Research Paper

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Generation of Land Cover Map and Ecosystem Map of Bungoh Catchment using Geospatial Tools

Environmental Science

KEYWORDS : Land cover map, ecosystem map, remote sensing, geography information system(GIS), confusion matrix, image processing, supervised classification.

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ABSTRACT

Mapping land cover and ecosystem of Bungoh Catchment is essential for a wide range of applications, includingdam development projects and other form of anthropogenic activities. The mapping process is being facilitated with the application of remote sensing and geographical information system (GIS). In this study, classification of forest was performed using the information generated from the data collected during the field work and also from the digitise topographic maps.Four major types of forest ecosystem have been identified and mapped. This includes the primary forest, old secondary forest, young secondary forest and angroforestry.The Landsat TM image, combined to field work were submitted to a supervised classification process in order to produce a land cover and ecosystem map. An accuracy assessment was performed on the map, generating the confusion matrix. The overall classification accuracy for the five types of ecosystem for both the TM image and ecosystem map were established as 87.93% and 86.92% respectively which were sufficient for the delineating of ecosystem types in order to be analysed.

1.0 Introduction

The classification of forest ecosystem, analysing land cover and ecosystem categories have been made possible with the application of remote sensing and Geographical Information System (GIS) (Ehlers etal.,1990; Harris and Ventura, 1995; Weng,2001; Sahebjalal and Heidari, 2011). Remote sensing imagery is the most important data resources of GIS. The remote sensing technique has the ability to represent various land cover and ecosystem categories by means of classification process (Sahebjalal and Heidari, 2011). GIS provides a flexible environment for collecting, storing, displaying and analysing digital data necessary for generating of land cover map and ecosystem map. It has the ability to interrelate spatially multiple types of information assembled from different sources (Aranha et al., 2008, Reis, 2008). In this study, the Land sat TM image has been used as the primary data to produce land cover map and ecosystem map using supervised classification. The supervised classification is a process of using training sample, samples of known identity to classify pixels of unknown identity. The quality of a supervised classification depends on quality of the training sites (Palaniswami et al., 2006; Perumal and Bhaskaran, 2010). The supervised classification follows the following sequence; defining of the training site, extraction of signatures and finally the classification of the image. The classification of land cover types provides useful classification in mapping vegetation and ecosystem types (Zhu, 1997;Hirataa et al., 2001; Vieira et al., 2003; Sahebjalal and Heidari, 2011). The land cover map and the ecosystem map are needed by planners, managers and decision makers to investigate the land cover and ecosystem distribution for the proposed development such as dam projects. The aim of this study is to generate the land cover map and ecosystem map of Bungoh catchment in the state of Sarawak, Malaysia using the remote sensing data and GIS technologies

2.0 Material and Method

2.1 Study area

The study was carried out at the Bungoh catchment which is a segment of Sarawak Kiri River catchment areas and upstream of Bungoh dam. It is located in latitude between 1.184° to 1.296° N and in longitude between 110.106° to 110.242° E and 60 km from Kuching, the capital of Sarawak. The catchment covers an area of approximately 127 square kilometres (Figure 1). The altitude ranges from 20m to 1300 m a.s.l. The forest ecosystem constitute primary forest, secondary forest and agroforestry. The climate is equatorial type with warm and humid weather throughout the year; and annual rainforest of the area is approximately 3.990 mm/year with a high proportion falling during the North West monsoon season from November to February. The driest period occurs from June to August. The mean temperature is approximately 26.6°C and meanrelative humidity is around 85.3%. The wind pattern in this area generally shows relatively calm condition with 33.9% of the time with wind blowing and light breezes were recorded for 42% of the time. The catchment is an area of complex geology involving a whole range of sedimentary rocks, igneous intrusive and extrusive rocks with associated metamorphism.

Figure 1. Location of the study area, the Bungoh Catchment, Sarawak, Malaysia

2.2 Data

The present study is based on mapping land cover from Landsat TM image, digitise topographic maps at the scale 1: 250000 and data collected during field work. The data was collected during the survey performed in August 2011, October 2011 and March 2012. The Landsat TM image was obtained from the Malaysian Remote Sensing Agency and the digitise topographic maps was provided by the Department of Survey and Mapping Malaysia (JUPEM).

2.3 Forests classifying

The classification of forest was performed using the information generated from the data collected during the field work and also from the digitise topographic maps. By processing those information in a GIS, a new thematic map was produced which showed the four major type of homogeneous forest parcels.

