Artificial Intelligence based Fertilizer Control for Improvement of Rice Quality and Harvest Amount

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***Abstract*—Artificial Intelligence: AI based fertilizer control for improvement of rice quality and harvest amount is proposed together with intelligent drone based rice field monitoring system. Through experiments at the rice paddy fields which is situated at Saga Prefectural Research Institute of Agriculture: SPRIA in Saga city, Japan, it is found that the proposed system allows control rice crop quality and harvest amount by changing fertilizer type and supply amount. It, also, is found the most appropriate fertilizer supply management method which maximizing rice crop quality and harvest amount. Furthermore, these rice crop quality and harvest mount can be predicted in the early stage of rice leaf grow. Therefore, rice crop quality and harvest amount becomes controllable.**

Keywords*—Nitrogen content; protein content; rice paddy field; remote sensing; regression analysis; rice crop quality; harvest amount; fertilizer

I. INTRODUCTION

In recent years, due to the diversification and lower price of sensing devices, the development of networks as infrastructure for aggregating and analyzing such information, generalization of mobile terminal devices, and higher functionalization of computers, ICT has been fully developed in the agricultural field The machine to utilize has matured. In addition, advances in small actuators and devices and Artificial Intelligence: AI that precisely controls them have also been developed, and technologies that enable the robot to be used in a more atypical environment have also developed. It is said that smartization[1] of agriculture will make full use of such technologies and efficiently realize high quality food production without introducing human power and time costs as before It is a challenging effort.

One of the biggest issues of smartization is agricultural field monitoring in an efficient and an effective manner and minimization of required resources including fertilizer, pesticide, electricity, water supply and labor cost. In particular, fertilizer is one of the biggest resources. Therefore, AI based fertilizer control for minimization of required fertilizer is developed together with the field monitoring system based on drone mounted Near Infrared: NIR cameras.

Vitality monitoring of vegetation is attempted with photographic cameras [1]. Grow rate monitoring is also attempted with spectral reflectance measurements [2]. Bi-Directional Reflectance Distribution Function: BRDF is related to the grow rate for tealeaves [3]. Using such relation, sensor network system with visible and near infrared cameras is proposed [4]. It is applicable to estimate nitrogen content and fiber content in the tealeaves in concern [5]. Also, damage grade is due to insects for rice paddy fields [6]. The proposed method is validated with Monte Carlo simulation [7]. Also Fractal model is applied to representation of shapes of tealeaves [8]. Thus, the tealeaves can be asse3ssed with parameters of the fractal model. Vitality of tea trees are assessed with visible and near infrared camera data [9]. These previously proposed methods do work for rice paddy fields.

Rice paddy field monitoring with drone mounted visible and NIR: Near Infrared camera is proposed [10] while the method for rice quality evaluation through nitrogen content in rice leaves is proposed [11]. The method proposed here is to utilize AI for estimation of fertilizer supply timing and amount of fertilizer together with evaluate rice quality through protein content in rice crop with observation of NDVI: Normalized Difference Vegetation Index which is acquired with visible and NIR camera mounted on drone.

Rice crop quality and amount evaluation method through regressive analysis between nitrogen content and near infrared reflectance of rice leaves measured from crone is proposed and validated successfully [12]. Meanwhile, estimation of protein content in rice crop and nitrogen content in rice leaves through regressive analysis with NDVI derived from camera mounted drone is conducted successfully [13]. On the other hand, relation between rice crop quality (protein content) and fertilizer amount as well as rice stump density derived from drone data is well investigated [14]. Then, estimation of rice crop quality and harvest amount from drone mounted NIR camera data and remote sensing satellite data is carried out [15]. Furthermore, effect of stump density, fertilizer on rice crop quality and harvest amount in 2015 investigated with drone mounted NIR camera data is well reported [16]. Moreover, method for NIR reflectance estimation with visible camera data based on regression for NDVI estimation and its application for insect damage detection of rice paddy fields is proposed and validated [16]. Also, there is the report about digital agriculture (AI-based sowing advisories lead to 30% higher yields)[2].

The proposed method is described in the next section followed by experiments. The experimental results are

[1] https://www.trcbook.com/electro/smafarm.html

[2] https://news.microsoft.com/en-in/features/ai-agriculture-icrisat-upl-india/

validated in the following section followed by conclusion with some discussions.

