RESEARCH ON OBSERVATION OF CARROT GROWTH STAGE USING UAV MULTISPECTRAL CAMERA AND APPLICATION TO FIELD MANAGEMENT

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ABSTRACT: The objective of this study is to examine the applicability of using a UAV multispectral camera to detect the harvest time of carrots. In order to detect the harvest time, changes in chlorophyll in the growth stage were observed at the same time with a pointwise hyperspectral sensor and a multispectral camera equipped with a UAV, and changes in chlorophyll in the growth stage up to the harvest time were observed. In this way, we examined an objective method to detect the harvest time and clarified the following contents.

From the results of comparison and verification at fixed points observation using a pointwise hyperspectral sensor and a UAV multispectral sensor, it was shown that even a multispectral camera can observe changes in chlorophyll in the growth stage up to the harvesting season.

The near-infrared reflectance of the leaves changes depending on the growth stage of the carrot, and the optimum harvest time is when the reflectance sharply decreases. From the distribution of chlorophyll in the field measured in a plane with a multispectral camera, it is possible to grasp the difference in the degree of growth due to the difference in management. It was shown that it is possible to provide data that leads to productivity improvement by reflecting the cause of the difference in the degree of growth in the management method.

1. INTRODUCTION

The average age of the agricultural worker population was 67.9 years old as of 2021, and the agricultural worker population continues to age. In addition, the number of new farmers as of 2020 was 53,000, which is only 3% of the total farmers, a serious problem [1]. In Japan, there has been concern about the rapid decline of the agricultural labor force due to the aging of the population. To improve this situation, there is an urgent need to introduce smart agriculture using AI and IoT technologies. The objectives of introducing smart agriculture are ① labor saving and labor reduction in agricultural work, ② transmission of agricultural technology, ③ improvement of food self-sufficiency. Japan's food self-sufficiency rate on a calorie basis was 38% in 2021, with imports exceeding domestic production, making it difficult to say that an appropriate balance is being maintained. In order to increase yields and increase self-sufficiency in the face of a shortage of human resources, it is expected that farming that does not rely on the senses will be necessary. Environmental parameters that until now could only be observed by satellites or aircraft can now be observed by UAV, thanks to the light weighting of various sensors. UAV can also make surface observations, rather than point observations. This observation technology has already been put to practical use in the observation of rice and wheat.

The purpose of this study is to investigate the applicability of UAV observation technology to the identification of harvest time for the vegetables grown outdoors. In order to determine the harvest time objectively, we observed the spectral changes in the growth stages. Then, changes in chlorophyll in the growth stages leading up to the harvest stage were observed, and an objective understanding of the harvest time was examined.

2. METHODOLOGY

The study flow is Fig. 1.

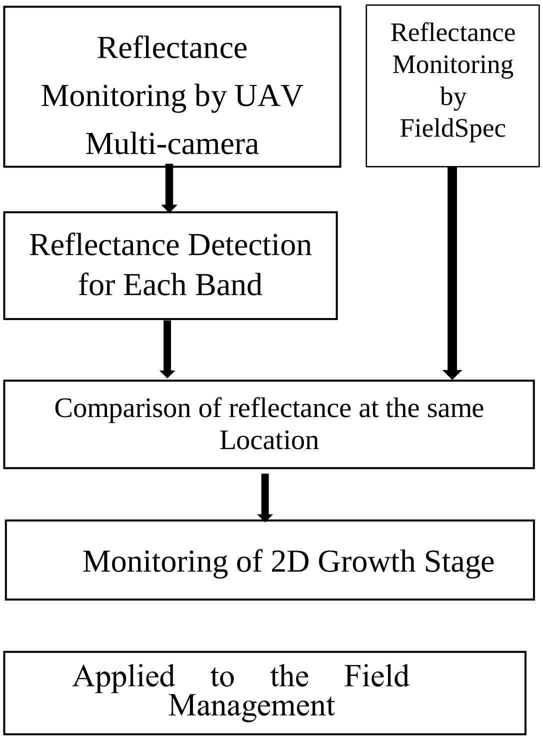


Fig.1 Study flow

2.1 STUDY AREA

The study area is the fields of Saitama Agriculture Management Junior College（Fig.2）, and vegetables grown outdoors such as broccoli and carrots were targeted.

