Remote Sensed Data and Multiphase Integration to classify Wetland types, Western Thailand

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Abstract. Exiting wetlands are highly valued for conservation. Due to amount of area declination and reduction of general properties. Remote sensing is required to wetland inventory. Especially monitoring and classification. This study aims to classify wetland types. Image enhancement and transformation were combined in image processing to detect wetlands in western Thailand. Fundamental features of hydrophytic vegetation, hydric soil and hydrology from field surveys in western Thailand were collected and used to lead image processing to classify wetlands for the entire area; supervised classification was used with a maximum likelihood method. Several techniques for image enhancement and transformation were processed. The study results found that the color composite image technique and the image operation technique with Normalized Difference Vegetation Index (NDVI) are appropriate when used to specify surveying points for field study and in training areas of image data. For the image stretching technique and Principal Component Analysis (PCA) it is appropriate when applied in image classification and detection with a maximum likelihood method. An assessment of accuracy for wetland classification found that the PCA technique has the highest accuracy: 98.92%. Then, a combination of two techniques: image stretching and the PCA technique showed an overall accuracy of 98.78%. For classification that used only linear stretching the overall accuracy was 94.11%, equal to original maximum likelihood using classification without technique.

Keywords: Remotely sensed data, Multiphase integration, Wetland classification one

1. Introduction

Wetlands are valued for storing water, protecting shorelines, maintaining water quality, and recharging groundwater (Daily, 1997). Local economies in several countries depend on fisheries, reed harvesting, grazing, and recreation in wetland areas. Providing suitable habitat for fish and wildlife, wetlands foster rich biological diversity, including for threatened and endangered species. Wetlands are also valued for their recreational opportunities and aesthetics (Barbier et al., 1994). Ramsar Convention emerges as an international treaty for the conservation and loss prevention of wetlands in the world, resulting in sustainable development in all regions (Office of Natural Resources and Environment Policy and Planning, 2007). Thailand, listed number 110 as a contracting party of the convention, nominated Kuan Ki Sian wetlands of the Thale Noi Non-hunting Area in Phatthalung province as the first Ramsar site in the country. This is under the commitment to the convention that all contracting parties must designate proper wetlands in their territories to be recorded in the List of Wetlands of International Importance.

According to the National Inventory of Natural Wetland in Thailand, there are 9.26 million acres of wetlands or 7.5 percent of the country’s total land. It led to the efforts of wetland prioritization and setting up measures towards the sites of national importance. The measures consist of conservation, awareness raising, study, research, and forest fire prevention. Later, the National Environment Board had a resolution to solve the increasing degradation and loss of wetlands in Thailand, which are prone to reach crisis stage. The management of wetlands requires co-operations from many bodies; thus, it is essential that conservation
measures and management are aligned in the same direction. Nowadays, main factors that reduce the amount of wetlands are threats in several forms of development such as an increase in population, ineffective use of wetlands, wetland conversion to other activities, and wetland mismanagement (Office of Natural Resources and Environment Policy and Planning, 2006). Although some wetlands are protected as conservation areas, the loss and problems in consequent with wetland degradation still occur. Monitoring wetlands is an urgent and crucial matter for wetland conservation in order to keep up with rapid development.

Remote sensing is a technology that enables prompt inventorying, monitoring, and assessment to benefit wetland conservation, especially for large geographic areas (Karin S. Schmidt, 2003). Satellite remote sensing helps increase accuracy of wetland detection and classification because of the spectral and spatial relationship between the light waves and physical characteristics of wetlands. Additionally, remote sensing helps reduce budget and time for examining large areas (Satellite remote sensing of wetlands, 2004). Data from satellite remote sensing and many enhancement techniques for the synthesis of wetland detection and classification have been studied and developed continuously through implementation in many wetlands around the world. In Thailand, the use of data derived from remote sensing for the study of wetlands is still limited.

