Barley Quality Estimation Method with UAV Mounted NIR Camera Data based on Regressive Analysis

Prediction Method of Anthocyanin, β-glucan and Water Contents in the Harvested Daishimochi of Barley Grains before the Harvest

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***Abstract*—Barley quality estimation method with Unmanned Aerial Vehicle: UAV based Near Infrared: NIR camera data based on regressive analysis is proposed. The proposed method allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested “Daishimochi” of barley grains before the harvest. The prediction method proposed here is based on regression analysis with the Near Infrared: NIR camera data mounted on UAV which allows to estimate barley quality, anthocyanin, β-glucan and water contents in the harvested “Daishimochi” of barley grains before the harvest.. This is the first original attempt for the prediction in the world. Through experiment, it is found that water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) can be predicted before the harvest with high R^2 value (more than 0.99). Therefore, farmers can control fertilizer and water supply for improvement of the Daishimochi barley grain quality.**

Keywords—Unmanned Aerial Vehicle: UAV; Near Infrared: NIR camera; Daishimochi; anthocyanin; β-glucan and water contents; barley quality

I. Introduction

There is a strong demand on a prediction of the harvested agricultural product quality before the harvest. If it is possible to predict, farmers may control fertilizer, water supply to get better quality of the agricultural products.

"Mochi barley" is composed only of amylopectin, and this difference creates stickiness when cooked. The reason why “mochi wheat” is receiving attention is the improvement of the intestinal environment. The key ingredient is the water-soluble dietary fiber called "barley β-glucan" that was introduced at the beginning. It has been reported that it functions as a food for good bacteria in the intestine to adjust the intestinal environment.

Furthermore, it has been reported that it suppresses the absorption of sugars and suppresses the rise in blood sugar level after eating. The function of "barley β-glucan" is not limited to that. It is also reported that it has a strong viscosity and absorbs cholesterol to help it be excreted from the body.

“Mugigohan" is the best way to efficiently take in "mochi wheat," which is full of energy for your body. Especially, it is recommended to incorporate it in "breakfast". The reason is that "barley β-glucan" suppresses the absorption of sugars and continues until the next meal. This feature is called the "second meal effect".

This barley (bare barley) was grown in 1997 at the Shikoku Agricultural Experiment Station in Zentsuji City, Kagawa Prefecture, and was named "Daishimochi" because of Kobo Daishi, who is associated with Zentsuji. Although the same mochi barley has different characteristics depending on the variety, "Sanuki Mochi barley Daishimochi" is a purple-colored grain with a sweetness and a fluffy, chewy texture. It contains about 30 times as much dietary fiber as polished rice and is rich in β-glucan (water-soluble dietary fiber).

The prediction method proposed here is based on regression analysis with the Near Infrared: NIR camera data mounted on UAV which allows to estimate barley quality, anthocyanin, β-glucan and water contents in the harvested “Daishimochi” of barley grains before the harvest. This is the first original attempt for the prediction in the world.

The following section describes research background and related research works. Then experiment is described with some remarks. After that, conclusion is described with some discussions and future works.

II. Research Background and Related Research Works

A. Research Background

The anthocyanins of the Daisimochi grain are mainly composed of cyanidin malonyl glucoside and localized in the pericarp. In recent years, physiological activities of anthocyanins such as antioxidative activity, anti-inflammatory activity and blood glucose lowering activity have been clarified, and cereals containing anthocyanin pigment have been attracting attention as a supply source thereof. The conventional glutinous barley and the cultivar "Daishimochi" which has improved cultivability have a characteristic of being colored purple during the ripening period, but the pigment is not used so much. Therefore, in order to effectively utilize the anthocyanin pigment contained in Daishimochi grain, its main component and the accumulation of the ripening process are clarified, and the localization in the grain is investigated by the polishing.

Daishimochi grains contain anthocyanins. The main component is cyanidin 3-(3″,6″-dimalonyl glucoside) containing 2 malonyl groups, then cyanidin 3-(6″-malonyl glucoside) containing 1 malonyl group and cyanidin 3-(3″) - Malonyl glucoside), and cyanidin 3-glucoside having no malonyl group.

