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Research article

Unmanned aerial vehicle imaging application for crop health in rice field

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ABSTRACT

Precision agriculture is now a topic that attracts many researchers due to the important of food security. In this topic, using the Unmmaed Aerial Vehicle (UAV) for pesticides, monitoring and mapping are under consideration. In addition, the combination of UAV and multi-spectral camera for imaging has been extensively used for vegetation mapping in the farm. This paper aims to introduce a method for mapping fields by using the multispectral camera mount on an UAV. Ariel images have been captured by multi-spectral Sentera camera mounted on Phantom 4 Pro. Successive images, including the NDVI spectral images and NDRE spectral images with GPS information, are the output of the Sentera camera. A combination of the UAV imaging and image processing techniques were used to create the rice planting area mapping. Agisoft software was used to create the Ortho-mosaic images of NDVI spectral image and NDRE spectral image. After that, digital maps contain information about Normalised Difference Vegetation Index (NDVI) and Normalised Difference Red-Edge (NDRE) were created. An observation area was created from the map to evaluate crop health by using these indices. This area included both the middle-stage rice field and the dragon fruits farm with cannels. The crop health is validated again by using the RGB aerial image. By comparing the maps and actual survey, the health of the rice fields is able to evaluate and improve the rice cultivation management. It seems that the NDRE value was the best indicator in visualizing the health of the rice field while the NDVI was better for the dragon fruits field. Utilizing these maps, field visits by farmers can be minimized and farmers can concentrate on the diseased location and give appropriate treatment.

Key words: NDVI images, NDRE images, rice cultivation, UAV image application, vegetation index

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INTRODUCTION

Any object on the earth's surface has an electromagnetic effect. Any object with a temperature higher than absolute zero (temperature k = -273.16°C) continuously emits electromagnetic waves (radiated heat). Because the composition of objects on the earth's surface is different, the absorption or emission of electromagnetic waves is different, and each type of plant also absorbs and emits different electromagnetic waves. Therefore, plant health can be determined based on the different spectral characteristics of each plant based on vegetation indices[1]. Vegetation indices (VI) separated from near-infrared, infrared and red bands are intermediate parameters from which different characteristics of plants or vegetation can be seen, such as biomass, leaf area index, photosynthetic capacity, and total seasonal biomass products that the crop or plant can produce.

The Normalized Difference Vegetation Index (NDVI) is a vegetation index determined based on the different reflections of plants between the visible and near-infrared spectral channels. NDVI index was introduced the first time in 1974[2] by NASA in the project monitoring vegetation in the Great Plains with ERTS. Since this time, the NDVI index is commonly used around the world for drought monitoring, agricultural production forecasting, fire zone forecasting support, and desert attack maps. In fact, by using Landsat NDVI time series, people can estimate the changes of environment for a period of time[3]; this index was also used to study the changing environmental quality in Hong Kong from 1987 to 1995[4], visualizing forest change dynamics[5]. The NDVI value is also useful to evaluate changes ofe animal ecology[6,7]. In agriculture, the NDVI index is used to monitor crop health. The integration of NDVI to facilitate crop monitoring and provide accuracy for fertilization and irrigation, and other field treatment operations, at specific growth stages[8,9]. NDVI data is derived from Landsat satellites and it is important resources for vegetation monitoring. Althought, NDVI data from Landsat satellites are able to cover a lager area for monitoring, it could not provide exactly expected data regarding to discontinous time-series data. Therefore, unmanned aerial vehicle (UAV) imaging technologies is prefered to be a data collection method to get NDVI

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images[10–13].

Besides, Normalized Difference Red-Edge (NDRE) was first introduced in 2000 by Barnes[14]. NDRE gives a more accurate solution in a period of crop maturation than NDVI because red-edge light can pass through the leaves far deeper than red light[15,16]. Although each index can explore the potential health of vegetation indices, the combination of NDVI and NDRE indices can improve surveying techniques and decision making processes in farming.

In this study, NDVI and NDRE images taken from Sentera camera mounted on drones have been analyzed and evaluated the growth level as well as the health of rice field in the study area. Data point out the wealthy and unwealthy location in the paddy field. Based on that, the requirements for the cultivation conditions of the paddy field need to be proposed to improve.

MATERIALS AND METHODS

Research location

The study area belongs to My Lac ward, Thu Thua district, Long An province, as shown in Figure 1. In this area, both rice and dragon fruit field have been growing. The drone is only set to take photo in the rice field.

