# Rice Crop Field Monitoring System with Radio Controlled Helicopter Based Near Infrared Cameras Through Nitrogen Content Estimation and Its Distribution Monitoring

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***Abstract*—Rice crop field monitoring system with radio controlled helicopter based near infrared cameras is proposed together with nitrogen content estimation method for monitoring its distribution in the field in concern. Through experiments at the Saga Prefectural Agricultural Research Institute: SPARI, it is found that the proposed system works well for monitoring nitrogen content in the rice crop which indicates quality of the rice crop and its distribution in the field in concern. Therefore, it becomes available to maintain the rice crop fields in terms of quality control.**

***Keywords-radio controlled helicopter; near infrared camera; nitrogen content in the rice crop leaves; remote sensing;***

## I. INTRODUCTION

There are strong demands for saving human resources which are required for produce agricultural plants. In particular in Japan, now a day, the number of working peoples for agricultural fields is decreasing quite recently. Furthermore, the ages of the working peoples are getting old. Moreover, the agricultural fields are also getting wide through merging a plenty of relatively small scale of agricultural fields in order for maintain the fields in an efficient manner. Therefore, the working peoples have to maintain their fields in an efficient manner keeping the quality in mind.

Vitality monitoring of vegetation is attempted with photographic cameras [1]. Grow rate monitoring is also attempted with spectral reflectance measurements [2]. One of the methods for monitoring the fields is to use remote sensing technology utilizing aircrafts, helicopters, hot air balloons, etc. with a wide field of view for monitoring relatively large scaled agricultural fields. In particular, there are remote sensing sensors which onboard radio controlled helicopters. Attitude stability of the radio controlled helicopters is getting well now a day. Field of view of the remote sensing sensors is good enough for relatively wide scale of agricultural fields.

One of the indexes which allows indicate quality of agricultural crops is nitrogen content in the agricultural crop leaves. The nitrogen content is proportional to the reflectance at Near Infrared: NIR wavelength regions. Therefore, it is possible to estimate quality of agricultural crops with radio controlled helicopter based near infrared camera data.

Through experiments at the Saga Prefectural Agricultural Research Institute: SPARI for the period of rice crop growing, it is found that the proposed system works well for monitoring quality of the rice crops. Also it is found that the proposed method for nitrogen content estimation with near infrared camera data. Furthermore, it is capable to check rice crop quality distribution in the rice crop fields in concern. Then quality control which depends on location by location of the rice crop fields can be made with the quality monitoring results.

The following section describes the proposed monitoring system and nitrogen content estimation method based on the relation between nitrogen content in the rice crops and near infrared camera data followed by some experiments. Then conclusion is described together with some discussions.

## II. PROPOSED SYSTEM

### A. *Radio Controlled Helicopter Based Near Infrared Cameras Utilizing Agricultural Field Monitoring System*

The helicopter used for the proposed system is "GrassHOPPER" [1] manufactured by Information & Science Techno-Systems Co. Ltd. The major specification of the radio controlled helicopter used is shown in Table 1. Also, outlook of the helicopter is shown in Figure 1. Canon Powershot S100 [2]

[1] http://www.ists.co.jp/?page_id=892

[2] http://cweb.canon.jp/camera/dcam/lineup/powershot/s110/index.html

(focal length=24mm) is mounted on the GrassHOPPER. It allows acquire images with the following Instantaneous Field of View: IFOV at the certain altitudes, 1.1cm (Altitude=30m) 3.3cm (Altitude=100m) and 5.5cm (Altitude=150m).

Fig. 1. Outlook of the Grasshopper

TABLE I. MAJOR SPECIFICATION OF GRASSHOPPER

| | |
|---|---|
| Weight | 2kg (Helicopter only) |
| Size | 80cm × 80cm × 30m |
| Payload | 600g |

In order to measure NIR reflectance, standard plaque whose reflectance is known is required. Spectralon[3] provided by Labsphere Co. Ltd. is well known as well qualified standard plaque. It is not so cheap that photo print papers are used for the proposed system. Therefore, comparative study is needed between Spectralon and the photo print papers.

The proposed system consist Helicopter, NIR camera, photo print paper. Namely, photo print paper is put on the agricultural plantations, tea trees in this case. Then farm areas are observed with helicopter mounted NIR camera. Nitrogen content in agricultural plants, rice crops in this case, is estimated with NIR reflectance.

### B. *Regressive Analysis for Estimation of Nitrogen Content with NIR Reflectance*

Linear regressive equation is expressed in equation (1).

$$N = a R + b \tag{1}$$

where *N*, *R* denotes measured Nitrogen content in leaves, and measured Near Infrared: NIR reflectance, respectively while *a* and *b* denotes regressive coefficients. There is well known relation between nitrogen content and NIR reflectance. Therefore, regressive analysis based on equation (1) is appropriate.

### C. *Proposed Method for Rice Crop Quality Evaluation*

Rice crop quality can be represented nitrogen content which is closely related to nitrogen content. Furthermore, it is well known that nitrogen content can be represented with NIR reflectance. Therefore, rice crops quality can be evaluated with measured NIR reflectance based on the equation (1).

The proposed method and tea farm area monitoring system with helicopter mounted NIR camera is based on the aforementioned scientific background.

### D. *Rice Crop Field at Saga Prefectura; Agricultural Research Institute: SPARI*

Figure 2 shows outlook of the test site of rice crop field at SPARI [4] which is situated at 33°13'11.5" North, 130°18'39.6"East, and the elevation of 52feet.

## III. EXPERIMENTS

### A. *Experiment Procedure*

In accordance with growing of rice crops, spectral reflectance of rice leaves and Green Meter: GM values (reflectance at green wavelength) as well as meteorological data (air temperature, relative humidity, wind direction and wind speed) are collected. MS-720[5] of spectral radiometer which is manufactured by Eiko Co. Ltd. is used for spectral reflectance measurements. Meteorological data collection instrument manufactured by Mistral Co. Ltd. is also used together with GM meter of SPAD 502 Plus[6] manufactured by Konica Minolta Co. Ltd. Figure 2 shows outlook of the Spectralon (right) and the MS-720 (left).

