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PRACTICAL TECHNIQUE FOR DETECTING MANGROVE VEGETATION USING DIGITAL MOS MESSR AND LANDSAT-5 TM IMAGES: A Case Study in Karawang Cape, West Java

Tehnik Praktis Mendeteksi Vegetasi Mangrove Menggunakan Citra Dijital MOS MESSR dan Landsat-5 TM: Study Kasus di Tanjung Karawang, Jawa Barat

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ABSTRAK

Studi ini menerangkan bagaimana algoritme-algoritme indeks separabilitas dan akurasi klasifikasi seyogyanya diterapkan secara benar untuk mendeteksi obyek-obyek yang dikehendaki secara optimal. Studi ini menemukan bahwa akurasi Kappa dan kriteria Separabilitas (Transformed Divergence) harus digunakan secara simultan. Evaluasi dengan hanya menggunakan akurasi Kappa saja atau separabilitas saja akan memberikan hasil yang keliru. Algoritme-algoritme yang diterapkan diujicobakan pada data dijital MOS MESSR (Marine Observation Satellite Multispectral Self-Scanning Radiometer) dan Landsat TM (Thematic Mapper) untuk mendeteksi distribusi vegetasi mangrove. Studi ini memperlihatkan bahwa algoritme-algoritme yang diujicobakan pada MESSR dan TM berhasil mendeteksi distribusi mangrove secara baik, dengan akurasi pengguna (user accuracy) dan akurasi pembuat (produ*cer's accuracy) yang cukup tinggi berkisar antara 55% dan 100%.*

INTRODUCTION

In Indonesia, the existences of mangrove forest are under pressured from land conversion activities. The uniqueness of mangrove region in swampy area that has been found suitable for fishpond had caused various conflict of interests. In the last decades, major parts of mangrove forest were converted into fishponds. The loss of mangrove forest might be accompanied by the loss of their ecological function, for instance, as a buffer of seawater intrusion, fuel wood resource, construction wood resource and as an habitat of scarce fauna, particularly bird species.

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In order to get reliable and timely information on the actual condition of mangrove vegetation, the use of terrestrial inventory could be time consuming and costly. Now, with the widespread availability of satellite remote sensing data in digital form, there is a possibility to get land cover information rapid and accurate manner. However, most of remote sensing practitioner is often focused on the advent of finer spatial resolution of the satellite data. Development of practical technique for detecting object of interest is often ignored.

Objective

Many kind of digital classification techniques have been developed and used to detect forest cover types, ranging from simple ones, such as single channel density slicing, to more complex techniques such as maximum likelihood classifier and principal component analysis. Most of the technique evaluation only relies on classification accuracy analysis. In this study, the authors hypothesized that interclass separability could give significant contribution to the success of the land cover discrimination. Therefore a practical technique using separability and Kappa accuracy algorithms for detecting mangrove vegetation were evaluated.

METHODS

Study Area and Data

The study area is located in Karawang Cape region, Muara Gembong District, Bekasi Utara Regency, West Jaya, extending from 106°59’25” to 107°06’05” East longitude; and from 05°54’45” to 05°59’30” South Latitude. Most parts of the study area are covered by mangrove vegetation, rice field, fishpond and bare land. The study was performed from mid May 1997 to October 1997.

The satellite images examined in this study were MOS MESSR (Marine Observation Satellite Multispectral Electric Self-Scanning Radiometer) acquired in 1991 and Landsat-5 TM (Thematic Mapper) acquired on 20 May 1992. Since the time interval between satellite data acquisition and ground check is nearly six years, the existing ancillary data such as land cover map, topographic map are also used as a reference. Interview data with local people concerning land conversion history were also collected as reference during establishing training data in the field.

Geometric Correction

In this study, image correction using standard procedure was done. This included (1) spatial interpolation using “affine transformation” and (2) Intensity interpolation using nearest neighbor method. The resampling size of MESSR and TM were 50x50 m^2 and 30x30 m^2 respectively. During Ground Control Point (GCP) selection, topographic map at scale of 1:50.000 was used as reference, producing RMSE less than 1 pixel.