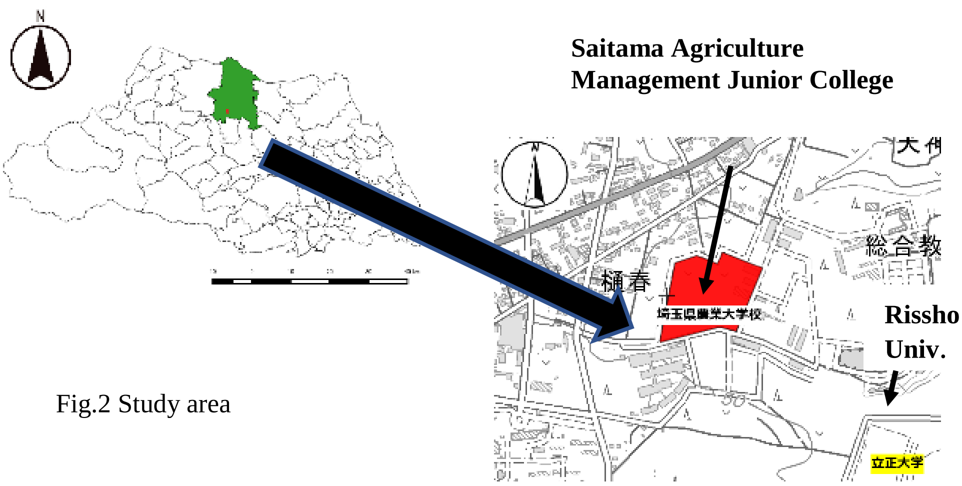


Fig.2 Study area

2.2 MONITORING METHODS

To observe spectral reflectance characteristics from ves grown outdoors, ground-based observations were made using a FieldSpec HandHeld2 (FieldSpecas) a hyperspectral sensor. To observe the areal spectral reflectance characteristics, observations were made with a UAV equipped with a RedEdge sensor, a multispectral sensor.
(RedEdge sensor:It has five bands of blue, green, red, red edge, and infrared, and is hereinafter referred to as UAV multi-camera to distinguish it from the frequency 'rededge')

The ortho mosaic was processed using SfM (Structure from Motion) model on Metashape. To observe chlorophyll at each carrot growth stage, spectra and carrot root diameters were measured. Measurements were taken from 2018/11/1 to 2018/12/13 (Tab.1). The carrots included were those seeded on 2018/7/25, with harvesting stage around 2018/11/1, and those seeded on 2018/8/18, with growth stage around 2018/11/1. Because of the expected variation in measurement parameters among varieties, the carrots were of the same variety (AIKOU).

Tab.1 Observation Schedule

		測定日					
		2018/11/1	2018/11/8	2018/11/15	2018/11/22	2018/11/29	2018/12/13
播種日	2018/7/25（播種からの日数）	（99日目）					
	2018/8/18（播種からの日数）	（75日目）	（82日目）	（89日目）	（96日目）	（103日目）	（117日目）

The harvesting stage is determined using empirical indicators of the college in a-c as follows.

a. More than 200g and less than 300g
b. Length less than 23cm
c. About 5 cm in diameter at the root

If the crop size becomes larger than the indexes a-c, the water content of the crop body will be low, and this size is considered as the harvesting stage. Generally, farmers determine the carrot harvesting stage from the root diameter. Therefore, in this study, the harvesting stage was determined from the root diameter.

3. TEST VALIDATION OF UAV MULTI-CAMERA

3.1 Test Monitoring of Growth Stage by UAV Multi-Camera

Compare the reflectance of each band of multispectral data from the Fieldspec and UAV multi-camera and at the same point. The target crops were broccoli, leeks, cabbage, and carrots. We calculated correlation coefficients for each of the bands measured by the Fieldspec and UAV multi-camera to validate the UAV multi-camera (Tab. 2).