Methodology

Image acquisition

Double 4K Precision NDVI + Precision NDRE camera from Sentera is mounted on Phantom 4 Pro for capturing the image of rice field. Field Agent software has been used for automatic capturing the image. Capture date is October 31st, 2021. The drone setting parameters in Field Agent software are shown in Table 1.

Image processing

Aerial photography is taken every 2 to 3 seconds during flight time with 70% of the area overlapped. Output of flight process includes 2 separate dataset of successive images: the NDVI dataset and NDRE dataset which have the same of 427 photos. They also include photo information: latitude, longitude and rotation angle (rolling, pitching and yawing) in decimal degrees. An orthomosaic image, which removes the geometric distortion and stitching overlap area, is created from successive images by using Agisoft Metashape Pro software. The process includes: add photo, align photo, build dense cloud, create digital elevation model (DEM) and export the orthomosaic photo.

- Add photo: import photos of the observation area.
- Align photo: The interior and exterior orientation parameters are given so the camera calibration is taken easily. After that, the position of photos is aligned in sequence.
- Build dense cloud: the dense point generates the depth maps using the stereo matching. The depth map is calculated based on the overlapping image pairs considering their ralative exterior and interior orientaion parameter with bundle adjusment. In this experiment, the overlapped area between each image is 70%.
- Digital elevation model (DEM): DEM represent the topographic surface including all objects of the observation area. It is conducted by the output of dense cloud points. Because the GSD value and GPS position is known, geographic projection method is chosen to build the DEM.
- The orthomosaic photo: the output of the DEM. This is an aerial photograph of the surveying area such that the scale is uniform, the ratio is same with the GSD value.

These steps are conducted with NDVI and NDRE dataset images (Figure 2).

Normalized difference vegetation index

NDVI is a method crop health by measuring the index of plant "greenness" or photosynthetic activity, and is one of the most commonly used vegetation indices. NDVI is a great general indicator of crop health, which help establish measurements during earlier growth stages. NDVI is a simple method of determining the overall health of durian orchards. Near Infrared (NIR) value from the collected data will hit the healthy leaves and then reflect the light back into the atmosphere. If the quality of chlorophyll is from low plants, it will reflect low NIR values. The algorithm of the mathematical NDVI analyzes the intensity of reflections from NIR and visible value (RGB). A value range from the calculated NDVI will produce a range of -1 to 1. Lower values indicate unhealthy plants as the highest rating for healthy plants according to chlorophyll quality. NDVI is calculated based on the following formular:

$$NDVI = \frac{NIF - VI}{NIF + VI}, \quad (1)$$

where NIF is near infrared spectrum and VI is visible band.

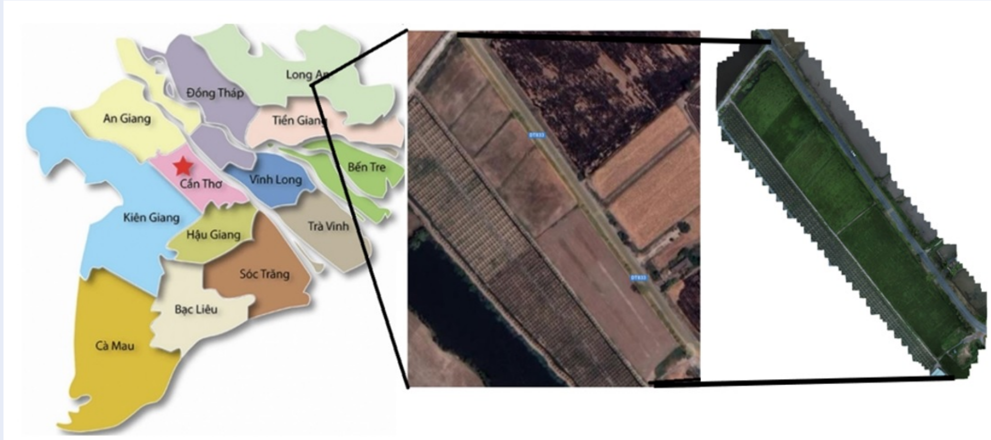

Figure 1: Research location

Table 1: Setting parameters in Field Agent software for Phantom 4 Pro V2

Area	Altitute	Speed	Overlap	GSD	Photo	Mode
1.5 ha	30 m	4 m/s	70%	0.9 cm/px	427	Polygon