Land Cover Categories

These multisensor images were analyzed independently. For MESSR data that was acquired in 1991, six land cover categories were established, i.e., (a) mangrove, (b) rice field, (c) dry cropland, (d) River, (e) fishpond and (f) Sea on the other hard, for Landsat-5 TM, eight categories were developed, namely (a) sea 1, (b) sea 2, (c) fishpond, (d) mangrove, (e) rice field, (f) settlement and (g) dry crop land. Descriptions of each category are as follows:

Mangrove

This category is a land is covered by mangrove vegetation. In the sparse density, the wet soil underlying the mangrove vegetation contributes significantly the reflectance of mangrove. This category presents in both MESSR and TM data.

Sea 1

In the TM image, the seawater was divided into two classes, i.e., sea 1 and sea 2. The sea 1 is the shallow sea water body that have much suspended sediments. In the true color image, this category appeared in light brown color. This category spread out in the surrounding coastal area.

Sea 2

The sea 2 is clear seawater that is located in relatively far from coastal area. Almost no sedimentation appeared in this category. In the true color image, this criterion appeared in dark blue color. In the MESSR image, the sea 1 and sea 2 were merged into single category and referred to as sea.

Fishpond

Fishpond is a land that used as coastal pond for raising fish. In this category, most part of the area is covered by water and by few trees over it scottered randomly.

Rice field

Rice field is an irrigated rice field that is used for rice cultivation. During the image acquisition (May), the senescent paddy areas were occured.

Settlement

This category is settlement area that consisted of community settlement buildings such as woody houses and cement/or brick houses.

Dry cropland

This category is unirrigated agricultural land. This field is usually located near the rice field but is used for vegetables and or other secondary crops.

River

Fresh water bodies dominate this category. The water quality is commonly muddy and appears to have light brown color in the true color of TM.

The training area representing each of land cover type was located in relatively homogenous and unchanged since the date of satellite data acquisition. The minimum size of training area in the image is 3x3 pixels and numbers of pixel selected in each category are ranging from 19 to 30 pixels. The ground condition describing each category and their appearance in the color composite images are depicted in Figure 1.

Detection Strategy and Data Analysis

A practical techniques applied in this study includes (1) separability analysis using Transformed Divergence (TD) measure, (2) maximum likelihood classification and (3) accuracy analysis using Kappa accuracy (κ) measure. In detail, the mathematical expression of the TD and Kappa accuracy and their variances can be found in Jaya (1993) and Jaya and Kobayashi (1995). Schematically, the strategy of the technique is depicted in Figure 2. The performed analysis covers the following steps:

Step 1: separability analysis

Interclass separabilities between mangrove and other land cover categories were evaluated and ranked. This step produced the best band combination that could separate the mangrove and other categories statistically. If there is inseparable distance between mangrove and other categories, merging process or re-selection of training area was then performed.

Step 2: Classification and accuracy analysis

The band combinations that provided the Kappa accuracy of more than 90% were selected and ranked in descending order. The statistical differences of the ranked Kappa accuracies were examined using Z_{test}. This step recognized a set of band combinations that provided high accuracies (> 90%) and statistical difference.

Step 3: Comparison analysis

The results obtained from the steps 1 and 2 were compared. A set of band combination that is recognized as the best combination both in step 1 and step 2 were selected. Then, the interclass separability provided by the selected band combination was re-evaluated, particularly among non-mangrove categories. Interactive evaluation of separability and accuracy using both separability and confusion matrices were done.

Step 4: Efficiency consideration

Since the data analysis using less number of bands could be performed faster and need less space in the hard disk memory, by considering the significant difference test, less number of dimensions in the band combination was preferred.

(a)

(b)

(c)

(d)

(e)

(f)

Figure 1. Ground condition of several land covers: (a) Mangrove condition along side the Citarum River; (b) Rice field; (c) Dry cropland; (d) Fishpond; and (e) Composite image of MESSR (band 1-2-4) and (f) False color of TM (band 4-3-2)

