Bi-directional Reflectance Effects on Mangrove Classification of IKONOS Multi-angular Images

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Abstract: Optical signals from an object may vary at different conditions caused by differences in light source and sensor position. Knowledge of these variations is necessary to enable calibration of the satellite images and confirmation of the sun and sensor angles influences of the spectral signals from the objects. With the use high-resolution Ikonos^{TM} multi-angular images, the bi-directional reflectance effects of mangrove trees were observed when three datasets were compared. The influence of bi-directional reflectance may affect the accuracy of interpreting satellite imagery and obtaining biophysical parameters mangrove and other vegetation by indirect means.

Keywords: Remote sensing, Bi-directional reflectance, Mangrove, Ikonos ^{TM}

1. Introduction

Mangrove forest occupy intertidal zones of the marine coastal environments, a portion where muddy sedimentation and complex root systems pervade rendering this portion of land harsh, restrictive yet dynamic. Remote sensing offers alternative ways by which necessary parameters for mangrove assessment [1] such leaf area index (LAI) and mangrove density can be obtained to avoid the difficult conditions of field survey. Existence of mangroves is valuable for sustaining the productivity of the ecosystems, protecting inland areas from tidal floods and supporting the livelihood of coastal inhabitants. To properly manage this area, there is a need to understand its conditions through good assessment of the resources and proper monitoring. The usual method is field observation by selective point control quadrant sampling.

Currently, Ikonos^{TM}, a high-resolution imagery is widely utilized from a variety of applications including mapping of coastal and agricultural resources [2] from its four multi-spectral bands with 4-meter spatial resolution. Its panchromatic band is popularly used to create orthophoto maps as an alternative to aerial photographs.

Spectral images are affected by interactions of the source of illumination of the image and the point location within the image due to the bi-directional nature of most natural targets [3]. The variability in bi-directional reflectance (BDR) obstructs tree cover change analysis; furthermore, the spectral responses from high-resolution images are direction dependent. Moreover, the variation of canopy reflectance with LAI depends on BDR, and also on the LAI value.

These measurable attributes such as LAI and optical signals of mangrove trees from remote sensing data could lead to the characterization of specie or a tree of certain age. Currently, these mangrove attributes are still mostly acquired through actual ground measurements, requiring a lot of manpower time and at times destruction of mangrove trees themselves.

BRD effects vary for various wavelength bands. The view of the sensor may be occupied by sunlit leaves, shaded leaves, soil and water [3], which makes mangrove canopy bi-directional reflectance modeling a challenging task.

This paper aims to utilize Ikonos datasets for mangrove spectral measurements leading to classification and determines the influence of difference in the sensor's angle of acquisition on the accuracy of classification through image processing, field validation and actual spectral reflectance measurements of some mangroves.

2. Materials and Methods

The study area is located at the mangrove forest in the

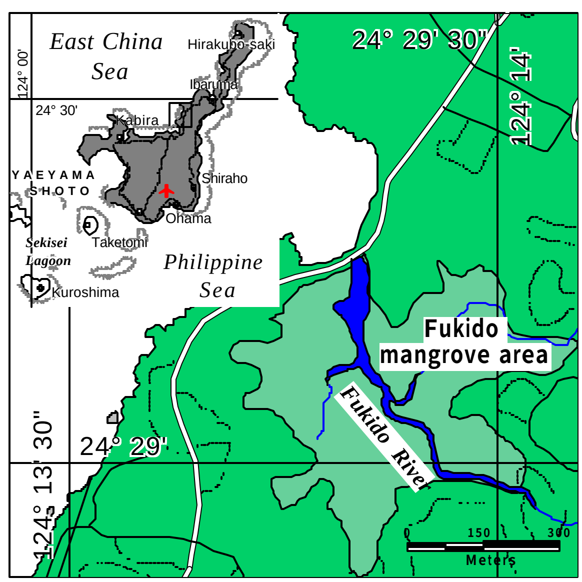

Fig. 1. The study area.

Tab. 1. Ikonos™ parameters.