Fig. 2. Outlooks of MS-720 and Spectralon

[3] https://www.google.co.jp/search?q=spectral+labsphere&hl=ja

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

[5] http://www.yamato-net.co.jp/product/advanced/analysis/radiometer/ms720.htm

[6] http://www.konicaminolta.jp/instruments/products/color/chlorophyll/index.html

Specie of the rice crop is Hiyokumochi[7] which is one of the late growing types of rice species. Hiyokumochi is one of low amylase (and amylopectin rich) of rice species (Rice No.216). Hiyokumochi rice leaves are planted 15 to 20 fluxes per $m^2$ on June 22 2012. Rice crop fields are divided into 10 different small fields depending on the amount of nutrition including nitrogen ranges from zero to 19 kg/10 a/nitrogen.

Nitrogen of chemical fertilizer is used to put into paddy fields for five times during from June to August. Although rice crops in the 10 different small fields are same species, the way for giving chemical fertilizer are different. Namely, the small field No.1 is defined as there is no chemical fertilizer at all for the field while 9, 11, and 13 kg/ 10 a/ nitrogen of after chemical fertilizer are given for No.2 to 4, respectively, no initial chemical fertilizer though. Meanwhile, 9, 11, 13 kg/10 a/nitrogen are given as after chemical fertilizer for the small field No.5, 6, and 7, respectively in addition to the 3 kg/10 a/nitrogen of initial chemical fertilizer. On the other hand, 12, 14, and 16 kg/10 a /nitrogen are given for the small fields No.5, 6, 7, respectively as after chemical fertilizer in addition to the initial chemical fertilizer of 3 kg/ 10 a/ nitrogen for the small field No. 15, 17, 19, respectively. Therefore, rice crop grow rate differs each other paddy fields depending on the amount of nitrogen of chemical fertilizer.

*B. Experimental Results*

*1) Outlook of the fields:* Figure 3 shows how a portion of the small fields in the early stage in June look like. These photos are portions of small field of C4-3 of top view and slant view respectively. Paddy fields are covered with water before rice leave plantation. Therefore, water surface is seen in these photos. These are growing up after that and do look like in July time frame as shown in Figure 4. There is no water surface can be seen any more from this period. After all, rice crops are grown up, and then these are harvested in September. Figure 5 shows how these rice crops look like just before the harvesting.

[7] http://ja.wikipedia.org/wiki/%E3%82%82%E3%81%A1%E7%B1%B3

(a)Slant view of the early stage of rice leaves

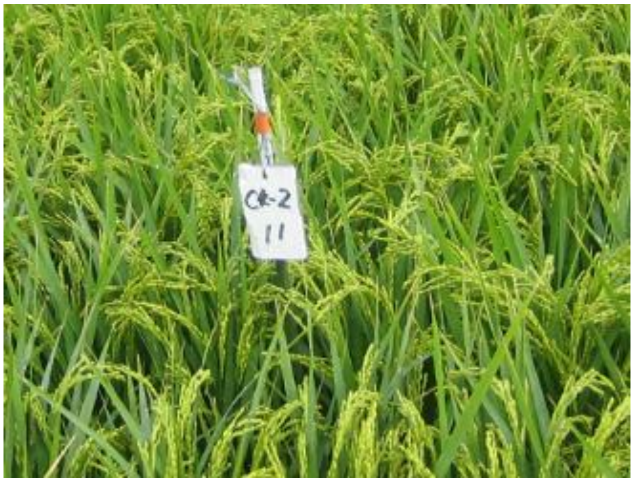
(b)Top view of the early stage of rice leaves

Fig. 3. Outlooks of the early stage of rice leaves in the early stage of rice leaves grow in June 2012.

(a)Top view of the middle stage of rice leaves of C4-2

(b)Top view of the middle stage of rice leaves of C4-3

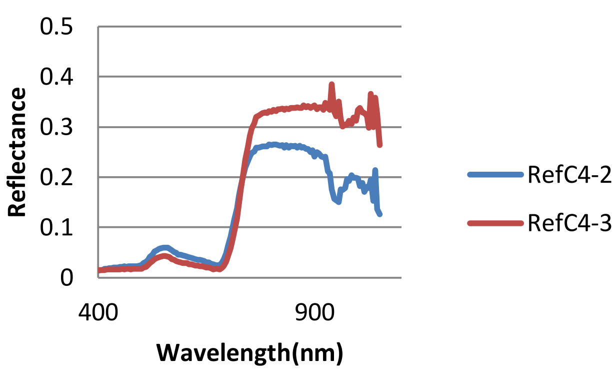
Fig. 4. Outlooks of the early stage of rice leaves in the middle stage of rice leaves grow in July 2012.



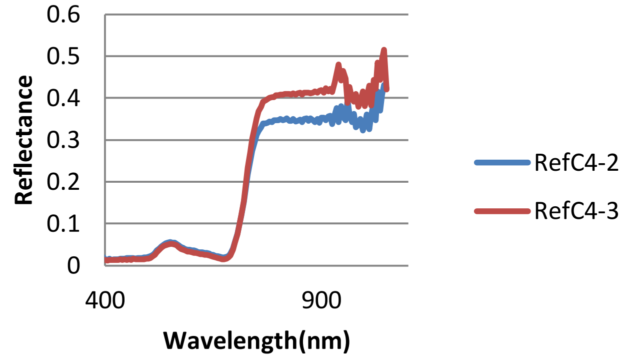
(a)Top view of just before the harvesting stage of rice leaves of C4-2

(b)Top view of just before the harvesting stage of rice leaves of C4-3

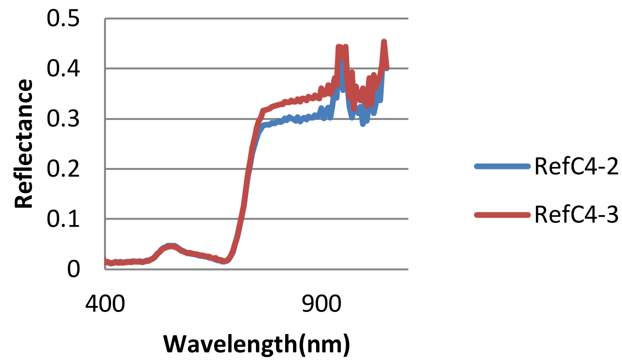
Fig. 5. Outlooks of the early stage of rice leaves in just before the harvesting stage of rice leaves grow in September 2012.