Wetland has been used for various purposes. Though stricken by flood and drought annually, it remains quite abundant (Royal Irrigation Department, 2006). Both inland and coastal wetlands exist here making it a suitable training site to be studied by remote sensing. This study focuses on western Thailand by investigating fundamental features of hydrophytic vegetation, hydric soil, and hydrology. The objective was to classified wetland types using image enhancement and transformation techniques. Outcome of these subjects are beneficial to data acquisition, assessment, and management of wetlands, in response to Thailand’s cabinet resolution and the Ramsar Convention.

2. Materials and methods

2.1. Data collection

Data of remote sensing collected in digital image files of Landsat TM from Geo-Informatics and Space Technology Development Agency, which correspond to all ground samples. Over the wetland areas collect some properties from the actual site of all study points (190 samples) about location, utilization, vegetation, soil, and hydrology. Which is extend 5,603 sqkm., covered by several wetland type. Ground samples were selected by means of a random sampling. During field investigations, each sample was described in term of wetland type. Sample reconnaissance and collection was carried out during February and March 2009.

2.2. Image preparation

Image preparation consists of image subset and geometric correction. Image subset was processed to the real study area in order to reduce data volume. The data needed to be georegistered and rectified to the reference image coordinate system. In this study, image-to-map correction was conducted. Images of systematic correction were rectified using non-systematic correction. It was the image-to-ground geocorrection using polynomial function. Ground Control Point (GCP) was identified based on the coordinate in the real coordinate from Global Positioning System (GPS), and then set up to normal band combination (345).

2.3. Data modification on image Enhancement and transformation

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2.4. Image classification and analysis

The process initially used individual or combined data from those modules, based on condition as follow; 1) each technique was applied to image data. Then, it was imported to wetland classification, 2) two best
techniques from the first process were incorporated to synthesize data for further classification, 3) all three techniques were incorporated to synthesize image data for wetland classification. Image classification was conducted with all images by maximum likelihood classification using ENVI program. This process classified into 5 types; 1) water source, 2) hydrophytic vegetation, 3) shrub, 4) forest in wetland, 5) farm in wetland. Beyond these classification types were not considered as wetland areas.

3. Results and discussion

3.1. Wetland characteristics and spectral reflection

Field survey is performed for studying on basic characteristics of wetlands and field data collection perspectives of wetlands vegetation, soil science and hydrology for being training area

3.1.1 Open-water Wetland

The study involved in 40 spots. There are 2 categories: fresh water and sea water. Concerning fresh water wetlands, this type of plant community is found that they are depended on water depth such as submerged plant, floating plants, Emerged Plants and Marginal Plants. Regarding soil property of study area, most of soil texture is clay, loam and sandy soil. Soil color is light gray to dark gray with high organic matter (40-70%). Concerning sea water of open-water wetlands, it is found that plant community is strand vegetation. Mainly are perennial trees that are Horsetail Tree (*Casuaria equisetifolia*), Manaila Tamarind (*Pithecellobium dulce Benth*), sensitive plant (*Mimosa pigra L.*), and understory vegetation, most of them are beach morning glory (*Lpomoea pescaprae L.*). They often found in sandy soil to sandy clay with high organic matter (20-50%).

Spectral signature showed high reflection on visible bands; band 1-3 then reflection is lower in infrared bands; band 4-7. Perceiving by spectral scattering that these materials absorbed in infrared bands thus graph was inclined decrease. Because of shallow water has sediment mix up with water effect to increase higher reflectance in infrared bands more than deep water.

3.1.2 Emerged Wetland

The study involved in 63 spots, water depth is of 1-3 meters. This area mainly constitute the similarity of plant community of Cat-tail (*Typha angustifolia L.*), Sedge (*Cyperus imbricatus Retz*) and American lotus (*Nelumbo Lutea*). Any areas are Influenced by salinity of seawater, found the salt tolerance plants such as Indian Marsh Fleabane (*Pluchea indica Less*), Atap palm(*Nypa fruticans Wurmb*) and coconut etc.

