A Study on Growth Condition Analysis of Rice Using Drone

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***Abstract*—Self-sufficiency of food is one of the most important target for Japan, however, because of decreasing the population of agriculture sector due to the progress of aging, it is difficult to realize this target. One of the main reasons of decreasing the population in agriculture is hard work in the field and requirement of experience. Our study focuses on supporting aging farmers, weekend farmers and new comers in the agriculture to reduce labor and cost, and providing system to compensate experience by using ICT. For this purpose, we are developing technology to evaluate growing condition of rice and vegetables in a field by using a drone and a multi-spectrum camera. By using this technology, it might be possible to reduce the hard work under the scorching sun and to support unexperienced young farmers. In this paper, we mention the outline of the technology that we used and the result of feasibility study to analyze growth condition of rice using drone. We measured normalized difference vegetation index (NDVI) and normalized difference red edge index (NDRE) from a drone and analyzed the data to estimate growth condition of rice. We found the it was possible to find the area where growth is delaying and estimate heading day.**

***Index Terms*—Growth Condition, Drone, Rice, Multi-spectral Camera, NDVI, NDRE.**

I. Introduction

Self-sufficiency of food is one of the most important target for Japan, however, because of decreasing the population of agriculture sector due to the progress of aging, it is difficult to realize this target. One of the main reasons of decreasing the population in agriculture is hard work in the field and requirement of experience. Our study focuses on supporting aging farmers, weekend farmers and new comers in the agriculture to reduce labor and cost, and providing system to compensate experience by using ICT.

In Japan, work force lack becomes the serious problem because of aging especially in agriculture sector, so that, introduction of robot technology and ICT is expected. Also such technologies are useful to promote employment to agriculture, especially youths and women with a little experience since agriculture requires know-how [1]. Therefore, we examined a growth condition analysis technology of rice using a drone in this paper.

Currently, satellites with sensors that can observe earth by taking pictures in various wavebands are used for growth condition analysis. By using measured data, we can calculate Normalized Difference Vegetation Index (NDVI) that can evaluate the growing condition of the vegetation. Plant, especially leaves, absorbs visible light but does not absorb near infrared light and reflects it. NDVI uses the characteristic and evaluate the condition of vegetation. We can estimate yield of rice [2] and protein contents which influences taste of rice by using NDVI [3].

However, when we use pictures taken by satellite for agriculture, there are four problems. First, sometimes ground is covered by a cloud. In the case, we can't calculate NDVI exactly. Second, cost is extremely high when we purchase pictures taken by satellites. In reference [10], average price of a picture is about $500. If we need 10 pictures to see the trend of NDVI, it costs about $5000. Analysis cost of pictures to calculate NDVI and estimate content amount of protein are additional. In some case, such additional cost requires $80 thousand to $100 thousand. Third, resolution is not so high. The finest picture has resolution of 30cm. If we would like to observe the growth of each rice plant, we require higher resolution such as 2cm. Fourth, we cannot get picture in real time. It is required at least two days to get picture. For this the duration of taking picture, a satellite can take picture of same place every two days.

Therefore, we used a small multispectral camera and a drone to take picture of rice field. By using this technology, it is possible to estimate growth condition of larger rice field. It may extend the rice field.

In this paper, we describe the results of analysis of growing condition of rice.

We introduce related work in section 2 and describe outline of growth situation investigation in section 3. Then the result of data analysis is discussed in section 4 and conclusion and the further study is mentioned in section 5.

II. Related Work

Yamagata University in Japan has developed the world first system to spread additional fertilizer by a drone based on the result of evaluation of growing condition of rice observed by the drone [5]. They took pictures of rice field from 30 m high and measured color and the number of stems of the leaf of rice plant. The resolution of the camera that they developed for this study was within 1.9 cm.

They firstly estimated variance of the amount of nitrogen absorption in the field. Then, they calculated required additional fertilizer and sprayed it from a drone. They compared two cases, one is the optimized fertilizing and another is normal (uniform) fertilizing. As the result, the optimized fertilizing method increased the amount of rice about 14~33%.

III. Outline of Growth Situation Investigation

A. Research plan

We used the farm of to the faculty of agriculture of Utsunomiya University located in Shimokomoriya, Moka-shi, Tochigi for this research. The rice field we used is 7,886.4m^2 (49.6m×159.0m) where “Yudai”, an original rice discovered at Utsunomiya University [6], is growing (Fig. 1). We planted the rice and fertilized on May 2. The rice was heading on August 3. And we harvested the rice on September 15.

