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BRDF model for new tealeaves and tealeaves monitoring with network cameras

By
Kohei Arai* and Long Lili*

Abstract: In order to monitor size of new leaves, Bi-directional Reflectance Distribution Function: BRDF model is created with Minneart function based on Monte Carlo Ray Tracing: MCRT model. New tealeaves grow up on old tealeaves, in general. It is difficult to monitor size of new tealeaves by measuring spectral reflectance from nadir view only. BRDF would help to estimate size of new tealeaves. BRDF, meanwhile, can not be measured easily. BRDF model is needed for estimation of size of new tealeaves. Through theoretical and simulation studies, BRDF model is created. In order to estimate size of new tealeaves, the most significant observation angles as well as the most effective wavelength regions for spectral reflectance measurement are estimated through simulation and experiments. Visible and near infrared cameras monitoring tea estates from 45 degrees of zenith angle of observation allows monitor size of tealeaves so that the most appropriate timing for pick tealeaves up (tealeaves harvesting) can be determined.

Key words: Bi-Directional Reflectance Distribution Function: BRDF, Monte Carlo Ray Tracing: MCRT, Minneart reflectance model

1. Introduction

There are a plenty models for representing canopy reflectance, (1) structural models (Campbel, G.S., 1984) which include Leaf Area Index (LAI), Leaf Angle Distribution, Fractal models, (2) optical models which include plane model (Allen W.A., 1973)which is represented as PROSPCT model (Jaquemond, S, et al., 1990), ray tracing model(Allen W.A. et al., 1973), stochastic models which is represented with Markov chain (Tacker C.G., 1977), (3) famous reflectance models of Lambert model(Heinrich, J., 1766), Minnaert model(Minnaert, J., 1954), etc. Meanwhile there are also a plenty methods which allows solve radiative transfer equation, Kubelka-Munk (Kubelka and Munk, 1931), two, four and eight stream models(Allen W.A., et al., 1969, Fukshansky, L., 1991), Gauss Seidel, successive ordering, discrete ordinate, etc.(Liang, S.L. 1993). Furthermore, there are also geometric optical models (Richardson A.J. et al., 1974), forward and backward Monte Carlo ray tracing model (Diseney, M.I., et al., 2000, Arai, K., 2000) and radiosity models (Borel, C.C., et al., 1991).

Moderate-resolution of Imaging Spectrometer: MODIS derived Normalized Vegetation Index: NDVI is related to Leaf Area Index: LAI. There is an empirical equation which depends on the fact that LAI in tea had significant and linear relationship with NDVI (R2 value is approximately 0.4 or below). MODIS based NDVI is significantly correlated to tea leaf yield at estate level. However it is also true that NDVI observation at different time period alone could not explained much variance in tea leaf yield. The statistical model for tea yield does not seem to be encouraging. It is also known that tea leaf yield is significantly related to NDVI at 95% level of significance, correlation is positive at 1% level of significance (Dutta, R., 2006).

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*Department of Information Science
@Faculty of Science and Engineering, Saga University

One of the major influencing factors to the relation between NDVI and LAI, tea leaf yield is observation angle. Swath width of MODIS is 2330km from the satellite altitude of 705km so that observation angle ranges from 0 to around ±30degree. BRDF has to be taken into account (Rajapakse, R.M., 2002).

Thus this paper deals with the aforementioned two measures for monitoring new tea leaf yield. The following section deals with proposed methods of BRDF utilizations with some experimental results. Finally conclusion and some discussions will be followed.

2. Proposed method

The proposed method utilizes BRDF dependency on new tea leaf yield for new tea leaf yield monitoring together with Earth observation satellite data which carries visible to near infrared radiometers. Using web cameras, BRDF can be measured easily. Fig.1 shows configuration of a simple BRDF monitoring system which allows estimation of length of new tea leaves. Fig.1 (a) shows frosty avoidance fans in the tea estate in Saga, Japan. It is easy to equip web camera near by fan to look down the tea estate. Observation angle depends on the location of tea trees and ranges from 0 to around 75 degree of observation zenith angle. In other word, BRDF can be monitored with web camera. Fig.1 (b) shows illustrative view of the proposed method. If it is assumed that BRDF of the tea leaves in concern are same wherever in the tea estate, BRDF can be calculated with observed brightness by location by location (or observation angle by observation angle). Also it is possible to calculate visible and near infrared BRDFs with different visible and near infrared cameras. In this proposed system, 640 by 480 pixels of visible and near infrared web cameras are used. Acquired camera images are transmitted to wireless Local Area Network: LAN terminal equipped at the nearest houses. Through internet, acquired camera images can be monitored then calculate new tea leaves grown rate will be displayed on a GIS as is shown in Fig.2 (d).