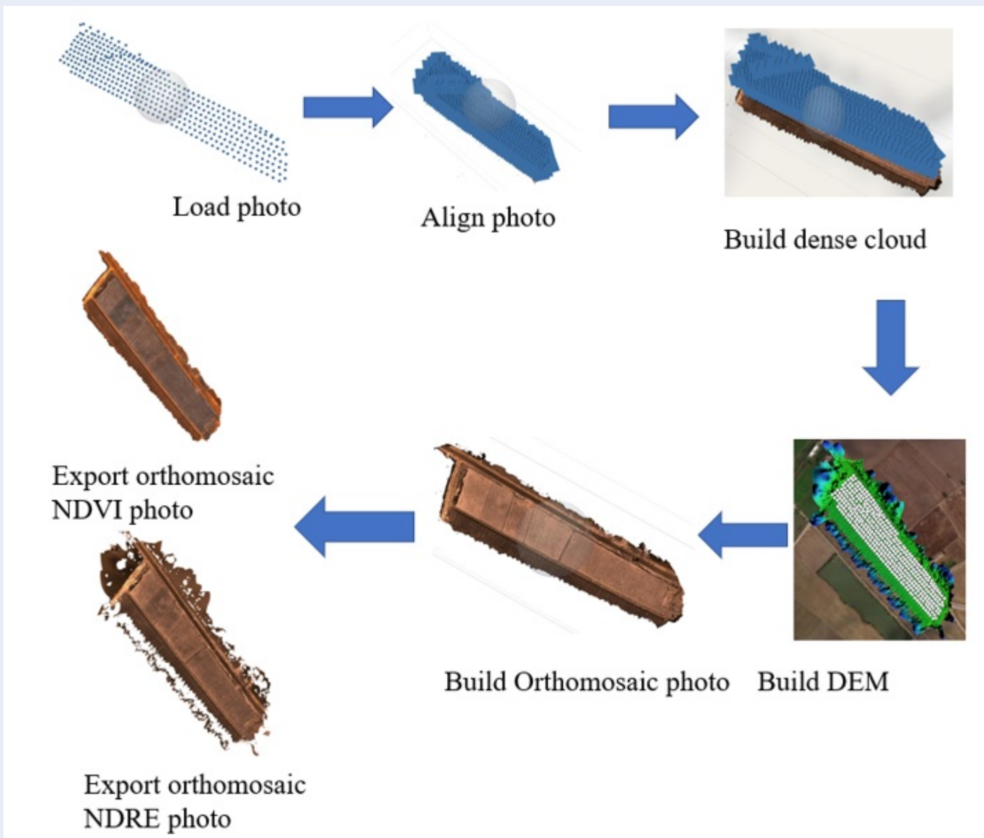

Figure 2: Orthomosaic photo step by step

Normalized difference red-edge

NDRE is a vegetation index to estimate crop health using the red edge spectrum. It is particularly useful for estimating plant health during the mid to late stages of growth when chlorophyll concentrations are relatively higher. The Red Edge sensors are able to detect changes in chlorophyll content within the leaf and through the plant canopy, making it more effective in later crop stages where NDVI tends to become saturated. NDRE is calculated based on the following formular:

$$NDRE = \frac{NIF - R}{NIF + R}, \quad (2)$$

where NIF is near infrared band and R is visible red band.

RESULTS AND DISCUSSION

Figure 3 shows the orthomosaic images of survey area. The image is in NDVI image, with very high resolution at 33603x25437 pixels. From this image, the boundary of each rice field can be observed easily. From this orthomosaic photo, it is easy to observe and calculate the value of NDVI and NDRE of distinct rice area. To evaluate the accuracy of the NDVI and NDRE equation, one observation area is generated (green rectangle in Figure 3).

The observation area includes two rice field, some dragon fruit trees and irrigation system. Figure 4 shows the observation area, NDVI distribution and NDRE distribution of this area. In case of NDVI, the distribution of 2 rice fields is similar with ranging between 0.7 to 0.8 and the value of the irrigation system is at 0.2. The dragon fruit trees can be seen separately, also share the similar level of NDVI distribution with the rice field, at 0.8.

