Method for Estimation of Oleic Acid Content in Soy Plants using Green Band Data of Sentinel-2/MSI

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***Abstract*—A method for estimation of oleic acid content in soy plants using green band data of Sentinel-2/MSI: Multi Spectral Imager is proposed. Conventionally, vitality of agricultural plants is estimated with NDVI: Normalized Difference Vegetation Index. Spatial resolution of Near Infrared: NIR band of Sentinel-2/MSI for calculation of NDVI, however, is 20 m. Therefore, a method for estimation of vitality with only green band data of Sentinel-2/MSI is proposed here. Through regressive analysis with the satellite data as well as drone mounted NDVI camera data together with component analysis data by gas chromatography, it is found the correlation between NDVI and green band data of the optical sensor (MSI) onboard Sentinel-2 as well as the component analysis data. It is also found that the new variety of soy plant, Saga University brand: HO1 contains about 50% much oleic acid in comparison to the conventional variety of soy plant, Fukuyutaka.**

Keywords*—Oleic acid; NDVI (normalized difference vegetation index); regressive analysis; soy plant; Multi Spectral Imager: MSI

I. Introduction

Oleic acid is a type of unsaturated fatty acid and is a monovalent unsaturated fatty acid. It is abundant in animal fats, vegetable oils, and nuts and seeds. Since it reduces only bad cholesterol without reducing good cholesterol, it helps prevent lifestyle-related diseases such as arteriosclerosis and heart disease. In addition, it is resistant to heat and is difficult to oxidize, suppresses fatty acids peroxide that may cause carcinogenesis, regulates gastric acid secretion, and activates intestinal motility.

In addition to amino acids, meat contains various health ingredients. Examples include "heme iron," which has an anemia-preventing effect, and "conjugated linoleic acid," which has anti-cancer effects, body fat reduction, and arteriosclerosis-preventing effects. Among them, "oleic acid", which is one of the fatty acids, is expected to have a preventive effect on lifestyle-related diseases.

Oleic acid, which is abundant in beef and pork, has the function of maintaining proper cholesterol in the blood. Cholesterol includes bad (LDL) cholesterol and good (HDL) cholesterol. Bad cholesterol causes arteriosclerosis, heart disease, and high blood pressure, but good cholesterol has a function to prevent arteriosclerosis. Oleic acid is said to have the effect of reducing only bad cholesterol without reducing this good cholesterol.

Another characteristic of oleic acid is that it is not easily oxidized. In general, when fat is oxidized, it binds to active oxygen in the body and damages DNA, causing cancer, arteriosclerosis, heart disease, brain disease, diabetes, and so on. Oleic acid has the effect of preventing cancer and lifestyle-related diseases.

The main varieties of Saga Prefecture are cultivated as standard, and the crops of the year are estimated by analyzing the growth reaction in climate change, and they are used as materials for soybean production guidance.

The new varieties were cultivated by Saga University, a national university corporation, and the application for cultivar registration was announced in 2019. The variety name is "Saga University HO1", which has a high oleic acid content, and "Fukuyutaka" has a high content of 80%, while 20% of the total fatty acid. In recent years, there have been requests from actual consumers and producers to expand cultivation in the midst of regional specialization, and there are voices in the Takeo / Kishima area requesting the establishment of technology for stable production. Therefore, the purpose is to obtain knowledge about the basic cultivation characteristics of this variety.

"High oleic acid soybean (Saga University HO1)" has a flowering period of 2 to 3 days and a maturity period of about 1 day earlier than "Fukuyutaka". The length of the main stem is a little short, and the height of the lowermost pod node is about 3 cm lower. The number of main stem nodes and the number of branches is about the same. There are many pods. Yieldability is considered to be about the same. Grains tend to be slightly flat and small in grain shape.

Relating to soy plant monitoring and content estimation in soy, there are the following papers.

Prediction of Isoflavone Content in Soybeans with Sentinel-2 Optical Sensor Data by Means of Regressive Analysis [1], and Soybean Quality Estimation with Sentinel-2 of Optical Sensor Data [2]. On the other hand, Sentinel-2 data analysis method related papers, there are the following papers.

Flooding and oil spill disaster relief using Sentinel of remote sensing satellite data [3], Sea breeze damage estimation method using Sentinel of remote sensing satellite data [4], ACIX-Aqua: A global assessment of atmospheric correction methods for Landsat-8 and Sentinel-2 over lakes, rivers, and coastal waters [5], Method for Most Appropriate Plucking Date Determination based on the Elapsed Days after Sprouting with NIR Reflection from Sentinel-2 Data [6], Prediction of

Isoflavone Content in beans with Sentinel-2 Optical Sensor Data by Means of Regressive Analysis [7].

Furthermore, agricultural plantation related research works, there are the following papers.