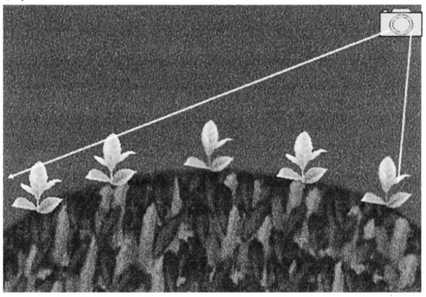
Fig.1(c), (d) and (e) shows changes of tea leaves for time duration, in general. New tea leaves are grown up on old tea leaves. For time duration, mass of new tea leaves is getting large. In the same time, amino-acid which is contained in the new tea leaves changes to Katekin ethillen so that taste of new tea leaves is getting worth. Therefore, the best timing for harvesting of new tea leaves is very important. In other word, monitoring of new tea leaf grow is the key issue to harvest a good quality of many new tea leaves.

3. Requirements of Papers

Total nitrogen is highly related to amino-acid which corresponds to the taste of tea as is shown in Fig.2 (a). Using MODIS 250m data, amino-acid is to be monitored as is shown in Fig.2 (a). Thus quality and mass of new tea leaves can be monitored by using near infrared camera and satellite images. Fig.2 (a) shows the relation between total nitrogen and fiber which is contained in vegetation (tea leaves) and reflectance at 870nm while Fig.2 (b) shows the relation between water content in vegetation (tea leaves) and reflectance at 935nm. Using these relations, it is possible to estimate total nitrogen, fiber and water content in the tea leaves. ASTER/VNIR, MODIS has, for instance, 870nm spectral band so that total nitrogen and fiber contents can be estimated with these satellite data. Fig.2 (c) and (d) shows MODIS250m and ASTER/VNIR derived total nitrogen as an example. Therefore, it is possible to monitor the taste of new tea leaves with acquired camera data and satellite data derived amino-acid and fiber.

During from February to July 2007, new tea leaves in the tea estates in Saga Japan change their spectral reflectance and BRDF. As is indicated in Fig.3, satellite images shows new tea leaf grow. Fig.3 (a) shows the location of Ureshino tea estate areas also shown satellite track on January 22 2007.

(a) BRDF measurment at the tea estates in Saga Japan.



(b) Monitoring configuration of new tea leaf yields with web camera

(c) New tea leaves yield again

(d) New tea leaves cover old leaves entirely

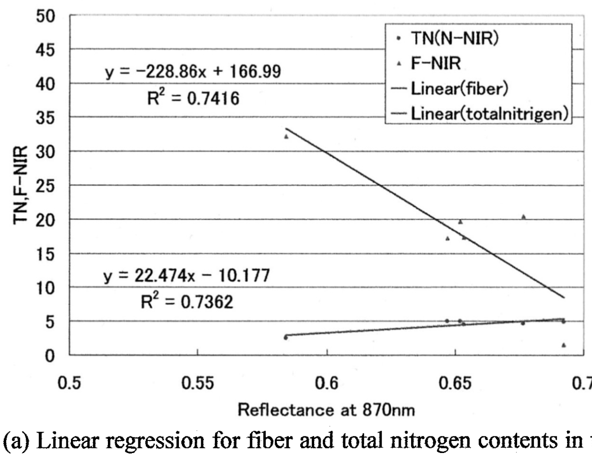
(e) New tea leaves are growing up

Fig.1 Proposed monitoring configuration of new tea leaf yields with web camera and actual observation of BRDF dependency on new tea leaves yield.

