Regressive Analysis on Leaf Nitrogen Content and Near Infrared Reflectance and Its Application for Agricultural Farm Monitoring with Helicopter Mounted Near Infrared Camera

Kohei Arai [1]
Graduate School of Science and Engineering
Saga University
Saga City, Japan

Sadayuki Akaisi [2], Hideo Miyazaki [2]
Saga Prefectural Tea Experiment Station
Ureshino City, Japan

Yasuyuki Watabe [3]
Information & Science Techno-Systems Co. Ltd.
Tsukuba City, Japan

Takaki Yoshida [4]
Biz-Works Co. Ltd.
Niiza City, Japan

***Abstract*—Method for evaluation of nitrogen richness of tealeaves with near infrared reflectance is proposed. Also tea farm monitoring with helicopter mounted near infrared camera is proposed. Through experiments and regressive analysis, it is found that the proposed method and monitoring system is validated.**

Keywords-regressive analysis; nitrogen content; tealeaves; near infrared cameras; t

I. INTRODUCTION

Vitality monitoring of vegetation is attempted with photographic cameras [1]. Grow rate monitoring is also attempted with spectral reflectance measurements [2]. Total nitrogen content corresponds to amid acid which is highly correlated to Theanine: 2-Amino-4-(ethylcarbamoyl) butyric acid so that total nitrogen can be used for a measure of the quality of tealeaves.

It is well known that Theanine rich tealeaves taste good while fiber content in tealeaves is highly correlated to the grow rate of tealeaves. Both total nitrogen and fiber content in tealeaves are highly correlated to the reflectance in the visible and Near Infrared: NIR wavelength regions and vegetation index derived from visible and NIR data so that it is possible to determine most appropriate tealeaf harvest date using the total nitrogen and fiber content in the tealeaves which are monitored with ground based visible and NIR cameras and with Helicopter mounted NIR cameras.

It is obvious that nitrogen rich tealeaves tastes good while fiber rich tealeaves tastes bad. Theanine: 2-Amino-4-(ethylcarbamoyl) butyric acid that is highly correlated to nitrogen contents in new tealeaves are changed to catechin [3],[4],[5] due to sun light. In accordance with sun light, new tealeaves grow up so that there is a most appropriate time for harvest in order to maximize amount and taste of new tealeaves simultaneously.

Regressive analysis is conducted with measured total nitrogen and NIR reflectance measured with ground based spectral radiometer and helicopter mounted NIR camera data. Both total nitrogen contents and NIR reflectance derived from ground based and helicopter mounted NIR camera shows a good coincidence. Therefore, it is concluded that the proposed method and monitoring system is validated and appropriate.

The following section describes the proposed method and monitoring system for estimation of total nitrogen content and followed by some experiments. Then conclusion is described together with some discussions.

II. PROPOSED METHOD

A. Regressive Analysis

Linear regressive equation is expressed in equation (1).

$$N = a\,R + b \quad (1)$$

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.

B. Proposed Method for Tealeaves Quality Evaluation of

Tealeaves quality can be represented Theanine content which is closely related to nitrogen content. Furthermore, it is well known that nitrogen content can be represented with NIR reflectance. Therefore, tealeaves 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.

C. Tea Farm Area Monitoring System with Helicopter Mounted NIR Cameras

The helicopter used for the proposed system is "GrassHOPPER" manufactured by Information & Science Techno-Systems Co. Ltd. Outlook of helicopter is shown in Figure 1. Table 1 shows major specification of GrassHOPPER.

Fig. 1. Outlook Of The Grasshopper

TABLE I. MAJOR SPECIFICATION OF GRASSHOPPER

weight	2kg（Helicopter only）
size	80cm × 80cm × 30m
payload	600g

Canon Powershot S100（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）.

In order to measure NIR reflectance, standard plaque whose reflectance is known is required. Spectralon 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, tealeaves in this case, is estimated with NIR reflectance.

