

ALGORITHM DEVELOPMENT OF VEGETATION INDICES FOR MONITORING AND ESTIMATING VEGETATION QUANTITIES FOR GCOM-C PROJECT. –FOCUSING ON PADDY FIELDS–

S. Furumi^a, K. Muramatsu^b, M. Daigo^c, N. Soyama^d

^aPreschool education, Nara Saho College, 806 Rokuyaon-cho, Nara, 630-8565, Japan
sfurumi@nara-saho-c.ac.jp

^bKYOUSEI Science Center for Life and Nature, Nara Women's University, Kita-Uoya-Nishi-Machi, Nara, 630-8506, Japan
muramatu@ics.nara-wu.ac.jp

^c Faculty of Economics, Doshisha University, Karasuma Higashi-iru Imadegawa-dori Kamigyo-ku, Kyoto, Japan
mdaigo@mail.doshiasha.ac.jp

^d Tenri University, 1050 Somanouchi, Tenri, Nara, Japan,
soyama@sta.tenri-u.ac.jp

Commission VIII/8

KEY WORDS: fertilization, chlorophyll, spectral reflectance

ABSTRACT:

Monitoring the vegetation activity is important for understanding the carbon cycle and the vegetation response to environmental changes. GCOM-C (Global Change Observation Mission for Climate) satellite will be launched in 2014, and it has a SGLI (Second-generation global imager) sensor with 250 m spatial resolution. In generally, it is used for monitor vegetation activities with satellite observation that vegetation indices such as normalized vegetation index NDVI ((Kidwell, K.B., 1990), enhanced vegetation index EVI ((Huete et al., 1999)) and so on. From the satellite observation, reflected light from the ground object has a mixture information such as vegetation coverage, depth, kinds of vegetation and vegetation activities. Vegetation indices characteristics are studied and reported in a lot of papers. We consider that a set of vegetation indices is needed to extract the quantities of vegetation. The set of vegetation indices is planned to use for estimating gross primary production of vegetation. To estimate gross primary production, chlorophyll content per leaf area is important parameter. We have studied the relationship between chlorophyll content per leaf area and spectral reflectance for several vegetation states for several kinds of broad leaf. In the previous study (S. Furumi et. al, 1998 (Furumi et al., 1998)) , the reflectance is reducing against the chlorophyll content is increasing for blue, green and red wavelength. For near infrared wavelength, the reflectance is not changed against the chlorophyll contents is increasing. In this study, we focus on paddy field. Appropriate fertilizer causes higher chlorophyll content of a leaf. We measured the spectral reflectance, photosynthesis, height of rice plant, the number of stem at the ground, the spectral reflectance using RC helicopter for fertilization and no-fertilization area at Nara prefectural agriculture center in Kashihara, Nara. Using these data, we studied the characteristics of spectral reflectance difference between fertilization and no-fertilization area. For ground measurement spectral reflectance, we found that the spectral shape difference between them. For fertilization rice leaf, the normalized reflectance of visible wavelength is lower than that for no-fertilization rice leaf. And the normalized reflectance of near infrared wavelength is higher for fertilization rice leaf than that for no-fertilization rice leaf. These results' tendency was agree with the previous study of characteristics of reflectance against chlorophyll contents of a leaf. Using this characteristics, the index for chlorophyll content is studied.

1 INTRODUCTION

Monitoring the vegetation activity is important for understanding the carbon cycle and the vegetation response to environmental changes. GCOM-C (Global Change Observation Mission for Climate) satellite will be launched in 2014, and it has a SGLI (Second-generation global imager) sensor with 250 m spatial resolution. In generally, it is used for monitor vegetation activities with satellite observation that vegetation indices such as normalized vegetation index NDVI((Kidwell, K.B., 1990)), enhanced vegetation index EVI ((?)) and so on. From the satellite observation, reflected light from the ground object has a mixture information such as vegetation coverage, depth, kinds of vegetation and vegetation activities. Vegetation indices characteristics are studied and reported in a lot of papers. We consider that a set of vegetation indices is needed to extract the quantities of vegetation. The set of vegetation indices is planned to use for estimating gross primary production of vegetation. To estimate gross primary production, chlorophyll content per leaf area is important parameter. We have studied the relationship between chlorophyll content per leaf area and spectral reflectance for several vegetation states for

