FOREST TYPE SCREENING BASED ON VEGETATION INDEXES: MYANMAR MANGROVE PERSPECTIVE

Kyaw Sann Oo*1, Van Ngoc An1, Wataru Takeuchi1, Nyan Hlaing2 and Maung Maung Than3
1Institute of Industrial Science, University of Tokyo
4-6-1, Komaba 4-chome, Meguro, Tokyo 153-8505 Japan
2GIS section, Forest Department, Ministry of Forestry, Myanmar
3Research and Training, Forest Department, Ministry of Forestry, Myanmar
*Corresponding author: ksoo@iis.u-tokyo.ac.jp

KEY WORDS: land cover, reflectance indexes, forest types, classification

ABSTRACT: National land covers for 10 years (2001 - 2010) are generated from MODIS monthly composites (Takeuchi W. and et al. 2010). The auto-generated land covers are needed to validate based on the local knowledge and local legend. On the other hand, SAFE's technical support provided AVNIR2 images for some training sites in Myanmar. The AVNIR2 image has advantage with better spatial resolution than MODIS. This advantage could be applied to validate the MODIS data. Thus, the training forest cover could be generated from the AVNIR2 image. In the satellite remote sensing, vegetation reflectance could be calculated from the multispectral images. While the land cover reflectance indexes are available, the forest types could be detected based on the decision logic classification. The study maps the mangrove forests of Meinmahla Island and Bogalay area in Ayeyarwaddy delta with overall accuracy of 92%.

1. INTRODUCTION

Auto-generated national land covers are available freely in the SAFE prototype website for Asia countries (www.safe.iis.u-tokyo.ac.jp). The land covers are generated from MODIS monthly composites for a decays since 2001 to 2010 (Takeuchi W. and et al. 2010). Though available land covers are in research level prototype, the validation and verification are require to promote to usable products for the end users. To be a successful validation process, the scientific legend which interpreted from the satellite images as IGBP 17 classes and local legend which interpreted by national standard should be matched.

The study is initiated to screen mangrove forests from a satellite image as local end-user demand. Mangroves or tidal forests are growth along the tidal affected areas by daily rise and fall of the tides or in sea water inundated delta or on sheltered muddy coastal areas (Chein Hoe, T. 1956). In Myanmar of the total mangrove forest area, 46% is located in Ayeyarwaddy delta, 37% in the Taninthayi region and 17% in the Rakhine state (Giesen et al. 2006). Among the three areas Ayeyarwaddy delta is selected as a study site for this study. The study area is covered 75 x 70 km by a satellite image which acquired from the AVNIR2 sensor of ALOS satellite with multispectral mode. From the remote sensing point of view, once a satellite image has multispectral channels it could generated vegetation indexes by calculation from difference channels. The difference kinds of vegetation indexes calculation methods are available with their advantages. The study is done on screening to the mangrove forests from satellite image using indexes.

2. DATA AND STUDY AREA

Color	Band	Spectral region (micrometer)
Blue	1	0.42~0.50
Green	2	0.52~0.60
Red	3	0.61~0.69
Near-infrared	4	0.76~0.89

Table 1. Multispectral Bands Of AVNIR-2 (©AVNIR-2 Image Copyright 2010 JAXA)

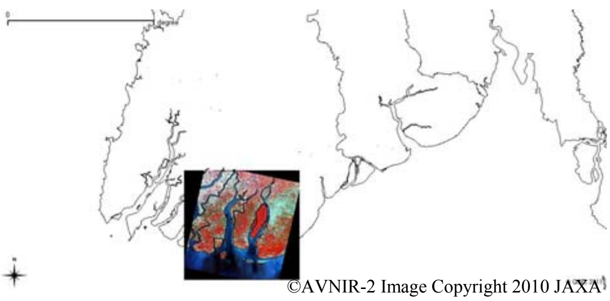

Figure 1. Study area and AVNIR-2 multispectral false color composite image.