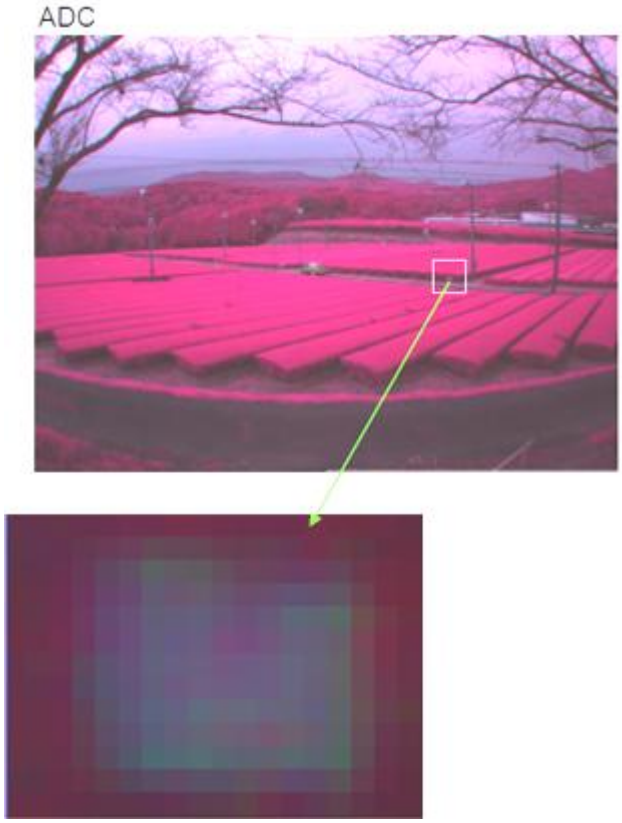
III. EXPERIMENTS

A. Preliminary Experiments

There are some candidates of NIR Cameras, Ricoh GX200, Cannon PowerShot S100, ADC3 which allows not only NIR image but also Normalized Deviation of Vegetation Index: NDVI iamge, etc. Before acquiring NIR reflectance data with helicopter mounted NIR cameras, ground surface images are acquired with the candidate ground based cameras. Figure 2(a) and (b) shows examples of the acquired images with Ricoh GX200 and ADC3, respectively. Although Ricoh GX200 is just a visible camera, NIR image is also acquired with the camera if NIR filter is attached to the optical entrance of the camera. On the other hand, ADC3 has NIR channel. Therefore, NIR image is acquired as shown in Figure 2 (b).

From the acquired images of Figure 2, a small portion of image is extracted and enlarged as shown in the bottom image of Figure 2 (a) and (b). In the portion of image, there is name board of tealeaves.

(a)Ricoh GX200



(b)ADC3

Fig. 2. Examples of the acquired images with Ricoh GX200 and ADC3

The name board of Figure 2 (a) is much clear than that of Figure 2 (b). Tea farm area is designated at Prefectural Tea Institute which is situated in Ureshino city, Saga, Japan. Preliminary tests are conducted for confirmation of the relation between helicopter altitude and IFOV with GrassHOPPER and ADC3. An example of acquired image is shown in Figure 3. Also, Figure 4 shows examples of images which are acquired with GrassHOPPER mounted ADC3 camera with the different altitudes.