The value of NDVI ranges between -1 and 1; and the healthy vegetation has high NIR reflectance and low VI reflectance. In this case, the value of rice field and dragon fruit trees was about 0.8, which means they were in a healthy situation. In addition, in case of dragon fruit farm, the plants can be seen clearly which means there was no grass and the farm was cleaned clearly.

In case of NDRE, rice field value is at 0.4 to 0.6 and the value of irrigation system is at 0.2. The distribution of dragon fruit tree is into a group and the value ranging betwwen 0.4 to 0.6.

NDRE value also ranges between -1 and 1; high NDRE value means the plants is high Nitrogen and high biomass. In this case, NDRE distribution is between 0.4 and 0.6 for rice field, which means it was in the middle stages. Similarly, the dragon fruit orchid was also in the middle period. To validate the NDRE distribution, the RGB image of the observation area was used (Figure 5), it is clearly that the rice field and dragon fruit orchid was in the middle stage.

Figure 5: RGB image of the observation area.

In discussion, the value of NDVI distribution is also nearly sarturated but the value of NDRE distribution can increase, so it seems that the NDRE is better indicator than NDVI to visualize the rice field. In contrast, the NDRE distribution in dragon fruit is much bluured out soils than that of NDVI values, so it seems that the NVDI value is better than NDRE value in the dragon fruit orchards.

CONCLUSIONS

In this study, NDVI and NDRE distribution have been used for analyzing and evaluating and producing a visual digital map of chlorophyll content both rice field and dragon fruit field. It is seems that NDRE value is the best indicator of vegetation health in dragon fruit orchards. Compared with the actual survey, the NDVI and NDRE indexes accurately assess the health of each dragon fruit tree. Farmers benefit from the use of these maps as field visits can be minimized. Using these maps, farmers can focus on stressed plants and provide appropriate treatment. The digital map was created to visualize the health of both dragon fruit and rice farming.

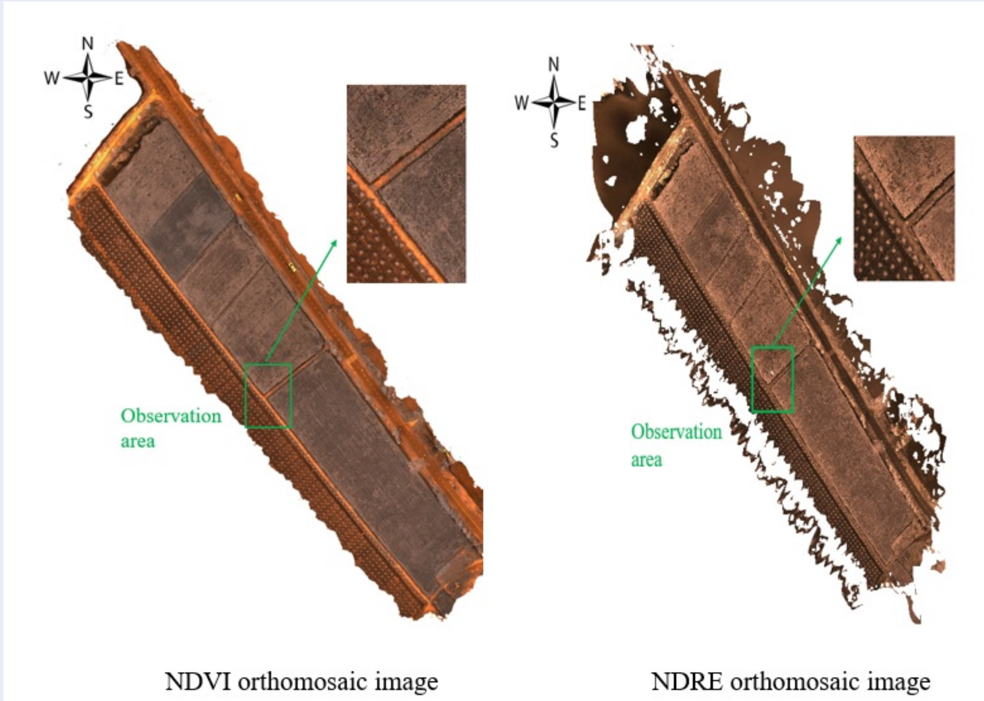

Figure 3: Orthomosaic image NDVI and NDRE of the rice field and observation area.

