Analysis of Vegetation Characteristics of Regional Soybean and Paddy Rice Fields Using UAV Images and Farm Maps

Dongho Lee1 and Jonghwa Park1,*
1 Department of Agricultural & Rural Engineering, Chungbuk National University, Rep. of Korea

*Corresponding author

Abstract. Remote sensing (RS) and GIS together provide an efficient and inexpensive way to assess vegetation characteristics and cultivated areas. Precision vegetation mapping provides important information for understanding crop conditions through the calculation of the vegetation index. In this study, a multispectral sensor was installed on an eBee (Sensefly), which is suitable for wide area photography taken by an unmanned aerial vehicle (UAV). UAV imagery acquisition was used to obtain spatial information on soybean and paddy rice cultivation areas in a wider region. The study area selected was Gimje, which is in the southwest of South Korea. Based on the designation of main areas according to the Ministry of Agriculture, Food, and Rural Affairs (MAFRA), the area was selected considering the cultivation area, production volume, number of farm households, and self-sufficiency ratio. The main producing areas are soybean cultivation areas defined as a city or county with a cultivation area of 30~1500 ha or more, respectively. The identification of the cultivation area of soybeans was made based on images taken in early September, when the growth characteristics of soybeans were clearly distinguished from other crops. The accuracy of the soybean and paddy rice cultivation area identification was improved by using the farm map (FM) prepared by the MAFRA in South Korea. The NDVI was analyzed based on the two periods of high growth activity of soybean and paddy rice. The accuracy of the cultivated area was improved by using the UAV images and the FM prepared by the MAFRA. As a result, this study shows that UAV images can be used more effectively by linking GIS with the FM as a basic map.

Keywords: remote sensing; vegetation; soybean; paddy rice; farm map; unmanned aerial vehicle.

1. Introduction

Soybean is a crop that has three major nutritional components: protein, fat, and carbohydrate. Among them, the percentage of protein is much higher than that in meat (20%) and wheat (10%). Therefore, soybean is known as a high-protein food. The global soybean market was estimated at $305.70/ton as of 7 September 2018. As the awareness of the health benefits of soybeans is growing globally, related markets have been growing rapidly due to the surge in demand for soybean-related products. In addition, the demand for soybeans in South Korea is increasing due to the globalization of Korean culture, known as the Korean Wave. The growth and competitiveness of the soybean market is thus growing in South Korea. Considering this point, research on soybean crops, the diversification of pest management, and quality control technology are urgent points of research in South Korea. Korea has four seasons with seasonal characteristics. There are many rainy and cloudy days during the growth period of soybean, and it is difficult to acquire spatial information of crops in the hot summer. The technology that has been suggested as a solution to this problem is the utilization of UAVs (unmanned aerial vehicles) and sensors. We have been dealing with various problems related to crops by employing UAVs equipped with
sensors in agricultural applications for 6~7 years [1,2]. Korea's agriculture includes a wide variety of crops grown in a short period of time in a small area, cultivating another crop after the first harvest. In order to understand the growth characteristics of crops, it is very important to understand the characteristics of spatial distribution over a wide area in a certain period via continuous monitoring. Since 2014, the Ministry of Agriculture, Food, and Rural Affairs (MAFRA) of South Korea has been producing and operating a farm map (FM) for the efficient use of spatial information in agriculture. However, it is costly and time-consuming to update and upgrade the FM. To overcome these problems, there we propose a way to improve efficiency by combining the FM and UAV imagery. The purpose of this study is to apply images of agricultural areas photographed by a UAV to the FM for the cultivation and management of crops such as soybean and paddy rice.

2. Materials and Methods

2.1. Field Experimental Area
This study was carried out during 2018 in soybean and paddy rice cultivation area (35°44’~48’N, 126°47’) located in the area of Gimje city, Jeonbuk, South Korea (Figure 1). The study area is located in Honam Plain, a granary zone. Topography formation is alluvial plain, and soils are composed of Jeonbuk Tong, so they are mainly used as paddy fields. This area is the largest rice and soybean producing area in the country, with the Dongjin River running to the west and the Wonpyeong Stream flowing in the center, and irrigation channels related to farming are developed. The study area is 36.8 square kilometers which consists of 48 villages, the number of households is 1,500, and the population is 2,800.

