Comparison of NDVI and NDRE Indices to Detect Differences in Vegetation and Chlorophyll Content

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Abstract

This paper reports a field-scale study to detect differences in the amount of vegetation and chlorophyll content of crops using an unmanned aerial vehicle (UAV) fitted with a multispectral camera. The purpose of this study, on the experimental farm of Niigata University, Niigata, Japan, was to identify poorly-growing areas of vegetation that might require additional soil fertilizer. The normalized difference vegetation index (NDVI) and normalized difference red edge (NDRE) were obtained from five spectral band images (red, green, blue, infrared (NIR) and red edge (REDGE)) that were processed by software into a full image map. We used the image map obtained to analyze the farmland and identify variations in the greenness of plants. We compared two layers with different indices and indicated differences in vegetation activity for NDVI and NDRE. NDVI showed visible green color wherever vegetation was present. With NDRE we observed crops with low chlorophyll content, indicating nitrogen limitation in the leaves. These observations demonstrate the efficacy of using NDRE as a sensitive index for monitoring chlorophyll content. Therefore, we propose that different indices may be most useful for different crops, plant density, seeding rates and growth stages.

Keywords : UAV, NDVI, NDRE, Chlorophyll

I. Introduction

Until recently, unmanned aerial vehicles (UAVs), unmanned aerial systems, remotely piloted vehicles or also often called drones, were mostly developed and used for military purposes. These systems are aircraft with remote controls. They are equipped with precision sensors, for example, inertial navigation systems, such as an accelerometer and a gyroscope, for recognizing the location of an aircraft in airspace. A microcomputer helps automate the flight process and simplifies navigation in piloting. Moreover, the control is accompanied by special software, which makes it
easy to manage all systems. For a specific type of tasks, auxiliary sensors and cameras of different ranges are used (Boiarskii and Hasegawa, 2017).

The necessity to improve the quality and profitability of agricultural production stimulates farmers to introduce new technologies. In recent years, unmanned aerial vehicle (UAV) technology has become a routine tool for farm management. For example, UAV monitoring can be used to produce map data for early-season soil analysis, which is useful in planning seed planting. It is a helpful step in the evolution of agricultural management systems toward increased efficiency of land use (Whelan and McBratney, 2012).

The use of NDVI in agriculture is beginning to develop rapidly, and the issue of introducing these technologies into agriculture sphere is becoming urgent. Modern hardware, such as multispectral cameras, make remote analysis more informative, and significantly expand their range of applications (Boiarskii and Hasegawa, 2017).

The multispectral camera is a useful tool for field monitoring, as it can provide data for use in crop forecasting, yield predictions, crop status mapping, and detecting weeds, diseases and nutrient deficiency (Berni et al., 2009).

Indices are defined as a ratio of the difference between the reflectance of different spectral bands, which provide different data layers. Decreasing photosynthesis rates and changes in leaf mesophyll are usually associated with decreasing reflectance of wavelengths within the NIR spectral range (Carter and Knapp, 2001).

This paper describes the use of a UAV to analyze crop vegetation on an experimental farm. We compared two indices, the NDVI and NDRE and examined the indices for potential application in agronomy and further research. The purpose of this study was to identify poorly-growing areas of vegetation that might require additional soil fertilizer and to visualize foliar nitrogen to indicate plant health.

The study site

The city of Niigata, Niigata Prefecture, Japan is located on Honshu main island, about 350 km northwest of Tokyo. Niigata Prefecture is one of Japan’s major rice-growing regions, producing premium high-quality rice, and is also important for growing soybean, vegetables and berries.

In 2014, the Japanese government appointed the city of Niigata as an agricultural special zone. This prompted Niigata City to invite companies to enter the agricultural business there, and also allowed the city to experiment in innovative agriculture.

The study site was a 15-hectare set of crop trial plots, such as vegetables, soybean, fodder crop and seedling, at Niigata University’s Muramatsu experimental station, located at in Gosen, Niigata Prefecture (Fig. 1). In this study site we detected deviation on example of cedar seedlings plot.
II. Methods

We used UAV model Matrice-100 (rotary wing drone), manufactured by DJI, China (Fig. 2(a)). Rotary wing drones allow for vertical takeoff, hovering, and closer crop inspection. Rotary wing drones are easier to control manually than fixed wing drones. The UAV had a multispectral RedEdge camera (MicaSense, USA) that captured five spectral bands (red 668 nm, green 560 nm, blue 475 nm, NIR 840 nm and red edge 717 nm).

The additional bands of the camera are REDGE and NIR. The NIR band is in the spectral region behind the red band and is useful in detecting state of plant health. Another constituent spectral region is the REDGE. This band is located between the red band and the NIR band. Plants increase the reflection coefficient between the red and NIR region, which leads to a sharp increase in the reflection coefficient through the REDGE band. Different combinations of the bands allowed us to observe different analytical layers (Fig. 2(b)).

![UAV and examples of data layers (5-bands, dtm and dsm layers)](image)

Fig. 2. UAV and examples of data layers (5-bands, dtm and dsm layers)
In this study we used NDVI and NDRE indices (see Results for definitions of the indices) to evaluate crop vegetation activity and chlorophyll content. We tested the UAV at various altitudes and speeds. In this study the UAV flew at 100 m altitude at 11 m/s. Each UAV mission was planned using Pix4Dcapture software on an Apple iPad (Fig. 3). Mission time was 15 minutes.