	Ikonos Dataset		
Parameter	**A**	**B**	**C**
Nominal Collection Azimuth (deg)	126.9279	106.6516	81.1273
Nominal Collection Elevation (deg)	53.53038	56.4061	54.93063
Sun Azimuth (deg) ϕ_s	117.9728	117.8483	117.722
Azimuth difference (deg) $\Delta\phi$	-8.9551	11.1967	36.5947
Sun Angle Elevation (deg) (90 -θ)	65.80446	65.73066	65.64149
Acquisition Date/Time	8/23/02 2:19	8/23/02 2:19	8/23/02 2:18

mouth Fukido River in Ishigaki Island (N 24° 29', E 124° 13' 50") and covered about 21 hectares of land. There are two dominant mangrove species in Fukido river, namely: *Bruguierra gymnorrhiza* (concentrated on inland portion) and *Rhizophora stylosa* (observed to be occupying the strip of land along the river/creek) as obtained from previous works of other researchers [4] and as observed during the field survey in Ishigaki. The relative sizes of trees in the area are almost the same.

Three geometrically corrected Ikonos datasets (Level 1b) of the study area with the same date of acquisition (23 August 2002) but with different collection azimuths (Fig. 1). Each of the images represents a particular position of the Ikonos sensor: one for the forward direction, another for the scene directly to the left of the sensor and another for the backward direction. Table 1 presents the different parameters for each corresponding images. A 1:25000 topographic map of the area was used for rectification of the satellite datasets and delimiting the area of the mangrove forest. Image co-registration was done on the data sets for them to fit with each other. All datasets share the same set of training sample locations.

From the training areas or ROIs (region of interests) for the different classes such as sand, water and mangrove; their corresponding digital numbers/values (DN) were extracted for all Ikonos bands (blue, green, red and NIR) in each dataset.

The following equation was applied [5]:

$$R_{0+}(l) = \frac{p\left[L(l)/a_{\mathrm{OZ}} - L_a(l) - L_{\mathrm{R}}(l)\right]d^2}{E_{0+}(l)\, t \cos J} \quad . \qquad (1)$$

$L(l)$ is the spectral radiance at the sensor's aperture further reduced for atmospheric effects caused by ozone absorption a_{OZ} ; aerosol and Rayleigh irradiances $L_a(l)$ and $L_{\mathrm{R}}(l)$; and diffuse transmittance t which can be obtained by running the 6S algorithm [6] assuming a tropical atmospheric condition with maritime aerosol content, 15 km visibility set at a sensor height of 600 km. The Earth-Sun distance in astronomical units, d is taken from an ordinary nautical handbook which changes seasonally. $E_{0+}(l)$ is mean sea surface irradiance measured from the field surveys while J is the scattering angle in degrees and is obtained from the Eq. 2.

$$\cos J = \cos q_s \cos q_v + \sin q_s \sin q_v \cos f \qquad (2)$$

where q_s is the zenith angle of the sun, q_v is the zenith angle of the sensor and f is the difference in azimuth between the sun and the sensor.

Applying Eq. (1) normalizes these values to common sun and sensor positions was made. These were needed to compare each sensor position with the bi-directional reflectance of the ground features.

Actual spectral information was gathered from the field to support the results and verify the effects of BDR to spectral measurements. Using a spectrometer with attached tilt sensor (SpectaCoop, Tokyo JAPAN) the spectral reflectance taken at different vertical angles of a mangrove tree was measured. This was accomplished by allowing the spectrometer to slide along an arc placed over the tree while spectral readings and angular positions were simultaneously acquired.

3. Results and Discussion

The discrepancies in the spectral reflectance values from the three datasets can be attributed to the bi-directional reflectance (BDR) phenomenon since the only distinct difference about the condition when the datasets were acquired is the relative position of sun and sensor. Fig. 2 shows that the smaller the difference in azimuth acquisition of datasets results to higher correlation of the DN. The correlation values of visible bands: blue, green and red, are decreasing more than that of NIR band as the different in azimuth acquisition is increasing.

In Fig. 3, the blocked bars represent the three raw datasets (A, B and C) of Ikonos™ while the striped bars refer to these datasets corrected for BDR effects.