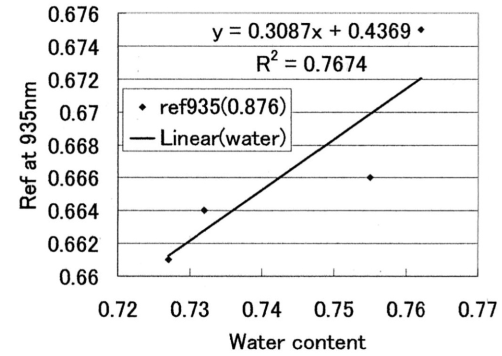
Our test site is situated in Kyushu, south portion in Japan. Fig.3 (b), (c) and (d) shows ASTER/VNIR images which is acquired on February 26, April 28 and May 14 2007. On February 26, no new tea leaf exists while new tea leaves are grown up in the early April. Then new tea leaves were harvested before April 28. New tea leaves are grown up again in the early May and then new tea leaves are on growing as is shown in Fig.3 (d). Fig.4 shows spectral reflectance changes of the new tea leaves for time being. The spectral reflectance on April 12 is raised remarkably compared to that of February 26 then it is dropped on April 28 and reaches to the almost original spectral reflectance on February 26 because new tea leaves are harvested. These firstly harvested new tea leaves contain amino-acid so that they taste good. After that, spectral reflectance of the tea leaves increase because new tea leaves are grown up. Fig.4 also shows spectral reflectance difference between well grown and poorly grown tea leaves as well as greenness, grown index and vegetation index and the measured spectral reflectance.

From the satellite data, reflectance at the several wavelengths, reflectance derived total nitrogen, fiber contents in the tea leaves from the nadir view. As is indicated before, BRDF is much effective for new tea leaves grow monitoring than spectral reflectance from nadir view. In order to show the effectiveness, Monte Carlo Ray Tracing: MCRT is used. Canopy model for MCRT is shown in Fig.5 (a). Old tea leaves are assumed to be flat with Lambertian surface while new tea leaves are assumed to be ellipsoidal shape with Lambertian surface. Computational cell of MCRT is illustrated in Fig.5 (b). New tea leaves are two dimensionally aligned with designated distance. There is not only reflection between new and old tea leaves but also mutual reflection among new tea leaves. In the atmosphere, molecular and aerosols are considered with the following parameters,

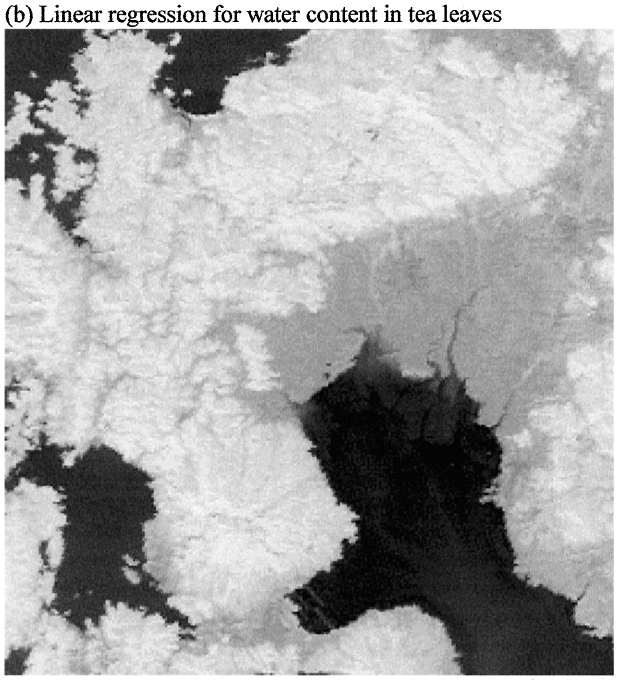
Wavelength: 550nm, Observation altitude: 50cm, Solar azimuth and zenith angles: 63 and 19degrees (as an example), short radius of new tea leaves: 2cm (measured with actual leaves), long radius of tea leaves: varied from 2 to 6cm which depends on grow index, distance between new tea leaves: 6cm (measured with actual leaves), optical depths of aerosols and molecules: 0.17 and 0.1 (typical optical depths measured at the test site for five months, February to July 2008), surface reflectance of new and old leaves: 0.1 (measured with actual leaves), the number of photons: 10^9.



