat soil in Johore giving incomes about 116 millions ringgit in 2016 with 38 762 tonnes of fruits has been produced [4].

Currently, technology from remote sensing has been widely applied towards the management of crops around the world to monitor the growth and yield estimation. The energy that was absorbed and reflected by crop can be detected through the multispectral imagery which is transmitted through their spectral signature. UAV platform equipped with multispectral sensor is able to obtain the vegetation healthiness data at large area coverage in a shorter time [5]. Drone application can be one of the helpful technology for the planters to monitor the healthiness of their crops. On the other hands, orthophoto of spectral RGB and NIR images can be produce for the whole area of study. The orthophoto produced from RGB and NIR images can be uses to produce the Near Difference Vegetation Index (NDVI) to check the healthiness of the crop in the area. Based on the NDVI scale, the condition and healthiness of the crop can be detected and identified [6].

2. Literature Review

Over the past few years, the methods used for actualisation have evolved from landscape based soil classification to digital soil mapping by drone. It is providing a big efficiency increase while maintaining accuracy. Drones have recently gained popularity in remote sensing studies and been used in a variety of high-resolution topographic mapping studies [7]. The ability of drone to fly in high altitude attracts users to use its advantage in large area mapping or photography. Compared to field mapping, drone mapping can be conducted more frequently at lower cost and with a finer resolution, which allows rapid monitoring and information of changes in natural soil states [8]. The map can contribute to one of its advantages in providing quantitative soil information for the environmental monitoring and modelling [9]. On the other hand, the prediction of the soil variables is widely used for the neighbouring soil properties in providing an adequate information about the soil. The physical properties at a specific location usually depend on the geographic position and also contributed by the soil properties of neighbouring locations. One of the specific advantages of the soil map is its capability to outline information about soil such as the type of soil and its physical properties. The information is expected to give contribution in solving various of soil problems in the future and a proper development of agricultural field can be planned without encounter soil problem [10].

Multispectral imaging camera sensors on drones are widely used in agricultural as it provides fastest method for the planters to manage crops, soil, fertilizing, irrigation and many more [11]. Both visible and invisible images of crops and vegetation can be captured from multispectral camera remote sensing imaging technology, which provides the use of Green, Red, Red-edge and Near-Infrared wavebands. An index of vegetation “greenness” can be identified by taking the ratio of red and near infrared bands from a remotely sensed image. Another way, NDVI is one of the methods to measure the health level of vegetation. NDVI for vegetation generally range from 0.3 to 0.8, with the larger values representing ‘greener' surfaces. Bare soils range from about 0.2 - 0.3. When the value of NDVI is high, it is possible that the it is showing healthy vegetations, otherwise it is possibly showing of less or no vegetation.

3. Methodology

3.1. Research Area

The area study of this research was located at a pineapple crop area in Parit Nipah, Batu Pahat near to UTHM Research Centre for Soft Soil research area, which is about 10 km away from UTHM main campus. This area was selected since most of the study about the soft soil was done at the area. The topography of the location is relatively almost flat with the height about 1.35 m to 1.80 m above the mean sea level and the ground water table for this area is around 0.5 m to 0.65 m. The area is widely used to cultivate Morris pineapple by the local farmers from the nearby area. From the sites, about 28 soil samples were taken from the field covering the three plots, as it is shown in Figure 1. Each soil sample taken at 20 cm depth from the surface. The plots divide the following sampling classification:

- Plot 1 has a size of 30 x 20 m with the pineapple crop age of 14 months, taking 12 soil samples,
• Plot 2 has a size of 28 x 20 m with the pineapple crop age of 8 months, taking 8 soil samples,
• Plot 3 has a size of 18 x 20 m with the pineapple crop age of 4 months, taking 8 soil samples.

![Figure 1. Plot from sample locations](image)

3.2. **Data Collection by Drone**
For this research, multispectral images were produced from the drone equipped with the multispectral imagery. All the data that were collected from the site were using DJI-Phantom 4 drone and Mapir Survey 3 multispectral camera. The drone was flown at the height of 24 m from the ground to cover all of the research area. The multispectral data obtained from the pineapple crops area are in form of NIR and RGB images.

3.3. **Peat Soil Physical Properties**
The peat soil samples was taken from the middle of each of the grid field were sealed in plastic bags with excess air expelled. Then, the samples were labelled on the outside as sample point number. They are referred as disturbed soil samples because of the structure and texture of the soils were already changed. All samples were transferred to the laboratory to be tested by using oven-drying method to obtain the moisture content of the soil and pH test. The test that conducted were in accordance to British Standard, BS1377.