Advance Visible and Near Infrared Radiometer type-2 (AVNIR-2) is one of ALOS satellite's three sensors. It has 10 meters spatial resolution image with 70 km swath width at nadir. One image has four multispectral bands and their wavelengths are listed in table 1. Multispectral bands are very useful to identify forest types. Concerning green leaves, they absorb solar radiation and appear relatively dark in the photosynthetically active radiation (PAR) spectral region while leaf cells reflect and transmit solar radiation and appear relatively bright in the near-infrared spectral region. Thus, calculated vegetation indexes are directly related to the photosynthetic capacity and hence energy absorption of plant canopies. Multispectral optical satellite images were used to generate forest cover map, as the matter the satellite sensors can detect wavelengths of vegetation reflectance. Although, the image pixels are representing in digital number (DN) in satellite image; the DN numbers could convert to reflectance values using provided parameters. The conversion process is presented in the following section.

3. SURFACE REFLECTANCE GENERATION

3.1 Radiance Calculation

Radiance (Lλ) for spectral band λ at the sensor's aperture (W/m2/μm/sr) can be calculated from digital number (equation 1).

$$L_\lambda = \frac{DN_\lambda}{Calcoef_\lambda \bullet Bandwidth_\lambda} \qquad (1)$$

where
Calcoefλ = Radiometric calibration coefficient (DN/ (mW/m2-sr))
Bandwithλ = Bandwidth of spectral band λ (μm)
DNλ = Digital Number of each band λ

The above method isn't work unless radiometric calibration coefficient is provided. In this occasion another process (equation 2) can be applied using absolute calibration coefficients (gain and offset) (Landsat 7 science data user's handbook).

Lλ = Grescale * QCAL + Brescale (2)

where
Lλ = spectral radiance at the sensor's aperture in Watts/(m2*ster*μm)
QCAL = the quantized calibrated pixel value in DN
Grescale = Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * μm)/DN
Brescale = Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * μm)

The provided absolute calibration coefficients are listed in the table (table 2) for each band of image.

3.2 Surface Reflectance Calculation

Reflectance images were calculated to reduce the image-to-image illumination differences by normalizing from solar irradiance. Band dependant planetary reflectance is defined as:

$$\rho_p = \frac{\pi \bullet L_\lambda \bullet d^2}{\mathrm{ESUN}_\lambda \bullet \cos\theta_s} \quad \text{or} \quad \rho_p = \frac{\pi \bullet L_\lambda}{(F_0 \bullet \cos\theta_s / d^2)} \qquad (3)$$

where
ρ_p = Unitless planetary reflectance
L_λ = radiance for spectral band λ at the sensor's aperture (W/m2/μm/sr)
d = Earth-Sun distance in astronomical units
F_0 or $ESUN_\lambda$ = Mean solar exoatmospheric irradiance (W/m2/μm)
θ_λ = Solar zenith angle

Mean solar exoatmospheric irradiance ($ESUN_\lambda$ or F_0) was adopted from the table of Hiroshi Murakami and et al. (2007) (table 2).

Table 2. Absolute calibration coefficients and mean solar exoatmospheric irradiance for AVNIR-2 image

Band	Gain/ offset	Spectral radiance λc[nm]	Solar irradiance F0[W/m2/μm]	Parameter [πLλd2]
1 (Blue)	0.588, 0.0	463.0	1943.3	1.838121
2 (Green)	0.573, 0.0	560.0	1813.7	1.791230

3 (Red)	0.502, 0.0	652.1	1562.3	1.569280
4 (NIR)	0.835, 0.0	825.0	1076.5	2.610257

In consequent, coefficient parameters were generated for all bands of each image (table 2).

4. VEGETATION INDEXES

4.1 NDVI Calculation

The previous works were considered on the used of NOAA weather satellite. Advanced very high resolution radiometer (AVHRR) of NOAA satellite has detectors; two of which are sensitive to the wavelengths of light for vegetation ranging from 0.55~0.70 and 0.73~1.0 micrometers. These two channels were used to calculate NDVI. The classification of these NDVI values for vegetation classes are ~0.1 for barren areas, 0.2~0.3 for shrubs and grassland, 0.6~0.8 for temperate and tropical rainforest, respectively (Eidenshink and Faundeen 1994). For the case of AVNIR-2, the classification of NDVI for vegetation classes can be used based on the similarity of band 3 and band 4 of AVNIR-2 with wavelengths of AVHRR (John Weier and David Herring 2000). NDVI is the most common measurement of vegetation classification. Satellite images are used to calculate NDVI using red band and near-infrared band of multispectral (equation 4) (Rouse 1973, Kageyama Koji and Wahid Din Ara 2007).