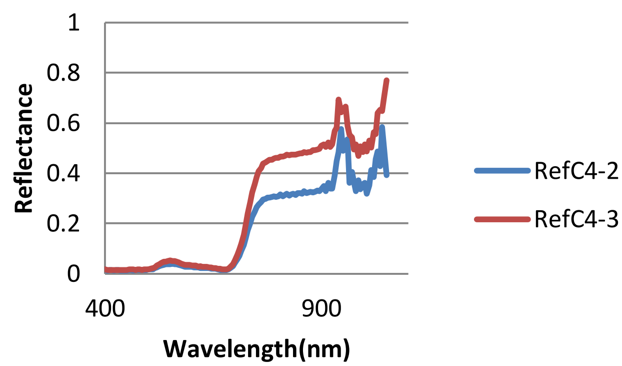

(a)August 15 2012, 13:15：35.6℃,61.0%,3m/s
GM=35.3 (C4-3), 31.0 (C4-2)



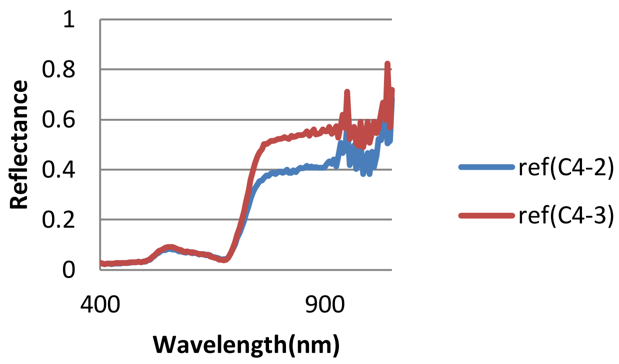

(b)August 17 2012, 9:30：32.2℃, 69.9%
GM=33.5 (C4-3), 32.4 (C4-2)




(c)August 20 2012, 8:45：1.76m/s, 28.9℃, 70%




(d)September 7 2012, 9:00：30.3℃, 72.3%
GM=44.1 (C4-3), 42.4 (C4-2)




(e)September 24 2012, 8:45：21.2℃, 74.1%
GM=38.8 (C4-2), 45.7 (C4-3)

Fig. 6. Spectral reflectance of NIR reflectance at C4-2 and C4-3 as well as air temperature, relative humidity, and GM values measured at SPARI

*2) Surface Reflectance:* During the period from August 15 to September 24 2012, spectral reflectance is measured from the top of the rice leaves. Figure 6 shows trend of rice leaf reflectance for C4-2 and C4-3 of the small fields at 700nm measure with MS-720 together with GM values as well as meteorological data.

The reflectance of C4-2 and C4-3 measured at 870nm (NIR reflectance) as well as GM values for these small fields are summarized in Table 2. Also these values are shown in Figure 7. NIR reflectance is increased with time during rice leaves are growing together with GM value. The rice crops are harvested in the begging of October. It is also confirmed that GM value and NIR reflectance of C4-3 are always greater than those of C4-2 due to the fact that chemical fertilizer of C4-3 is greater than that of C4-2. Obviously, there is strong relation between NIR reflectance and GM value as shown in Figure 8. Around 0.77 of $R^2$ value is confirmed between both.

Not only mean of NIR reflectance but also variance of NIR reflectance differs by small fields depending on the amount of nitrogen of chemical fertilizer.

*3) Uniformity Evaluation with Radio Conrtrolled Helicopter Based NIR Camera:* During the period from August 15 to September 24 2012, the rice crop fields are observed with radio controlled helicopter mounted NIR camera.

TABLE II. NIR REFLECTANCE AND GM VALUES MEASURED

| | C4-2 | C4-3 | GM(C4-2) | GM(C4-3) |
|---|---|---|---|---|
| Aug.15 | 0.258 | 0.338 | 31 | 35.3 |
| Aug.17 | 0.345 | 0.413 | 32.4 | 33.5 |
| Aug.20 | 0.305 | 0.345 | | |
| Sep.7 | 0.324 | 0.485 | 42.4 | 44.1 |
| Sep.24 | 0.413 | 0.547 | 38.8 | 45.7 |