II. Proposed Method and System

A. *Proposed AI based Fertilizer Control for Improvement of Harvested Rice Crop Quality and Harvest Amount*

Proposed AI based fertilizer control for improvement of harvested rice crop quality and harvest amount is based on the acquired data of SPAD, spectral reflectance of rice leaves @ 550 nm, 870 nm, plant height, number of stems, culm length after heading, ear length, number of panicles (book / stock) air temperature, relative humidity, atmospheric pressure. Then, AI learns the timing and fertilizer amount of basal fertilizer, fertilizer application, panicle fertilizer. The rules from learned results as follows,

Draining is one of the following: ① Suppression of ineffective tilling. ② Promotion of new root elongation and maintenance of vitality until later. ③ Improvement of soil breathability and elimination of harmful gases. ④There are effects such as lodging reduction. However, if the longevity is delayed, not only these effects will be insufficient, but also it will be impossible to apply proper amount of panicle fertilizer properly. Furthermore, it may adversely affect the panicle of rice. When effective stems (stems that become 17 to 18 ears of one stock) are secured, they fall off early. 7 to 8 days to the extent that small cracks will enter the field. Completion by the early yolk formation stage (heading 25 days), let's prepare for the application. Especially, since it is delayed every year in ordinary plantation areas such as after wheat, let's finish it by late July after 30 days after rice planting as a guide. Even when using one type of base fertilizer type fertilizer, to avoid overgrowth due to continuation of fertilization and to prevent declining in the latter term, carry out a moderate disposal exactly.

Hodo fertilizer is important for securing yield and quality, such as preventing the degeneration of differentiated spikelet, increasing the number of spikelet, preventing leaf color deterioration and withering and promoting grain enrichment. However, if the application period is too early, lodging is increased, and in case of large application or slow application, the crude protein content in the brown rice is increased and the adverse effect such as lowering the taste is given. It is important to properly apply the appropriate amount according to variety, rice planting time, degree of fertility of the field, growing situation of rice, etc. Since the application time of panicle is delayed every year, predict the heading time from rice planting date beforehand, and make a diagnosis by length of larva spreading, leaf color, iodine dyed etc., 3 to 4 days before that, judge the suitable period for application . The standard of Hibari fish and the panicle length were "Kohikari" at 18 days before heading (8 to 10 mm in length of panicle) in consideration of the prevention of lodging, "colorfulness of color" at June plant was 25 days before heading (0.5 panicle length ~ 1 mm), and the other varieties are 20 to 23 days before heading (ear panicle length 1.5 to 2 mm). The application rate is based on the nitrogen content of 2 to 3 kg per 10 a, and it increases and decreases by performing the growth situation, the leaf color or the iodocaine staining diagnosis. In addition, late fertilization just before heading and heading will reduce application, so it will not be applied.

These knowledge and rules are acquired from the past three years rice crop productions. Then knowledge base system is created for increasing rice crop quality and harvest amount with minimizing the required fertilizer. Also, weather data are input to the knowledge base system together with SPAD[3], the number of stem, leaf length, culm length, panicle length, the number of panicle, grain weight, harvest amount and protein content in rice crops.

B. *Method for Estimation of Rice Crop Quality and Harvest Amount*

Rice crop quality is defined with protein content which is closely related to the nitrogen content in rice leaves. The nitrogen content in rice leaves can be estimated with reflectance in near infrared wavelength region of the rice leaves. Therefore, it is possible to estimate rice crop quality with NIR reflectance of the rice leaves in concern. On the other hand, harvest amount can be estimated with the regressive equation derived from the regression analysis with the harvest amount data and NIR reflectance of the rice leaves in concern.

III. Experiment

A. *Example of Time Series Input Data for AI Learning*

SPAD, spectral reflectance of rice leaves @ 550 nm, 870 nm, plant height, number of stems, culm length after heading, ear length, number of panicles (book / stock) as well as meteorological data are time series of input data. Then, AI learns the timing and fertilizer amount of basal fertilizer, fertilizer application, panicle fertilizer. One of the examples of the input data of “Hiyokumochi in 2015” of rice paddy field data is shown in Fig.1. In the example, all the parameters are observed on June 24, July 14, 30, August 13, 26, September 16, 24 and October 1. All these data has been gathered for 5 years for Ai learning. One of examples of results of correlations between protein content in rice crops and the other factors are shown in Fig.2.