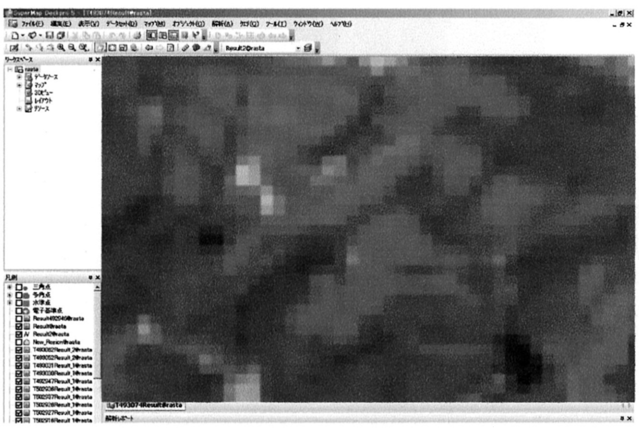
(a) Linear regression for fiber and total nitrogen contents in tea leaves



(b) Linear regression for water content in tea leaves

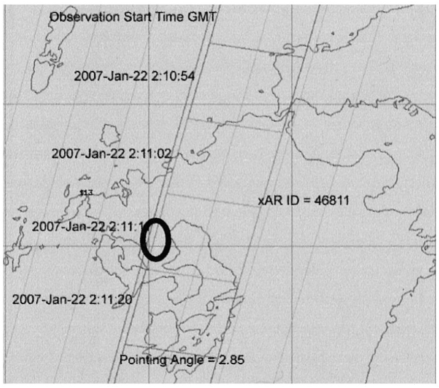


(c)MODIS 250m derived total nitrogen which is contained



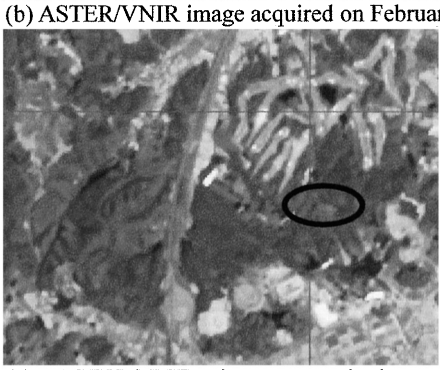
(d) ASTER/VNIR derived total nitrogen which is contained in vegetation displayed on GIS (bright portions are tea estates)

Fig.2 Linear regression of water, fiber and total nitrogen contents in tea leaves derived from reflectance at 870nm for fiber and nitrogen and 935nm for water contents measured at east, north and south tea estates in Ureshino, Saga Japan on June 11 2007.

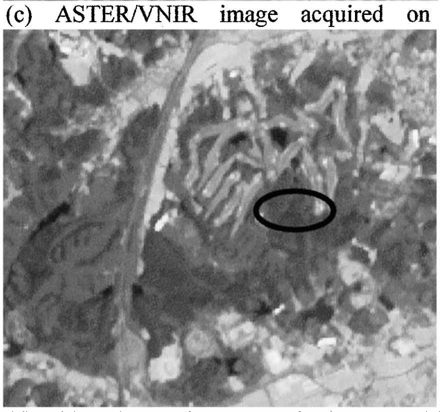


(a) Location of test site at Ureshino tea estate and satellite track

(b) ASTER/VNIR image acquired on February 26 2007

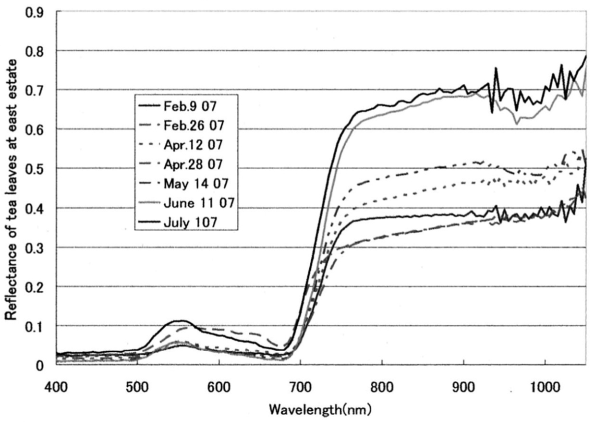


(c) ASTER/VNIR image acquired on April 28 2007



(d) ASTER/VNIR image acquired on May 14

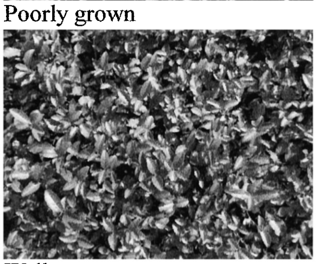
Fig.3 Location of test site of Ureshino tea estate in Saga, Japan and acquired ASTER/VNIR images of (a)before new tea leaf yield (February 26), (b) just after harvesting new tea leaf (April 28) and (c) during new tea leaf yield again (May 14)