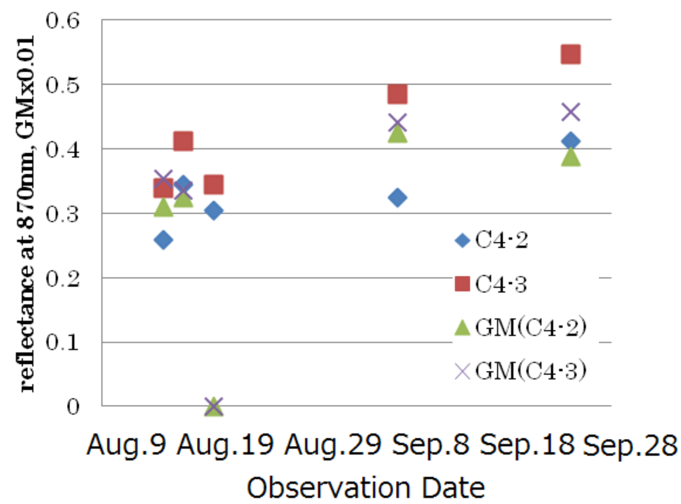



Fig. 7. NIR reflectance trend

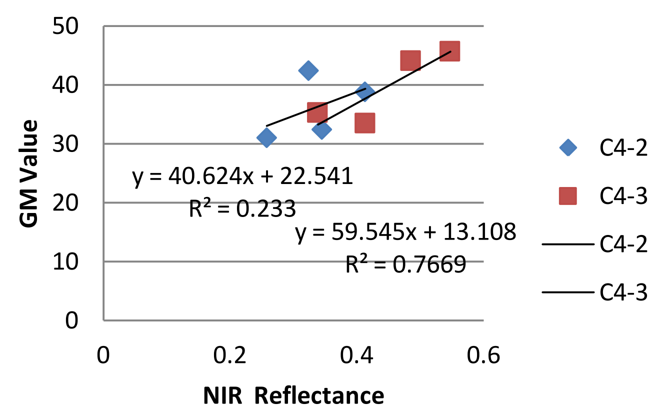
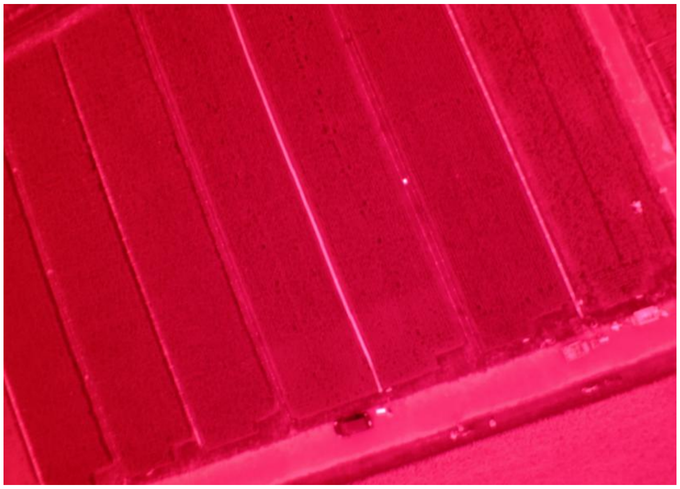


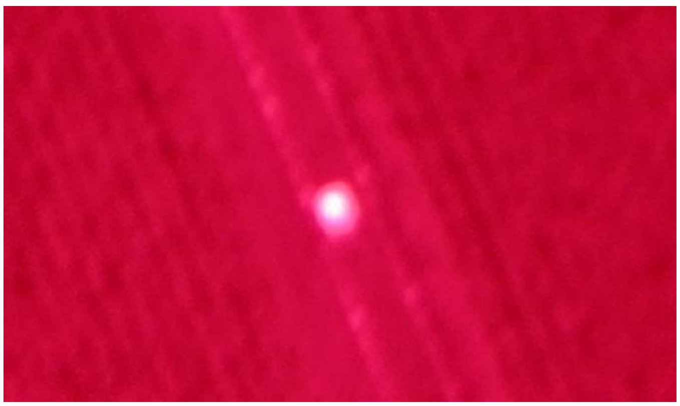

Fig. 8. Relation between GM value and NIR reflectance

Examples of the acquired images on September 28 are shown in Figure 9. C4-2 is situated on the right side of the photos while C4-3 is seen on the left hand side. In the middle of the photos, there is spectralon. It looks a small dots due to the fact that helicopter altitude is 30 m so that Instantaneous Field of View: IFOV is around 1.1 cm (Pixel size). Figure 9 (a) shows entire one shot of the acquired image with FOV of PowerShot of NIR camera while Figure 9 (b) shows enlarged portion of the acquired image. Meanwhile, Figure 9 (c) and (d) shows another shot of image at the different time on the same day. These show a good repeatability and reproduceability. NIR reflecttance can be calculated by taking the ratio of the pixels value of the fields and that of Spectralon.

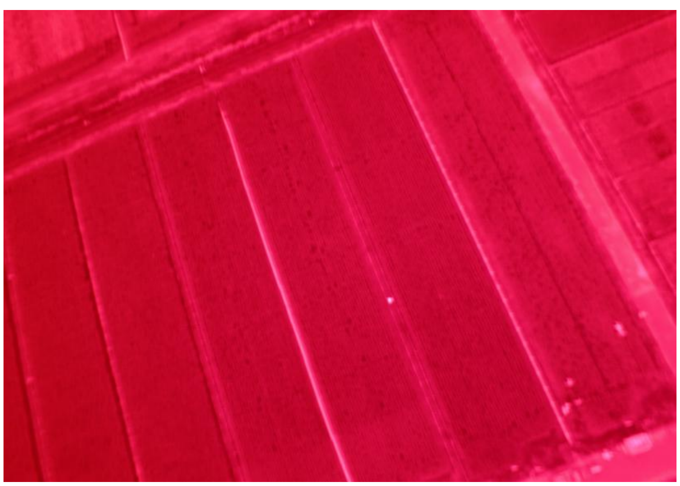
Uniformity in the small fields, C4-2, C4-3 are relatively good. Meanwhile, mean and variance are different by the samll fields due to the fact that the given chemical firtilizers are different each other small fields.



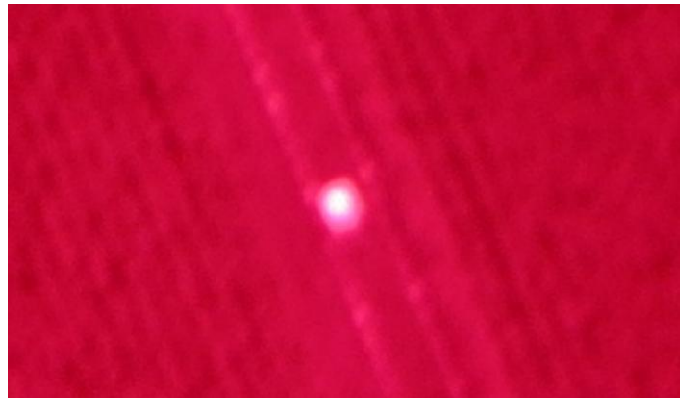
(a)Whole area of the Test site of C4-2 and C4-3



C4-2 (b)Enlarged image portion between C4-2 and C4-3 C4-3



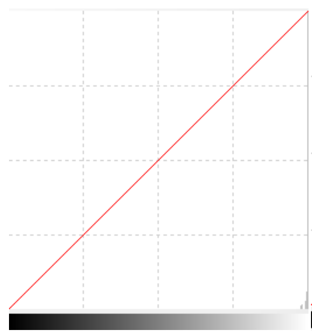
(c)Whole area of the Test site of C4-2 and C4-3