In Daisimochi kernels, anthocyanins accumulate after 28 days after flowering, peak at 35 days after flowering, and decrease at 42 days after flowering. The most abundant cyanidin 3-(3″,6″-dimalonyl glucoside) is contained throughout the ripening period. The anthocyanin accumulation time is later than the accumulation time of catechin and proanthocyanidins, which are the causes of browning after heating and are the main polyphenol components of barley grain.

The method proposed here allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested “Daishimochi” of barley grains before the harvest. Through experiment, it is found that the barley quality can be predicted before the harvest with high R^2 value (more than 0.99). Therefore, it is possible to control fertilizer and water supplies before the harvest.

B. Related Research Works

Regressive analysis on leaf nitrogen content and near infrared reflectance and its application to agricultural farm monitoring with helicopter mounted near infrared camera is proposed [1]. Also, effect of sensitivity improvement of visible to near infrared digital cameras on NDVI measurement in particular for agricultural field monitoring is proposed [2]. On the other hand, smartphone image based agricultural product quality and harvest amount prediction method is proposed and validated [3].

A computer aided system for tropical leaf medicinal plant identification is attempted [4]. Meanwhile, product amount and quality monitoring in agricultural fields with remote sensing satellite and radio-control helicopter is proposed and evaluated [5]. On the other hand, computer vision for remote sensing is lectured in the Special Lecture on Computer Vision for Remote Sensing of Agriculture [6] together with Remote Sensing for Agriculture [7].

Intelligent system for agricultural field monitoring is proposed and realized [8]. Also, multi-level observation system for agricultural field monitoring is recommended [9] together with multi-layer observation for agricultural field monitoring [10]. On the other hand, another intelligent system for agricultural field monitoring is systemized and realized [11].

Another multi-level observation system for agricultural field monitoring is presented [12] together with multi-layer observation for agricultural field monitoring [13]. Meanwhile, another multi-layer observation for agricultural (tea and rice) field monitoring is realized and evaluated its performance [14]. bigdata platform for agricultural field monitoring and environmental monitoring is presented for global monitoring particularly [15].

Degree of polarization model for leaves and discrimination between pea and rice types leaves for estimation of leaf area index is investigated [16]. Also, nitrogen content estimation of rice crop based on Near Infrared (NIR) reflectance using Artificial Neural Network (ANN) is proposed [17]. On the other hand, effect of stump density, fertilizer on rice crop quality and harvest amount in 2015 investigated with drone mounted NIR camera data is evaluated [18].

Relation between rice crop quality (protein content) and fertilizer amount as well as rice stump density derived from helicopter data is investigated [19] together with estimation of rice crop quality and harvest amount from helicopter mounted NIR camera data and remote sensing satellite data [20].

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 [21]. Meanwhile, artificial intelligence based fertilizer control for improvement of rice quality and harvest amount is proposed and well reported [22].

III. PROPOSED METHOD

The method proposed here allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested “Daishimochi” of barley grains before the harvest. Using the results from the regressive analysis with UAV mounted NIR camera data and chemical content measurements about anthocyanin, β-glucan and water contents in the harvested barley crops, it is possible to predict these contents with the UAV mounted NIR camera data acquired in the future.

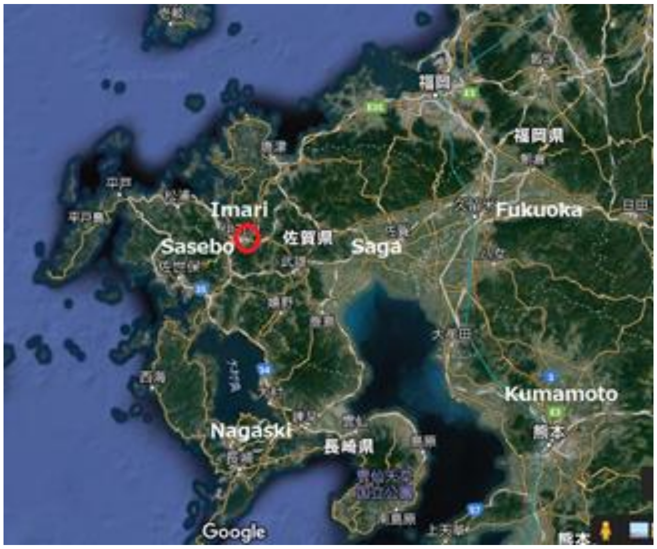
IV. EXPERIMENT

A. Intensive Study Area

The intensive study area is situated Kisu, Imari City, Saga in Kyushu, Japan (33:29N, 129:86E) sown in Fig. 1.