several kinds of broad leaf. In the previous study (S. Furumi et. al, 1998 (Furumi et al., 1998)) , the reflectance is reducing against the chlorophyll content is increasing for blue, green and red wavelength. For near infrared wavelength, the reflectance is not changed against the chlorophyll contents is increasing. In this study, we focus on paddy field. Appropriate fertilizer causes higher chlorophyll content of a leaf. The spectral characteristics leaf for fertilization and not fertilization will be studied.

2 OBSERVATIONS IN PADDY FIELD

At Nara prefectural agriculture center in Kashihara, Nara, rice plants were reared with controlling fertilization and no-fertilization. The area with controlling fertilization was 6m × 35m, and that with no-fertilization is 60m × 20m. The fertilizer was spread on the soil on 31 May, 4 Aug., and 14 Aug.. The amount of fertilizer was 5kg per 10a on May, and 2.5kg per 10a on August, 2006. The rice plant growth was measured with the height and the number of stem on 8 June, 25 July, 9 Aug., 23 Aug. 7 Sep., 20 Sep, 2006.

In addition to our observations, the data observed on Aug. 2, 2005 was provided by the Nara prefectural agriculture center. The height, the number of stem, and SPAD (Soil and Plant Analyzer Development, Konica Minolta Holdings Inc.) value were observed for fertilization and no-fertilization area. SPAD values have high correlation with chlorophyll contents of a leaf.

In the fertilization and no-fertilization area, the observation were carried out such as the spectral reflectance and photosynthesis for leaves on 16 June, 11 July, 25 July, 9 Aug., 23 Aug. 7 Sep., 20 Sep., and 2 Oct., 2006. The canopy reflectance was observed by RC helicopter carried out on 22 and 23 Aug, 2006. Spectral reflectance of a leaf and a canopy were measured using FieldSpec FR (ASD Co.) . The observation using RC helicopter was carried out from 30m or 50m altitude. Using RC helicopter, the observation area is 3.9m or 6.5m diameter's circle for 30m or 50 m altitude, respectively.

3 RESULTS

3.1 The rice plant growth observation

The result of the height of rice plant observation is shown in Figure 1. The date of the observation is shown in x-axis and the height is shown in y-axis. The height of fertilization and no-fertilization plants are same as each other until July. From the beginning of Aug., the height difference between fertilization and no-fertilization plants was gradually growing. From the beginning of Sep., the height was not growing and the height difference was stable.

The result of the number of stem is shown in Figure 2. The date of the observation is shown in x-axis and the number of stem is shown in y-axis. The number of stem was increasing until the end of July for both of fertilization and no-fertilization. For fertilization rice plant, it was stable until end of September. For no-fertilization plant, it was gradually reducing until the end of August, and then was stable.

The results of data observed by the Nara prefectural agriculture center on Aug. 2, 2005 are as follows. The number of samples are ten for the fertilization and no-fertilization area. The height, the number of stem and the SPAD value for the fertilization area are $81.8 \pm 1.7 \text{ cm}$, 19.7 ± 2.0 and 36.7 ± 1.5 , respectively. Those for no-fertilization area are $73.8 \pm 1.5 \text{ cm}$, 17.8 ± 1.4 and 33.8 ± 1.5 , respectively. The difference of SPAD average value for the fertilization and no-fertilization area are analyzed with t-test. These two values are different with each other with 0.01 significance level. From these results, suitable fertilization does not make high growth of rice plant but also high chlorophyll contents of a leaf in this field.

The video image of the site from 30m altitude observed by RC helicopter on Aug. 22. is shown in Figure 3. Left area is fertilization and right no-fertilization. Left area of fertilization is darker green than right no-fertilization area. We consider that these color difference might be extracted from spectral reflectance of each leaf.

3.2 Spectral reflectance of a leaf

From the previous subsection 3.1, the height was different each other for fertilization and no-fertilization area in August. Since the August data set was selected for the study of the spectral reflectance to extract the characteristics of the fertilization condition difference. The spectral reflectance of the wavelength of LANDSAT/TM sensor was extracted and is shown in Figure 4.