Regressive analysis on leaf nitrogen content and near infrared reflectance and its application to agricultural farm monitoring with helicopter mounted near infrared camera [8], Effect of sensitivity improvement of visible to near infrared digital cameras on NDVI measurement in particular for agricultural field monitoring [9], Smartphone image based agricultural product quality and harvest amount prediction method [10], A computer aided system for tropical leaf medicinal plant identification [11], Product amount and quality monitoring in agricultural fields with remote sensing satellite and radio-control helicopter [12], Intelligent System for Agricultural Field Monitoring [13], Multi-level observation system for agricultural field monitoring [14], Multi-Layer Observation for Agricultural (Tea and Rice) Field Monitoring [15], Bigdata Platform for agricultural field monitoring and environmental monitoring [16].

Prediction of isoflavone content in beans with Sentinel-2 optical sensor data by means of regressive analysis is made [17]. Meanwhile, method for most appropriate plucking date determination based on the elapsed days after sprouting with NIR reflection from Sentinel-2 data is proposed and validated [18].

The purpose of this study is to establish a method for estimation of oleic acid content in soy plants using NDVI derived from optical sensor (MSI) onboard Sentinel-2 satellite. Traditionally, it is used to use drone mounted NDVI data for the estimation. It does cost. It cannot be used for the windy condition. Turns out, Sentinel-2/MSI data can be accessible from the ESA web site freely even for windy condition, it cannot be used for cloudy and rainy conditions, though. In terms of spatial resolution of drone mounted NDVI camera, it is fine about a couple of cm depending on altitude of the drone. On the other hand, spatial resolution of Sentinel-2/MSI is 10 m for visible bands and is 20 m for Near Infrared: NIR band. Therefore, spatial resolution of NDVI which is derived with visible and NIR is 20 m. It is not good enough for Japanese soy plantation fields. In order to estimate NDVI with 10 m of spatial resolution using Sentinal-2/MSI optical sensor data, green band data derived from visible band of Sentinel-2/MSI is used in the proposed method. Through regressive analysis with the satellite data as well as drone mounted NDVI camera data together with component analysis data by gas chromatography, it is found the correlation between NDVI and green band data of the optical sensor (MSI) onboard Sentinel-2 as well as the component analysis data. It is also found that the new variety of soy plant, Saga University brand: HO1 contains about 50% much oleic acid in comparison to the conventional variety of soy plant, Fukuyutaka.

The next section describes the proposed method. Then experiments with drone mounted NDVI data and Sentinal-2/MSI of green band data together with component analysis data by gas chromatography followed by concluding remarks and future research work.

II. Proposed Method

A method for estimation of oleic acid content in soy plants using NDVI derived from optical sensor onboard Sentinel-2 satellite is proposed. Table I shows Sentinel-2 fast track service compliance to land user requirements. Every 10 days, Sentinel-2 observes the same location of Earth's surface.

Major specification of Multispectral Imager: MSI is as follows, MSI covering 13 spectral bands (443–2190 nm), with a swath width of 290 km and a spatial resolution of 10 m (four visible and near-infrared bands), 20 m (six red edge and shortwave infrared bands) and 60 m (three atmospheric correction bands).

MSI spatial resolution versus wavelength: Sentinel-2's span of 13 spectral bands, from the visible and the near-infrared to the shortwave infrared at different spatial resolutions ranging from 10 to 60 m on the ground, takes land monitoring to an unprecedented level. Table II shows MSI spectral band specification. Green band in the MSI spectral bands can be used for estimation of oleic acid containing soybeans in living soy plantations.

The spatial resolution of Sentinel-2 is 10 m for visible bands and is 20 m for Near Infrared: NIR band (865 nm). Therefore, spatial resolution of NDVI which is derived with visible and NIR is 20 m. It is not good enough for Japanese soy plantation fields. To estimate NDVI with 10 m of spatial resolution using Sentinal-2 optical sensor data, green band data derived from visible band of Sentinel-2 is used in the proposed method.

TABLE I. SENTINEL-2 FAST TRACK SERVICE COMPLIANCE TO LAND USER REQUIREMENTS

Fast Track Service (Land Monitoring Core Services)	Compliance of the Sentinel-2 system
Geographic coverage	All land areas/islands covered (except Antarctica)
Geometrical revisit	5 days revisit cloud free fully in line with vegetation changes
Spectral sampling	Unique set of measurement/calibration bands
Service continuity	Sentinel-2A launch in 2014: the mission complements the SPOT and Landsat missions.
Spatial resolution	< 1 ha MMU (Minimum Mapping Unit) fully achievable with 10 m
Acquisition strategy	Systematic push-broom acquisitions, plus lateral mode capability for emergency events monitoring
Fast Track Service (Emergency Response Core Service)	Compliance of the Sentinel-2 system
Spatial resolution down to 5 m	Reference/damage assessment maps limited to the 10m SSD (Spatial Sampling Distance)
Accessibility/timeliness down to 6 hrs offline & 24hrs in NRT	Fully compliant (retrieval of already archived reference data in < 6 hrs, and delivery of data after request in NRT in 3 hrs for L1c)