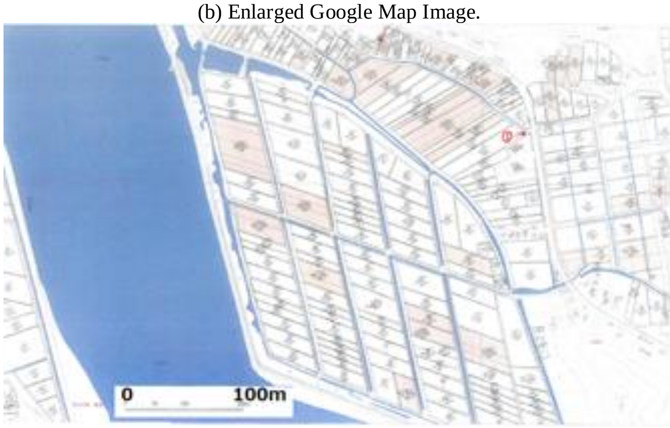
The late of November to the begging of December in 2018, Daishimochi of barley is planted in the intensive study farm areas. After the fundamental fertilizer is supplied, barley trampling is conducted a couple of time. Then additional fertilizer is put in the farm areas. Afterall Daishimochi barley is harvested in May 2019.

Fig. 2(a) shows photos of the scenery of the farm area just before the harvest while Fig. 2(b) shows the outlook of the harvested Daishimochi barley grains. Approximately, one month before the harvest, the farm areas are observed by the UAV mounted NIR camera (Fig. 2(c)).



(a) Kisu Town in Imari City (Red Circle).

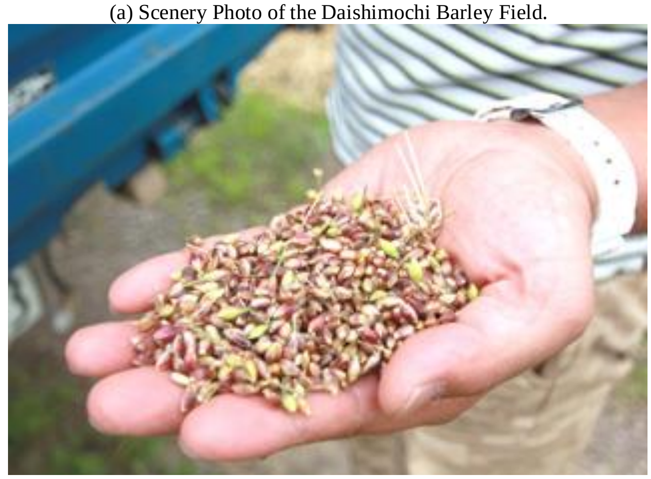
(b) Enlarged Google Map Image.



(c) Location of Intensive Study Area (Red Circle).

Fig. 1. Intensive Study Area.

(a) Scenery Photo of the Daishimochi Barley Field.



(b) Outlook of the Harvested Daishimochi Barley Grains.

(c) UAV Carrying NIR Camera.

Fig. 2. Phtos of Daishimochi Berley Field and the Harvested Grains and the Outlook of the UAV Carrying NIR Camera.

B. Acquired NIR Images of the Daishimochi Barley Fields

During the NIR image acquisition with UAV mounted NIR camera, standard plaque is put on the Daishimochi barley fields (1), (2), (3) and (4). Fig. 3 shows the acquired images of the fields. Meanwhile, close-up NIR images of standard plaque and the Daishimochi barley of the fields (1), (2), (3) and (4) are shown in Fig. 4. Standard plaques for each field are marked with yellow circles in Fig. 4. The NIR images and histograms of the standard plaque and Daishimochi barley of the field #1 are shown in Fig. 4(a) and (b), respectively while those of the field #2 are shown in Fig. 4(c) and (d). On the other hand, those of the field #3 are shown in Fig. 4(e) and (f) while those of the field #4 are shown in Fig. 4(g) and (h), respectively.