Tab. 2 Correlations between Fieldspec and RedEde sensors in each band

Bands	Correlation coefficient
Blue	0.28039411
Green	0.492066139
Red	0.167211174
Nir	0.958184557
RedEdge	0.747594474

For comparison with FieldSpec, the average of the reflectance at five points by frequencies corresponding to the width of the UAV multi-camera wavelengths was used for comparison. Because, it is difficult to make the Fieldspec and UAV multi-camera targets the same point on the order of a few centimeters, and each band of the UAV multi-camera has its own wavelength width. Fig.3 and Fig.4 compare multispectral sensor and hyperspectral data for fresh and dead broccoli, respectively. The results in Fig.3 show that when both sensors are targeting the same point, the measurements of both sensors are highly correlated, but when the broccoli is wilted, shown in Fig.4, the correlation in the Blue-Red frequency range decreases. In addition, if the target is misaligned, such as when soil is used as a target, the correlation is reduced. These results indicate that the UAV multi-camera can be used if the target is accurate.

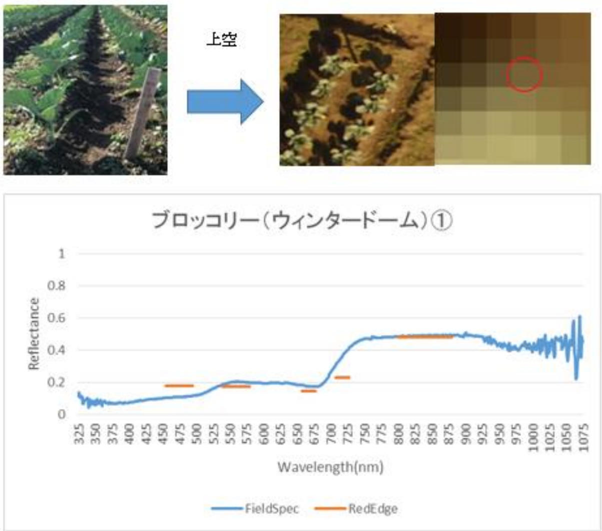


Fig.3 Results of the fresh broccoli measurement (2017/12/03/12:00)

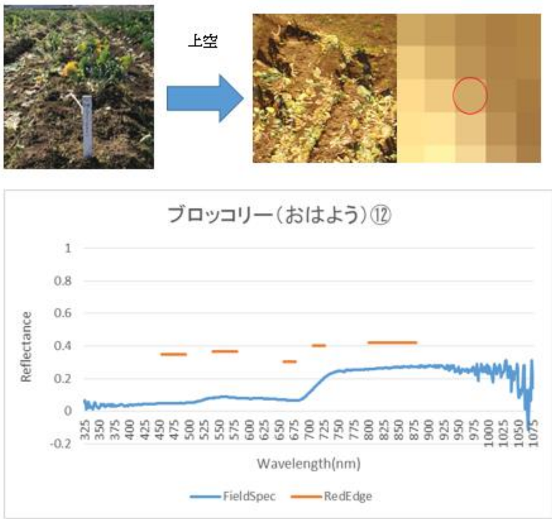


Fig.4 Results of the dead broccoli measurement (2017/12/03/12:00)

3.2 Monitoring of Carrots Growth Stage by Fieldspec

Spectra and growth indices of carrot leaves at different growth stages were measured according to the observation schedule shown in Tab. 1. The first measurement targeted 7 carrots (AIKOU) at the harvesting stage and 4 carrots (AIKOU) at the growing stage. 5 spectral measurements were taken per carrot, and the average was calculated and compared. For the second and subsequent measurements, 8 carrots (AIKOU) of the growing stage were targeted, and 5 spectral measurements were taken per carrot, and the average was calculated and compared.

Fig.5 shows the results of the reflectance comparison between the average at the harvesting stage (seeded on 2018/7/25) for carrots (AIKOU) at 99 days after sowing and the average at the growing stage (seeded on 2018/8/18) for carrots (AIKOU) at 75 days after sowing. Measurements were taken 7 times for carrots at the harvesting stage (seeded on 2018/7/25) and 4 times for carrots at the growing stage (seeded on 2018/8/18). Fig.5 shows that the reflectance in the near-infrared region is higher in the growing stage(seeded on 2018/8/18) than in the harvest stage (seeded on 2018/7/25).