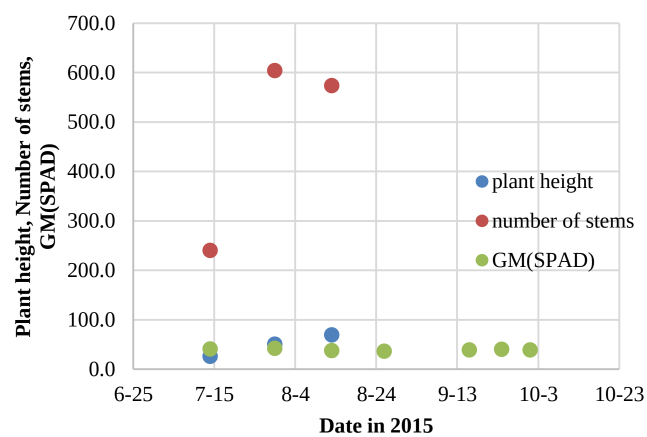


Fig. 1. Input Data of “Hiyokumochi in 2015” of Rice Paddy Field for AI Learning.

[3] https://www.rex-rental.jp/sek/spad-502plus.html

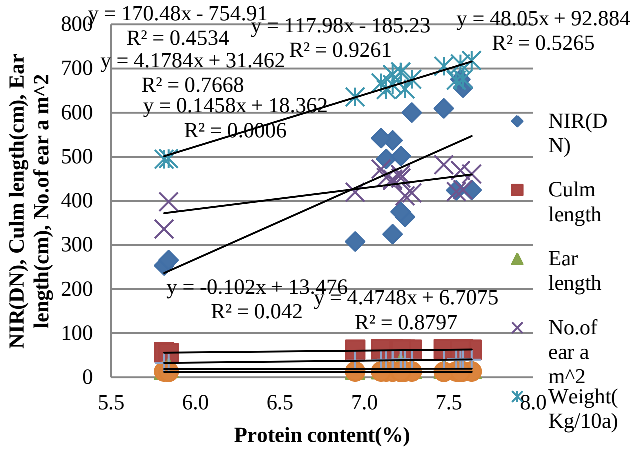


Fig. 2. Examples of Results of Correlations between Protein Content in Rice Crops and the Other Factors.

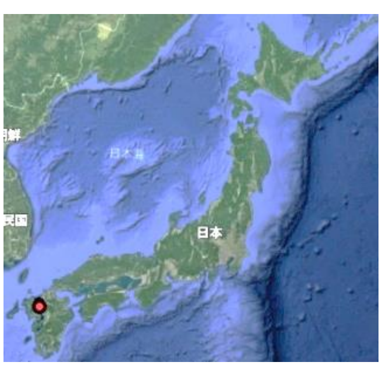
B. Rice Paddy Field in Concern

These measurements have been conducted at the Saga Prefectural Research Institute of Agriculture: SPARI[4] which is situated at 33°13'11.5" North, 130°18'39.6" East, and the elevation of 52 feet. Fig. 3 (a) and (b) shows layout of the test site of rice crop field. Just beside the SPARI, there is the test site of Saga Prefectural Agricultural School of College: SPASC. Black rectangle in the Fig. 3 (a) and (b) shows the test site.

C. Fertilizer Conditions

Paddy field No. 4-3 of the SPACS is divided into 7 different fields with the different fertilizer condition. “Saga-Biyori” of rice species is planted in all of the fields. Fertilizer conditions are shown in Table 1. Slow release fertilizer called “One shot N5.6” is used for the field No. 1.

The area of field No. 1 is 486 m^2. Therefore, 19.4 kg of fertilizer for the field No. 1 means 40 kg/10 a. This is the same condition for the field No. 6. Therefore, the fertilizer of the field No. 6 is 13.1 kg. The areas of the No. 2 to No. 7 are same as 327 m^2. The fertilizer conditions of the field No. 2 and 4 are same. That is “Standard”. One the other hand, the fertilizer condition of the field No. 3 is same as the field No. 5. That is “Multi fertilizer”.



(a)Test Site on Map(Test Site is Situated at the Red Circle)

[4] http://www.pref.saga.lg.jp/web/shigoto/_1075/_32933/ns-nousisetu/nouse/n_seika_h23.html

(b)Test site on 3D aerial photo image of Google map

Fig. 3. Test Site.