We used different manure of the field east and west. We used more delayed-acting manure in the field east than west. Fig. 1 shows the size of rice field [12].

Fig. 1. The size of Rice field.

B. Measuring method / date and time

In this study, we use multi-spectral camera “Sequoia” [11] that can measure four waveband. Detectable wavebands of Sequoia are described in TABLE I. The weight is 72g. It is possible to carry on a small drone and taking picture any time. Also, resolution of the camera of Sequoia is 1.2 million pixels. A photograph taken from 70m high means 8.6cm/px and from 15m, 2cm/px. Sequoia costs about $4000, it is almost equivalent to 8 pictures taken by satellite.

In this study, the drone fly 30m high from the rice field. The typical flying patter is described in Fig.1.

In addition, about 75 % of each neighbor images were overlapped based on the requirements of ATLAS [7], a cloud-based data server for agriculture operated by Micasense [8].

As our calculation, the drone can cover 400,000m^2 in 20 minutes (average flying time of a drone) if the multi-spectral camera can take a picture every second and overlap ratio is 75%.

We put Sequoia on Phantom2 as described in Fig. 2. Fig. 3 shows size of Sequoia. TABLE I shows the detectable wavebands of Sequoia.

TABLE II shows the date and time when we took picture from a drone in 2016.

Fig. 2. Phantom2 and Sequoia.

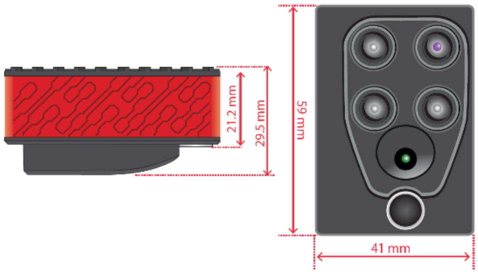

Fig. 3. Size of Sequoia.

TABLE I. Detectable wavebands at Sequoia.

Waveband	Wavelength(nm)	Band width(nm)
Green (G)	550	40
Red (R)	660	40
Red Edge (RE)	735	10
Near InfraRed (NIR)	790	40

TABLE II. Date and time of observation.

Times	Date	Starting time of measurement
1	June. 15	13:38
2	June. 22	10:45
3	July. 1	11:12
4	July. 4	17:27
5	July. 11	9:04
6	July. 13	13:01
7	July. 15	9:13
8	July. 19	9:05
9	July. 21	8:42
10	July. 25	8:59
11	July. 29	9:29
12	August. 1	8:58
13	August. 4	9:04
14	August. 10	13:50
15	August. 16	8:45
16	August. 19	9:15
17	August. 24	8:33
18	August. 26	8:27
19	August. 29	9:05
20	September. 1	9:12
21	September. 5	9:16
22	September 7	14:18
23	September 8	9:15
24	September 12	9:18
25	September 14	9:22

C. Methods of analysis

We uploaded the pictures to ATLAS to analyze pictures and calculate Normalized Difference Vegetation Index (NDVI) and NDRE (Normalized Difference Red Edge index). It cost \$50/month for basic access and cheaper than usual picture analysis to calculate NDVI and NDRE. It can make a mosaic images which data of the reflectance of each waveband entered. We processed a provided mosaic images by GIS software, and calculated NDVI and NDRE. Equation (1) and (2) shows calculation of NDVI and NDRE.

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

$$NDRE = (NIR - RE) / (NIR + RE) \quad (2)$$

Here, NDVI and NDRE take values from -1 to 1. The bigger value of NDVI, the more vegetation.

When we processed mosaic images by GIS software, I distributed the east side and the west side of the farm. This is because the manure which we used in the west is different from the east side.

IV. Data Analysis

A. Result of measurement

Fig. 4 to 7 shows a part of the pictures that captured by Sequoia on July 25. The whiter area in the picture means the higher reflection area.

Fig. 4. The reflectance of Green waveband.

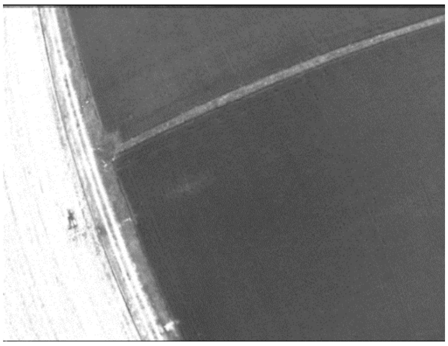

Fig. 5. The reflectance of Red waveband.