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (4)$$

where
NDVI = Normalized Difference Vegetation Index
ρ_{NIR} = Spectral reflectance of near infrared region
ρ_{RED} = Spectral reflectance of visible region (red)
NDVI values will range from -1 to +1, where vegetated areas are in greater than or around zero.

4.2 Brightness Index Calculation

Brightness index (BI) is a composite channel of spectral reflectance of visible red and near infra red to measure the global luminance intensity (Mathieu et al. 1997). The BI allowed a good discrimination between temporary high reflectance surface and constant high reflectance over time (King et al., 1989).

$$BI = \frac{\rho_{RED}^{2} + \rho_{NIR}^{2}}{2} \quad (5)$$

where
BI = Brightness Index
ρ_{NIR} = Spectral reflectance of near infrared region
ρ_{RED} = Spectral reflectance of visible region (red)

4.3 Soil Adjusted Vegetation Index Calculation

In order to overcome the limitation of soil background brightness, Soil Adjusted Vegetation Index (SAVI) is proposed by using a soil-adjustment factor, L, to account for the first order, non-linear, differential NIR and red radiative transfer through a canopy (Huete 1988). However, several modifications have been made to the SAVI equation; the original SAVI is considered in the study.

$$SAVI = (1+L)\frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED} + L} \quad (6)$$

where
SAVI = Soil Adjusted Vegetation Index
ρ_{NIR} = Spectral reflectance of near infrared region
ρ_{RED} = Spectral reflectance of visible region (red)
L = Soil Adjustment factor (L=1)

4.4 Enhanced Vegetation Index Calculation

Considering improvement on sensitivity in high biomass regions and vegetation monitoring through a de-coupling of canopy background signal and a reduction in atmosphere influences, EVI was developed. EVI2 is introduced as extension of EVI to skip the use of blue band (Jiang, Z., et at. 2008).

$$EVI = G \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + C_1\rho_{RED} - C_2\rho_{BLUE} + L} \quad (7)$$

$$EVI2 = 2.5 \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + 2.4\rho_{RED} + 1} \quad (8)$$

where

EVI = Enhanced Vegetation Index
EVI2 = Enhanced Vegetation Index for two band
ρ_{NIR} = Spectral reflectance of near infrared region
ρ_{RED} = Spectral reflectance of visible region (red)
ρ_{BLUE} = Spectral reflectance of visible region (blue)
L, C1, C2, G = Factors (L=1, C1=6, C2=7.5 and G=2.5)

Finally, vegetation condition indexes (VCI) are calculated for above indexes. The VCI approximates the weather component in NDVI value (Kogan, F. N., 1995). Once VCI is accepted for NDVI value, it could be the relation with other indexes. Therefore, VCI is calculated for BI, SAVI, EVI and EVI2 other then NDVI (equations 9).

$$VCI_{NDVI} = \frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}}$$
$$VCI_{BI} = \frac{BI - BI_{\min}}{BI_{\max} - BI_{\min}}$$
$$VCI_{SAVI} = \frac{SAVI - SAVI_{\min}}{SAVI_{\max} - SAVI_{\min}} \quad (9)$$
$$VCI_{EVI} = \frac{EVI - EVI_{\min}}{EVI_{\max} - EVI_{\min}}$$
$$VCI_{EVI2} = \frac{EVI2 - EVI2_{\min}}{EVI2_{\max} - EVI2_{\min}}$$

where

VCI = Vegetation Condition Index
NDVI = Normalized Difference Vegetation Index
BI = Brightness Index
SAVI = Soil Adjusted Vegetation Index
EVI = Enhanced Vegetation Index
EVI2 = Enhanced Vegetation Index for two bands
max = the maximum value of the index
min = the minimum value of the index

5. MANGROVE FOREST SCREENING

The vegetation indexes (NDVI, BI, SAVI, EVI and EVI2) are calculated using above formula from the generated spectral reflectance values. Once the preliminary indexes, further vegetation condition indexes are calculated for each index. The output indexes are compared in the figure (figure 2) using sample pixels which are collected from three difference features. The represented features for the first stage samples collection are vegetation, land and water. There are 20 samples for each feature in visible differences. The threshold points between water, land and vegetation are collected from the graph (figure 2) while the respected indexes are crossing each other.