TABLE I. FERTILIZER TYPES AND AMOUNT

NO.	FERTILIZER	N(KG/10A)
1	ONE_SHOT SLOW RELEASE FERTILIZER	5.6
2	STANDAR_5020	7
3	MULTI_FERTILIZER_5222 HIGH YIELD FERTILIZE	11
4	STANDARD_5020	7
5	MULTI_FERTILIZER_5222 HIGH YIELD FERTILIZE	11
6	ONE_SHOT SLOW RELEASE FERTILIZER	5.6
7	NONFERTILIZER	0

One shot fertilizer is supplied to the field No. 1 and 6 at once as Former “diat” or basement. Meanwhile, Standard fertilizer is supplied for the field No.2 and 5 before the plantation as 5 (basement), then fertilizer 2 and “hirona” of 2 after the heading.

On the other hand, Multi fertilizer is supplied to the field No. 3 and before the plantation as 5 (basement), the fertilizer 2 and 2 as well as “hirona” of 2 after the heading.

Growth survey is carried out three times. That is maturity searches, yield, yield components, palatability-related traits (near infrared analysis). Meanwhile, ground based measurements of spectral reflectance are conducted on August 18 2017, August 28 2017, and September 19 2017. If the harvest amount is predicted on August 28, then another fertilizer is supplied to the fields which show grows inadequate for increase the supposed harvest amount. That is the same thing for rice crop quality, protein content in rice crops.

D. Experimental Results

Example of the measured spectral reflectance is shown in Fig. 4. Unfortunately, weather condition is bad, cloudy condition. Therefore, the spectral reflectance of August 18 2017 is just a reference. Another field experiment is conducted on August 28 2017. drone based NIR camera data of the field No. 1 to 7 is acquired.

Natural color image acquired with visible camera is shown in Fig. 5 (a) while Fig. 5 (b) shows the image with the NIR filter attached camera. In the figure, rice paddy fields from the fields A to I correspond to the field No. 1 to 7.

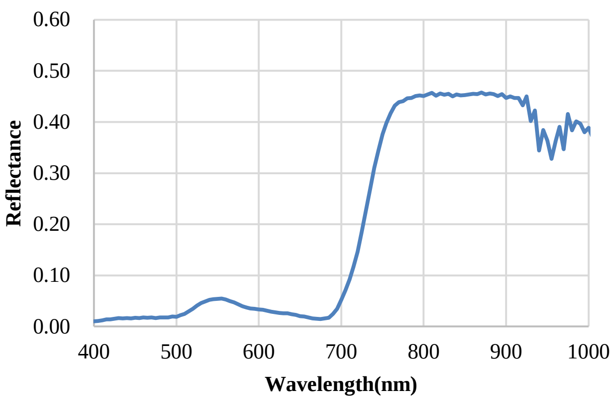


Fig. 4. Example of the Measured Reflectance of the Field No.1 On August 18 2017.

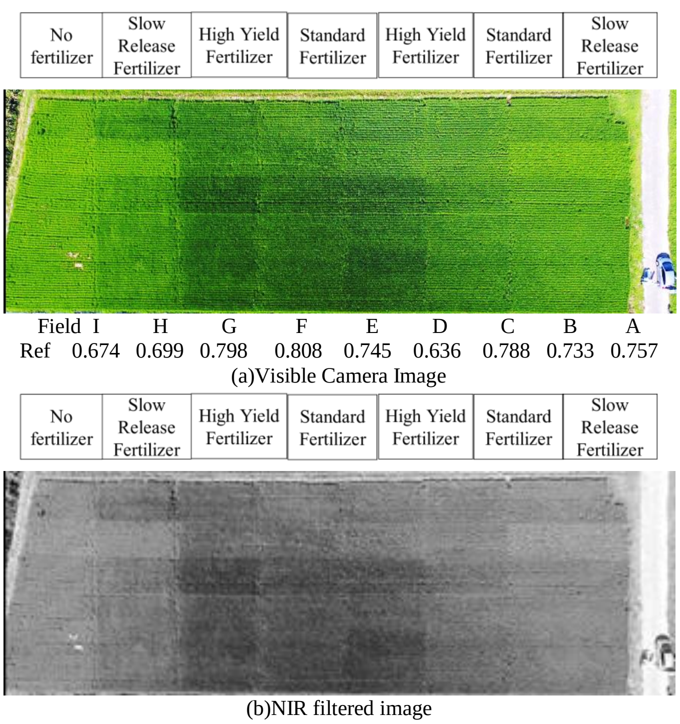


Fig. 5. DRONE Derived Reflectance at 800 nm (Aug.28 2017).