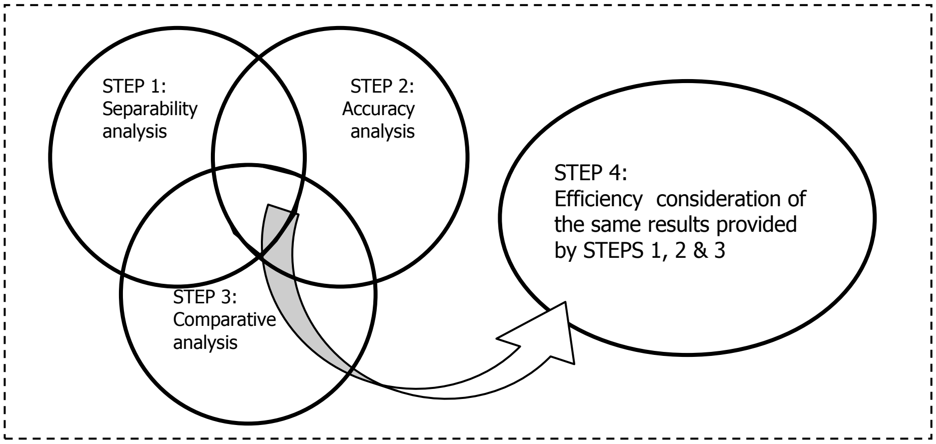

Figure 2. Venn Diagram of the technique applied in this study

RESULTS AND DISCUSSION

Spectral Signatures

MESSR images

To get a better understanding on spectral behavior and potential discriminator ability, a comparison of spectral signatures among land covers was performed. The spectral signatures of the mangrove category provided by either MESSR or TM data was compared against other land cover categories, i.e., rice field, dry crop land, river, sea, fishpond and settlement. The comparisons were accomplished by graphical evaluation of the MESSR and TM bands as depicted in Figures 3 and 4, respectively.

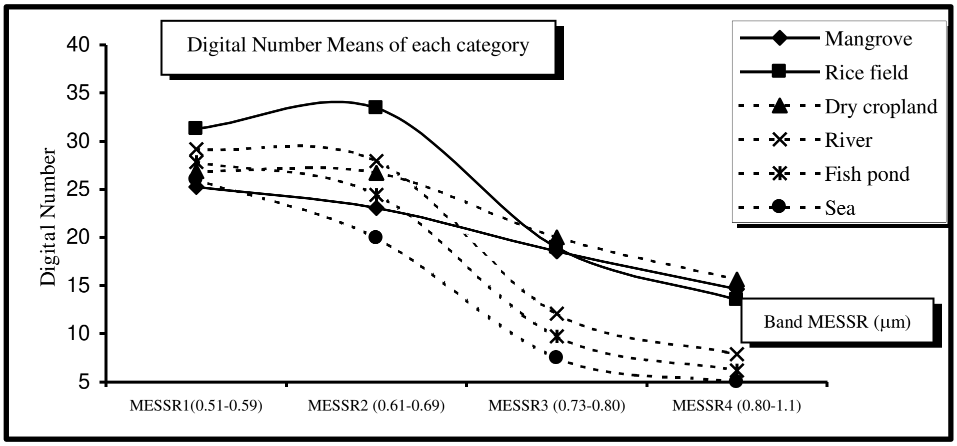

Figure 3. The spectral signatures of the land cover categories in the study site provided by MESSR bands

As described in Figure 3, the reflectance of mangrove category decreases when the wavelength of MESSR bands increases. This condition might be due to sparse condition of mangrove vegetation so that the underlying wet surface predominantly contributes the reflectance of mangrove. Starting from the green band (MESSR band 1[0.51µm-0.59µm]); then the red band (MESSR band 2 [0.61-0.69 µm), up to infrared band (MESSR band 3[0.73µm-0.80µm] and 4[0.80µm-1.10µm]), the reflectance of wet surface decreases when the wavelength increases. This coincides with the curve of water reflectance characteristic. According to Richards (1993), the water reflects about 10% or less in the blue-green range, a smaller reflectance in the red and certainly no energy in the infrared range. Within the study area, since the water of Citarum River contains much suspended sediments (turbid water), the high reflectance from the water will occur. Even in the clear water body, shallow depth of Citarum River could allow reflection from the bottom material of the water. Rice field, fishpond and dry cropland also present similar patterns of the spectral signatures. From Figure 3, it is also shown that a better discrimination is provided by MESSR 2 (band 2) than other MESSR bands (bands 1, 3 and 4). The DN mean values of each category are well separated. This MESSR2 band is red band suitable for discriminating land covers is related to green biomass and water contents (Jaya and Kobayashi, 1996), i.e., forested/vegetated area, bare land, and swampy and dry cropland.