2.4 Landsat TM image classifying

The forests were masked out of the Landsat TM image to classify the remaining area only (Geneletti 2002). By using the collected data from the survey and following the guidelines of the CORINE land-cover system (Bossardetal.,2000), a suitable map legend was set. Five classes were identified in the study area. Those classes encompass the primary forest, old secondary forest, young secondary forest, agroforestry and shifting cultivation. The survey that was performed in August 2011, October 2011 and Mac 2012 involved all four different types of forest ecosystem. The study area was sampled as homogeneously as possible and the total area surveyed for each forest type was proportional to the total cover of that forest type within the image. Based on the topographic map at scale 1:25000 and the data collected during field work, two types of data were established. Those included the training data and the test data. The Landsat TM image was classified using supervised classification method and subsequently the land cover map was produced. The land cover map and the ground truth map were compared to determine the accuracy of classification (Sahebjalal and Heldari 2011). The calculation of accuracy assessment of classification was performed using the confusion matrix which is the most common way to present the accuracy of the classification results (Fan et al., 2007; Reis 2008). Based on the confusion matrix, the overall accuracy, the average accuracy and the average reliability could be determinedand the Kappa statistic were then derived from the error matrices.The Kappa statistic incorporated the off diagonal elements of the error matrices and represented agreement obtained after removing the proportion of agreement that could be expected to occur by chances(Selcuk, 2008). Computing the Cohen's Kappa Coefficient of agreement was done using the following expression.

$$K = \frac{(Po - Pe)}{1 - Pe}$$

K= Cohen's Kappa
Po = Proportion of corrected classified pixels
Pe = Proportion of correctly classified pixels expected by chances

3.0 Results and Discussions

Four major types of forest ecosystem had been identified and mapped. This included the primary forest, old secondary forest, young secondary forest and angroforestry. Community farm was also being identified and was scattered within the old secondary forest and young secondary forest.The five different types of ecosystem type found in study area were described as bellows.

3.1 Community Farms

Community farms were scattered within the secondary forest. The common community farms included paddy, pepper, cocoa and vegetables. Most areas which had been abandoned were mainly dominated by herbs, grasses and sedges. Pure lalang (ImperatacylindriciaRaueschel) stands were frequently found in abandoned farms.

3.2 Secondary Forests

Secondary forests are mainly the fallows of shifting cultivation. This vegetation has different stages of succession. The forest types are classified according to structure (physiognomy). These forests offer a distinct contrast to the primary forests, both structurally and floristically.The first category consists of young secondary forest, which is mainly less than 3 or 4 years old. This vegetation is dominated by herbs, sedges, ferns and young shrubs. Trees generally grow up to 3 m. This area is well represented by several *Macaranga* species as well as leban (*Vitexpubescens*), legai (*Adinandradumosa*), Callicarpapentandra var. pentandra, manyam (*Glochidion spp.*), rentap, pulai (*Alstonia spp.*), terap (*Artocarpuselasticus*) and the fig, *Ficusgrossularioides*. In highly disturbed areas, for example, along roadsides, are found simpor air (*Dilleniasuffruticosa*), empitap (*Naucleapeduncularis*), tembusugajah (*Fagraearacemosa*), the giant grass (*Erianthussaccharinum*), and the ground orchid, (*Bromheadiafinlaysoniana*).The second category of young secondary forest which is 5 to 8 years after shifting cultivation. Emerging shrubs and trees are still very common and significantly characterise this vegetation. Trees may reach 6 m in height but canopy is still rather open with pockets of shade by taller trees. The most dominant species in this stage of succession is *Macarangabecceriana*, *Selaginellacanaliculata*, and *Croton oblongus*(Appendix A). The figs such as *Ficusuncinata* and *Ficusgrossulariodes*which are sometimes foundis also accompanied by different *Macaranga sp.*, *Callicarpa sp.*, ginger (*Achasma sp.*) and wild banana (*Musa sp.*). Making appearance also are *Artocarpuselasticus*, *Tremaorientalis*, Simpor (*Dillenia sp.*) and legai (*Adinandradumosa*). All of the original grasses,and sedges such as *Scleriapurpurascens*, ferns and herbs are still present although the pioneer herbs are on the decline. In this stage, also seen are *Euryanitida* and lalang (*Imperata cylindrical*).Canopy closure takes place at the beginning of young secondary forest about 10 to 15 years old. This stage of succession is conspicuously dominated by *Castanopsishypophoenicea*. Associates such as*Artocarpusnitidus*, *Artocarpuselasticus, Artocarpusanisophyllus, and M. beccariana* may form. They are occasionally in pure stands. Light demanding herbs, grasses and sedges from the young secondary forest havelargely been shaded out, except *Blechnumorientale*, ginger and *Nephrolepisbiserrata*. Licuala is quite commonly found among the more sparse ground cover. Various ginger species (*Zingiberaceae*), bamboo together with other shade tolerance species are locally common.The old secondary forest (more than 15 years old), the dominance of the fast growing pioneer trees is approaching an end. This vegetation is a transition to mixed dipterocarp forest. Shade demanding species have established and are gradually taking over. This type of vegetation occupies a small area along the edge of the mixed dipterocarp forest.