Considering to soil characteristic, many areas are plenty of clay with fossil. The soil color is gray to blackish with high organic matter(40-70%). Only some zones contain sandy clay, loose soil, and sandy soil with high organic matter(20-30%).

Spectral signature showed high reflectance in band 4 and rise up in band 5. Because of environment condition in dry season this area rather bare field area mixed together with vegetation and other way, 30
meters of resolution of each pixel combine both bare field area element and vegetation area element so this class similar to scrub wetland and finish or dry rice field that also combine these element but a little lower of reflectance in band 5 because of bare field area was less than.

3.1.3 Scrub Wetland

The study involved in 26 samples, water depth is of 0-1.50 meters. The areas mainly constitute the plant community of sensitive plant (Mimosa pigra L.), grass, cactus, Tooth brush tree (Streblus asper Lour). The other perennial trees are also found within the area; Indian Marsh Fleabane (Pluchea indica Less.), Manaila Tamarind (Pithecellobium dulce Benth.), jute (Corchorus sp.) and Egyptian (Cyperus papyrus L.). Most of soil is clay, sandy clay, and sandy loam with brown to gray and high organic matter (20-50%).

Spectral signature showed reflection similar to emerged that showed high reflectance in band 4 and rise up in band 5. But scrub wetland has little higher reflectance in band 5 because of bare field area in scrub wetland was more. Also in band 4, scrub wetland has higher reflectance because of more element of chlorophyll or vegetation element.

3.1.4 Farmland Wetland

The study involved in 43 spots. Land use pattern is mainly for rice farming and shrimp culture. Vegetation consist of Rice (Oryza sativa L.), the dominant plant species. Influenced by high salinity, the salt tolerance plants are found tiny plot in the rice farming and shrimp culture such as Indian Marsh Fleabane (Pluchea indica Less.) and seablite (Suaeda maritima Dum.) etc. Determined as inundation in some seasons, its water depth is of 0-2 meter depending land use pattern. Almost of soil is mainly brown to dark gray with high organic matter (20-50%). Few is sandy clay, sandy soil with yellowish, brown to red and less organic matter (20-30%).

Spectral signature on this wetland type showed much difference of reflection especially in band 4 and band 5 because of environment and physical element on vegetation and soil are difference with these 2 classes. The high rising up on band 5 of finish or dry rice field mean the high bare area with soil element reflectance after finished rice field season. The pretty highs on band 4 of finish or dry rice field mean some decline vegetation in study area. For salt and shrimp field has similar reflection with shallow water because of water flood made by human to prepare pond or field for salt and shrimp, also this area was less vegetation so reflectance in infrared bands, band 4-7 are low.

3.1.5 Forest Wetland

The study involved in 18 spots, consist of mangrove forest located on the Eastern part. Forest wetlands size are relatively changed by tidal effect 0-3 meter. Plant community is composed of olive mangrove (Avicennia marina Vierh.), Red Mangrove (Rhizophora mucronata Poir), Nipa Palm (Nipa fruticans Wurmb) Soil texture is clay, mud, and some of them are clay based with sandy soil. Salinity is high (5-35 %) and high organic matter (50-70). Another part is the western massive forest that is not affected by sea water. The plant community is Deciduous Dipterocarp Forest that consists of Siamese Sal (Shorea obtusa Wall), Burmese sal (Shorea siamensis Miq.), Burmese Ironwood (Xyli xylocarpa var. kerrii) and Eucalyptus (Sindora siamensis Teijsm).

Spectral signature showed a little difference reflection in band 4 between mangrove on coast and mangrove on ground because density and element of vegetation. Mangrove on ground has higher reflectance in band 4 means on ground has more mangroves. In band 5, mangrove on coast showed higher reflectance than mangrove on ground because of clay, mineral and sand that high effective reflection in this band. For overall reflection on both classes of forest wetland showed high reflection on visible bands, band 1-3 because moisture and water that continually cover this area. More over chlorophyll or vegetation was the cause of graph rising up on band 4.