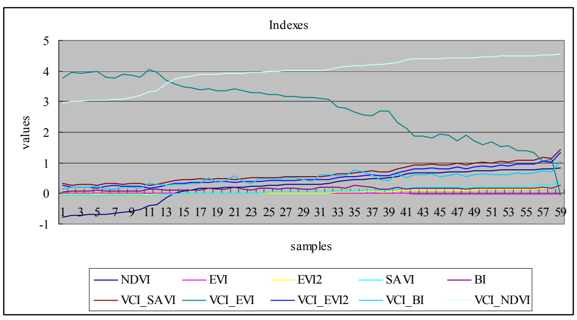

Figure 2. Indexes of water land and vegetation

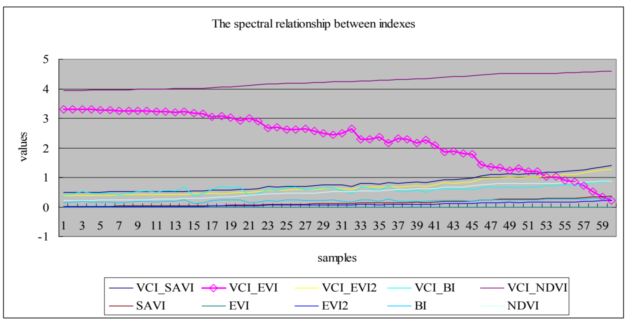

Figure 3. Indexes of mangrove and other landcover

The threshold point between water and land appeared on SAVI value equal to 0.0047 by crossing of EVI and EVI2 at the point. Thus, the water and land could be threshold on this point. Another threshold point between land and vegetation appeared on the SAVI value equal to 0.1619 by the BI crossing at the point. Thus, the land and vegetation boundary could be on this value.

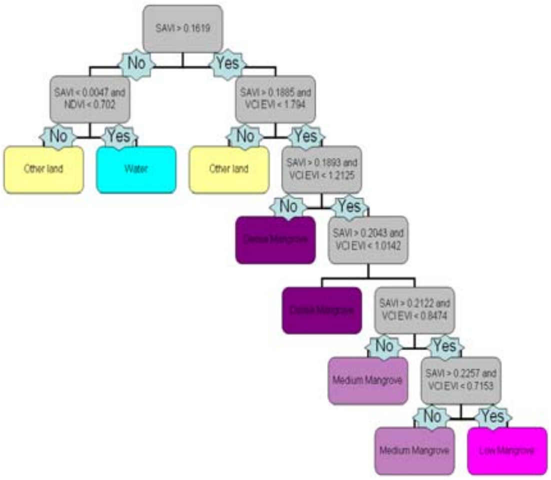

Figure 4. Screening logic of mangrove forests

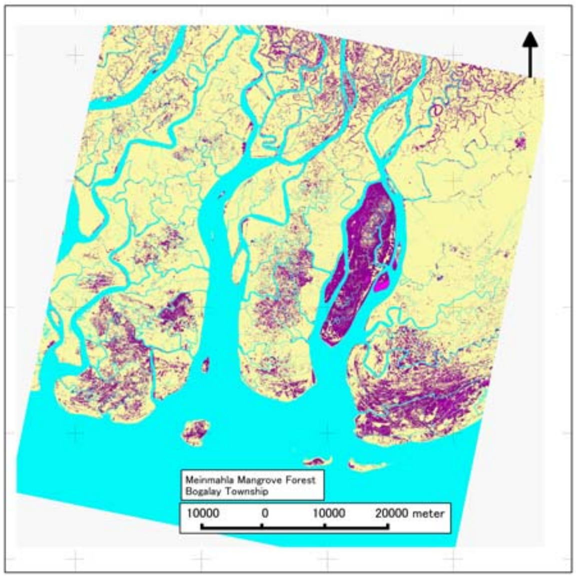

Figure 5. The mangrove forest map of Ayeyarwaddy delta

Though vegetation is separated from the land and water by above two threshold turning points, the mangrove forest and other vegetation are appeared while SAVI values greater than 0.1619.