3.3 Agroforestry

Agroforestry is dominated by *Heveabrasiliensis, Artocarpuselas ticus,Nepheliumlappaceum, Duriozibethinus,Shoreamacrophylla and Shoreapalembanica*. The underground vegetation is dominated by *Selaginellacanaliculata,Pronephriumasperum,Pneuma tropteris truncate and Areca triandra*

3.4 Primary forest

Primary forest is well represented by *Shorea sp, Koompassia excels,Syzygium sp, Tristaniopsiswhiteana, Alangiumkurzii, Ilex cissoidea, Artocarpuskemando, Litsea sp., Knema sp., Myristica* *lowiana,Pometiapinnata,Sterculia sp.Ilex cissoidea, Xylopiafer-ruginea, Dryobalanopsbeccarii,Cratoxylumglaucum,Mangifera foetida,* and*Ficus sp.*whereas the ground is covered by *Macaranga gigantean, Alphitonia excels,Saurauia sp., Adinandra sp.,Ficussp., Musa sp,Pronephriumasperum,Syzygium sp.* and*Artocarpuselasticus*

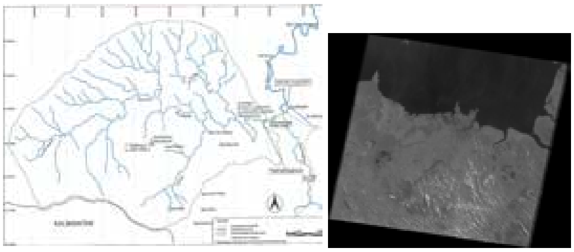

Figure 2 : Location of study area showed on the Landsat TM image, Bungoh Catchment, Sarawak, Malaysia

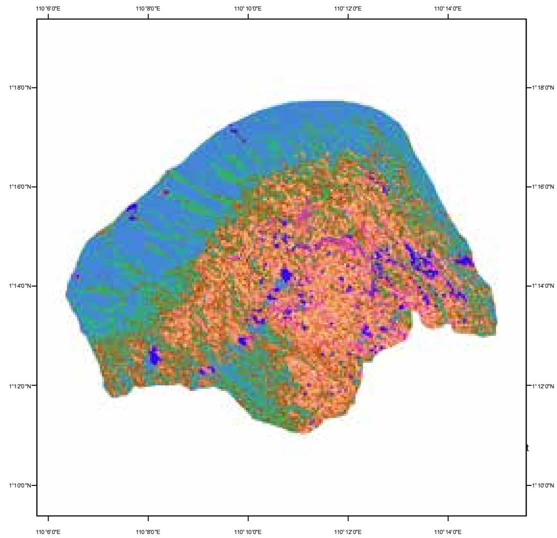

Figure 3: Classified image of study area.

Table 1.Accuracy assessment for supervised classification of Landsat TM image base on confusion matrix.