Actually, the fields A, B correspond to the field No. 1, the field C correspond to the field No. 2, the field D is corresponding to the field No. 3, the fields E, F are corresponding to the field No. 4, the field G, H, and I correspond to the field No. 5, 6, and 7, respectively.

The spectral reflectance of the field A to I which is measured with the Spectral radiometer is shown in Fig. 6. Then, regressive analysis between the measured protein content and the measured reflectance at 800 nm is carried out. Fig. 7 shows the result from the analysis. R^2 value of the regression is more than 0.6. Therefore, it is possible to estimate protein content in rice crops using the measured reflectance of rice leaves at 800 nm (NIR). That is the same thing for the harvest amount estimation. Fig. 8 shows the results from the regressive analysis between measured harvest amount and the measured reflectance of rice leaves at 800 nm (NIR), R^2 value is not so high though.

Furthermore, SPAD[5] measuring instrument is an instrument that expresses the amount of chlorophyll (chlorophyll) contained in plant leaves as SPAD value (value indicating chlorophyll content) necessary for knowing the health of plants. The chlorophyll meter can be measured instantaneously on the spot without sample collection, and it can be measured even in the rain since it is a muffler specification. Fig.9 shows relation between SPAD measured on August 30 2017 and reflectance at 550 nm on August 28 2017.

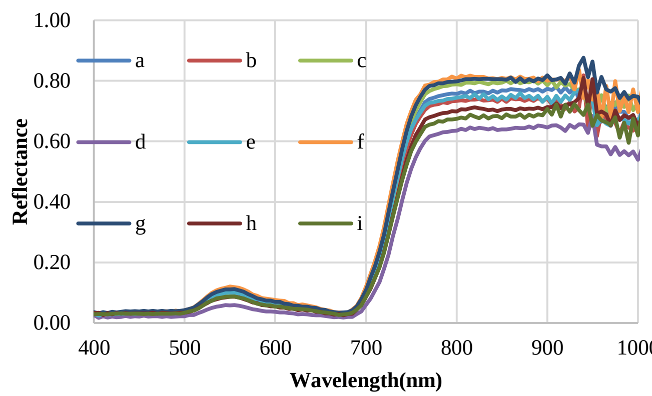


Fig. 6. Measured Reflectance of the Field No.1 on August 28 2017.

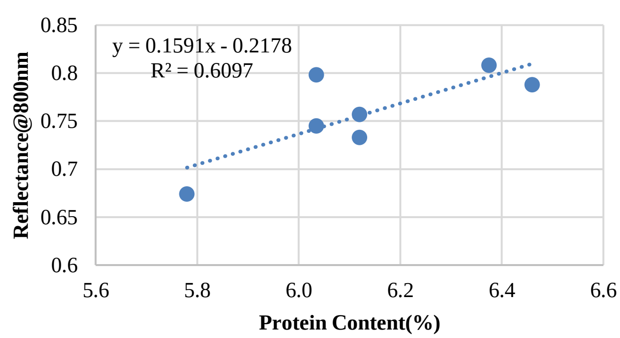


Fig. 7. Relation between Protein Content and Reflectance at 800nm(August 28 2017).

[5]https://www.konicaminolta.jp/instruments/products/color/chlorophyll/index.html

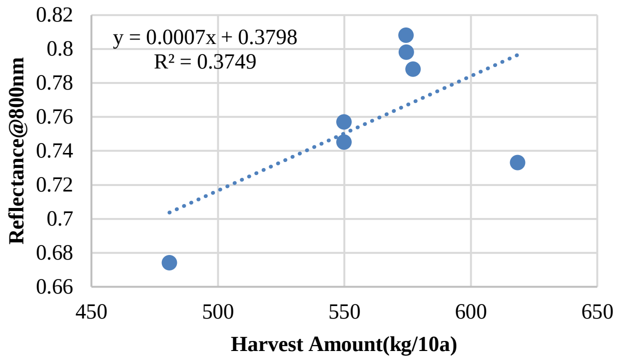


Fig. 8. Relation between Harvest Amount and Reflectance at 800nm(August 28 2017).