The wetland type in western Thailand can be classified into 5 categories: 1) Open-water Wetland 2) Emerged Wetland 3) Scrub Wetland 4) Farmland Wetland and 5) Forest Wetland, which is similar to the wetland classification system on Ramsar Convention by Simba Chan and team (2005) including 1) Marine and Coastal Wetland 2) Inland Wetland and 3) Human-Made Wetland. The first two types consist of two sub-types like the wetland classification of Cowardin et al. (1979) while 3 types of 5 wetland types include Emerged Wetland, Scrub Wetland and Forest Wetland. Since there is no inundation in the forest area within the wetland for a long time, the forest wetland does not appear clearly as the coastal wetland with mangrove
forest wetland, which can continually sustain the ecosystem. The third wetland type of Human-made Wetland in the study area contains rice farm, shrimp farm and salt farm while the other 2 types of 5 wetland types based on the wetland classification of Cowardin et al. (1979) are Aquatic bed wetland and Unconsolidated bottom/shore that found very little and included as part of the Open water wetland.

3.2. Image processing with multiphase integration

This research interest to combine 3 main aspect; basic technique (composite band), enhancement and transformation techniques. A supervised classification then performed to classify unknown area by the method called maximum likelihood with the training area that user define base on field study data to input in the program operation. Each pixel was justified to the class considering from the highest probability. The image of study area was classified into first 24 classes then conclude to be 9 classes are 8 wetland classes for 5 wetland type and the other class. On maximum likelihood classification found that Image operation with Normalized Difference Vegetation Index-NDVI cannot classify because of the real reflectance of each pixel was calculated to -1 to 1 for new reflectance value by equation of Normalized Difference Vegetation Index-NDVI. However Image stretching with linear stretching and Image with Principal Component Analysis-PCA were classified with the clear result so these two techniques were combine.

![Fig. 2: Wetland types.](image)

1) Open-water  
2) Emergent  
3) Scrub  
4) Farmland  
5) Forest

![Reflection vs Band](image)

1) Open-water  
2) Emergent

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3) Scrub

4) Farmland

5) Forest

Fig. 3: Spectral signature of wetland types.

Fig. 4: Wetland type classification.

3.3. Accuracy assessment

Accuracy assessment was considered by Kappa coefficient, overall accuracy, and percentage of commission pixel and omission pixel from the cross tabulation Table 1.
The original image without multiphase integration that classified by maximum likelihood method showed K 0.9303 accuracy assessment 94.10% equal to classification of linear stretching image. This because of linear stretching used just basic equations ratio to compare all actual reflectance of each pixel in image to new value by capacity of computer. Computer 8 bite microprocessors has stretching level from 0 to 255 so this enhancement techniques was stretched all reflectance to 256 levels. All of image pixels stretched by this method so overall component of image reflectance not much affected thus accuracy assessment by overall accuracy and Kappa coefficient are same original image.

For principal component analysis-PCA image with maximum likelihood classification method showed highest accuracy assessment K 0.987 accuracy assessment 98.91 %. This because of calculation by algebra combined mechanics equation to decrease great number of image data by all principle components still remain. Result of this analysis provided new components or new bands from linear regression of many of old bands, result new bands have almost major elements of old bands but its less data number than old bands. This technique decreases much time and data size with highest accuracy assessment from components or bands after regression.

For linear stretching and PCA image with maximum likelihood classification method showed higher accuracy assessment K 0.9854 accuracy assessment 98.78 %. The accuracy assessment is higher than original image and linear image but lower than principal component analysis-PCA image because equation and complicated calculation. The PCA calculation is more complicated calculation than linear stretching so the combination of linear stretching and PCA was decrease efficiency of PCA. In the other way linear stretching used basic ratio calculation with image reflectance of all pixel caused reflectance image stretched and affected remaining of some band components. Finally, PCA image with maximum likelihood classification provided the highest efficiency accuracy assessment on wetland detection and classification on this study.