Ecosystem	Primary Forest	Old Secondary forest	Young Secondary forest	Agroforestry	Community farm	Bare soil	Accuracy(%)
Primary Forest	120.00	8.00	0.00	0.00	0.00	0.00	93.75
Old Secondary forest	4.00	100.00	0.00	0.00	3.00	0.00	93.46
Young Secondary forest	0.00	14.00	131.00	17.00	0.00	0.00	80.86
Agroforestry	0.00	2.00	2.00	50.00	2.00	0.00	89.29
Community farm	0.00	0.00	6.00	0.00	61.00	4.00	85.92
Bare soil	1.00	2.00	0.00	0.00	1.00	19.00	82.61
Reliability(%)	96.00	79.37	94.24	74.63	91.04	82.61	

Table 2. Result of accuracy assessment of Landsat TM image classification

Average reliability(%)	Average accuracy(%)	Overall accuracy(%)	Cohen's Kappa(K)
86.32	87.65	87.93	0.85

3.5 Image classification

Supervised image classification technique was applied and this enabled the research party to produce an accurate ecosystem map for its subsequent use in GIS based application on dam site suitability assessment. The result of the classified image is shown in Figure 3. To access the accuracy of an image classification result, it is a common practice to create a confusion matrix as shown in Table 1.Table 2 shows the result of the accuracy assessment of the image classification. The confusion matrix result indicates a good overall accuracy (87.93%) and average reliability (86.32%). The highest error occurs with classification of young secondary forest (80.86%). Pixels in this class wrongly classified were instead classified as old secondary forest. The average accuracy was also high (87.69%). The higher value Kappa Coefficient (0.86) shows that the result presented in the confusion matrix are significantly better than random results.

Figure 4: The ecosystem map of Bungoh Catchment, Sarawak, Malaysia.

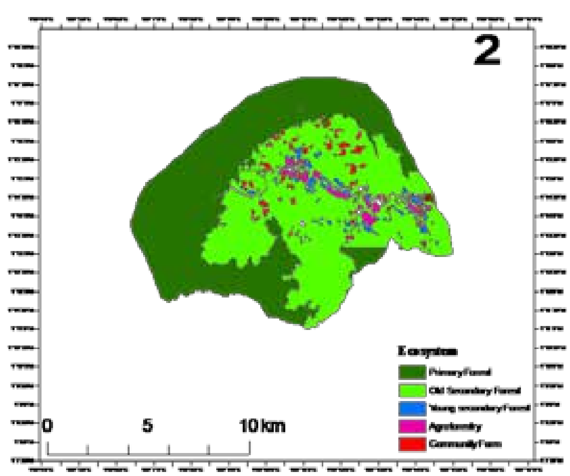

Table 3.Confusion matrix of ecosystemmap of the study area.

Ecosystem	Primary Forest	Old Secondary forest	Young Secondary forest	Agroforestry	Community farm	Accuracy (%)
Primary Forest	125.00	7.00	0.00	0.00	0.00	94.70
Old Secondary forest	10.00	105.00	5.00	3.00	2.00	84.00
Young Secondary forest	0.00	0.00	50.00	5.00	0.00	90.91
Agroforestry	0.00	5.00	0.00	40.00	2.00	85.11
Community farm	2.00	0.00	2.00	0.00	25.00	86.21
Reliability(%)	91.24	89.74	87.72	83.33	86.21	

Table 4. Result of accuracy assessment ofecosystem map of the study area.

Average reliability (%)	Average accuracy (%)	Overall accuracy (%)	Cohen's Kappa(K)
87.65	88.18	86.92	0.85

3.6 Ecosystem map classification results

The ecosystem map obtained is shown in Figure 4. An accuracy assessment was performed on the map, generating the confusion matrix shown in Table 3. The average reliability and accuracy are given 87.65 % and 88.18% respectively (Table 4). The identification of virtually all the ecosystem types had improved with respect to the result of the classification of the TM image only. The confusion between old secondary forest and young secondary forest was significantly reduced. The higher value of Kappa, 0.85 (Table4) indicates that the classification process was avoiding 85.00% of the errors that a completely random classification would generate. This justify that the results in the error matrix were better than random results.

The overall classification accuracy for the five types of ecosystem for both the TM image and ecosystem map were established as 87.93% and 86.92% respectively which are sufficient for the delineating of ecosystem types in order to be analysed.

4.0 Conclusions

Remote sensing techniques and the application of GIS can be used to develop the ecosystem map. GIS will be required to integrate spatial data from different source such Landsat TM images and to perform basic spatial operations encompasses image analysis. The classification of the Landsat images help to reveal four major types of forest ecosystem in Bungoh catchment. The four types of forest ecosystem are the primary forest, old secondary forest, young secondary forest and agroforestry. The classification results indicated that classification of Landsat images to produce ecosystem map has a high overall accuracy. The classification of the Landsat TM images was merged with the classification of the forest, generating the ecosystem map of Bungoh catchment. Therefore the ecosystem map can be used for the purpose of development projects such as the construction of dam.

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