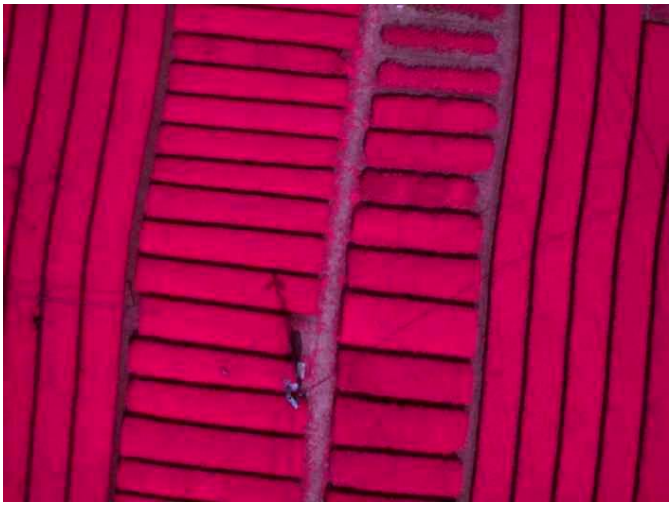
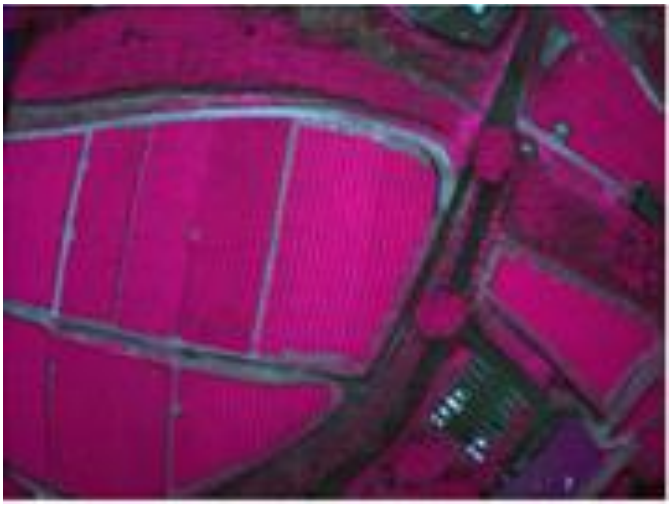


Fig. 3. Example of acquired image with GrassHOPPER mounted ADC3 camera.

(a)h=30m, IFOV=2.5cm



(b)h=100m, IFOV=8cm

(c)h=150m, IFOV=12cm

Fig. 4. Examples of acquired image with the different altitudes

Figure 4 (a) shows the acquired image at the helicopter altitude of 30m while Figure 4 (b) shows that at 100m. Figure 4 (c) shows the image at the helicopter altitude of 150m.

Due to the fact that standard plaque is required for estimation of NIR reflectance, and Field of View of the Cameras is limited, not so small number of standard plaques is required for the wide areas of tea farm area and agricultural farm areas. Therefore, relatively cheap photo print papers are used as standard plaque. Through a comparison between well qualified standard plaque of Spectralon and the proposed photo print papers, usability of the photo print papers is confirmed as a standard plaque.

Figure 5 shows example of acquired image with GrassHOPPER mounted ADC3 camera. Standard plaque has to be acquired within a range of Field of View of the camera. Green rectangle shows four shots of acquired image with the camera (ADC3) from the 50 m of altitude.

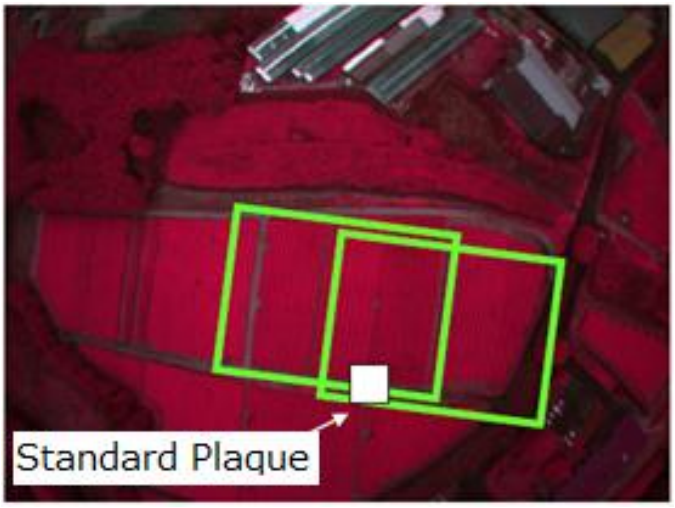


Fig. 5. Example of the acquired image with GrassHOPPER mounted ADC3 camera.