C. Chemical Composition Analysis

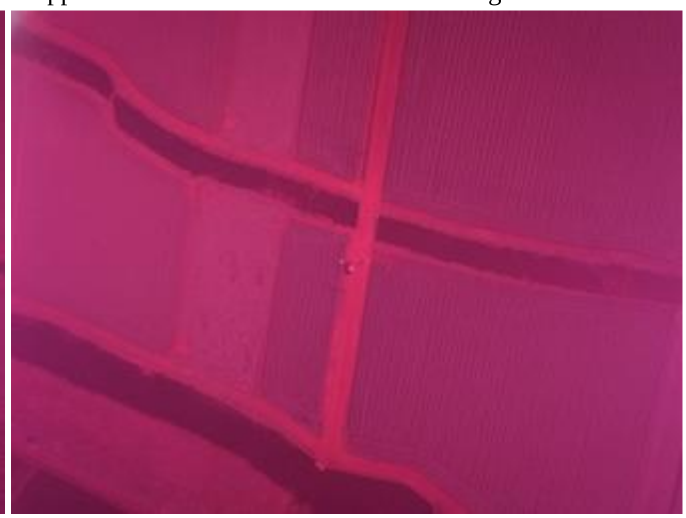
Chemical composition analysis is made for the harvested Daishimochi barley grains from the fields #1, #2, #3, and #4. As the chemical composition, water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) are selected because these factors are significant specific feature of the Daishimochi barley grains. The results are shown in Table I.

In the table, the mean of the acquired NIR reflectance is also shown. There is strong positive correlation between NIR reflectance and water content obviously while there is negative correlation between NIR reflectance and Anthocyanin content as well as Anthocyanin (corresponding to dry matter). On the other hand, there is positive correlation between barley β-glucan and NIR reflectance as shown in Table I.

D. Regression Analysis

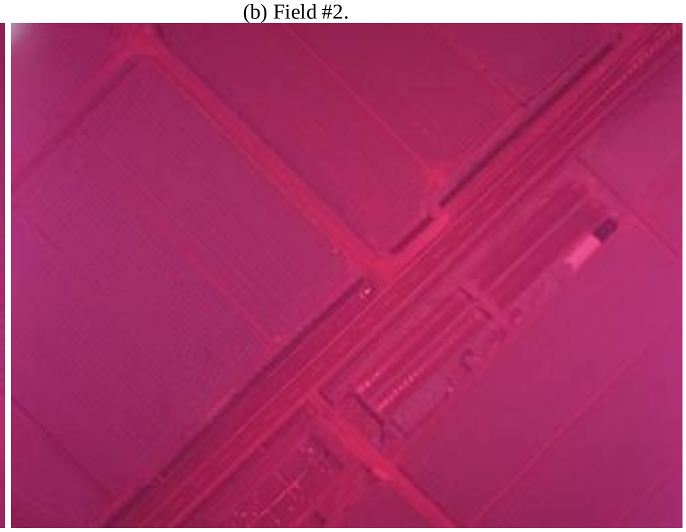
Regression analysis is made among NIR reflectance and Water content, barley β-glucan, Anthocyanin content as well as Anthocyanin (corresponding to dry matter) with linear approximation. The results are shown in Fig. 5.

(a) Field #1.