Fig. 6. The reflectance of Red Edge waveband.

Fig. 7. The reflectance of NIR waveband.

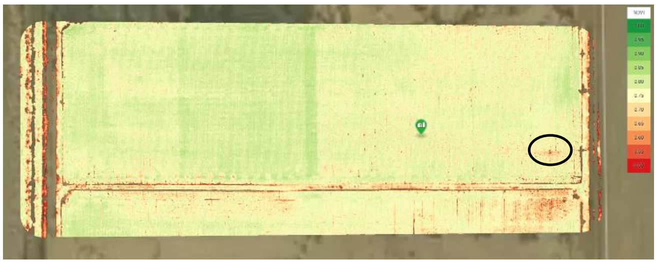

Fig. 8. NDVI map of July 25.

We uploaded the pictures to ATLAS, and ATLAS generated NDVI and NDRE maps. Fig. 8 shows NDVI map of July 25.

In the right bottom of this figure, there is an area where NDVI value is lower than neighborhood area (black circle in the picture). When we checked the rice field after receiving this result, we found that the rice plant of this part fell down and weakened.

In this way, we can discover the rice which weakens by making NDVI map using Sequoia.

B. Result of analysis

Fig. 9 and 10 show transition of each waveband of the East of the field and West of the field. The value took eastern and western overall average each.

It was found that the reflectance of the Red Edge and NIR waveband is higher than a Green and Red waveband in the East and West. This is because the reflectance in the infrared wavelength range is higher than visible light wavelength range, as mentioned above.

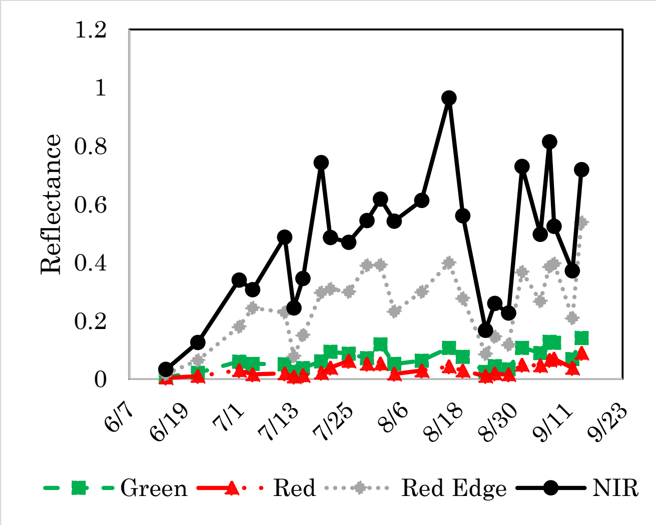

Fig. 9. Transition of each waveband of the field (East).

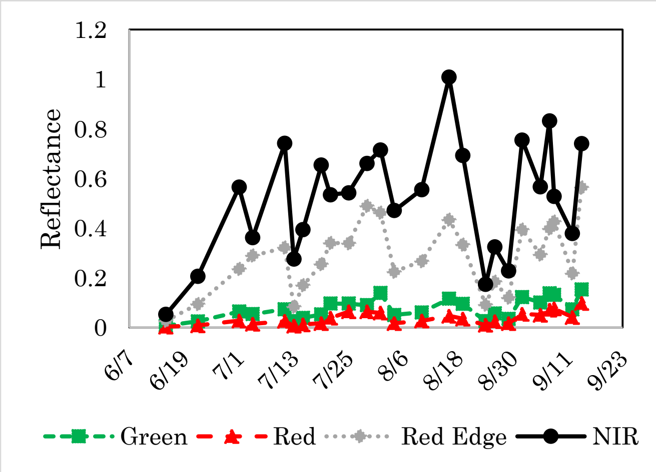

Fig. 10. Transition of each waveband of the field (West).

Fig. 11 and 12 shows transition of NDVI and NDRE of the field east and west. Each value took eastern and western overall average. The dotted line in each figure shows August 3 when rice was heading. From graph, NDVI shows tendency toward the increase until July 19 that passed from planting for 78 days in east and west (a term between Transplanting and Panicle formation in Fig. 13). NDVI reaches a peak on July 19 and falls down from the day (a term between Panicle formation and Flowering in Fig. 13). NDVI is beyond 0.9 on August 4 when one day passed from heading day and tendency to decrease later (Ripening phase in Fig. 13).