TABLE II. MSI SPECTRAL BAND SPECIFICATION

Spectral bands (center wavelength in nm/SSD in m)	Mission objective	Measurement or calibration
B1 (443/20/60), B2 (490/65/10) & B12 (2190/180/20)	Aerosol correction	Calibration bands
B8 (842/115/10), B8a (865/20/20), B9 (940/20/60)	Water vapor correction	
B10 (1375/20/60)	Circus detection	
B2 (490/65/10), B3 (560/35/10), B4 (665/30/10), B5 (705/15/20), B6 (740/15/20), B7 (775/20/20), B8 (842/115/10), B8a (865/20/20), B11 (1610/90/20), B12(2190/180/20)	Land cover classification, Leaf chlorophyll content, leaf water content, LAI, fAPAR, snow/ice/cloud, mineral detection.	Land measurement bands

The online services provided by Amazon for web operators and developers are called AWS (Amazon Web Services). Among them, a large amount of data taken by Sentinel-2 is stored in Amazon's cloud storage called Amazon S3 (Amazon Simple Storage Service), and his AWS service that provides the data taken by Sentiel-2 is Sentinel- It's called 2 on AWS. Users can now download satellite imagery data via Amazon S3 storage. Amazon publishes a huge amount of geospatial data in a project called Earth on AWS, including not only satellite images, but also terrain tiles, SpaceNet machine learning training data, next-generation weather radar (NEXRAD) weather data, and more. It also provides a variety of geospatial data and is accessible to anyone. With a paid service, you can analyze this huge amount of data on the cloud, so there is no need to download data for analysis or perform troublesome preprocessing, and it is a larger project than before. It can be realized in a shorter period of time.

Download satellite images of where you need them. Access the Sentinel Image browser. The search screen is displayed. Specify the period to search for the image and the amount of clouds, display the area where you want to download the image, and click the [Submit] button to display the detailed information and preview of the image, the amount of clouds, the date and time when the image was acquired, the product level, etc. can be confirmed. Select the image you want to use from the search result field and click the link button. Then it can be gotten a link to the image, click AWS path (link above). After that, Launch ArcGIS Pro (or ArcMap) and add the downloaded data from the Project window (in the case of ArcMap, add it from the Catalog window). This time, we will synthesize a multi-spectral band, so add B02.jp2 to B04.jp2. Since it is added for each band, it does not look natural as it is. Next, composite each band to synthesize the true color. Click the Raster Function button on the Analysis tab to bring up the Raster Function window. Expand Data Management and click the Composite icon. Click the Raster pull-down button under Composite Properties to add each band. Add all the bands, sort them by B04, B03, B02 from the top, and click the Create New Layer button. A "Composite" layer has been added to the Content window to composite the true color multiband image.

III. EXPERIMENT

A. Intensive Study Area

Intensive study area is situated at the Saga Prefectural Agriculture Research Institute: SPARI which is situated at 33°13'11.5" North, 130°18'39.6" East as shown in Fig. 1. Fig. 1(a) shows the intensive study area in Japan while Fig. 1(b) shows the soy plantation areas for the new variety of soy (Saga University originated HO1) and for the conventional variety of soy (Fukuyutake). Both soy plantation areas are indicated in red and white rectangles in Fig. 1.

(a) Intensive Study site in Japan (Red Circle).

(b) Red Rectangle: Conventional Fukuyutaka, White Rectangle: New Variety of HO1.

Fig. 1. Intensive Study Area.

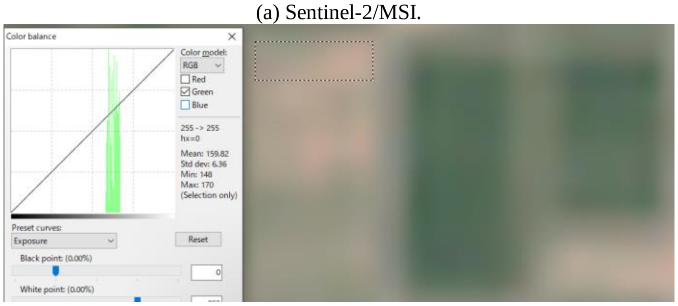
B. *Acquired Drone Mounted NDVI Camera Data and MSI Imagery Data of Sentinel-2*

Examples of the drone mounted NDVI camera data and Sentinel-2/MSI imagery data which are acquired on 29 July 2021 and on 30 July 2021, respectively are shown in Fig. 2. Fig. 2(a) shows Sentinel-2/MSI image which is acquired on 30 July 2021 while Fig. 2(b) shows the histogram of the green band data of the Fukuyutaka field of the Sentinel-2/MSI image. On the other hand, Fig. 2(c) shows the histogram of the green band data of the HO1 field of the Sentinel-2/MSI image. Meanwhile, Fig. 2(d) shows the natural color image of drone mounted NDVI camera data which is acquired on 29 July 2021 while Fig. 2(e) shows the histogram of the NDVI image of drone mounted NDVI camera data of the Fukuyutaka. On the other hand, Fig. 2(f) shows the histogram of the NDVI image of drone mounted NDVI camera data of the HO1.