(a) Spectral reflectance changes of the east tea estate observed from the nadir for five months on several days in 2007

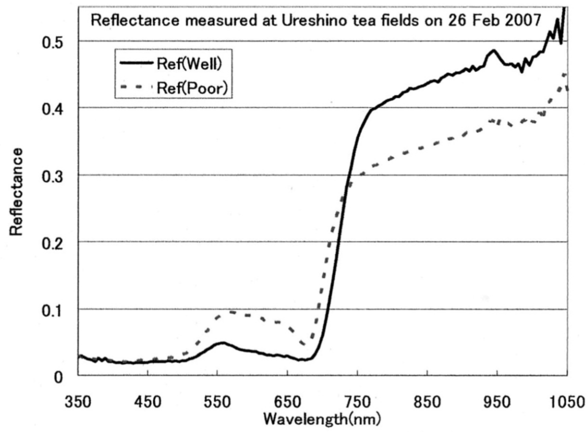
	Grow Index	Greenness	Veg.Index
Good	69	394	0.689
Poor	56	353	0.563

Poorly grown



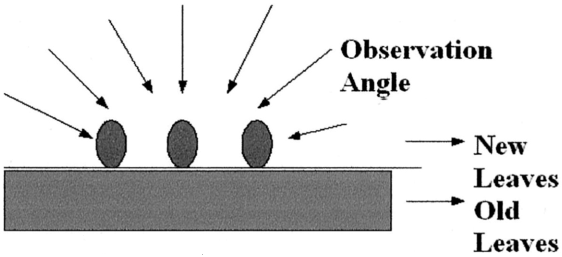
Well grown

(b) Well grown and poorly grown tea leaves

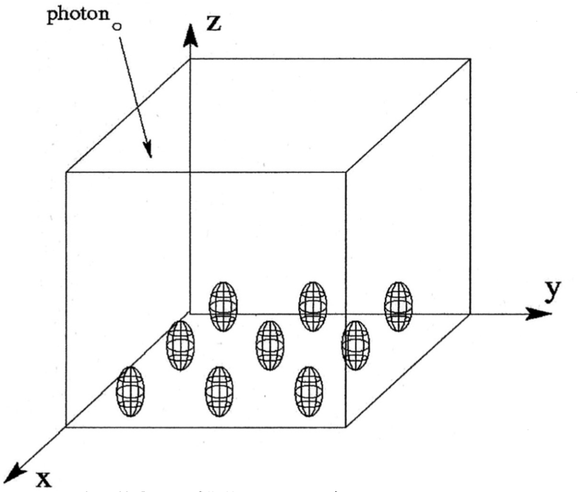


(c) Spectral reflectance of well grown and poorly grown tea leaves

Fig.4 Spectral reflectance changes for five months when new tea leaves grown up, harvests and re-grow again.