Similar to NDVI, NDRE falls down from July 19 and suddenly rises on August 4 after heading. We thought about a inclination of NDVI and NDRE, and the drop of the value from July 19 to 21. TABLE III shows inclination and fallen value of NDVI and NDRE. Each value is east and west average.

TABLE III. Inclination and Fallen value.

	Inclination	Fallen value
NDVI	-0.048	0.090
NDRE	-0.10	0.21

From the above reasons, it seems that heading begins about 14 days after time when the inclination and fallen value of graph of NDVI and NDRE is almost the value mentioned above.

Fig. 14 shows transition of Red waveband of the field east and west. From the graph, Red waveband has a bigger reflectance after July 19 until August 1 just before heading than a previous value. From Equation (1), if value of R becomes big, NDVI becomes small. Therefore the reason why NDVI before heading became small is that the reflectance of Red waveband became big. Thus, it seems that the reflectance of Red waveband grows big before heading.

Fig. 15 and 16 show transition of color of the leaf (SPAD: Soil & Plant Analyzer Development) in Togo-cho, Tatebayashi-shi, Gunma in 2014 and 2015. SPAD is the traditional technology to estimate the growth of rice plant from the color of leaves. Unfortunately, we have not yet get the data of SPAD in 2016, however we could understand the difference of the data of SPAD and NDVI/NDRE.

Each SPAD figures has four lines that indicate the name of the test area. The dotted line in each figure shows rice heading date. SPAD shows chlorophyll content. From the graphs, value of SPAD falls down before heading, just like NDVI and NDRE. They are likely to have a correlation. Without using satellite images, we estimated the growing condition of rice to see a leaf color from experience until now. However, the leaf color is easy to be influenced by neighboring brightness i.e. weather because of visual observation. I mention it later, but it seems that NDVI is hard to be influenced by weather. It is likely that NDVI can estimate the growing condition more exactly.

From Fig. 11 and 12, NDRE reaches a peak on July 13 and the lowest on July 4. It seems that weather and measurement time influence NDRE. From

TABLE II, we measured in the morning except 4 and 13 in July. Because NDRE has a high association with chlorophyll [9], it is likely that NDRE rises in the noon when light of the sun is strong. Therefore, NDRE of July 13 when we measured at 13 o'clock rises. Also, we measured 17 o'clock when light of the sun becomes weak and it rained 7.5 mm on July 4. Therefore, NDRE of July 4 became low. Conversely, we can't discover the big change of NDVI due to weather and measurement time. Fig. 9 and 10 show big vibration of NIR, however we can't discover big vibration of NDVI from Fig. 11 and 12. Thus, it seems that NDVI is hard to be influenced by weather and NDRE is easy to be influenced in contrast.

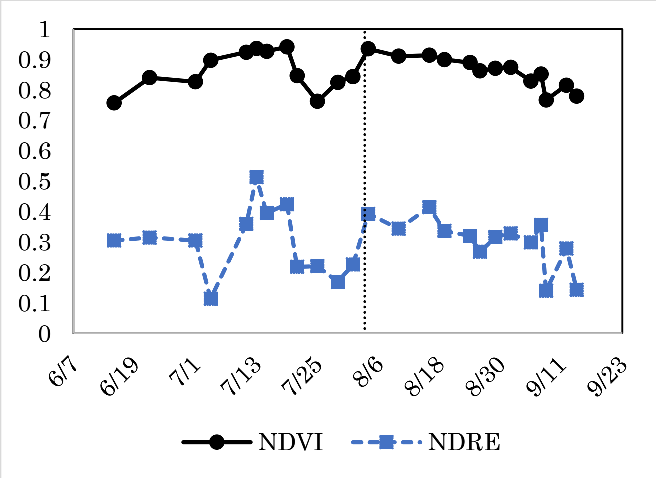

Fig. 11. Transition of NDVI and NDRE of the field (East).