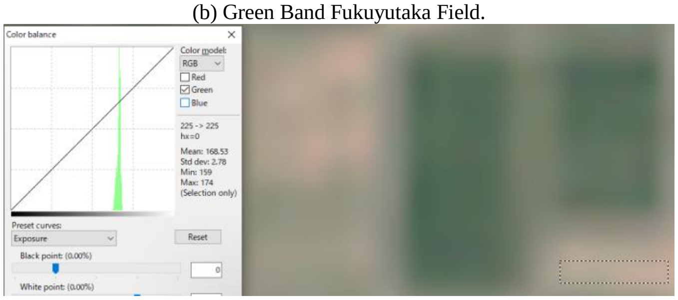
C. *Relation between Sentinel-2/MSI and Drone Mounted NDVI Camera Data*

The trend of the means of the Sentinel-2/MSI data of the Fukuyutaka and the Saga University originated HO1 of new variety of soy fields is shown in Fig. 3(a) while Fig. 3(b) shows both trends of Sentinel-2/MSI and drone mounted NDVI camera data of the same soy fields. Although mean and standard deviation are different each other, trends are almost same. Therefore, the green band data of the Sentinel-2/MSI can be used for growing process analysis of soy fields.

(a) Sentinel-2/MSI.

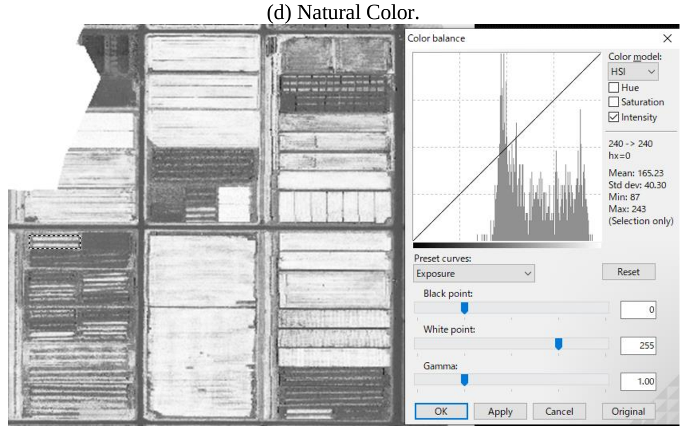


(b) Green Band Fukuyutaka Field.

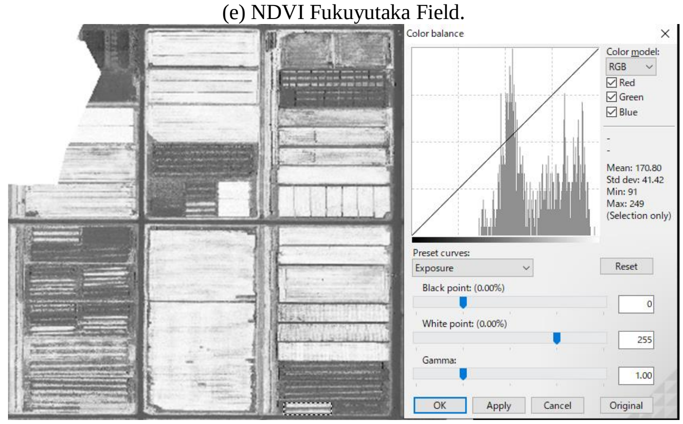


(c) Green Band HO1 Field.

(d) Natural Color.

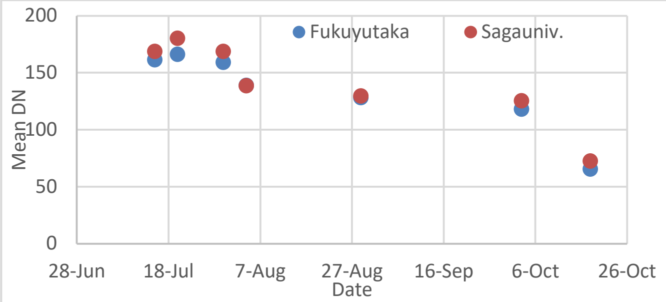


(e) NDVI Fukuyutaka Field.