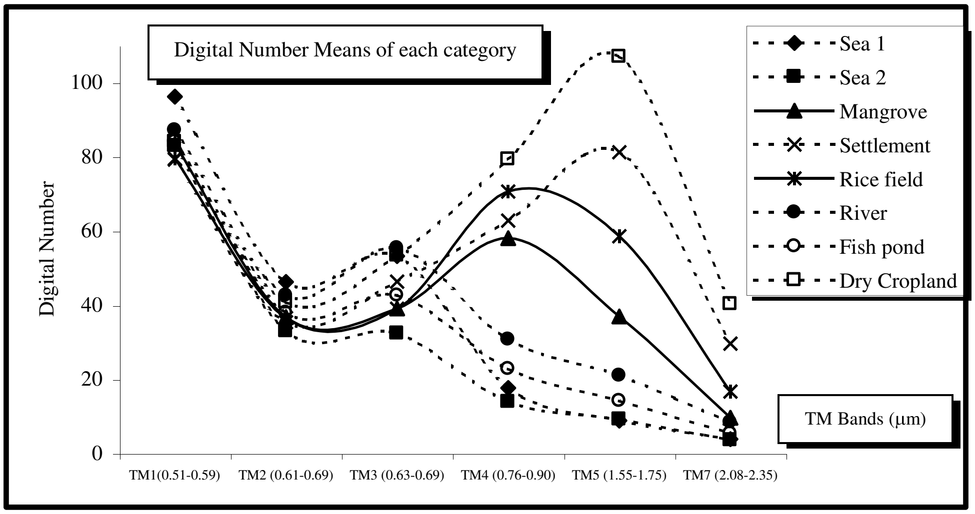

Figure 4. The spectral signatures of the land cover categories in the study site provided by Thematic Mapper bands

Spectral signature evaluation was also performed on TM data that acquired in 1992. In Figure 4, TM data visually depict good separation between classes, particularly using TM band 3, 4, 5 or 7. As recorded by Landsat TM in 1992, the visual inspection revealed that the mangrove density might increase, so that the reflectance of mangrove vegetation follows the common spectral reflectance curve of vegetation as described by Richards (1993). The mangrove reflectance shall increase when the wavelength increases from TM band 3 (red [0.63-0.69μm]) to TM band 4 (near infrared [0.76-0.90μm], then decreases when moving to middle infrared (TM band 5[1.55-1.75μm] & 7 [2.08-2.35μm]). The similar pattern is also given by rice field category. For dry cropland and settlement categories, from TM 2 to TM 7, the reflectance increase continuously achieving the peak at TM band 5 then decreases when it moving to band 7.

In quantitative classification, particularly when the maximum likelihood decision rule or mahalanobis distance is applied, the classification result depends upon their class signatures, i.e., their means and variances. Although two or more categories show very close DN means, their statistical separations could be influenced by their variance significantly. In this study, statistical evaluation for measuring interclass separation was also performed using the Transformed Divergence separability index. This index considers both means and variances of the categories to be compared. The separation criteria could be found in Jensen (1986); Jaya (1993); and Jaya and Kobayashi (1995).

As described in Table 1, this study shows that better separations are provided by inclusion of MESSR1, MESSR2 plus MESSR3 or MESSR4 in the band combination (1-2-3 or 1-2-4). The MESSR1 is green band, while MESSR3 and MESSR4 are within the range of the infrared band. Although single MESSR1 provides relatively clustered DN means than MESSR3 and MESSR4, their contribution is significant on enhancing interclass separation. As shown, the combinations of MESSR bands 1-2-3 (1998.3) and 1-2-4 (1998.5) give higher TD average (TD_{avg}) than MESSR 1-3-4 (1893.1) and 2-3-4 (1887.5). This study noticed that the MESSR3 and MESSR4 have redundant information, so that inclusion of these two bands together could not improve interclass separation significantly. The band combinations 1-3-4 and 2-3-4 of MESSR band are fail to separate between mangrove and dry cropland significantly as depicted by their TD values less than 1600. i.e., 1477.6 and 1500, respectively.

Thematic Mapper images

Referring to the wavelength of the TM bands, band 1 and band 2 of the MESSR are equal to band 2 (green) and band 3 (red) of the Thematic Mapper (TM), respectively. Meanwhile, bands 3 and 4 of the MESSR are included within the range of TM band 4. As shown by many researches, e.g., Jensen (1986), Richards (1993), Jaya and Kobayashi (1995), and Jaya (2000a) and 2000b), the infrared band shows superior performance as compared to the visible bands for discriminating vegetated and non-vegetated land covers. In this study, the MESSR results were compared with the optimal TM band combination, i.e., TM bands 1-3-4 (blue-red-near infrared) in detecting mangrove vegetation. As shown in Figures 3 and 4, better interclass separations are provided by the infrared band, either near infrared or middle infrared. Using TM bands, better discrimination was provided by TM bands, giving TD_{avg} of 1-3-4 is 1999.9, which is almost excellent. Noting the interclass separability between mangrove and other land covers, only a little confusion occurred between mangrove and settlement (Table 1).