3.4. **Data Processing**
During the data processing, the NIR and RGB images was processed to form orthomosaic images and then was transferred to ArcGIS software to form NDVI map for the area of study. The NDVI was calculated by using equation (1) and then it was used to check the healthiness of the pineapple crop by referring to the NDVI healthiness indication table as shown in Table 1. The NDVI value from the pineapple crop were correlated with the physical properties of the peat soil samples.

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\text{NDVI} = \frac{(\text{Near Infrared Radiation} - \text{Visible Red Radiation})}{(\text{Near Infrared Radiation} + \text{Visible Red Radiation})}
\]  

(1)
| Value of NDVI | Indication                          |
|--------------|------------------------------------|
| < 0          | Intimate / dead material, soil, dead materials |
| 0 ≥ 0.33     | Unhealthy plant material           |
| 0.33 ≥ 0.66  | Healthy plant material             |
| ≥ 0.66       | Very healthy plant material        |

4. Result and Discussions

This research was conducted to obtain the physical properties of the peat soil and to correlate with the healthiness of pineapple crop. The pineapple crop was separated into three plots according to the age of pineapple crop.

4.1. Laboratory test result

From the laboratory test result, moisture content and pH of peat soil samples from Figure 2 shows different trends and slightly different from each other. The plots indicated the moisture content of the soil was increasing (or closing) to 100 % of water ratio, while the value of pH of acidity was decreasing. This shows that the moisture content of the soil inversely related to the value of pH. Based on the results, it was proof that the peat soil is acidic. The confirmation and validation results for this research were done with the results from laboratory test. The test found that the high amount of water content from the peat soil decrease the value of pH.

![Figure 2](image_url)

**Figure 2.** pH value versus moisture content (a) Plot 1, (b) Plot 2 (c) Plot 3
4.2. Pineapple Crop Healthiness

NDVI used as one of the parameters to show the index of healthiness of the pineapple crops which is widely used in currently agricultural technology. NDVI determine the healthiness of the crops by measuring the reflectance index originates from the colour reflectance and absorption by the leaves of the crop. An active vegetation, classified as healthy vegetation, reflects near infrared light and green light while absorbing red and blue light showing the vegetation was having a good photosynthesis process. While unhealthy crops that having stress or dead are reflecting red and blue light while absorbing green and near infrared light [12]. The pineapple crops for 3 plots are showing different tone of colour due to the reflectance and absorption of light that showing the healthiness of the crops as shown in Figure 3. In order to check the healthiness of the pineapple crops, NDVI maps were produces in ArcGIS software to check the light reflectance for each of the pineapple plots. The NDVI value checked based on each grid and compared with the moisture content and pH value. The results of the pineapples grids healthiness decided based on the NDVI scale at Table 1.

![NDVI map with healthiness scale indication](image)

**Figure 3.** NDVI map with healthiness scale indication (a) Plot 1, (b) Plot 2 (c) Plot 3

Table 2 shows the result of the pineapple crops healthiness. Plot 1 shows the crops of 14 months age and the height of 80 cm to 140 cm. Sample number 9 is the highest moisture content and the lowest pH give a very healthiness of the crops (Table 2). Meanwhile point number 12 is the lowest moisture content with the highest pH indicated the healthy crops. It is because of the age of the plant and the average number of leaf influence the light tolerance and photosynthetic activity. On the other hand, Plot 2 with the crops of 8 months age and the height of 50 cm to 80 cm. Meanwhile plot 3 with the crops of 4 months
age and the height of 15 cm to 30 cm. The plots shows the indication of very healthy crops with highest moisture content and less acidic (Table 3 and 4). It is because the planters correcting soil acidity by the use of lime. Even though some crops grow best in the 6 to 7 pH range, but this area grow well under slightly acidic conditions.