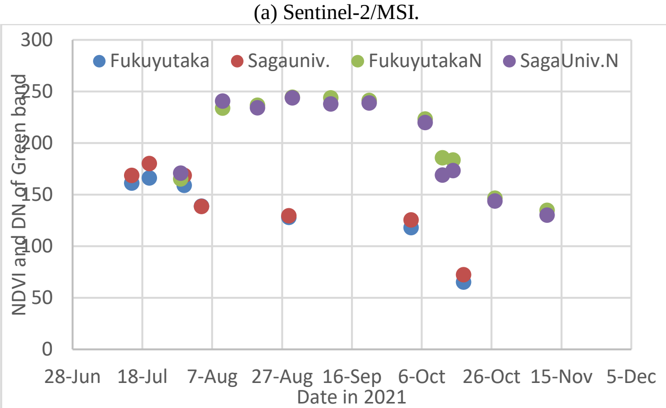


(f) NDVI HO1.

Fig. 2. Examples of the Drone Mounted NDVI Camera Data and Sentinel-2/MSI Imagery Data which are Acquired on 29 July 2021 and on 30 July 2021, respectively.



(a) Sentinel-2/MSI.



(b) Both Sentinel-2/MSI and Drone Mounted NDVI Camera.

Fig. 3. Relation between Sentinel-2/MSI and Drone Mounted NDVI Camera Data: The Trend of the means of the Sentinel-2/MSI Data of the Fukuyutaka and the Saga University Originated HO1 of New Variety of Soy Fields.

D. Experiment Procedure

Field experiments are conducted as follows:

Tillage overview:

1) Field: C4-10 (previous crop: wheat, previous summer crop: paddy rice).

2) Test variety: High oleic acid soybean "Saga University HO1" (Control: "Fukuyutaka")

3) Sowing method: After plowing and leveling, hand-sown 4 seeds per plant → 2 tailoring (Hirataka ridge)

4) Weeding: After sowing and before budding) Laxar granules 4kg / 10a (Growth period) Weeding as appropriate

5) Fertilization: No fertilization

Composition of test plot is as follows:

Ward sowing period Planting style:

1) Early sowing practice zone Late June 75 cm between rows * 20 cm between stocks * 2 (13.3 / ㎡)

2) Early sowing sparsely planted area Late June Joma 75 cm * Strain 30 cm * 2 (8.9 shares / ㎡)

3) Conventional sowing area Mid-July 75 cm between rows * 20 cm between stocks * 2 (13.3 / ㎡)

4) Control area (Fukuyutaka) Mid-July 75 cm between rows * 20 cm between stocks * 2 (13.3 / ㎡)

Survey items are as follows:

Understanding the growth stage (budding stage, flowering stage, pod setting stage, grain enlargement stage, yellow leaf stage, leaf fall stage, maturity stage).

Seedling survey is as follows:

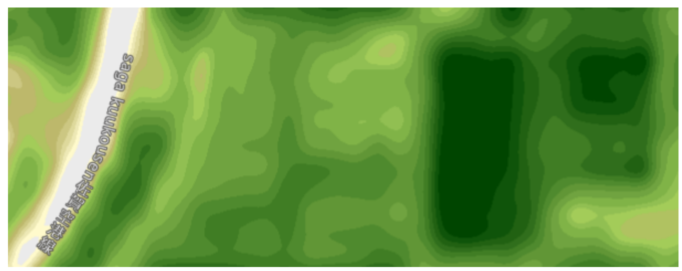
1) Yield survey (grain weight, stem weight, 100 grain weight, particle size composition).

2) Decomposition survey (main stem length, number of main stem nodes, bottom pod height, number of branches, number of pods, number of grains).

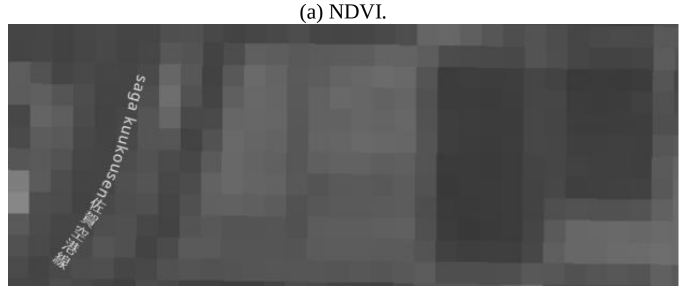
3) Quality survey (inspection grade, protein content).

E. Relation between Sentinel-2/MSI Derived NDVI and Green Band Data

Relation between Sentinel-2/MSI derived NDVI and green band data is investigated. If the relation between Sentinel-2/MSI derived NDVI and the green band data is high, then vegetation vitality can be estimated with green band only. Fig. 4(a) shows Sentinel-2/MSI derived NDVI while Fig. 4(b) shows green band data of the intensive study area acquired on July 30 2021.



(a) NDVI.



(b) Green Band.

Fig. 4. Comparison between Sentinel-2/MSI Derived NDVI and Green Band Data of the Intensive Study Area Acquired on July 30 2021.