Figure 6 (a) shows outlook of the tea farm area while Figure 6 (b) shows Spectralon of standard plaque and photo print paper (Both are aligned together closely) which are put on the tea trees. Also Figure 7 shows rectified three strips of GrassHOPPER tranck. In the first strip, standard plaque and photo print paper can be seen in the acquired image.

(a)Tea farm area

(b)Spectralon and photo print paper

Fig. 6. Outlook of the tea farm area and Spectralon of standard plaque and photo print paper which are put on the tea trees

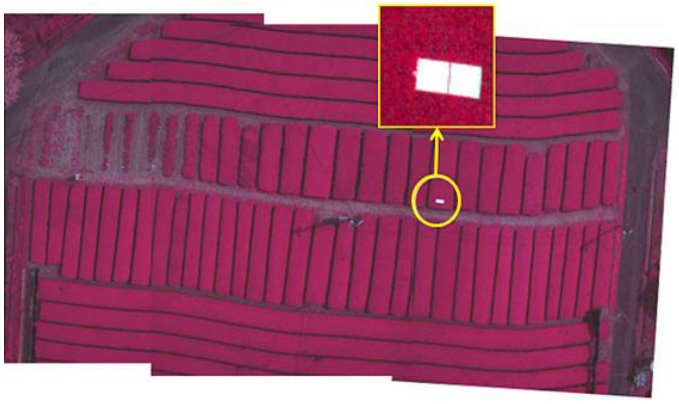


Fig. 7. Rectified three strips of GrassHOPPER tranck.

As the results, it would be better to put photo print papers in all strips of GrassHOPPER traks. Then NIR reflectance can be estimated with a reference to the pixel value of the photo print paper in the image in the corresponding strip.

B. Comparison Between GrassHOPPER Mounted ADC3 Acquired Reflectance and Measured Reflectance with Ground Based MS-720 of Spectral Radiometer

A comparison between GrassHOPPER mounted ADC3 acquired reflectance and measured reflectance with ground based MS-720 of spectral radiometer manufactured by Eiko Co. Ltd., Japan is conducted. MS-720 is reliable radiometer with 5nm of wavelength resolution. This experiment is conducted at Saga Prefectural Tea Experiment Station of Ureshino City, Saga Japan, on April 9 2012.

By comparing between the reflected radiance from the Spectralon and the reflected radiance from the tealeaves, the reflectance can be measure. On the other hand, GrassHOPPER mounted ADC3 derived reflectance is estimated by comparing the pixel values of the Spectralon image portion and that of the tealeaves of image portion. Table 2 shows the average and the

standard deviation of GrassHOPPER mounted ADC3 derived reflectance and ground based MS-720 derived reflectance. Both show a good coincidence between mean values as shown in Figure 8. The horizontal axis of Figure 8 is GrassHOPPER mounted ADC3 derived reflectance while the vertical axis is ground based MS-720 derived reflectance.

TABLE II. MEAN AND STANDARD DEVIATION OF NIR REFLECTANCE MEASURED WITH GRASSHOPPER MOUNTED ADC3 AND GROUND BSED MS-720 OF STECTRAL RADIOMETER

	GrassHOPPER	MS-720
Mean	0.451	0.421
Standard Deviation	0.0428	0.0325

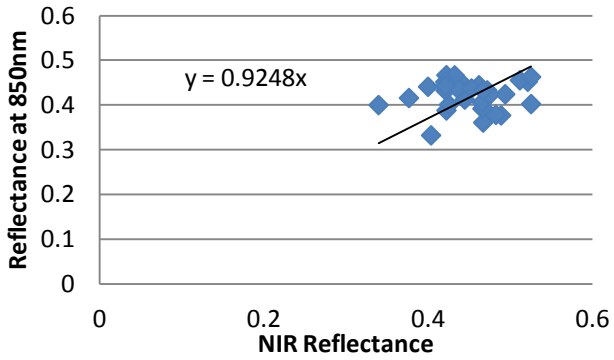


Fig. 8. Relation between GrassHOPPER mounted ADC3 derived reflectance and ground based MS-720 derived reflectance.