Table 2. Result of peat soil physical properties with NDVI indication for Plot 1

| Pineapple Plot | Location of Peat Sample | Moisture Contents % | pH Value | NDVI          | Indication     |
|----------------|-------------------------|---------------------|----------|--------------|----------------|
| 1              | 5                       | 377.00              | 4.05     | 0.672131     | Very healthy   |
| 6              | 424.41                  | 4.14                | 0.734694 | Very healthy |
| 7              | 366.74                  | 4.19                | 0.639871 | Healthy      |
| 8              | 580.23                  | 3.81                | 0.814947 | Very healthy |
| 9              | 618.11                  | 3.61                | 0.917293 | Very healthy |
| 10             | 540.96                  | 3.79                | 0.808124 | Very healthy |
| 11             | 614.23                  | 3.62                | 0.868132 | Very healthy |
| 12             | 285.90                  | 4.04                | 0.554878 | Healthy      |

Table 3. Result of peat soil physical properties with NDVI indication for Plot 2

| Pineapple Plot | Location of Peat Sample | Moisture Contents % | pH Value | NDVI          | Indication     |
|----------------|-------------------------|---------------------|----------|--------------|----------------|
| 2              | 1                       | 356.20              | 3.89     | 0.645161     | Healthy        |
| 2              | 417.91                  | 3.90                | 0.722973 | Very healthy |
| 3              | 678.85                  | 3.70                | 0.931818 | Very healthy |
| 4              | 577.25                  | 3.71                | 0.861314 | Very healthy |
| 5              | 467.06                  | 3.78                | 0.789474 | Very healthy |
| 6              | 718.60                  | 3.66                | 0.961538 | Very healthy |
| 7              | 736.52                  | 3.56                | 0.961538 | Very healthy |
| 8              | 432.24                  | 3.91                | 0.746575 | Very healthy |

Table 4. Result of peat soil physical properties with NDVI indication for Plot 3

| Pineapple Plot | Location of Peat Sample | Moisture Contents % | pH Value | NDVI          | Indication     |
|----------------|-------------------------|---------------------|----------|--------------|----------------|
| 3              | 1                       | 438.13              | 3.81     | 0.795775     | Very healthy   |
| 2              | 491.96                  | 3.78                | 0.80212  | Very healthy |
| 3              | 430.04                  | 3.89                | 0.771245 | Very healthy |
| 4              | 535.95                  | 3.98                | 0.834532 | Very healthy |
| 5              | 670.44                  | 3.54                | 0.939164 | Very healthy |
| 6              | 518.86                  | 3.67                | 0.814947 | Very healthy |
| 7              | 630.09                  | 3.57                | 0.854545 | Very healthy |
| 8              | 634.91                  | 3.62                | 0.836798 | Very healthy |

4.3. Peat Soil Properties Map

In order to produce the peat soil physical properties map, all data from the laboratory test and multispectral camera need to be compares to check the significance for each other. From both laboratory test and multispectral camera result, the physical properties of the peat soil such as moisture content and pH value found as one of the major factors that contributing towards the pineapple crop healthiness. The
peat soil samples taken from the site was tested to obtain the moisture content and the pH value. By using ArcGIS software, the correlation between the pineapple crop healthiness by utilizing the NDVI were process to produce a map. Maps containing peat soil physical properties information for the pineapple crop at the research area correlated with the pineapple crop healthiness can be seen in Figure 4. Most of the highest moisture content is from plot 2, 3 and 1. The pH acidic located at plot 3, 2 and 1.

Figure 4. Physical properties map (a) Moisture content (b) pH

5. Conclusions and Recommendation for Future Work
As the conclusion, this research has shown the ability of drone equipped with multispectral imagery to obtain the healthiness index of the pineapple crop according to their age. The healthiness index of the pineapple crop was correlated with the physical properties of the peat soil obtained from the specific laboratory test to show the proportionality. From both results, the moisture content of the peat soil was influencing the pH of the peat soil. This happened due to the presence of pores inside the peat soil were increased the amount of water to enter inside the soil. The peat soil then will be reacted with the soil, which produces the acidity condition of the soil. Both of the physical properties of the peat soil were dominating factor contributing towards the healthiness of the pineapple crop in this research area. The highest moisture content and lowest pH indicated the highest number of NDVI. The lowest moisture content and the highest pH (acidic) given the unhealthy of the crops.

In the future, there are several things that can be improves to obtain a good result. But first, in order to obtain the better correlation of result for the map produced, the soil data and the NDVI data need to be taken as many as possible to make sure the result are shown the same as the previous research conducted. The data also needs to be taken repeatedly and several checking procedures need to be conducted to ensure that it complies with the previous research. Besides that, the procedure to obtain the physical properties of the peat soil also needs to be taken into account as it can give an impact towards the research. The proper testing, procedure and equipment need to be prepared before the testing started to take place. Since peat soil is different from other soil types due to the presence of the organic material. Hence, the right testing method and procedures need to be planned thoroughly. Further more,
a professional drone pilot has crucial task to complete the work which from here number of errors can be minimized. The procedure to flight the drone also needs to be study thoroughly before to take off the drone on the research area.

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