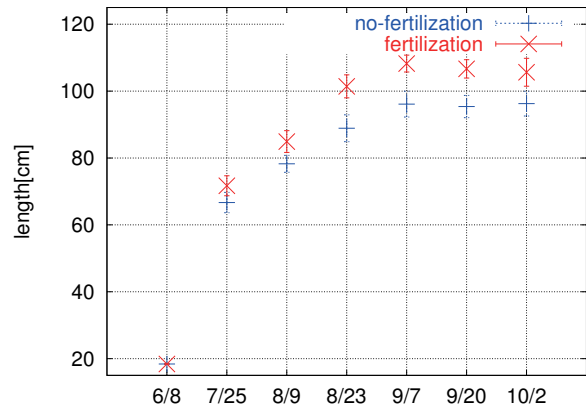


Figure 1: Height of rice plant for fertilization and no-fertilization

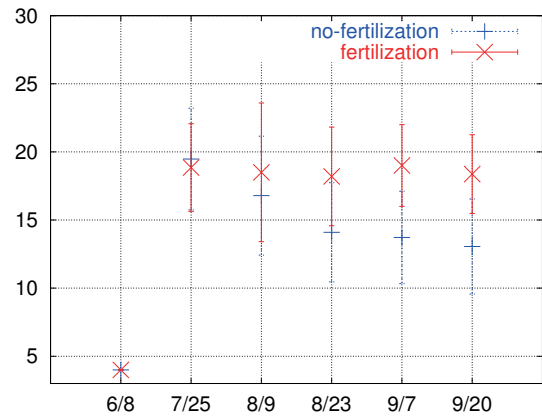


Figure 2: The number of stem of rice plant for fertilization and no-fertilization



Figure 3: Image from 30m altitude of fertilization and no-fertilization area.

The spectral reflectance values are changed against the roughness of a leaf. To reduce these effects and to extract the characteristics of the spectral shape pattern, the reflectance spectral values are normalized as shown in Figure 5. Although the absolute reflectance values are different each samples, the normalized patterns are divided into two groups of fertilization and no-fertilization. The normalized reflectance value of band 2 for no-fertilization samples is higher than that for fertilization samples. And the normalized values of band 4 for no-fertilization sam-

ples is lower than that for fertilization samples. These results are corresponded to the darker green observed with video image in Figure 3. For a leaf, we can consider these results reflect the difference of chlorophyll contents of a leaf.

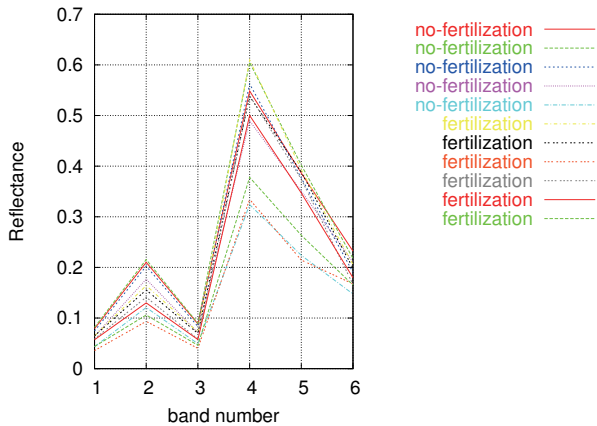


Figure 4: Spectral reflectance of fertilization and no-fertilization leaf samples for LANDSAT/TM spectral bands.