The correlation coefficient between both is more than 0.95. Therefore, it is concluded that vegetation vitality can be estimated with green band only.

F. Comparisons among the Several Band Combinations of Sentinel-2/MSI Data

Fig. 5(a) to (d) show the following several band combinations of Sentinel-2/MSI imagery data.

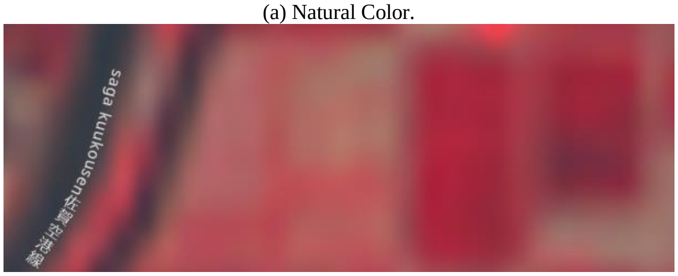
a) Natural Color.

b) False Color.

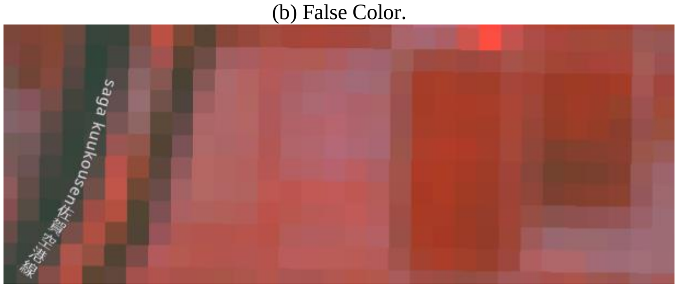
c) R: Band 8, G: Band 3, B: Band 4 and.

d) NDVI.

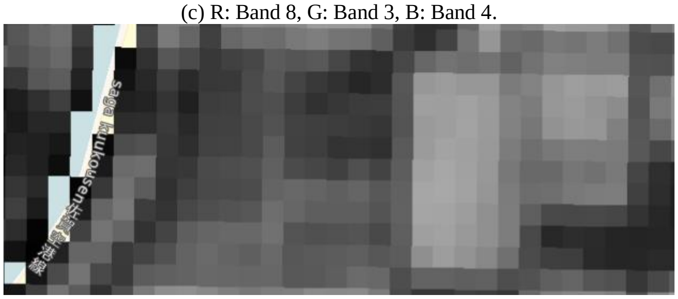
(a) Natural Color.



(b) False Color.



(c) R: Band 8, G: Band 3, B: Band 4.



(d) NDVI.

Fig. 5. Several Band Combinations of Sentinel-2/MSI Imagery Data.

Fig.6 shows the relation between the NDVI (Fig. 5(d)) and the green band data (Fig. 4(b)). Correlation coefficient between both is 0.977 and the NDVI is estimated with the green band data with regressive equation in Fig. 6 with R^2 value of 0.954.

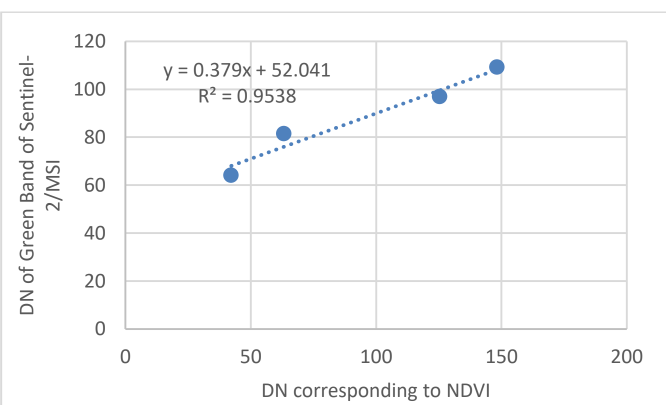


Fig. 6. Correlation between NDVI and Green Band Data.

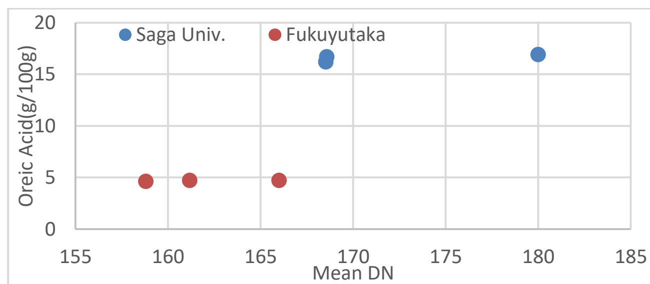
Through a comparison between Fig. 4(b) and Fig. 5(d), it is confirmed that vegetation vitality can be estimated with green band only.