2.2. Materials
The aerial images of the UAVs used in this study were collected using a small, lightweight fixed wing UAV (eBee, Parrot, France) with a body weight of around 700 g. This aircraft can automatically set the flight path and is equipped with an automatic landing function, so it is safe and easy to take images. The vegetation index was measured using a sensor (S110, Cannon, Japan) capable of photographing green, red, and near-infrared (center wavelength: green 525 nm, red 625 nm, NIR 850 nm). The aerial photographs were taken three times (28 May, 28 August, and 16 October 2018), and the spectral characteristics of the sites were investigated using a spectroradiometer (ASD).

The captured images were combined with location information on the elevation, direction, etc. of the aviation body using an image pre-processing program (Emotion, Parrot, Swiss) (Image Tagging). Image synthesis and reflectance were calculated using mosaic image and reflectance image in the Pix4D mapper (Pix4D, Swiss) program. Figure 2 shows the process of the image being taken by the UAV and multispectral sensors [3]. Table 1 shows the specifications of the employed UAV system and sensors. The UAV measurement accuracy was minimized by using the FM and the GPS-RTK method.
2.3. Methodology

The farm map (FM) is a cropland electronic map that is consistent with satellite or aerial images, filling the need for the production of a map of agricultural land with the identification of specific crop fields. The need for an FM was raised due to the inconsistency between the cadastral map of South Korea and the actual farmland boundaries. The accuracy of the FM image reading was improved by a professional reader who read the image data and divided the boundaries. The image reading was separated into seven land use classifications: rice paddy, crop field, orchard, facility, ginseng planting area, resting area, and abandoned farming area. Figure 3 shows the flow chart of the research conducted using UAV images and the FM.

Table 1. UAV (unmanned aerial vehicle; eBee) specifications

| Item               | Specifications                        |
|--------------------|---------------------------------------|
| Weight             | 690 g                                 |
| Size               | 960 × 800 × 160 mm                    |
| Material           | EPP foam                              |
| Sensors            | GPS, IMU, Pitot                       |
| Image sensor       | Cannon Powershot S110 (Red, Green, Blue, NIR) |
| Max flight time    | 50 min                                |
| Flight altitude    | 260 m                                 |
| Ground resolution  | 0.08m                                 |

Figure 2. The process of the image taken by UAV and sensors

Figure 3. Flow chart of field measurement and analysis
The growth conditions of soybean and paddy rice were investigated by selecting 30 parcels. Field surveys were conducted, investigating nine items such as plant length and height. The NDVI was calculated as the difference between the reflectance in NIR and Red wavelengths, as shown in Eq. (1):

$$\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}$$

where $\text{NIR}$ is the near-infrared wavelength band and $\text{Red}$ is the visible red wavelength band. The NDVI values ranged from $-1$ to $+1$.

3. Results and Discussions

3.1. Precision Farmland Mapping

The cadastral map is a plan map made by the state to indicate the location, lot number, ground point, and boundaries of farmland. However, the cadastral map in the agricultural field has the problem of not showing accurate agricultural boundaries. Most of the study area is agricultural area, but it is difficult to grasp the cultivation area and yield because land ownership relation is shown separately from the cadastral map of cropland, simply because land ownership relations are complicated. Therefore, we used the FM, which is a farmland electronic map that divides the boundaries of agricultural fields and agricultural realities through aerial imagery, satellite imagery, and field survey. The FM consists of major items such as the PNU code, parcel coordinate, read code, readjustment attribute of arable land, and parcel area (Figure 4). We used the WGS 1984 UTM Zone 52 as the coordinate system of the UAV for the unification of the coordinate system. Figure 5 is a DSM (digital surface model) composed of synthesized RGB images captured by UAV in the study area. The FM showed very high accuracy because the study area was composed mostly of agricultural areas.

Figure 4. Comparison of the farm map (FM) and cadastral maps boundaries of farmland.