By dividing the all values in datasets A, B and C by the values in dataset A (for both uncorrected and corrected categories respectively), a comparison of discrepancies of reflectance magnitudes among the three datasets was possible. It was generally observed that the reflectance values among different corrected datasets

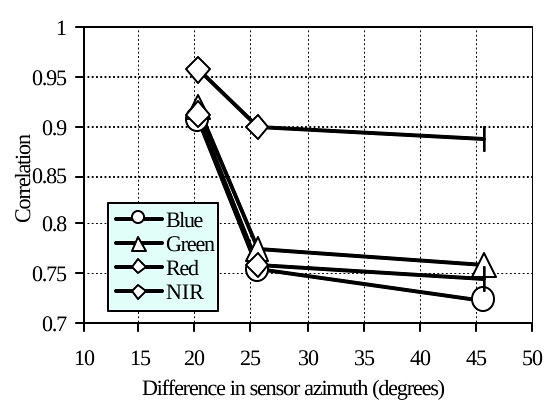

Fig. 2. Correlation of bands among datasets.

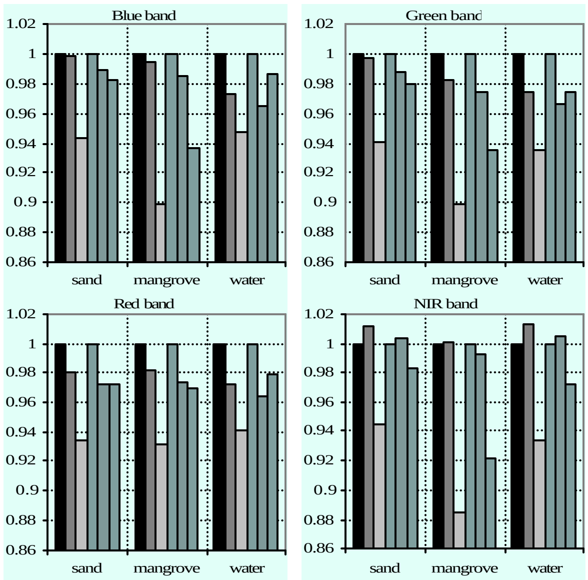

Fig. 3. Comparison of uncorrected and corrected reflectance data.

were closer to each other regardless of the feature observed. In terms of cover, mangrove manifested the greatest discrepancy of values among datasets, even after correction. This may be attributed to the non-planar surface of mangrove as compared to sand and water, in addition to biophysical properties of mangrove.

Also the uneven distribution of the increase/decrease of the reflectance values for same features is a cause for further investigation of the BDR phenomenon. Fig. 4 shows the calibrated values of spectral measurement of a mangrove tree using a spectrometer equipped with a tilt sensor. It can be seen that for a single tree the magnitude of the reflectance is not constant. The sun at the time of the measurement was almost coincident at about +35 degrees. The idea that the reflectance would be highest if the sensor and source of light are coincident is proven true here. However, another peak occurred at about −35 degrees, this time the same reason cannot be applied. Since a review of literature mentions that LAI values may have some contribution to this variability in reflectance especially in NIR band, it may be helpful to consider the measurement LAI and other geometric

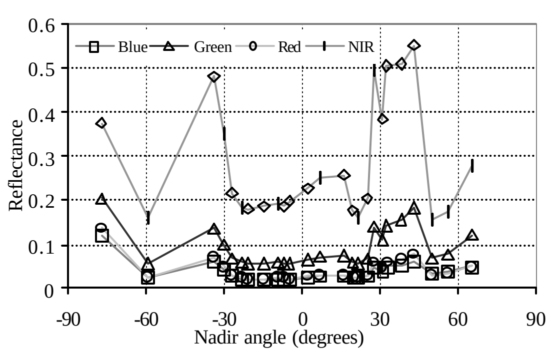

Fig. 4. Reflectance vs. sensor view angle.

properties of some mangroves within the study area in the future. In this way, the degree of the contribution of BDR to the variability of reflectance can be clearly distinguished.

4. Conclusions

We have presented that sensor's angle of collection has some effects on the obtained reflectance of different objects. From the initial assessment, variations exist in the spectral values of comparison of classification using the three Ikonos datasets. Commonly, only one dataset from a particular sensor is used for the image classification. In this research three datasets from the same sensor were used. If the contribution of BDR to the variability of reflectance were determined in this work, then other biophysical parameters may be measured from the remaining contribution. Thus, BDR phenomenon is one effect that is worth considering in mangrove forestry applications.

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