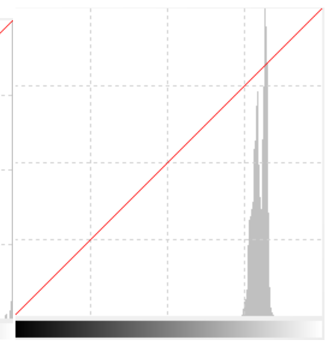


C4-2 (d)Enlarged image portion between C4-2 and C4-3 C4-3

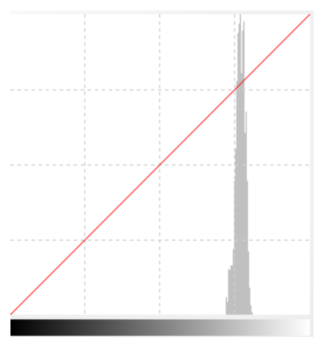
Fig. 9. Examples of the acquired images with radio controlled helicopter mounted NIR camera of PowerShot

*4) Histogram of the Acquired Pixel Values of Spectralon and the Small Fields:* Figure 10 shows the histograms of the acquired pixel values of C4-2 and C4-3 of small fields acquired at around 9:30 on September 28 2012, while Figure 11 shows those acquired at the different time (15 minutes after the acquisition of the previous scene) on September 28 2012.



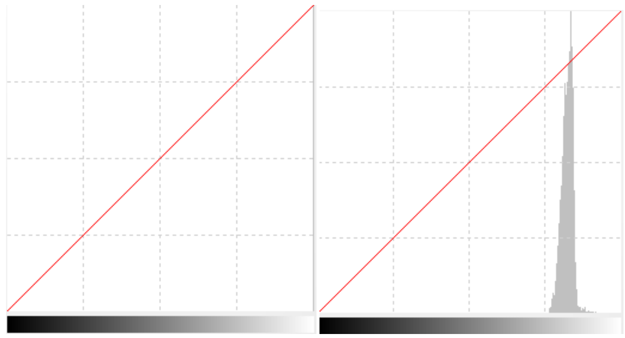


(a)Spectraron (b)C4-3: NIR Reflectance=0.787

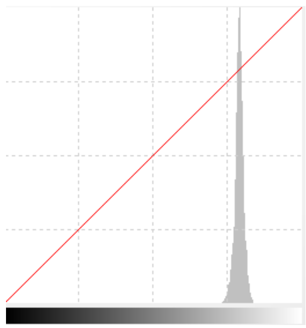


(c)C4-2: NIR Reflectance=0.765

Fig. 10. Histograms of the pixels in C4-2 and C4-3 acquired on September 24 2012.



(a)Spectralon (b)C4-3: NIR Reflectance=0.813



(c)C4-2: NIR Reflectance=0.787

Fig. 11. Histograms of the pixels in C4-2 and C4-3 small fields acquired on September 28 2012

*5) Relation Between Nitrogen Content in the Rice Leaves and NIR Reflectance:* Nitrogen content in the rice leaves is measured based on the Dumas method[8] (a kind of chemistry method) with Sumigraph NC-220F [9] of instrument. The measured total nitrogen content is compared to the NIR reflectance. Figure 12 and Table 3 shows the relation between the measured total nitrogen content and the measured NIR reflectance. Both show a good coincidence with not so large $R^2$ values around 0.25. There is a good correlation bteween rice crop quality and nitrogen content in the rice leaves. Therefore, it is confirmed that rice crop quality can be estimated with NIR reflectance measured with NIR cameras mounted on radio controlled helicopter.

## IV. CONCLUSION

Rice crop field monitoring system with radio controlled helicopter based near infrared cameras is proposed together with nitrogen content estimation method for monitoring its distribution in the field in concern. Through experiments at the Saga Prefectural Agricultural Research Institute: SPARI, it is found that the proposed system works well for monitoring nitrogen content in the rice crop which indicates quality of the rice crop and its distribution in the field in concern. Therefore, it becomes available to maintain the rice crop fields in terms of quality control. It is fund that the relation between the measured total nitrogen content and the measured NIR reflectance. Both show a good coincidence with not so large $R^2$ values around 0.25. There is a good correlation between rice crop quality and nitrogen content in the rice leaves. Therefore, it is confirmed that rice crop quality can be estimated with NIR reflectance measured with NIR cameras mounted on radio controlled helicopter.

[8] http://note.chiebukuro.yahoo.co.jp/detail/n92075

[9] http://www.scas.co.jp/service/apparatus/elemental_analyzer/sumigraph_nc-220F.html

TABLE III. NIR REFLECTANCE AND NITROGEN CONTENT

| Nitrogen Content (%) | NIR Reflectance |
|---|---|
| 2.591256 | 0.8 |
| 2.573044 | 0.8375 |
| 2.401106 | 0.825 |
| 2.422404 | 0.82 |
| 1.90562 | 0.7375 |
| 2.2527 | 0.7625 |
| 2.600833 | 0.7625 |
| 2.583339 | 0.775 |
| 2.462955 | 0.7875 |
| 2.61153 | 0.8125 |
| 3.030643 | 0.8125 |
| 2.969303 | 0.8 |
| 2.857584 | 0.8 |
| 2.757784 | 0.795 |

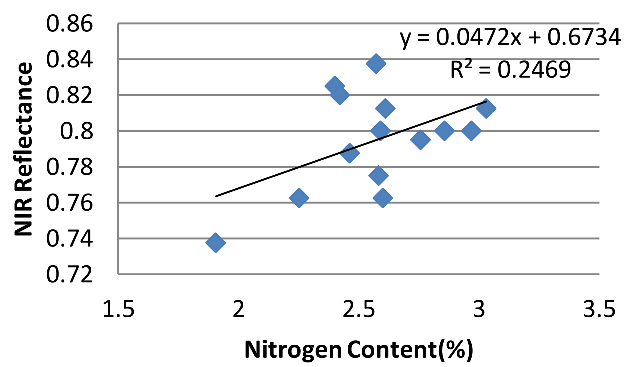



Fig. 12. Relation between nitrogen content in the rice leaves and NIR reflectance