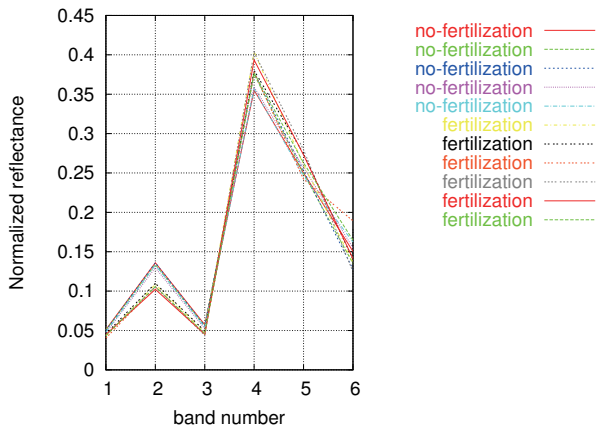


Figure 5: Normalized spectral reflectance of fertilization and no-fertilization leaf samples of Figure 4 for LANDSAT/TM spectral bands

3.3 Spectral reflectance of canopy

The spectral reflectance for LANDSAT/TM sensor wavelength and the normalized reflectance are studied for the canopy observed from 50m altitude by RC helicopter. The spectral reflectance is shown in Figure 6 and the normalized spectral reflectance for the same sample of Figure 6 is shown in Figure 7. The values of the spectral reflectance are different for each samples. Although, the normalized spectral pattern has the similar tendency with the case of a leaf. The band 2's values of fertilization are lower than those of no-fertilization, and the band 4's values of fertilization are higher than those of no-fertilization. These tendency can be observed both of a leaf and a canopy reflectance.

4 CANDIDATE OF VEGETATION INDEX

From the previous section, normalized reflectance of band 2 and band 4 have information of plant condition difference for fertilization. Since the ratio of each band's reflectance is studied. The relationship between band2/band3 and band4/band2 for a leaf and a canopy is shown in Figure 8.

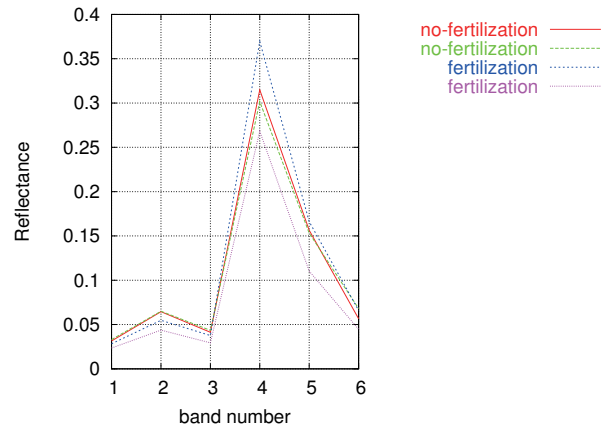


Figure 6: Spectral reflectance of fertilization and no-fertilization samples observed using RS helicopter for LANDSAT/TM spectral bands.

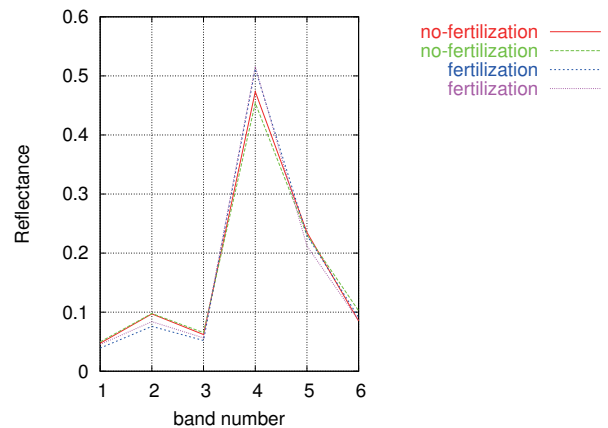


Figure 7: Normalized spectral reflectance of fertilization and no-fertilization samples observed using RS helicopter for LANDSAT/TM spectral bands.

In the Figure 8, the values of band4/band2 can be divided into two groups. On group has the values from 3.3 to 3.9 and another is from 2.4 to 2.9. Higher value's group is correspond to no-fertilization samples and lower to fertilization samples.

For the canopy, the relationship between band2/band3 and band4/band2 are shown in Figure 9. In the Figure 9, flight 3 was observed from 30m altitude, and flight 4 from 50m. For the canopy case, the tendency is the same as for a leaf case. The values of band4/band2 can be divided into two groups, and one group has the values from 5.8 to 7.7 and another is from 3.9 to 5.3. Higher values's group is correspond to no-fertilization samples and lower to fertilization samples. For the canopy case, the value of band4/band2 from higher altitude is lower than that from lower altitude. If compare with the values for a leaf and a canopy, canopy ones have higher values. The band2's reflectance value from helicopter is lower than that of a leaf cause the difference.