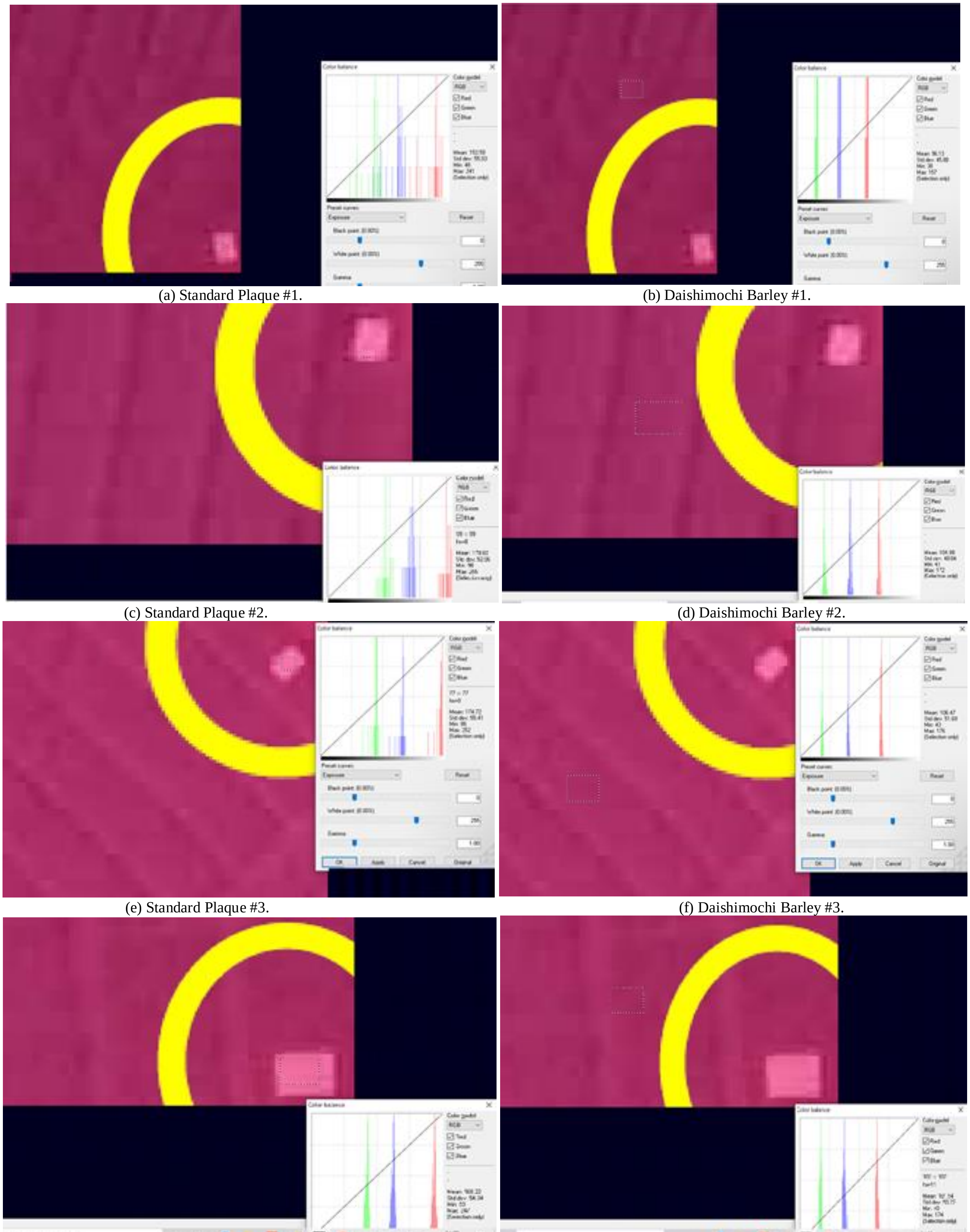
(b) Field #2.

(c) Field #3.



(d) Field #4.

Fig. 3. Acquired NIR Images of the Daishimochi Barley Fields.



(a) Standard Plaque #1. (b) Daishimochi Barley #1.

(c) Standard Plaque #2. (d) Daishimochi Barley #2.

(e) Standard Plaque #3. (f) Daishimochi Barley #3.

(g) Standard Plaque #4. (h) Daishimochi Barley #4.

Fig. 4. Acquired NIR Images and Histograms of each Daishimochi Barley Fields and Standard Plaques.