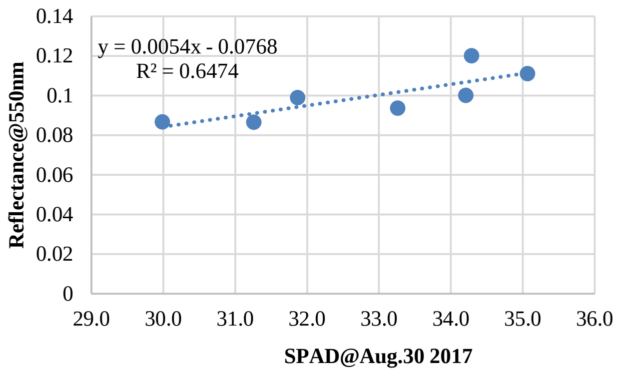
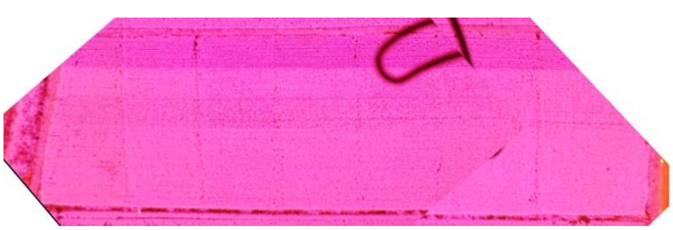


Fig. 9. Relation between SPAD Measured on August 30 2017 and Reflectance at 550 nm on August 28 2017.

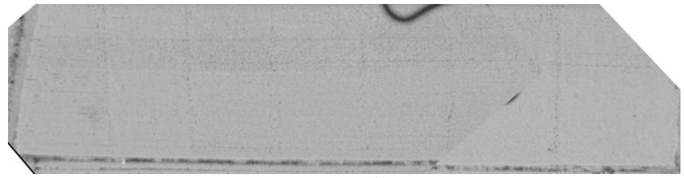
In this test, it was found that the 800 nm wavelength in the near-infrared region may be able to predict protein content and yield. If it can be predicted a little earlier, in early August, it is also possible to control by fertilization Drone based NIR camera data of the field No. 1 to 7 is acquired. NIR image is shown in Fig. 10. from the fields A to K correspond to the field No. 1 to 7. The fields A, B correspond to the field No. 1, the field C correspond to the field No. 2, the fields D, E are corresponding to the field No. 3, the field F is corresponding to the field No. 4, the fields G, H are corresponding to the field No. 5, the field I correspond to the field No. 6, the fields J, K are corresponding to the field No. 7, respectively.

No fertilizer	Slow Release Fertilizer	High Yield Fertilizer	Standard Fertilizer	High Yield Fertilizer	Standard Fertilizer	Slow Release Fertilizer

K	J	I	H	G	F	E	D	C	B	A
0.431	0.418	0.447	0.507	0.554	0.499	0.519	0.506	0.535	0.554	0.570



(a)Acquired NIR image



(b)Estimated reflectance

Fig. 10. Drone derived NIR Image Derived NIR Filter Attached Camera from Acquired on September 19 2017.

The spectral reflectance of the field A to K is shown in Fig. 11.

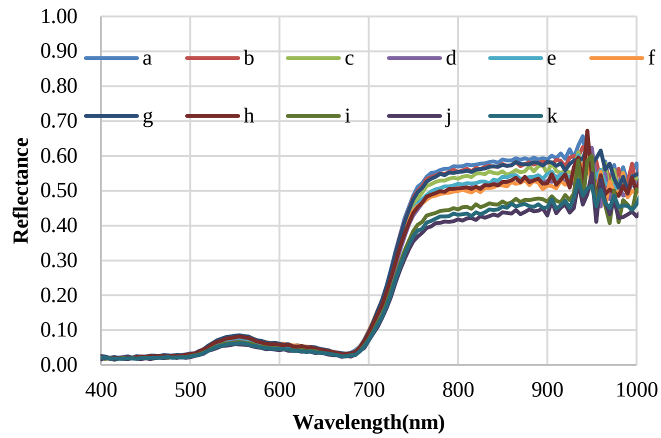


Fig. 11. Measured Reflectance on September 19 2017.