Figure 5. Comparison of the farm map (FM) and digital surface model (DSM) of RGB images acquired by UAV.
3.2. Variation Characteristics of Vegetation Index of Soybean and Paddy Rice

The growth characteristics of soybean vary greatly depending on cultivation area and seeding time (Figure 6). In this study, the vegetation index (NDVI) analysis was determined for two different growth stages (R4 and R7) of vegetation activity. The sowing time was similar for across the area but the difference was about 15 days depending on previously cultivated crops and cultivars. In seeds sown in mid-June showed a higher vegetation index than those sown in late June. The NDVI was close to 0 at the early stage of growth. In addition, 2018 was considered to be largely characterized by the effects of high temperature. The growth characteristics of soybean and paddy rice cultivation areas were analyzed by field survey using a spectroradiometer (ASD) (Figure 7) and the NDVI was determined using images taken by UAV. As a result, there was a slight difference in each parcel, but the field survey value obtained by the spectroradiometer (ASD) tended to be higher than that obtained by UAV. These results indicate that the observation distance is high and the atmospheric effect between the sensor and soybean field affects the accuracy of the information obtained by UAV.

Figure 6. Soybean growth stages.

Figure 7. Spectral reflection characteristics of soybean growth stages.

3.3. NDVI of UAV and FM Merged Imagery

R4-NDVI obtained by the merging of UAV and FM images showed very good growth characteristics of soybean (Figure 8). The R4 growth stage is the period in which the soybeans are formed full pods and the activity of soybean plants is the most active. The NDVI of this period showed a very high value overall (Figure 9). The NDVI distribution histogram taken at the R7 stage showed that the soybean plants were mature and the soybean activity decreased, so the NDVI was lower than that in the R4 stage (Figure 10).
3.4. Extraction of Cultivation Area Using a Hybrid (Hierarchical and Object-based) Classification Technique

Table 2. Error matrix analysis results.

| Classification | UAV image classification | User Accuracy(%) |
|----------------|--------------------------|------------------|
| Field Survey   |                          |                  |
| Bean (Yellow)  | 548                      | 85.36            |
| Bean (Green)   | 23                       | 97.58            |
| HARVEST        | 1                        | 92.05            |
| Rice           | 67                       | 74.69            |
| Column Total   | 619                      | 84.21            |
| Producer Accuracy(%) | 88.53  | 81.76  |
| Overall Accuracy(%) | 87.10  | 76.10  |

The classification of crops was made by object classification based on the spectral characteristics of Red, Green, Blue, and the NDVI for each parcel. Since Seopo-ri, Juksan-myeon, Gimje-si cultivates only two crops (soybean and paddy rice), the object class was divided into four classifications. An accuracy analysis was performed using an error matrix. This method is mainly used to evaluate the accuracy of land cover classification based on satellite and UAV images. The classification accuracy was correct for 992 parcels out of 1178 parcels. The overall accuracy was 84.21% and the Kappa coefficient was 0.75. The classification accuracy showed Bean (Green) > Harvest > Bean (Yellow) > Rice. The accuracy was 97.58% > 92.05% > 85.36% > 74.69%, respectively. Therefore, the classification accuracy of soybean, which showed normal growth, was the highest.
4. Conclusion
Vegetation monitoring is very important to evaluate current growth conditions and to identify potential vegetation vitabilities. Due to their low cost, high precision, and simplicity, UAVs have been widely used in the evaluation of agricultural fields and the quantification of growth conditions. UAVs are gaining popularity for the purpose of vegetation cover estimates, as they can reduce the effort, time, and additional interpretation of fieldwork in the future. We acquired NDVI values from UAV image data responding to site-based surveys. This study was carried out to investigate characteristics of growth stages of soybeans and to investigate the effects of conventional field survey methods compared to UAV techniques. We found that it is important to know the exact timing of the greatest growth change and to know how to use various combinations of information to determine growth characteristics. This study shows that the area of cultivated paddy rice and soybean can be identified accurately. In order to predict the growth characteristics and yield of soybean and paddy rice, the proposed UAV image and FM integrated method can be very useful.

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