Another 50 sample points are collected on the vegetation and land features to find the threshold point of mangrove and other vegetations. The secondly collected sample points are presented in the graph (figure 3). The graph shows the crossing points of VCI EVI with other indexes (VCI SAVI, VCI EVI2, VCI BI, SAVI, EVI2, BI, and NDVI). The threshold values are presented in the logic screening (figure 4).

6. RESULT

The screened result of mangrove forests are presented in map (figure 5) and the statistics for the full scene and Meinmahla island are presented in the table (table 3).

Table 3. The statistics of result classes for full scene and Meinmahla Island.

Classes	Sq. KM (full scene)	Percentage (full scene)	Sq. KM (Meinmahla Island)	Percentage (Meinmahla Island)
Water	2085.372	30.1 %	77.941	24.4 %
Very dense Mangrove	522.9483	7.5 %	107.7631	33.8 %
Medium dense Mangrove	41.9074	0.6 %	12.0867	3.8 %
Low dense Mangrove	9.675	0.1 %	3.0147	0.9 %
Other land	4278.767	61.7 %	118.2046	37.1 %

7. RECOMMENDATION AND FUTURE WORKS

The accuracy is assessed using confusion matrix from collected samples. The over all accuracy shows 92% and measurement of agreement is 86% while procedure’s accuracy is 100% and user accuracy is 90% for the mangroves.

Recent study found that the threshold points for vegetation could be map from the crossing of vegetation indexes. Thus, it can be possible to find the threshold points for other land covers in future works.

References:

Eidenshink, J.C. and Faundeen, J.L., 1994. The 1km AVHRR global land data set: first stage in implementation, International Journal of Remote Sensing, 15 (17): 3443-3462, 1994

Giesen, W., Wulffraat, S., Zieren, M., Scholten, L. 2006. Mangrove Guidebook for South East Asia. Bangkok: FAO.

Hiroshi Murakami, et al., 2007. Brightness mutual proofreading of AVNIR-2 and MODIS that uses directionality function of the atmospheric top reflectivity, ALOS special issue, Journal of the Japan Society of Photogrammetry and Remote Sensing, Vol. 27, No. 4, 2007 p. 354-362.

Huete, A. R. 1988. A soil-adjusted vegetation index (SAVI). Remote sensing of Environment, 25, 295-309.

Jensen, John R. 1996. Introductory Digital Processing: A remote sensing perspective, 2nd Edition. Prentice Hall, Upper Saddle River, New Jersey, pp. 247-251.

Jiang, Z., A. R. Huete, K. Didan, T. Miura, 2008. Development of a two-band enhanced vegetation index without a blue band. Remote Sensing of Environment, 112, 3833-3845.

John Weier and David Herring, 2000. Measuring Vegetation (NDVI & EVI), internet information, URL:http://earthobservatory.nasa.gov/Features/MeasuringVegetation/, NASA (last date accessed: 15 Dec 2009)

Kageyama Koji and Wahid Din Ara, 2007. ALOS/AVNIR-2 satellite image's phonologic. JSPRS, Vol. 46, No. 4, 2007, p. 16-19.

King, C., Maucorps, J., Aumonier, F., Renaux, B. and Lenotre, N., (1989). Detection d'indices d'brosion par SPOT dam les sols limoneux du Nord-Pas de Calais, une etude multidate. Bull. SFPT 14: 10-13.

Landsat 7 Science Data User's Handbook, internet information, URL: http://eospso.gsfc.nasa.gov/eos_homepage/mission_profiles/docs/Landsat7.pdf, NASA (last date accessed: 15 Aug 2011)

Mathieu, R., C. King, Y. Le Bissonnais, 1997. Contribution of multi-temporal SPOT data to the mapping of a soil erosion index: the case of the loamy plateaux of northern France. Soil Technology, Vol. 10, p. 99-110.

Rouse, J. W., R. H. Haas, J. A. Schell, and D. W. Deering, 1973. Monitoring vegetation systems in the Great Plains with ERTS, Third ERTS Symposium, NASA SP-351 I, 309-317.

Shien Hoe, T., 1956. The Forest Type of Burma. Published by the Chief Conservator of Forests, Burma.

Smith, J., 1987a. Calibration tests of industrial and scientific CCD cameras. Photogrammetria, 42 (1), pp. 47-56.