G. Experimental Results

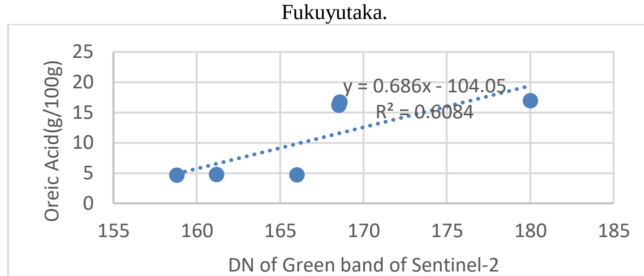
Oleic acid content in the harvested soybeans is measured with gas chromatography. Fig. 7(a) shows the results from the gas chromatography measurements for Saga University originated HO1 and conventional Fukuyutaka against mean of digital Number: DN of the Sentinel-2/MSI of the green band data for each test site. On the other hand, Fig. 7(b) shows the relation between oleic acid content and mean of the green band data derived from Sentinel-2/MSI. It is found that the R^2 value of the relation between oleic acid content and mean of the green band data derived from Sentinel-2/MSI is much more than 0.6. Therefore, it can be said that it is possible to estimate oleic acid content by using the mean of the green band data derived from Sentinel-2/MSI.

The relationship between sowing time, number of repetitions and amount of oleic acid) for Fukuyutaka is shown in Fig. 8 while effect of n-piece stands on Saga University originated HO1 variety (sown on June 28) is shown in Fig. 9, respectively. In this connection, the number of iterations is defined as follows:

For those with a small number of iterations, the number of iterations had to be reduced because the field was small. The difference in the number of iterations is meaningless.



(a) Relation between Oleic Acid Content and mean od DN of the Green Band Data of Sentinel-2/MSI for the Saga University Originated HO1 and Fukuyutaka.



(b) Relation between Oleic Acid Content and Mean of the Green Band Data Derived from Sentinel-2/MSI.

Fig. 7. Relation between Oleic Acid Content and Mean of the Green Band Data Derived from Sentinel-2/MSI.

On the other hand, the number of tailoring is defined as follows:

To be exact, it was "difference between strains (difference in planting density)" rather than the number of tailored plants. The correct treatment for "Saga University originated HO1" is that the seeding on June 30 is 30 cm (13.3 seeds / ㎡) and the seeds are 20 cm (8.9 seeds / ㎡), and the seeding on July 13 is 20 cm between the stocks. Regarding the planting density, we have set two styles that can be handled by mechanical sowing at the site in order to examine the appropriate planting density that enables stable production.

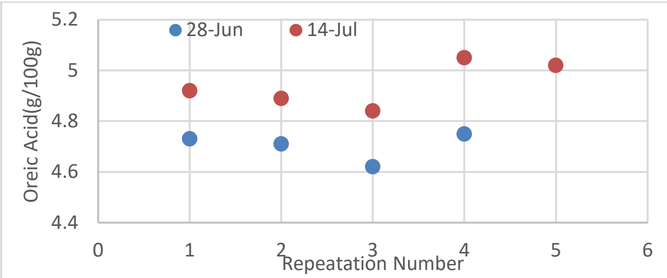


Fig. 8. Relationship between Sowing Time, Number of Repetitions and Amount of Oleic Acid) for Fukuyutaka.

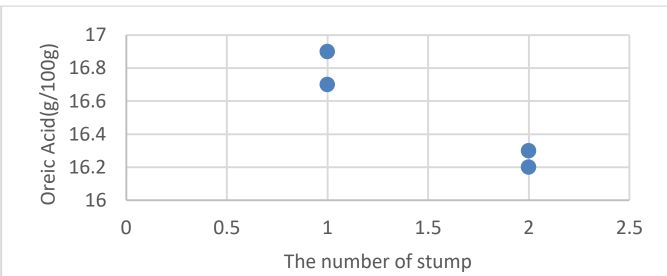


Fig. 9. Effect of n-piece Stands on Saga University Originated HO1 Variety (Sown on June 28).

Meanwhile, regressive analysis for estimation of harvest number of soybeans is made. Fig. 10 shows the result. It is found that harvest amount can be predicted with DN of green band data of Sentinel-2/MSI data about three months before the harvest with R^2 value of 0.965.

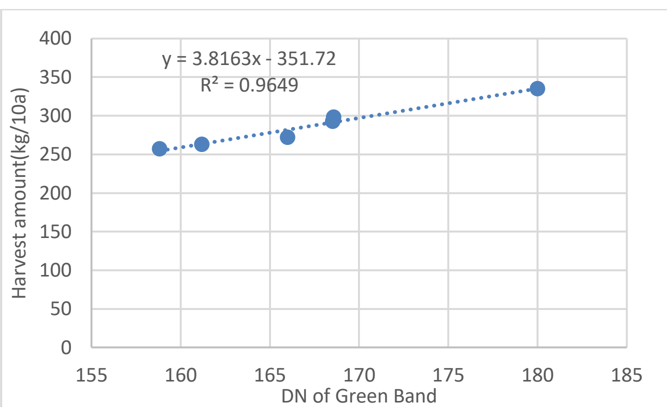


Fig. 10. Harvest Amount Prediction with Green Band Data of Sentinel-2/MSI.