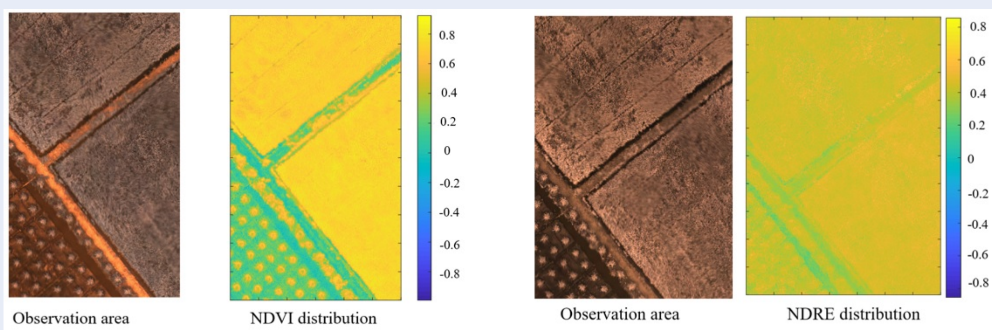

Figure 4: Observation area and NDVI distribution

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ABBREVIATION

DEM: Digital Elevation Model
NDRE: Normalised Difference Red-Edge
NDVI: Normalised Difference Vegetation Index
NIR: Near Infrared
RGB: Red, Green, Blue
UAV: Unmanned Aerial Vehicle
VI: Vegetation Indices

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

CONTRIBUTION

Van Huu Bui: data acquisition, proposed method, evaluate data.

Quang Hieu Ngo: data acquistion, proposed method.

Huu Cuong Nguyen: image processing method.

Trong Hieu Luu: estimate NDVI and NDRE distribution.

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Bài nghiên cứu

Ứng dụng không ảnh để đánh giá sức khỏe cây trồng trên ruộng lúa

Bùi Văn Hữu[1], Ngô Quang Hiếu[1,*], Nguyễn Hữu Cường[1], Lưu Trọng Hiếu[2]

TÓM TẮT

Nông nghiệp chính xác đang là xu hướng nghiên cứu hấp dẫn nhiều nhà khoa học do tầm quan trọng của an ninh lương thực lên toàn thế giới. Trong chủ đề này, sử dụng máy bay không người lái (UAV) để phun thuốc trừ sâu, giám sát các điều kiện và xây dựng bản đồ đang là chủ đề chủ đạo. Bên cạnh đó, sự kết hợp giữa UAV và máy ảnh đa quang phổ để lập bản đồ thực vật tại vùng trang tại cũng đang nhận được sự quan tâm. Bài báo này trình bày một phương pháp xây dựng bản đồ bằng cách sử dụng máy ảnh đa quang phổ được gắn trên UAV. Không ảnh phổ được chụp từ máy ảnh phổ Sentera được gắn trên Phantom 4 Pro. Các ảnh liên tiếp, bao gồm ảnh phổ NDVI và NDRE có thông tin GPS, là kết quả thu thập được từ máy ảnh phổ. Tiếp đó, một phương pháp xử lý ảnh để xây dựng bản đồ từ các ảnh này được đề xuất. Phần mềm Agisoft được sử dụng để xây dựng ảnh Ortho cho ảnh phổ NDVI và ảnh phổ NDRE. Tiếp đó, một bản đồ số thể hiện chỉ số thực vật khác biệt chuẩn hóa (NDVI) và chỉ số khác biệt chuẩn hóa rìa đỏ (NDRE) được tính toán. Một vùng quan sát từ vùng ảnh phổ sẽ được sử dụng để đánh giá tính chính xác của các hệ số này. Vùng quan sát bao gồm lúa giữa mùa, thanh long và các kênh đào dẫn nước. Kế quả đánh giá sức khỏe thực vật được kiểm định lại bằng ảnh màu RGB. Bằng cách so sánh kết quả trên bản đồ, sức khỏe của cây lúa có thể được đánh giá và cải thiện quản lý và canh tác lúa. Kết quả cho thấy chỉ số NDRE đánh giá tốt cho ruộng lúa trong khi chỉ số NDVI lại tốt hơn cho vùng thanh long. Bằng cách sử dụng bản đồ này, nông dân có thể giảm thiểu thời gian thăm đồng và tập trung hơn vào vị trí bị bệnh cũng như đưa ra các phương pháp trị bệnh thích hợp.

Từ khoá: ảnh NDVI, ảnh NDRE, vùng trồng lúa, ứng dụng UAV, hệ số thảm thực vật

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