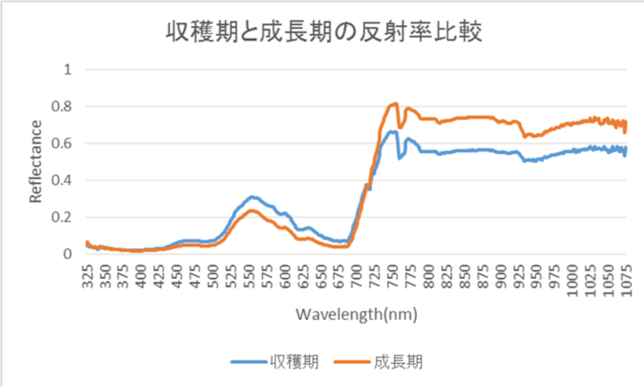
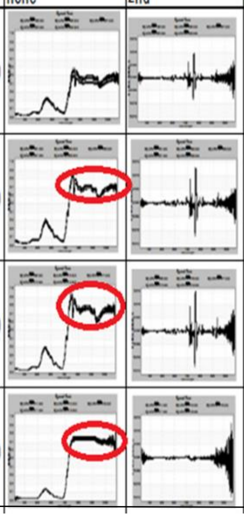


Fig.5 Comparison of reflectance averages between the harvesting and growing stage

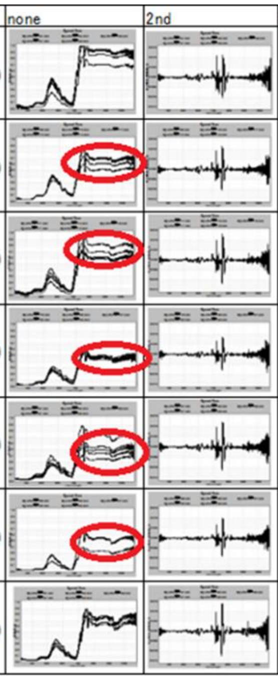
Tabl. 3 and 4 compare leaf spectra and the carrot diameter measurements of the carrot at harvest and growing stages. These Tables show that the near-infrared spectra at the harvesting stage were reduced compared to the growing stage, suggesting a decrease in chlorophyll content.

Tab. 3 Reflectance and diameter of carrots (AIKOU) at the growing stage (seeded on 2018/8/18)



name	none	2nd	直径(cm)
愛紅_0818①			1.5
愛紅_0818②			2
愛紅_0818③			2.6
愛紅_0818④			2.5

Tab. 4 Reflectance and diameter of carrots (AIKOU) at the harvesting stage (seeded on 2018/7/25)



name	none	2nd	直径(cm)
愛紅_0725①			5.4
愛紅_0725②			4.5
愛紅_0725③			4.2
愛紅_0725④			4.3
愛紅_0725⑤			4.5
愛紅_0725⑥			4.8
愛紅_0725⑦			3.4

Fig.6 shows a comparison of the reflectance of the carrots (AIKOU) 2018/8/18), surveyed at regular intervals. Fig.6 also shows that reflecta approaches.

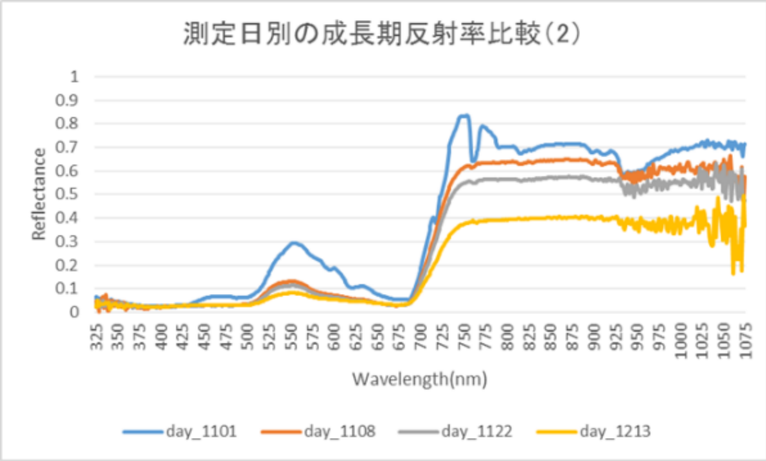


Fig.6 Comparison of the reflectance of the carrots (AIKOU)
during the growing stage (seeded on 2018/8/18)