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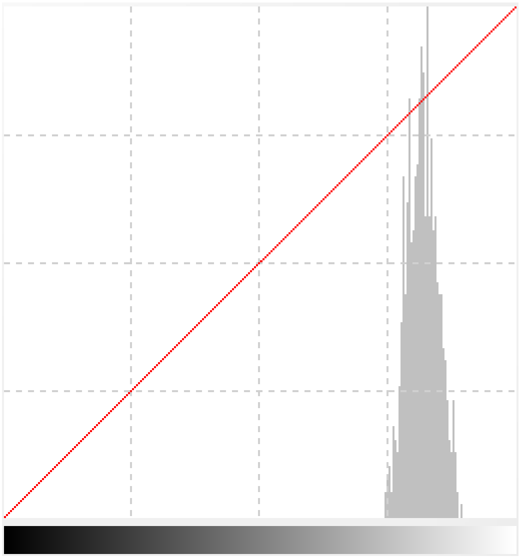
[2] C.Wiegand, M.Shibayama, and Y.Yamagata, Spectral observation for estimating the growth and yield of rice, Journal of Crop Science, 58, 4, 673-683, 1989.

AUTHORS PROFILE

**Kohei Arai,** He received BS, MS and PhD degrees in 1972, 1974 and 1982, respectively. He was with The Institute for Industrial Science, and Technology of the University of Tokyo from 1974 to 1978 also was with National Space Development Agency of Japan (current JAXA) from 1979 to 1990. During from 1985 to 1987, he was with Canada Centre for Remote Sensing as a Post Doctoral Fellow of National Science and Engineering Research Council of Canada. He was appointed professor at Department of Information Science, Saga University in 1990. He was appointed councilor for the Aeronautics and Space related to the Technology Committee of the Ministry of Science and Technology during from 1998 to 2000. He was also appointed councilor of Saga University from 2002 and 2003 followed by an executive councilor of the Remote Sensing Society of Japan for 2003 to 2005. He is an adjunct professor of University of Arizona, USA since 1998. He also was appointed vice chairman of the Commission "A" of ICSU/COSPAR in 2008. He wrote 30 books and published 332 journal papers



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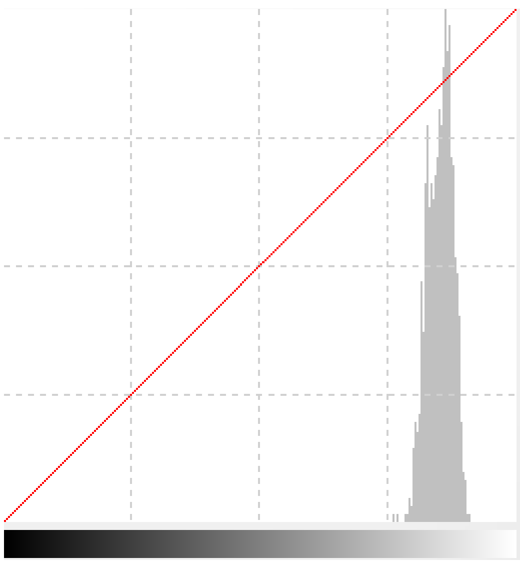

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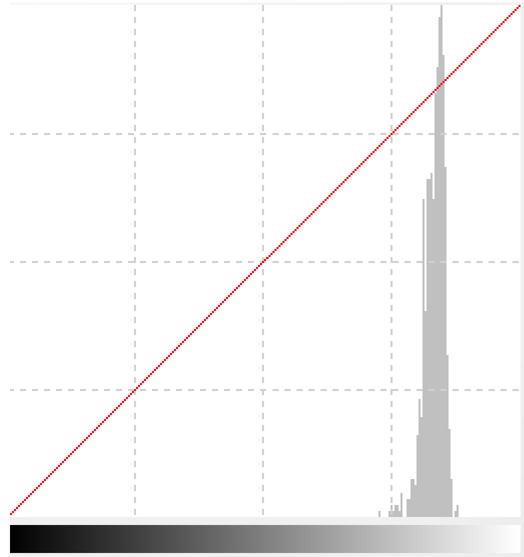

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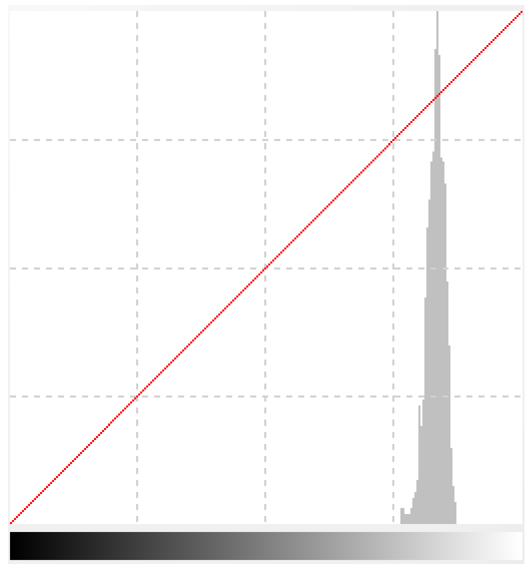

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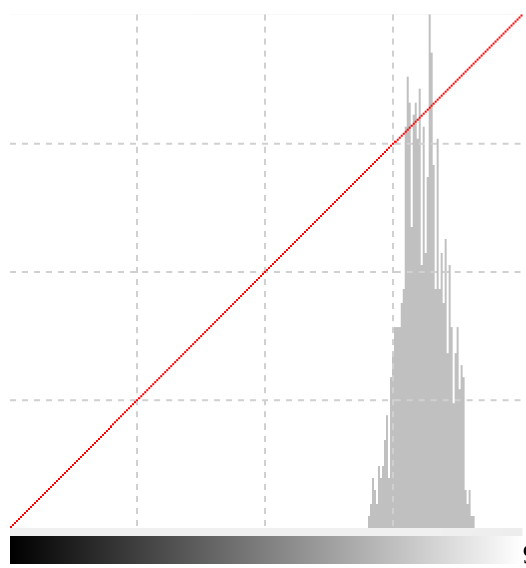