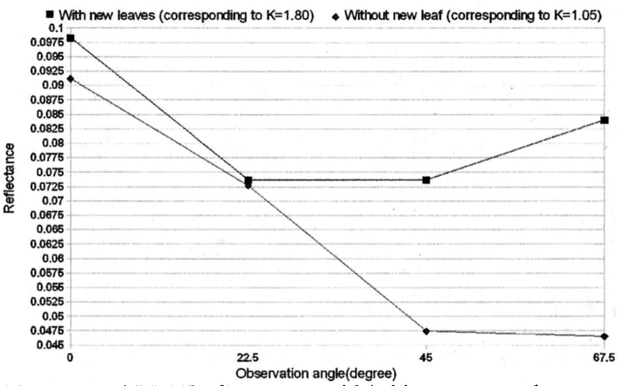


(a) Tea tree and leaf model in MCRT simulation

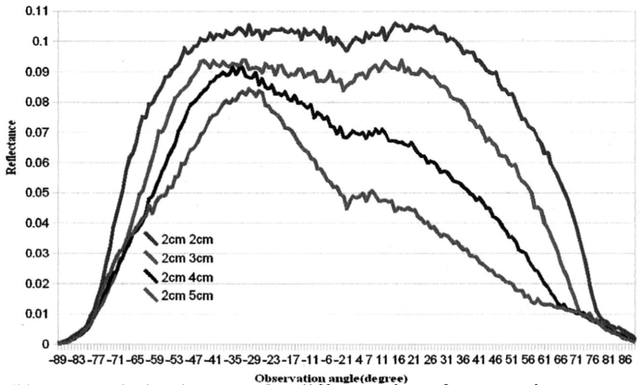


(b) Assumed cell for MCRT computation

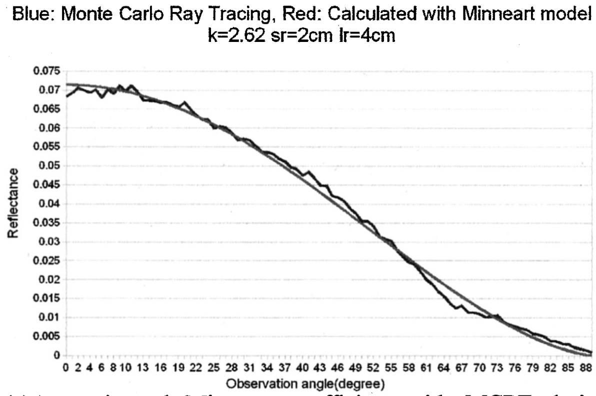
Fig.5 Proposed canopy model of tea tree and leaves for MCRT simulation.



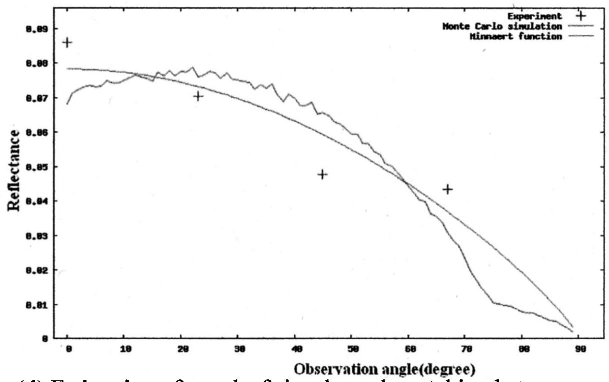
(a) Measured BRDF of tea estate with/without new tea leaves



(b) MCRT derived BRDF for different size of new tea leaves



(c)Approximated Minneart coefficient with MCRT derived BRDF



(d) Estimation of new leaf size through matching between for new tea leaf of which short and long radius is 2, 4cm, respectively measured and calculated BRDF by MCRT and Minneart

Fig.6 Measured and calculated BRDF based on MCRT and theoretical Minneart model

Fig.6 (a) shows an example of measured BRDF in principal plane. In accordance with new tea leaf grow; BRDF is getting far from Lambertian surface. BRDF of old tea leaves is approximated as Lambertial while BRDF of new tea leaf is no longer Lambertian. Fig.6 (b) shows MCRT derived BRDF for the different size of new tea leaves. The measured BRDF is matched to MCRT derived BRDF as is shown in Fig.6 (c) so that it can be concluded that length of new tea leaf in this case is around 4cm, matching accuracy is not good enough as is indicated in Fig.6 (d) though.

4. Concluding Remarks

It is found that the proposed new grow tea leaf monitoring is useful through field experiments of BRDF measurement with the matching BRDF derived from MCRT as well as Minneart model. Acquired images with visible and near infrared web cameras mounted on the frosty avoidance fan are also useful to monitor the mass and quality of new grow tea leaf because observation angle ranges from zero (Nadir) to 75degree which is very sensitive to the size (length) of new tea leaves in the sense on BRDF changes. Thus the most appropriate time for harvesting new tea leaves is determined. Also it is possible to estimate mass and quality of new tea leaves based on monitored camera imagery data and satellite imagery data derived total nitrogen and fiber contents in the new tea leaves.

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