The NIR reflectance (which is proportional to total nitrogen content and Theanine of amino acid in the tealeaves) is increasing in accordance with tealeaves grow as shown in Table 3 and Figure 9.

TABLE III. TABLE TYPE STYLES

	9 April	23 April
Mean	0.497	0.622
Standard Deviation	0.0548	0.0539

Horizontal and vertical axis of Figure 9 shows different species and NIR reflectance, respectively. On the other hand, Blue, Red, and Green colored bar denotes, NIR reflectance which is measured on April 9, 10, and 23, respectively. Most of species of tea trees are grown up during this period and are harvested in the begging of May.

Total nitrogen content of the tealeaves is measured based on Kjeldahl method (a kind of chemistry method). The measured total nitrogen content is compared to the NIR reflectance. Figure 10 shows the relation between the measured total nitrogen content and the measured NIR reflectance. Both show a good coincidence.

As aforementioned, the pixels for standard plaque in the helicopter strip image are required for estimation of NIR reflectance. FOV of the helicopter mounted NIR cameras are limited. Therefore, not so small number of helicopter strips which is corresponding to the number of standard plaques are required for cover the entire tea farm areas.

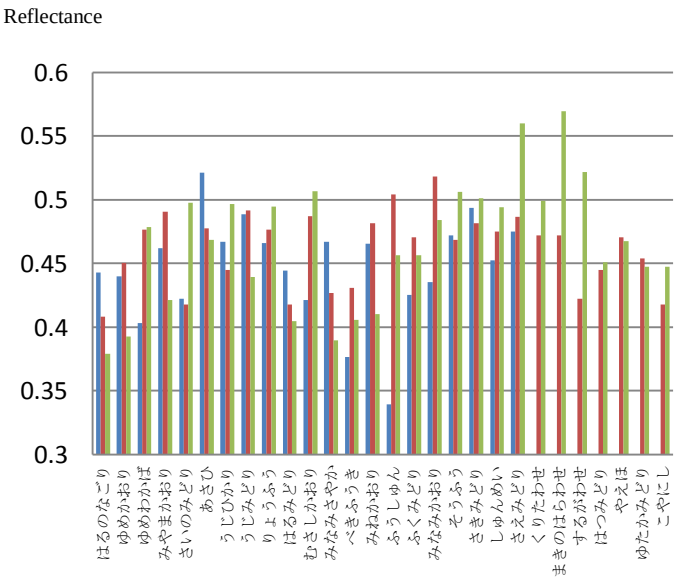


Fig. 9. NIR reflectance trend from April 9 to 23 2012.

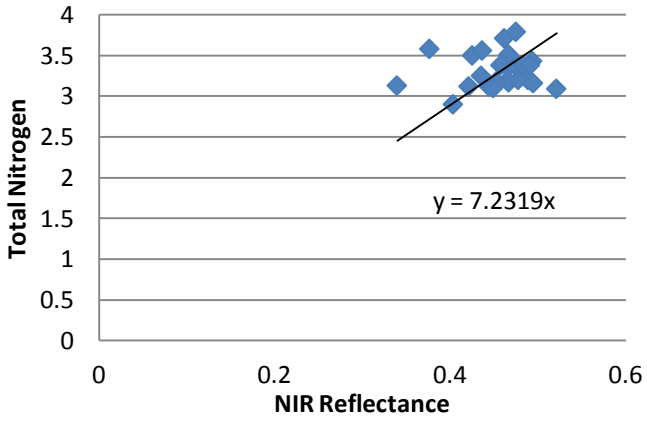


Fig. 10. Shows the relation between the measured total nitrogen content and the measured NIR reflectance

Then relatively cheap photo print paper is used on behalf of Spectralon of standard plaque. Therefore, it would be better to compare the mean and standard deviation of measured NIR reflectance between standard plaque and photo print paper. Table 4 shows the comparison between both.