TABLE I. NIR REFLECTANCE, WATER CONTENT

Field	NIR Ref.	Water content	Anthocyanin	Anthocyanin(D)	barley β-glucan
#1	0.6259	12.8	3.1	3.6	5.1
#2	0.5891	12.5	9.1	10.5	3.2
#3	0.6094	12.6	6.9	7.9	
#4	0.6036	12.6	6.5	7.4	

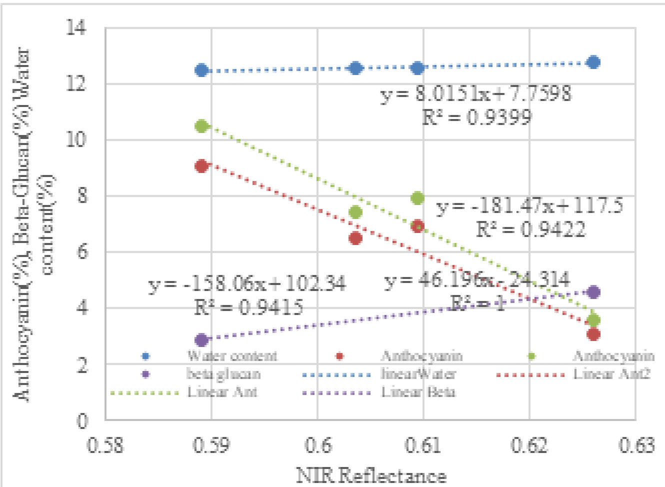


Fig. 5. Results from the Regressive Analysis among NIR Reflectance and Water Content, Barley β-glucan, Anthocyanin Content as well as Anthocyanin (Corresponding to Dry Matter) with Linear Approximation.

As the results, the following calibration curves (linear regressive equations) are obtained.

$$y_w = 8.0151x_w + 7.7598 \quad (1)$$

$$y_a = -181.47x_a + 117.5 \quad (2)$$

$$y_{ad} = -158.06x_{ad} + 102.3 \quad (3)$$

$$y_g = 46.196x_g - 24.314 \quad (4)$$

where y_w and x_w are water content and NIR reflectance while y_a and x_a are Anthocyanin content and NIR reflectance. Meanwhile, y_{ad} and x_{ad} are Anthocyanin content (corresponding to dry matter) and NIR reflectance while y_g and x_g are barley β-glucan and NIR reflectance, respectively. Thus it is found that water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) can be predicted before the harvest. Therefore, farmers can control fertilizer and water supply for improvement of the Daishimochi barley grain quality.

V. CONCLUSION

Barley quality estimation method with Unmanned Aerial Vehicle: UAV based Near Infrared: NIR camera data based on regressive analysis is proposed. The proposed method allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested "Daishimochi" of barley grains before the harvest.

Through experiment, it is found that Daishimochi barley grain quality, water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) can be predicted before the harvest. Therefore, farmers can control fertilizer and water supply for improvement of the Daishimochi barley grain quality.

VI. FUTURE RESEARCH WORKS

The proposed method has to be validated with the other types of agricultural products. Also, further experiments with drone mounted NIR camera data are required for validation of the proposed method.

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REFERENCES

[1] Kohei Arai, Sadayuki Akaishi, Hideo Miyazaki, Yasuyuki Watabe, Takaki Yoshida, Regressive analysis on leaf nitrogen content and near infrared reflectance and its application to agricultural farm monitoring with helicopter mounted near infrared camera, International Journal of Advanced Research in Artificial Intelligence, 2, 3, 38-43, 2013.

[2] Kohei Arai, Takuji Maekawa, Toshihisa Maeda, Hiroshi Sekiguchi, Noriyuki Masago, Effect of sensitivity improvement of visible to near infrared digital cameras on NDVI measurement in particular for agricultural field monitoring, International Journal of Advanced Research on Artificial Intelligence, 4, 12, 1-8, 2015.

[3] Kohei Arai, Osamu Shigetomi, Yuko Miura, Satoshi Yatsuda, Smartphone image based agricultural product quality and harvest amount prediction method, International Journal of Advanced Computer Science and Applications IJACSA, 10, 9, 24-29, 2019.

[4] Yeni Herdiyeni, Kohei Arai, Ellyn Danayanti, Ervizal A.M. Zaherdi, A computer aided system for tropical leaf medicinal plant identification (2013), Proceedings of the 1st International Conference on Sustainable Agriculture, Food and Energy, SAFE 2013.