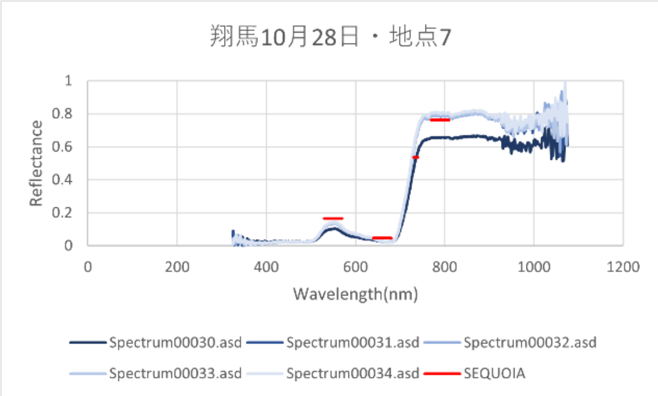
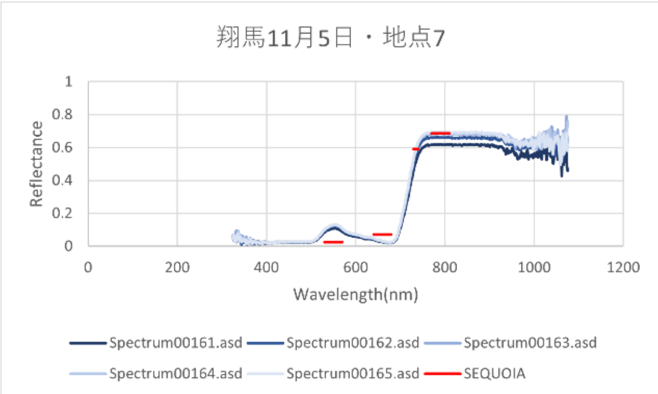
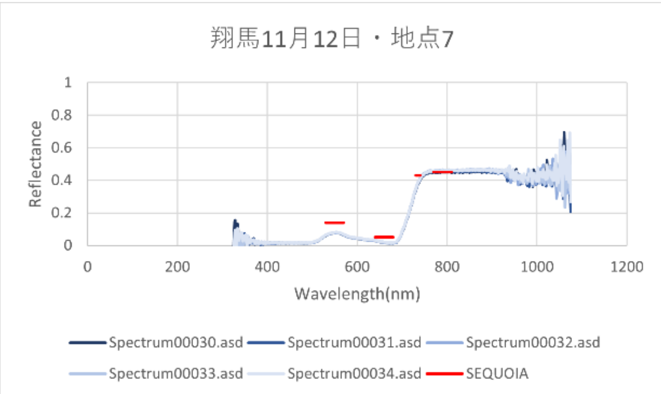
4. VERIFICATION OF MONITORING ACCURACY OF GROWTH STAGE BY UAV MULTI-CAMERA

In the study so far, if the positional accuracy of the measurement points of the UAV multi-camera
can be secured, it was shown that the UAV multi-camera can be used to monitor the growth stage in the same way as the observation result of the point observation by Fieldspec.