IV. Conclusion

A method for estimation of oleic acid content in soy plants using NDVI derived from optical sensor onboard Sentinel-2 satellite is proposed. Through regressive analysis with the satellite data as well as drone mounted NDVI camera data together with component analysis data by gas chromatography, it is found the correlation between NDVI and green band data of the optical sensor (MSI) onboard Sentinel-2 as well as the component analysis data. It is also found that the new variety of soy plant, Saga University brand: HO1 contains about 50% much oleic acid in comparison to the conventional variety of soy plant, Fukuyutaka.

It is found that the R^2 value of the relation between oleic acid content and mean of the green band data derived from Sentinel-2/MSI is much more than 0.6. Therefore, it can be said that it is possible to estimate oleic acid content by using the mean of the green band data derived from Sentinel-2/MSI.

The limitation of the proposed method is caused by the observation frequency of fine Sentinel-2/MSI data. The revisit cycle of Sentinel-2 satellite is 10 days. It is not possible to get fine data when the weather condition is not fine (cloudy and rainy).

V. Future Reaesrch Work

Next thing we would like to do is estimation of most appropriate harvest date with Sentinel-2/MSI data. Also, deep learning is applied to these estimations.

Acknowledgment

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References

[1] Kohei Arai1, Osamu Shigetomi, Hideki Ohtsubo, Eri Ohya, Prediction of Isoflavone Content in Soybeans with Sentinel-2 Optical Sensor Data by Means of Regressive Analysis, Proceedings of the IntelliSys Conference 2021, 2021.

[2] Kohei Arai, Soybean Quality Estimation with Sentinel-2 of Optical Sensor Data, General Lecture of Postgraduate Program on Computer Science IPB "Satellite Image Processing for Smart Agriculture and Forestry" Wednesday 20 October 2021, Time: 10.00 – 12.00 WIB (Jakarta time).

[3] Kohei Arai, Flooding and oil spill disaster relief using Sentinel of remote sensing satellite data, International Journal of Advanced Computer Science and Applications IJACSA, 10, 12, 290-297, 2019.

[4] Kohei Arai, Sea breeze damage estimation method using Sentinel of remote sensing satellite data, International Journal of Advanced Computer Science and Applications IJACSA, 11, 2, 40-47, 2020.

[5] Nima Pahlevan, Antoine Mangin; Sunadarabalan Balasubramanian; Brandon Smith; Krista Alikas; Claudio Barbosa; Simon Bélanger; Caren Binding; Mariano Bresciani; Claudia Giardino; Daniela Gurlin; Yongzhen Fan; Tristan Harmel; Moritz K Lehmann; Ronghua Ma; Leif Olmanson; Natascha Oppelt; Steef Peters; Nathalie Reynaud; Lino A Sander de Carvalho; Evangelos Spyrakos; François Steinmetz; Kerstin Stelzer; Sindy Sterckx; Thierry Tormos; Quinten Vanhellemont; Mark Warren; Martin Ligi; Kohei Arai; Peter Hunter; Joji Ishikaza; Susanne Kratzer; Andrew Tyler; Yanqun Pan, ACIX-Aqua: A global assessment of atmospheric correction methods for Landsat-8 and Sentinel-2 over lakes, rivers, and coastal waters, Journal: Remote Sensing of Environment, 258 (2021) 112366, 1-22, RSE-D-20-01482R1, 2021.

[6] Kohei Arai, Yoshiko Hokazono, Method for Most Appropriate Plucking Date Determination based on the Elapsed Days after Sprouting with NIR Reflection from Sentinel-2 Data, (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 12, No. 4, 22-29, 2021.

[7] Kohei Arai, Prediction of Isoflavone Content in beans with Sentinel-2 Optical Sensor Data by Means of Regressive Analysis, Proceedings of SAI Intelligent Systems Conference, IntelliSys 2021: Intelligent Systems and Applications pp 856-865, 2021.

[8] 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.

[9] 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.

[10] 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.

[11] 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.

[12] Kohei Arai, Product amount 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.

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

[14] 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.

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

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

[17] Kohei Arai, Prediction of Isoflavone Content in beans with Sentinel-2 Optical Sensor Data by Means of Regressive Analysis, Proceedings of SAI Intelligent Systems Conference, IntelliSys 2021: Intelligent Systems and Applications pp 856-865, 2021.

[18] Kohei Arai, Yoshiko Hokazono, Method for Most Appropriate Plucking Date Determination based on the Elapsed Days after Sprouting with NIR Reflection from Sentinel-2 Data, (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 12, No. 4, 22-29, 2021.

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