[5] Kohei Arai, Product amont and quality monitoring in agricultural fields with remote sensing satellite and radio-control helicopter, Proc. of the 40th Science Assembly of the COSPAR (Solicited), Advanced RS Methods and Technics, ID12566, A3.1-0041,2014.

[6] Kohei Arai, Computer vision for remote sensing, Proceedings of the Special Lecture on Computer Vision for Remote Sensing of Agriculture, #1, 2015.

[7] Kohei Arai, Remote Sensing for Agriculture, Proceedings of the Special Lecture on Computer Vision for Remote Sensing of Agriculture, #2, 2015.

[8] Kohei Arai, Intelligent System for Agricultural Field Monitoring, Proceedings of the SAI Intelligent Systems Conference 2016.

[9] Kohei Arai, Multi-level observation system for agricultural field monitoring, Proceedings of the 1st International Conference on Sustainable Information, Engineering and Technology, Keynote Speech, 2016.

[10] Kohei Arai, Multi-Layer Observation for Agricultural Field Monitoring, Proceedings of the 1st ICON-EEI 2016 Conference, Keynote Speech, 2016.

[11] Kohei Arai, Intelligent System for Agricultural Field Monitoring, Proceedings of the SAI Intelligent Systems Conference 2016.

[12] Kohei Arai, Multi-level observation system for agricultural field monitoring, Proceedings of the 1st International Conference on Sustainable Information, Engineering and Technology, Keynote Speech, 2016.

[13] Kohei Arai, Multi-Layer Observation for Agricultural Field Monitoring, Proceedings of the 1st ICON-EEI 2016 Conference, Keynote Speech, 2016.

[14] Kohei Arai, Multi-Layer Observation for Agricultural (Tea and Rice) Field Monitoring, Proceedings of the Seminar at Bogor Agriculture University, Keynote Speech, 2016.

[15] Kohei Arai, Bigdata Platform for agricultural field monitoring and environmental monitoring, Proceedings of the 4th LISAT Symposium (Invited Speech), p.37, 2017.

[16] Kohei Arai and Yui Nishimura, Degree of polarization model for leaves and discrimination between pea and rice type s leaves for estimation of leaf area index, Abstract of the 50th COSPAR(Committee on Space Research/ICSU) Congress, A3.1-0010-08 ,991, Montreal, Canada, July, 2008.

[17] Setis Darmawan Afandi, Yeni Herdiyeni, Lilik Prasetyo, Wahyudi Hasbi, Kohei Arai, H. Okumura, Nitorogen Content Estimation of Rice Crop Based on Near Infrared (NIR) Reflectance Using Artificial Neural Network (ANN), Proceedings of the 2nd International Symposium on LAPAN-IPB Satellite 2015, 1-7, 2015.

[18] Kohei Arai, Gondoh, Miura, Shigetomi, Effect of Stump density, Fertilizer on Rice Crop Quality and Harvest Amount in 2015 Investigated with Drone mounted NIR Camera Data, International journal of Engineering Science and research Technology, 2, 2, 1-7, 2016.

[19] Kohei Arai, Masanori Sakashita, Osamu Shigetomi, Yuko Miura, Relation between rice crop quality (protein content) and fertilizer amount as well as rice stump density derived from helicopter data, International Journal of Advanced Research on Artificial Intelligence, 4, 7, 29-34, 2015.

[20] Kohei Arai, Masanori Sakashita, Osamu Shigetomi, Yuko Miura, Estimation of Rice Crop Quality and Harvest Amount from Helicopter Mounted NIR Camera Data and Remote Sensing Satellite Data, International Journal of Advanced Research on Artificial Intelligence, 4, 10, 16-22, 2015.

[21] Kohei Arai, Kenji Gondoh, Osamu Shigetomi, Yuko Miura, Method for NIR Reflectance Estimation with Visible Camera Data Bsed on Regression for NDVI Estimation and Its Application for Insect Damage Detection of Rice Paddy Fields, International Journal of Advanced Research on Artificial Intelligence, 5, 11, 17-22, 2016.

[22] Kohei Arai, Osamu Shigetomi, Yuko Miura, Artificial Intelligence Baed Fertilizer Control for Improvement of Rice Qualityt and Harvest Amount, IJACSA, 9, 10, 61-67, 2018.

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