TABLE IV. COMPARISON OF THE MEAN AND STANDARD DEVIATION OF MEASURED NIR REFLECTANCE BETWEEN STANDARD PLAQUE AND PHOTO PRINT PAPER.

	Standard Plaque	Photo Print Paper
Mean	0.465	0.484
Standard Deviation	0.0484	0.0503

The mean of the NIR reflectance which is measured with photo print paper is a little bit greater than that with standard plaque while the standard deviation of the NIR reflectance which is measured with photo print paper is a little bit greater than that with standard plaque.

NIR reflectance measurement experiments are conducted at Saga Prefectural Tea Experiment Station, Ureshino, Saga, Japan during from April 9 to April 23 2012. During the period, 8 times measurement data are obtained. Figure 11 shows the trend of NIR reflectance at the period.

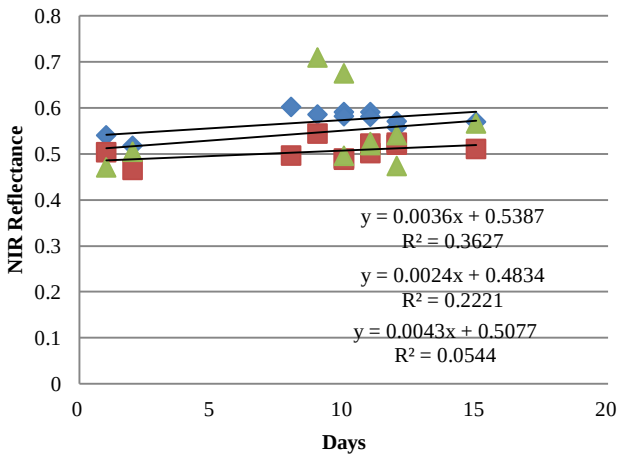


Fig. 11. Trend of NIR reflectance for the period starting from April 9 to April 23.

During this period, measured NIR reflectance is increasing in accordance with the time duration. Black solid lines show linear approximated lines for the different species of tealeaves. Variability of the NIR reflectance may be caused by the weather condition (Illumination, waving tealeaves due to the wind, influence due to shadow and shade, etc.).

IV. Conclusion

Method for evaluation of nitrogen richness of tealeaves with near infrared reflectance is proposed. Also tea farm monitoring with helicopter mounted near infrared camera is proposed. Through experiments and regressive analysis, it is found that the proposed method and monitoring system is validated.

In particular, relation between measured NIR reflectance and total nitrogen content is clarified. Also it is found that photo print paper can be used as the reference target for estimation of NIR reflectance.

Acknowledgment

The authors would like to thank laboratory members for their nice discussions and comments as well as suggestions during this research works.

References

[1] J.T.Compton, Red and photographic infrared linear combinations for monitoring vegetation, Journal of Remote Sensing of Environment, 8, 127-150, 1979.

[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.

[3] J.E. Greivenkamp, *Field Guide to Geometrical Optics*. SPIE Field Guides vol. FG01. SPIE. ISBN 0-8194-5294-7, 2004.

[4] R. Seto, H. Nakamura, F. Nanjo, Y. Hara, *Bioscience, Biotechnology, and Biochemistry*,Vol.61 issue9 1434-1439,1997.

[5] M. Sano, M. Suzuki, T. Miyase, K. Yoshino, Maeda and M. Yamamoto, J. Agric. Food Chem., 47 (5), 1906-1910 1999.

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