The ratio of band2 and band4 is one candidate of vegetation index for detecting the vegetation condition for chlorophyll content of a leaf.

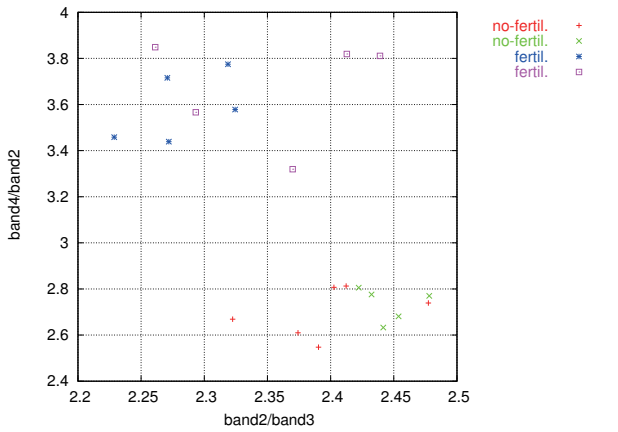


Figure 8: The relationship between band2/band3 and band4/band2 for leaf samples of fertilization and no-fertilization

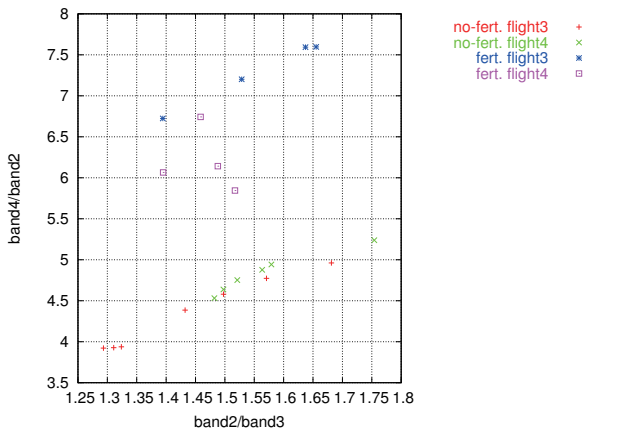


Figure 9: The relationship between band2/band3 and band4/band2 for canopy samples of fertilization and no-fertilization.

5 CONCLUSIONS AND FUTURE WORK

We studied the characteristics of spectral reflectance difference between fertilization and no-fertilization area. For ground measurement spectral reflectance of a leaf and for the canopy observation using RC helicopter, we found that the spectral shape difference between them. For fertilization rice leaf, the normalized reflectance of visible wavelength is lower than that for no-fertilization rice leaf. And the normalized reflectance of near infrared wavelength is higher for fertilization rice leaf than that for no-fertilization rice leaf. These results' tendency was agree with the previous study of characteristics of reflectance against chlorophyll contents of a leaf. Using this characteristics, the band4/band2 values are studied. The values are divided into two groups for fertilization and no-fertilization. The higher values group correspond to fertilization and lower values no-fertilization. This characteristics is one candidate for detecting the vegetation condition for chlorophyll content of a leaf.

ACKNOWLEDGEMENTS

This study was part of the GCOM-C projects organized by the Japan Aerospace Exploration Agency. The authors would like to thank Nara prefectural agriculture center in Kashihara, Nara.

REFERENCES

Shinobu Furumi, Ayami Hayashi and Kanako Muramatsu, and Noboru Fujiwara. Relation between vegetation vigor and a new vegetation index based on pattern decomposition method. Journal of Remote Sensing Society of Japan Volume 18, Number 3, pp. 17-34, 1998

Kidwell, K.B. Dept. of Commerce/National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service, National Climatic Data Center, Satellite Data Services Division.

Huete, A., Justice, C., and Leeuwen, W.V. MODIS vegetation index (MOD13) Algorithm theoretical basis document, Version 3,