Table 1 Kappa coefficient and overall accuracy

<table>
<thead>
<tr>
<th>No.</th>
<th>Technique</th>
<th>Kappa Coefficient</th>
<th>Overall Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None (normal band combination)</td>
<td>0.9303</td>
<td>94.1079</td>
</tr>
<tr>
<td>2</td>
<td>Linear stretching</td>
<td>0.9303</td>
<td>94.1079</td>
</tr>
<tr>
<td>3</td>
<td>Principal component analysis (PCA)</td>
<td>0.987</td>
<td>98.9166</td>
</tr>
<tr>
<td>4</td>
<td>Linear stretching and PCA</td>
<td>0.9854</td>
<td>98.784</td>
</tr>
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</table>

Table 2 Percentage of commission pixel and omission pixel

<table>
<thead>
<tr>
<th>Classification class</th>
<th>Percentage of Commission pixel and Omission pixel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original</td>
</tr>
<tr>
<td></td>
<td>Com</td>
</tr>
<tr>
<td>1 Deep water</td>
<td>0</td>
</tr>
<tr>
<td>2 Shallow water</td>
<td>16.07</td>
</tr>
<tr>
<td>3 Emerged</td>
<td>7.06</td>
</tr>
<tr>
<td>4 Scrub</td>
<td>13.56</td>
</tr>
<tr>
<td>5 Finish or dry rice field</td>
<td>0.68</td>
</tr>
</tbody>
</table>
The original image without enhancement and transformation techniques classified by maximum likelihood classification method showed confused percentage of pixels in 6 classes are shallow water, emerged, scrub, finish or dry rice field, shrimp and salt field in order. While deep water, mangrove on coast and mangrove on ground were not found any confused percentage. Result on this classification method same as linear stretching image that shallow water has highest percentage of commission 16.07% then scrub 13.56%, emerged 7.06%, shrimp and salt field 4.7% and finish or dry rice field 0.68%. And scrub showed highest percentage of omission 17.07% then shallow water 13.76%, shrimp and salt field 5.59%, emerged 1.25% and finish or dry rice field 0.68%.

For principal component analysis-PCA image Maximum likelihood classification method showed confused percentage of pixels in 5 classes. Scrub and finish or dry rice field are both have commission and omission. While shallow water and Emerged showed just commission error and shrimp and salt field showed just omission error. Scrub has highest percentage of commission 17.19% then shallow water 1.8%, emerged 1.23% and finish or dry rice field 1.13%. Also scrub showed highest percentage of omission 13.82% then finish or dry rice field 1.13% and Shrimp and salt field 0.62%.

For linear stretching and PCA image with maximum likelihood classification method showed confused percentage of pixels in 5 classes, scrub and finish found both commission and omission error, shallow water and Emerged found just commission error while shrimp and salt field found just omission error. Scrub still showed highest confused percentage, 22.9% for the commission and 17.89% for the omission. Emerged has 2.44% commission error then finish or dry rice field 0.92% for commission error and 2.72% for omission.

4. Conclusion

Multiphase integration can improve wetland type classification. Especially Principal component analysis (PCA) has the highest accuracy: 98.92%. The image stretching technique and PCA combination has overall accuracy is 98.78%. The results allow to demonstrate the extent of wetlands in western Thailand. The areas being covered by open water 66.04 km², emergent 179.11 km², Scrub 980.87 km², Farmland 356.36 km², Forest 2070.08 km². Moreover the research provide some results that has lower accuracy, Linear stretching and normal band combination.

In conclusion, it remains necessary to apply these approaches under different conditions such as high resolution sensor, multi sensor on various sites in order to increase the accuracy of the methods developed.

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6. References


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