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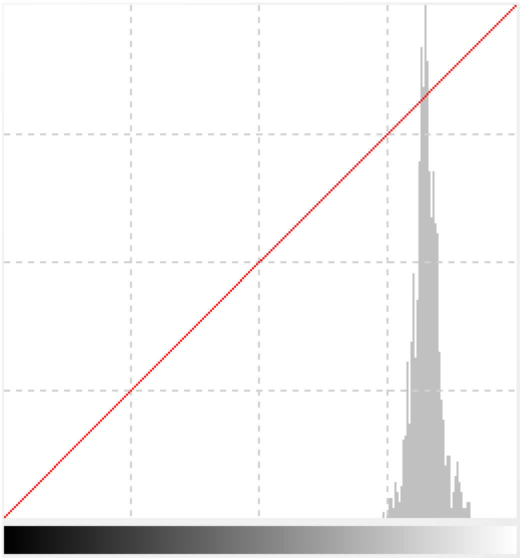
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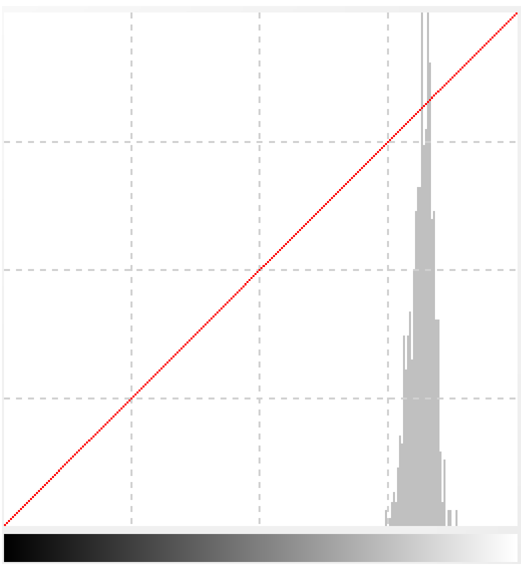
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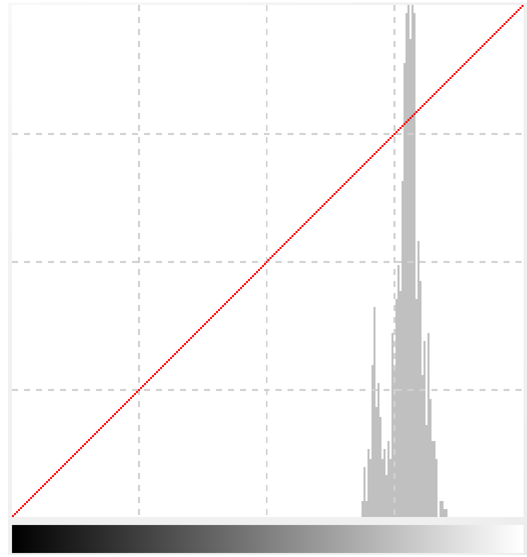
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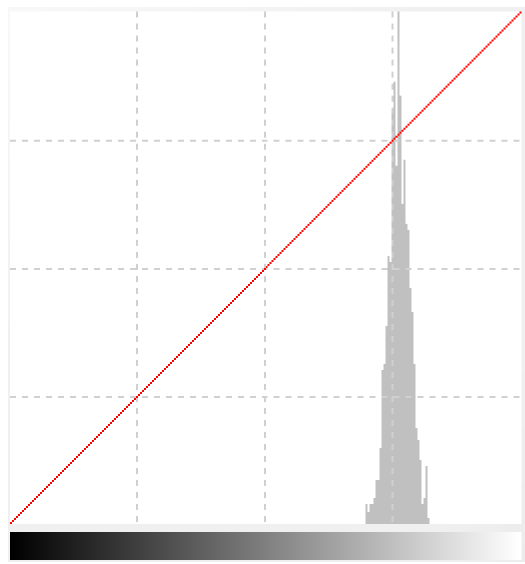
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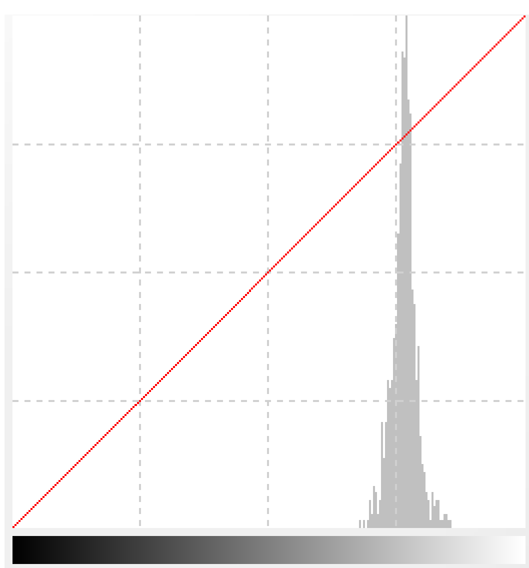
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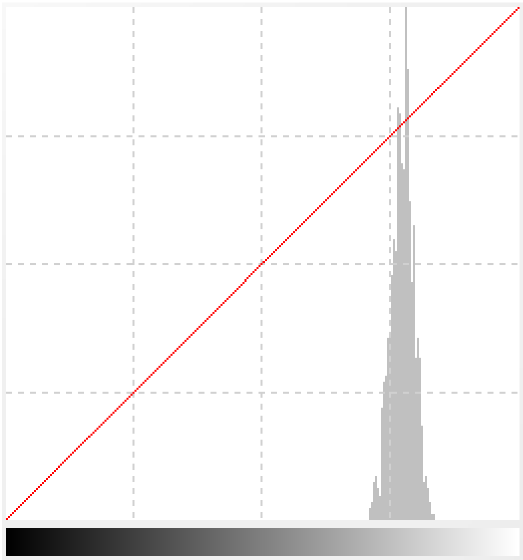