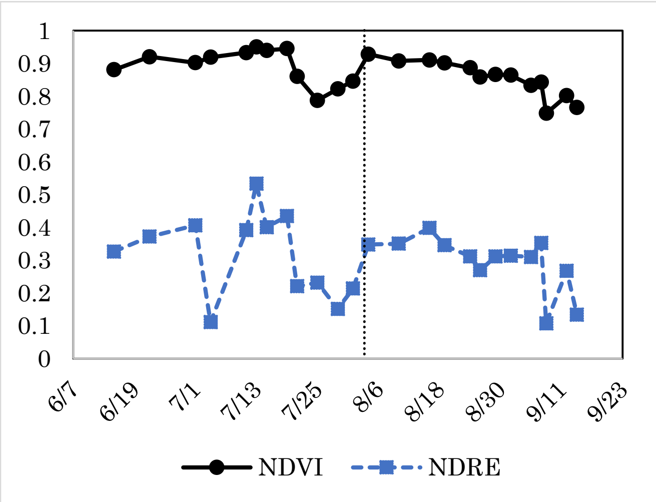

Fig. 12. Transition of NDVI and NDRE of the field (West).

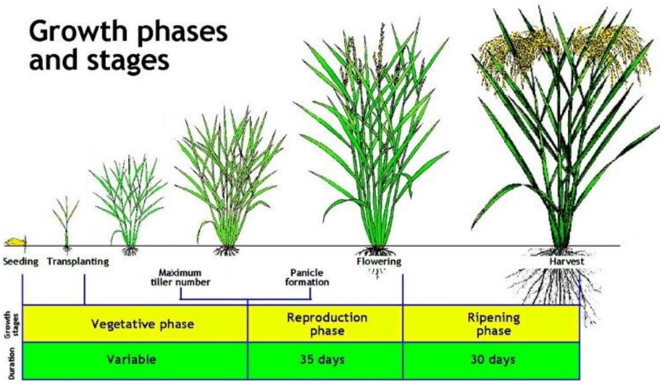

Fig. 13. Growth Stages of Rice [13]

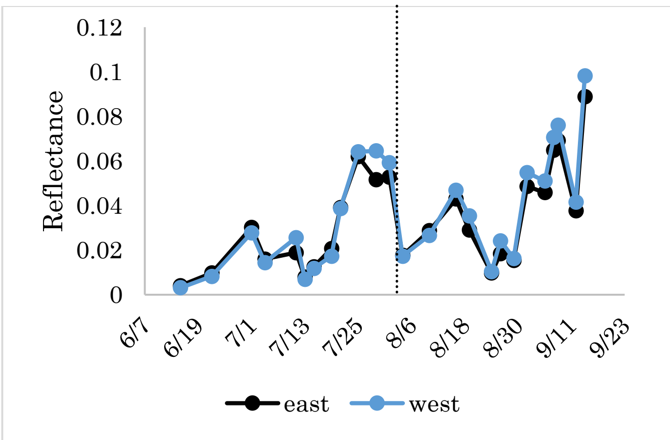

Fig. 14. Transition of Red waveband of the field (East and West).

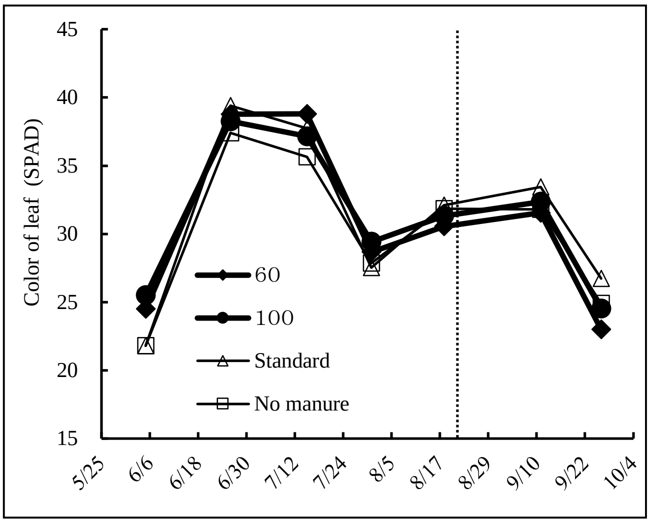

Fig. 15. Transition of SPAD in 2014.