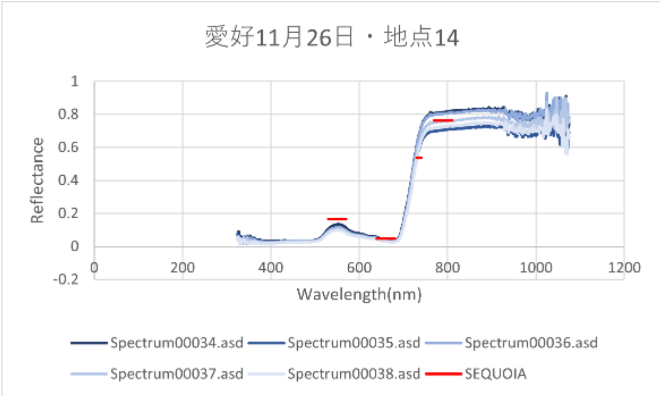
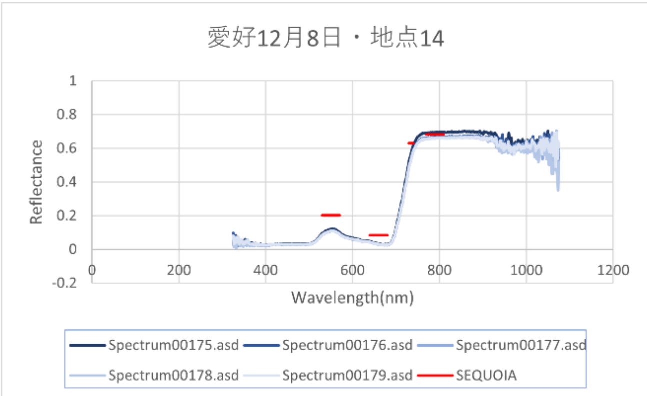
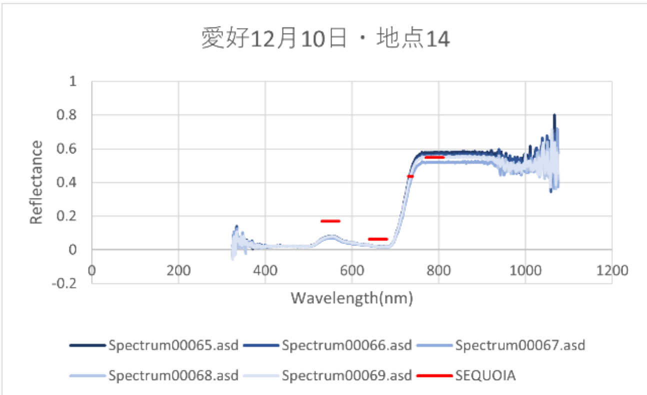
In this chapter, we will focus on carrots that will be harvested around 2020/11/12 (Carrots SHOMA, seed on 2020/8/3) and carrots that will be harvested around 2020/11/12 (Carrots AIKOU, seed on 2020 8/6). As shown in Tab.5 and 6, the reflectance was measured by FieldSpec and UAV multi-camera during 2020/10/28-11/11 and 2020/11/26-12/10, respectively, and the root diameter of the carrot was measured at the same time. We examined the accuracy of monitoring up to the harvest time.As for the harvesting time, it was decided to be the harvesting time because it was harvested when the diameter of the root was 5 cm according to the hearing from the farmers. Tab. 5 and 6 summarize the observation results.
From these results, it can be seen that the reflectance in the near-infrared region of the UAV multi-camera also reflects the change in the diameter of the carrot as it shifts to harvest time, as with FieldSpec.

This is a result of the fact that the amount of chlorophyll in the leaves decreased and the reflectance of the near-infrared rays decreased as a result of supplying nutrients to the roots of carrots as the harvest season progressed.
The above results show that it is possible to monitor the growth stage of carrots by using the reflectance of the near-infrared region of the UAV multi-camera.

Tab. 5.Reflectance and diameter using FieldSpec and UAV multi-camera for harvested carrots
(SHOMA, seeded on 2020/8/3)

Name	Reflectance	Photo	Diameter
carrots (SHOMA) P7 2020/10/28(12:00)			4.2cm
carrots (SHOMA) P7 2020/11/5 (12:00)			4.7cm
carrots (SHOMA) P7 2020/12/12 (12:00)			4.9cm

Tab. 6. Reflectance and diameter using FieldSpec and UAV multi-camera for harvested carrots (AIKOU, seeded on 2020/8/6)

Name	Reflectance	Photo	Diameter
carrots (AIKOU) P14 2020/11/26 (12:00)			4.7cm
carrots (AIKOU) P14 2020/12/8 (12:00)			5.1cm
carrots (AIKOU) P14 2020/12/10 (12:00)			5.1cm

5. MONITORING OF GROWTH STAGE OF CARROT FIELD BY UAV MULTI-CAMERA

From the comparison results of the reflectance by FieldSpec and UAV multi-camera so far, it is confirmed that the growth stage can be monitored only by the reflectance from near infrared without considering the reflectance from Red. In the future, near-infrared reflectance will be used to monitor the surface growth stage in the field.

Monitoring of the growth stage of the field with a UAV multi-camera is based on carrots (SHOMA, seeded on 2020/8/3) which will be harvested around 2020/11/12 and carrots (AIKOU, seed on 2020/8/6) which will be harvested around 2020/12/10. Fig.7-1, 2, 3, 4, 5, and 6 show the surface timeseries changes in near-infrared reflectance for carrots in the entire field captured by the UAV multi-camera.