Land cover discrimination

To know the degree of confusion among land covers, the classification was evaluated using the Kappa accuracy measure. This measure was used since it can be used either to evaluate both the classification accuracy and statistical difference between two confusion matrices. Table 2 summarizes the Kappa accuracies provided by several band combinations. It is shown that the MESSR combinations 2-3, 2-4, 1-2-4 and 2-3-4 provide as good as accuracy obtained from all MESSR bands (1-2-3-4). Statistically, they have no significant difference. This means that the detection of mangrove vegetation and other surrounding land covers is well done using those MESSR combinations. However, since the separability indexes should also be considered all at once, then only the combination of MESSR 1-2-4 and 1-2-3-4 are identified as good enough for detecting mangrove vegetation The combination of MESSR bands 1-2, 2-4 and 2-3-4 have lower performance than 1-2-4 and 1-2-3-4 owing to their failure to separate settlement and dry cropland categories, while MESSR 1-2-3 provides significantly lower accuracy (94.7%) than MESSR 1-2-4 or 1-2-3-4. Furthermore, for efficiency reason, the MESSR 1-2-4 is more recommended than MESSR 1-2-3-4. The terclass separation using MESSR is summarized in Table 3. Schematically, the practical technique found in this study is shown in Table 5.

Table 1. Transformed divergence measures between mangrove and other land cover categories using several combination of MESSR and combination of TM bands 1-3-4.

Land cover category	Mangrove					
	MESSR band combination					Thematic Mapper Bands 1-3-4
	1-2-3	1-2-4	1-3-4	2-3-4	1-2-3-4	
Rice field	2000.0	2000.0	1992.0	1998.6	2000.0	2000.0
River	2000.0	1998.4	1996.0	1950.7	1997.9	2000.0
Fish pond	2000.0	1996.0	2000.0	1988.1	2000.0	2000.0
Dry cropland	1991.5	1998.1	1477.6	1500.0	2000.0	2000.0
Sea	2000.0	2000.0	2000.0	2000.0	2000.0	
Sea 1						2000.0
Sea 2						2000.0
Settlement						1999.0
Average	1998.3	1998.5	1893.1	1887.5	1999.6	1999.9

Remarks: The criteria of the Transformed Divergence measures are as follows (Jaya and Kobayashi, 1995): excellent: TD = 2000; good: TD between 1900 and < 2000; fair: TD between 1700 and <1900; poor: TD between 1600 and <1700; and inseparable: TD < 1600.

Table 2. The Kappa accuracies of MESSR and TM band combinations.

MESSR band combination	Kappa accuracy (%)	TM band combination	Kappa accuracy (%)
All band (1-2-3-4)	96.97	All six reflective bands (1-2-3-4-5-7)	98.05
2-3-4	96.21	1-2-3-4-5	97.38
1-3-4	96.21	2-3-4-5-7	97.38
2-4	96.21	1-2-3-4	91.50
2-3	95.45	1-3-4	91.50
1-2-3	94.70	3-4-5	90.42
1-2-4	89.39	2-3-4	90.35
1-4	89.39	Other 3 band combination	< 90.00
1-3	86.33		
1-2	84.89		
3-4	66.66		

Remarks: Kappa accuracy values that are connected by line express that those values are not significantly different at 95% confidence level.

When the TM is applied, the combination of band 1-3-4 and 1-2-3-4 gave similar accuracy. Although all six reflective TM bands were used, the interclass separation between mangrove and other categories could not be improved significantly. However, for detecting mangrove vegetation, the combination of band 1-3-4 provides good and excellent interclass separabilities (Table 4) and quite high accuracy (Table 7). Applying more than 3 band could be time consuming and inefficient.

During visual interpretation using MESSR images the settlement areas could not be well recognized due to their size that less than 2 ha and their randomly scattered distribution. Since the settlement areas are often confused with the mangrove categories, the settlement areas are then merged with the mangrove category. In this study, although