The camera focal size was 5.5 × 4.8 mm, and the ground sampling distance from the 100 m altitude flight was 6.82 cm/pixel. Front overlap and side overlap of successive flight paths were set at 75% and 80%, respectively. We obtained 1805 raw images in five-band or 361-point images (Fig. 4). We selected high overlap to increase the precision and quality of the output data.

There are numerous options for flight management software, many of which are free applications that can be used. The preferred application will vary depending on the characteristics of the drone and the sensors, but, as a rule, the user has several compatible options, between tools and software.

The UAV images were processed in Pix4Dmapper software into stereo pairs using photogrammetry algorithms. The stereo pairs consisted of images with different geolocations. The stereo image pairs were used to generate a point cloud (3D points) from which we derived an orthophoto plan.
We processed the captured images using Pix4Dmapper software to obtain five-band maps. Red, green and blue (RGB) colors cannot be recognized by the human eye from the mixed five-band map. The raw five-band map is represented as a gray-scale image (Fig. 5).

III. Results and Discussion

Several different index values have been used in agriculture to analyze crop health at certain growth stages, the presence of weeds and crop moisture status. The use of remote sensing data offers the potential to improve the prediction of crop diseases and weeds (Homolova et al., 2013). Indices are used to contrast the stronger chlorophyll absorption of red wavelengths with the higher reflectance of NIR wavelengths for
NDVI, and the red edge (REDGE) wavelength to indicate chlorophyll content (Carlson and Ripley, 1997).

A formula must be applied to the raw data to obtain agronomically useful information. We used QGIS (free version) software to calculate NDVI and NDRE indices. NDVI is defined as a ratio of the difference between the NIR band and the red band versus the sum of the two bands (Eq. 1). NDRE is defined as the same ratio as for NDVI, but using REDGE instead of the red band (Eq. 2) (Tucker, 1979).

\[
NDVI = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \tag{1}
\]

\[
NDRE = \frac{\text{NIR} - \text{REDGE}}{\text{NIR} + \text{REDGE}} \tag{2}
\]

We compared two layers with different indices and indicated differences in vegetation activity for NDVI and NDRE. We found a uniform distribution of NDVI wherever vegetation was present. NDVI provides an indicator of the amount of healthy vegetation, measured on a scale from 0 to 1, where the closer to the index 1, the higher the amount of vegetation (Fig. 6). On our field we observed crop without visible depressed greenery. This index is most useful at early and middle growth stages: it indicates the health of crops (such as poor growth or crop diseases) as measured by reflectance of NIR and red bands, which are both commonly used to indicate the greenness of actively growing leaves.

![Fig. 6. NDVI layer](image)

From NDVI and NDRE indices we detected differences in the greenness of crops and chlorophyll content. On example of cedar seedlings plot the NDVI showed visible green color wherever vegetation was present, with relatively little variation in index value (Fig. 7).
The REDGE spectral band, as provided by the MicaSense company in their RedEdge camera, was used in our research to indicate chlorophyll content (Fig. 8). The REDGE wavelength of 717 nm provides a sensitive indicator of chlorophyll content in leaves (how green a leaf appears), density of leaves, and soil background effects. NDRE image we are able to see lower readings where less Nitrogen was applied. Chlorophyll has maximum absorption in the red band wave, and so red light cannot penetrate beyond a few layers of leaf cells. Leaves are more translucent to red-edge light than red light: the REDGE wavelength penetrates a leaf much more deeply than red or blue wavebands. Therefore, NDRE is more suitable for middle and late growth stages, when crops have accumulated high concentrations of chlorophyll in the leaves and red light will penetrate poorly.
With NDRE we observed cedar seedlings plot with low chlorophyll content, indicating nitrogen limitation in the leaves, in areas where NDVI gave no such indication (Fig. 9). Therefore, we propose that different indices may be most useful for different crops, plant density, seeding rates and growth stages.

In this study, we compared two indices in their usefulness for detecting differences in the observed data. NDVI is most effective when used to analyze large areas of land for vegetation density and how green a crop appears. It enables evaluation of the health of crops, effectiveness of cultivation and seeding rates. NDRE enables visualization of chlorophyll content in leaves. It allows identification of areas that might benefit from chemical analysis of the soil or that may have additional fertilizer requirements (especially nitrogen) or may have had improper application of fertilizer.

In future studies we will compare data obtained by UAV with data from a handheld chlorophyll meter (SPAD) at ground level.

We proposed comparison of other indices such as Green NDVI (GNDVI), Green-Red Vegetation Index (GRVI) and Optimized Soil Adjusted Vegetation Index (OSAVI) that may increase the precision of analyzing plant health.

IV. Conclusions

1. UAVs are useful for field surveying and high-resolution monitoring. They produce precise map data for early soil analysis, which is useful in planning seed planting.
2. In this study, we used NDVI and NDRE to analyze an experimental site and detect areas of poorly growing vegetation.
3. We compared the two indices to determine the effectiveness of using different wavelengths for agronomic monitoring.
4. The data layers we obtained and processed will be communicated to farmers to help them evaluate areas where it may be necessary to conduct a chemical analysis of the soil and additional application of fertilizers.
5. NDRE index can made important contribution to world agriculture production, not only for improving yield, but introducing solution in serious environmental

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problems, it is Nitrogen application. Nitrogen management technologies may become new standard in agriculture industry in a compartment with the use of indices.

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