According to Fig.7-1, 2, 3, 4, 5, and 6, the use of UAV multi-cameras makes it possible to monitor not only fixed-point growth stages but also two-dimensional growth stages of carrots. This is a recognition that the same management is performed over the entire area, but it is possible to extract uneven growth, investigate the cause of the uneven growth individually, and propose countermeasures.

For example, in the observation results other than Fig. 7-6, there is a part in the lower part of the figures where the reflectance from the near-infrared is always high. These areas are areas where carrots are always growing, where chlorophyll is higher than in other areas and proteins are produced through photosynthesis, indicating that the harvesting season is late. Looking at the causes of the uneven growth, it can be seen that there is a height difference in the field, and since this part is low, it is a place where water is constantly supplied compared to other areas. From the next year onwards, a countermeasure was put forward that this is a place where the difference in elevation should be averaged. The effect of monitoring the growth level by such a UAV multi-camera can be expected to be more effective for monitoring the growth stage in a wider area.

6. CONCLUSION

In this research, we clarified the following contents.

Based on the reflectance associated with changes in the growth stage by a hyperspectral sensor (FieldSpec), the time when the carrot growth stage near-infrared reflectance rapidly decreases is the suitable time for harvesting, and the harvest time of carrots can be captured.

This phenomenon can be explained by the change in photosynthesis in the leaves that accompanies the change in the growth stage from the growing stage to the harvesting stage.

It was shown that it is possible to monitor the growth stage including the harvest time of carrots from the two-dimensional observation results of the surface reflectance by the UAV multi-camera.

For example, UAV multi-camera can evaluate the impact of surface unevenness due to water management on productivity in fields.

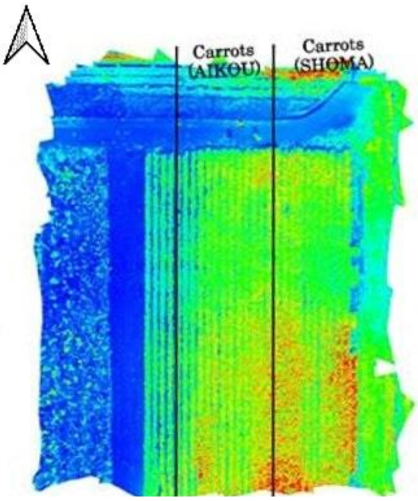
REFERENCES

[1] Ministry of Agriculture, Forestry and Fisheries (2022): Agricultural Census.

[2] Kikuro Takemoto, Hisashi Seki, Masao Makiuchi, Hideo Takahashi, Hirotaka Motoyama (1999):Near-infrared light sensing technology for biological and environmental measurements, Science Forum Co., Ltd., p210-217.

[3]Shintaro Goto (2010):
New Developments in Agricultural Products and Food Inspection Methods, Chapter 10: Monitoring the Sweetness of Fukaya Negi Using Hyperspectral Images - Quality Judgment Method for Welsh Onions: Its Measurement Principles and Applications -, p75-84.

UAV multi-camera Monitoring image of growth stage of carrot field



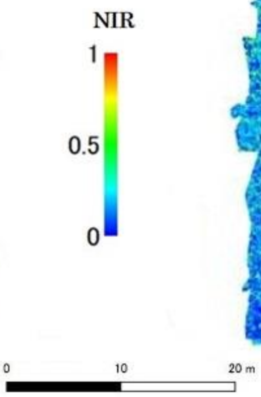


Fig.7-1 2020/10/28(12:00)