Then, regressive analysis between the measured protein content and the measured reflectance at 800 nm is carried out. Fig. 12 shows the result from the analysis. R^2 value of the regression is more than 0.45. Therefore, it is possible to estimate protein content in rice crops using the measured reflectance of rice leaves at 800 nm (NIR).

That is the same thing for the harvest amount estimation. Fig. 13 shows the results from the regressive analysis between measured harvest amount and the measured reflectance of rice leaves at 800 nm (NIR), R^2 value is not so high though.

Furthermore, Fig. 14 shows relation between SPAD measured on Aug.30 2017 and reflectance at 800 nm on September 19 2017.

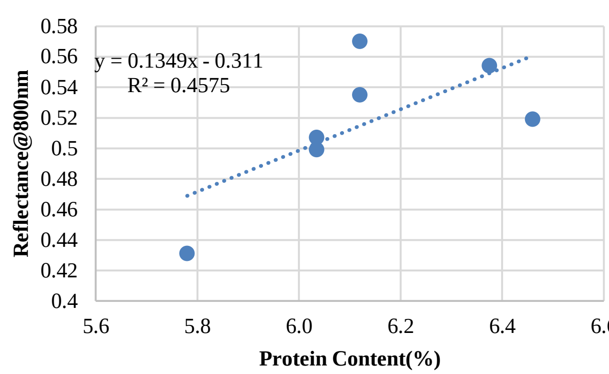


Fig. 12. Relation between Protein Content and Reflectance at 800nm(September 19 2017).

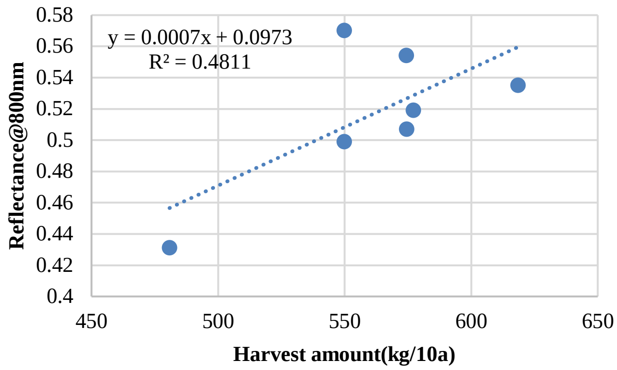


Fig. 13. Relation between Harvest Amount and Reflectance at 800nm(September 19 2017).

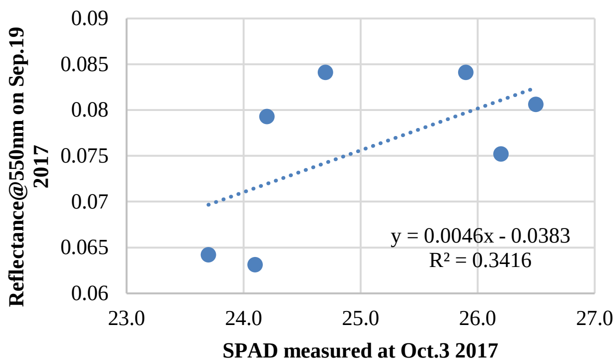


Fig. 14. Relation between SAPD Measured on October 3 2017 and Reflectance at 550nm on September 19 2017.

IV. Conclusion

The proposed Artificial Intelligence: AI based fertilizer control for improvement of rice quality and harvest amount with intelligent drone based rice field monitoring system dose work for increasing harvested rice crop quality and harvest amount with minimizing the required fertilizer. Through experiments at the rice paddy fields which is situated at Saga Prefectural Research Institute of Agriculture: SPRIA in Saga city, Japan, it is found that the proposed system allows control rice crop quality and harvest amount by changing fertilizer type and supply amount. In this test, it was found that the 800 nm wavelength in the near-infrared region may be able to predict protein content and yield. If it can be predicted a little earlier, in early August, it is also possible to control by fertilization.

Also, it is found that SPAD value which indicates chlorophyll concentration (related to rice crop quality) of rice leaves can be estimated with the measured reflectance of rice leaves at 550 nm. Since the relationship between SPAD value and protein content is SPAD value of 8/30, $R^2 = 0.63$ (protein), $R^2 = 0.35$ (yield), so is not it equivalent to 800 nm.

Further research works are required for improvement of the prediction accuracy of rice crop quality and harvest amount. Also, cost performance evaluation is required for fertilizer managements.

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