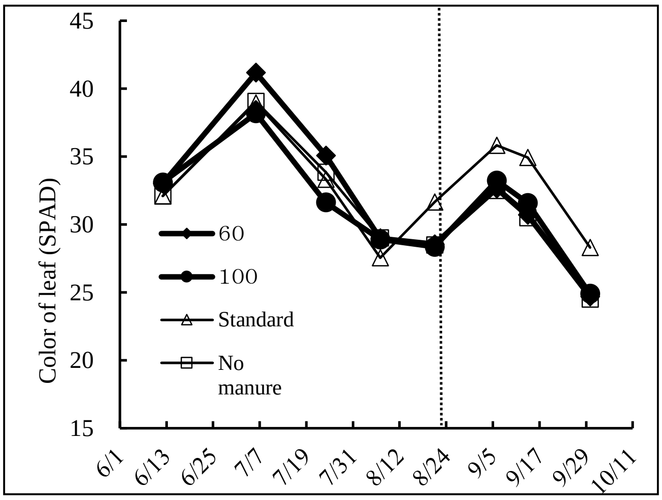

Fig. 16. Transition of SPAD in 2015.

Fig. 17 and 18 show Comparison of NDVI and NDRE in the field east and west.

From Fig. 17, there are few eastern and western differences after July 4. Therefore, the effect of the delayed-acting manure was given about 60 days after fertilization (May 2).

Fig. 18 shows difference of NDRE on June 22, July 1 and August 4. There are few difference of east and west otherwise.

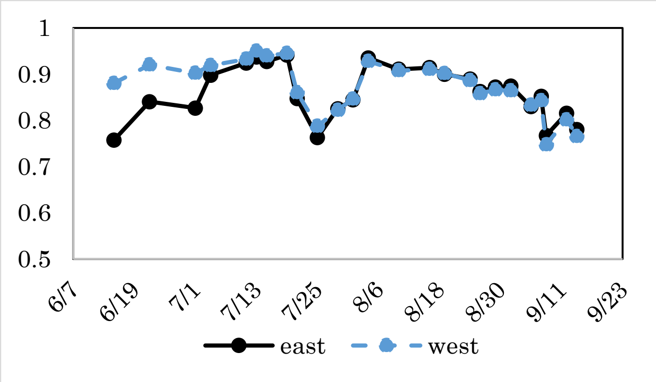

Fig. 17. Comparison of NDVI in the field (East and West).

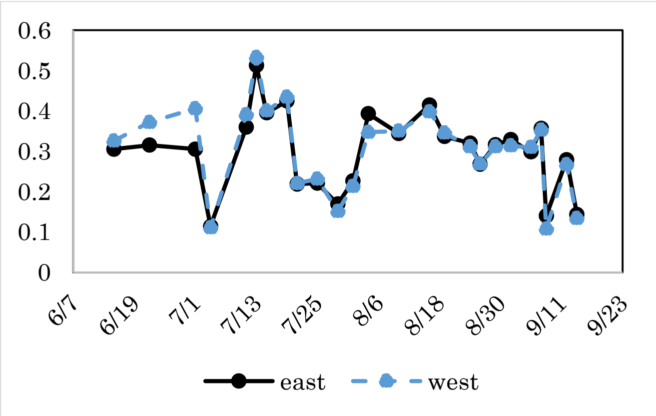

Fig. 18. Comparison of NDRE in the field (East and West).

V. Further Study

Using NDVIs which we measured, we would like to investigate a relationship with SPAD and estimate yield of rice, proper season of harvesting and rice grain protein contents. However, many data are necessary to raise predictive precision. Therefore we want to increase data by increasing farms to measure. More data may enable to judge which rice is disease by using deep learning. Also, it is necessary to take pictures at different soil in order to compare these results.

Moreover, we would like to find the species of the weed from pictures taken by a drone by using machine learning technology. We should determine the species of weed to define the most appropriate medicine to kill weed.

In addition, we would like to use GPS so that the person who isn't used to drone operation measures NDVIs. GPS can set flight path, therefore they can easily fly drone.

VI. Conclusions

This study focuses to support aging farmers, part time farmers who are working in a town and work as a farmer on weekend and new comers in the agriculture. For that purpose, we are developing technology to evaluate the growing situation of rice and vegetables in a field by using a drone and a multi-spectral camera. By using these technologies, it might be possible to reduce the work of under the scorching sun and run agriculture for people with a little experience. For this, we describe the result of measurement of growing situation of rice.

As a result of putting a multi-spectral camera on a drone and measuring NDVI, we discovered rice which weakened and confirmed an effect of the manure. Also, from transition of NDVI and NDRE, we understood that predicting the heading stage is possible. We will increase measurement data and aim at proper season of harvesting and prediction of taste in future.

We feel that it might be possible to realize low cost precision agriculture such as supplying fertilizer to limited delayed growth area and insecticide to limited damaged area.

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