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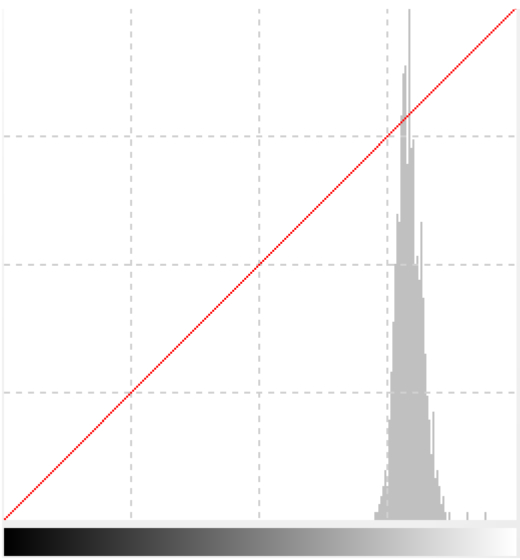
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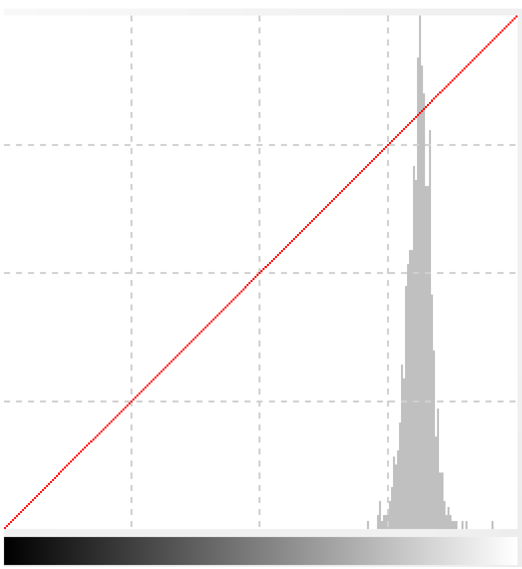
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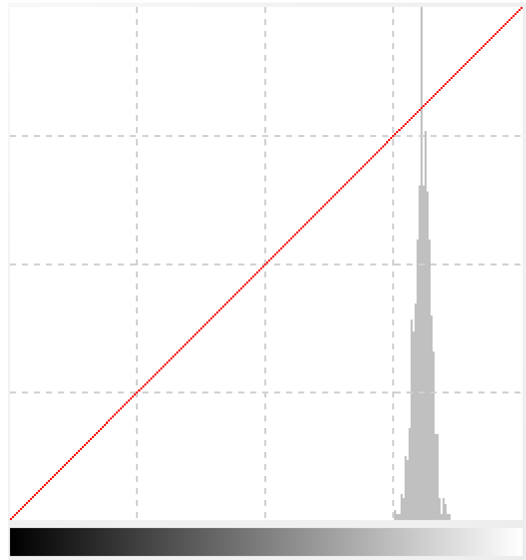
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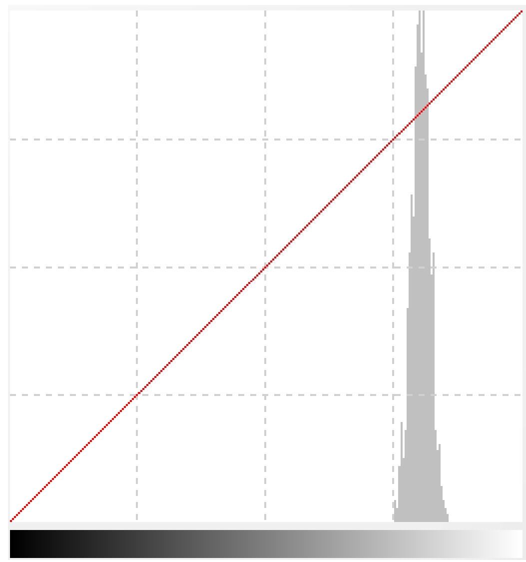
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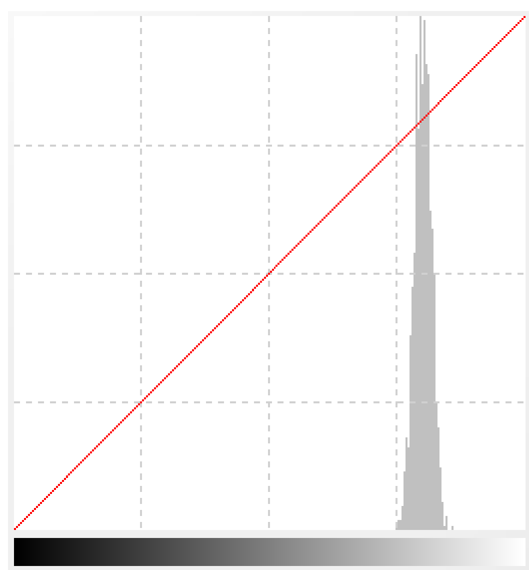
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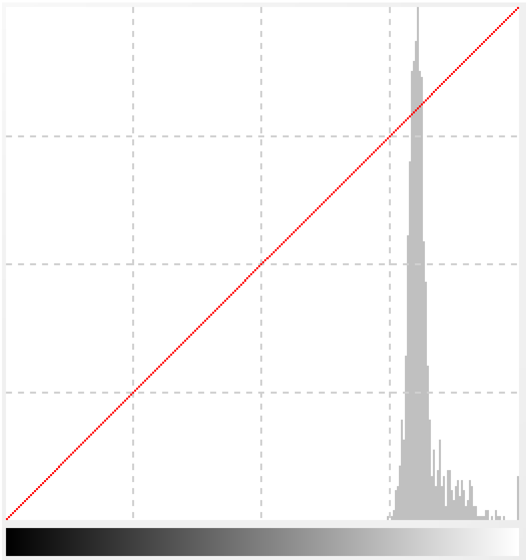

10