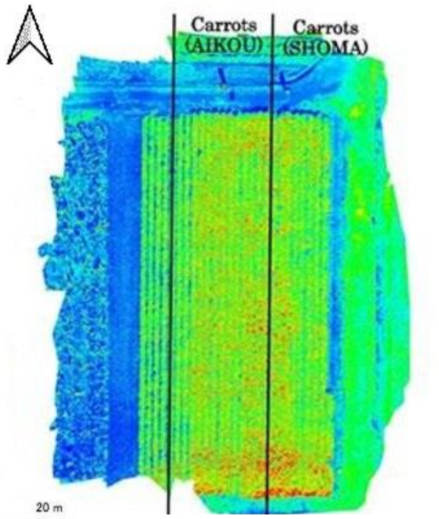
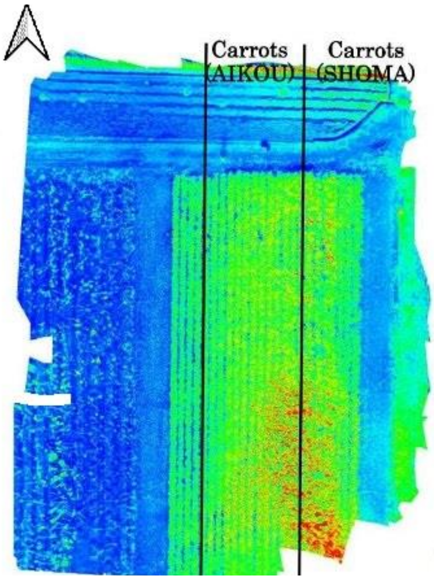


Fig.7-2 2020/11/5(12:00)



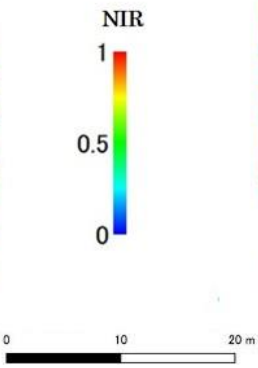


Fig.7-3 2020/11/12(12:00)

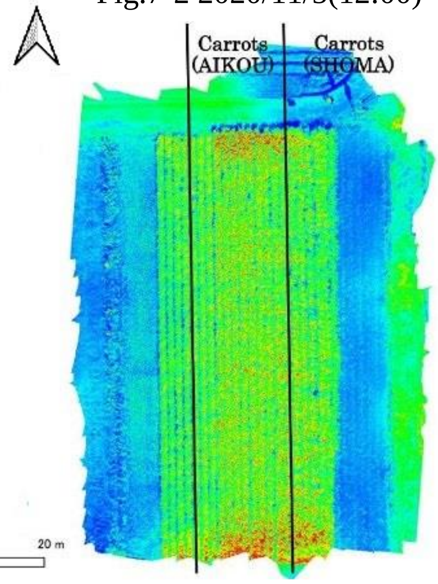
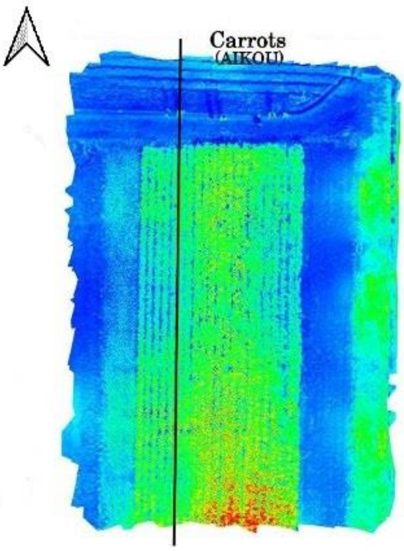


Fig.7-4 2020/11/19(12:00)



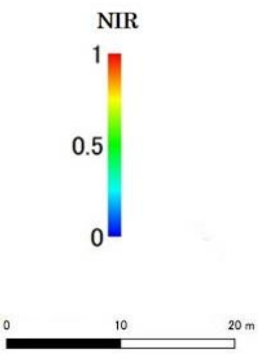


Fig.7-5 2020/11/26(12:00)

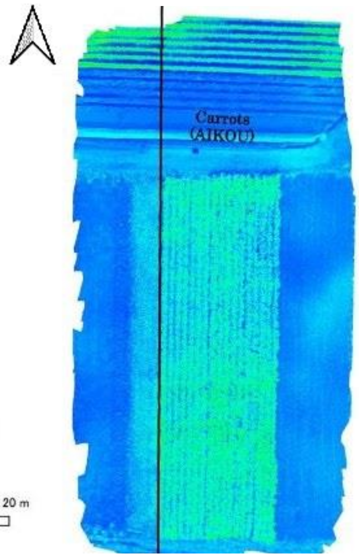


Fig.7-6 : 2020/12/10(12:00)