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THE IMPACT OF LAND USE CHANGE ON MANGROVE ECOSYSTEM AND EVALUATION OF ECOSYSTEM SERVICE USING REMOTE SENSING TECHNOLOGY IN SG. MERBOK FOREST RESERVE, MALAYSIA

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Abstract: Mangrove forests are an important ecosystem which provides socioeconomic value to humankind. Despite their great value, mangroves have one of the highest rates of degradation of any global habitat, which is about 1% of the existing area per year. In fact, the socioeconomic value and ecosystem services of mangroves as a natural product are underestimated. The ecosystem services provided by mangroves are often ignored by the ongoing process of mangrove conversion. This is a major reason why conservation of this ecosystem is not a popular alternative. Thus, the main objective of this study is to evaluate the changes in mangrove forests and valuation of their ecosystem services. SPOT 5 imageries of years 2000 and 2010 have been used for change detection analysis. The vegetation index, such as NDVI and AVI and unsupervised classification technique were employed in image processing. In order to obtain the value of socioeconomic impact from the mangrove changes and biodiversity disturbances, the ecosystem service valuation (ESV) model was applied. Results show that the total value of the existing mangrove forest ecosystem service was RM1, 901,859.84. The value per unit area is about RM 1,650.92 /ha. The total values of others were RM161, 33.2 (crop land) and RM3,107,500 (water bodies), respectively. It is evident that Sungai Merbok's Mangrove Forest Reserve is very important for coastal ecology, where the orientation of mangrove ecosystem is huge and serves to provide essential services for the community. It also plays a crucial role in providing ecological balance to the coastal environment.

Keywords: Mangrove, ecosystem service valuation, changes detection, remote sensing

INTRODUCTION

Ecosystems around the globe create and preserve an environment suitable for human survival. Today, ecosystem services are increasingly faced with threats globally. This trend is partially due to a lack of valuation, because resources are not valued in the market and are hence ignored in management decisions. The world's tropical mangrove forests are disappearing at an alarming rate with the rapid growth in human population and conversion to other land uses. Mangrove ecosystems represent natural resources which are capable of producing a wide range of goods and services for coastal environments and communities. Ecosystem services provided by mangroves comprise all goods and services and modified ecosystems that benefit human well-being as well as support sustainable resource management. These include food production, provision of building materials and medicines, regulation of microclimate, disease prevention, and generation of productive soils and clean water resources as well as landscape opportunities for recreational and spiritual benefits (Daily, 1997; Costanza and Folke, 1997; MEA, 2005; Boyd and Banzhaf, 2007 and Wallace, 2007). The usefulness of mangrove forests stems from the diversity of the forests as well as diversity of goods and services they provide.

Despite this need for understanding the components of mangrove ecosystem value, it is prohibitively expensive and unrealistic to conduct a detailed empirical non-market valuation. The need for ecosystem valuation information is especially great for public good services of ecosystems that are not popular in the market (Barbier et al., 1997; Carson, 1998). In particular, it is crucial that the value of mangrove ecosystems in developing countries be assessed. According to Katherine et al. (1998), understanding the importance and best use of different parts of a forest may help in formulating management policies that enable continuous supply of essential goods and services. The Economics of Ecosystems and Biodiversity (Sukhdev, 2008), increasingly recognise the critical role of ecosystem service valuation for sustainable development.

Remote sensing data and GIS are used as tools for the following purposes: to assess biodiversity and land cover change as well as classification index at the mangrove landscape; to identify the relationship between the degree of disturbance and the nature of fragmentation processes in the study area; and to develop methodology that allows integration of land cover change processes and environmental changes into decision-making. All these are carried out together with strategies in the context of conservation biology and sustainable forest management at the landscape/within community level. Therefore, the objective of this study is to evaluate impact of mangrove changes on the socioeconomic value. This is achieved by conducting ecosystem service evaluation in Sungai Merbok's Mangrove Forest Reserve, Peninsular Malaysia.

METHODS

Study area

This study focuses on the Sungai Merbok Forest Reserve (SMFR) in the district of Sungai Petani, Kedah, Peninsular Malaysia. The location of the study area is within the following geographic coordinates: latitude of 5^0 25' N to 5^0 39' N and Longitude of 100^0 19' E to 100^0 32' E. The mangrove area covers an area of 4,037 hectares with 18 compartments. The SMFR is the most extensive and most well-managed mangrove in the state of Kedah; it has been gazetted as a permanent forest reserve since 1951. The average daily temperature varies from 22^0C to 32^0C, humidity ranges from 80–90%, and annual rainfall ranges between 200 and 250 cm. Mangrove species that dominate the area are *Rhizophora apiculata, Rhizophora mucronata, Brguiera parvifolia, Avecennia spp., Brugueria spp* and *Sonneratia spp*. (Ong et al., 1991).

Data collection and ecosystem classification

The land use data of the study area were obtained from Malaysian Remote Sensing Agency (MARS) in Kuala Lumpur. The data were extracted from high resolution 2.5 m SPOT 5 satellite images and SPOT 5 multispectral (10 m) resolutions obtained in 2000 and 2010. Land use map of the area was obtained from Department of Agriculture Malaysia and forest map was from Kedah State's Forestry Department. Based on the characteristics of prevailing land cover and actual condition of SMFR, a total of four generic ecosystems were identified, namely Mangrove Forest, Crop Land, Water Bodies and Barren Land.

Image processing

The SPOT 5 imageries were geo-rectified to 1:50,000 scale topographical map. After geo-correction, the next step was to extract information about the greenness of the study area. Multitemporal SPOT 5 imageries from the years 2000 and 2010 were analysed using vegetation index, such as Normalised Difference Vegetation Index (NDVI) =B3-B2/B3+B2) and Advanced Vegetation Index (AVI) = [(B1+1) x (256-B2) x B5)] ^ (1/3) &B5=B1-B2)]). As a result, AVI was applied to the study area, because AVI offers more detailed information about all vegetation elements. An AVI has proven to be more sensitive to forest density and hysiognomic vegetation classes in this area (Mohd Hasmadi et al., (2011). The unsupervised classification technique (Figure 1) was applied to AVI image. Unsupervised classification is based on K-mean algorithms (four classes were developed based on ecosystem classification).

Mangrove ecosystem changes estimation

In order to understand how a mangrove ecosystem changes, information is needed on what changes occur, where and when they occur as well as the rates at which they occur. Despite ongoing research efforts on ecosystem patterns, there is much room for research on development of basic land-cover datasets providing quantitative, spatial land-cover information (Xavier and Szejwach, 1998). The method applied to estimate the mangrove ecosystem changes was by conducting plot sampling on satellite image maps to detect changes in forest cover and land use during 2000 and 2010 for the study areas; field verification was also carried out to identify causes of the changes. Then, GIS analysis was used to analyse the land use change and the transition matrix between land use types for the above-mentioned period of 10 years.

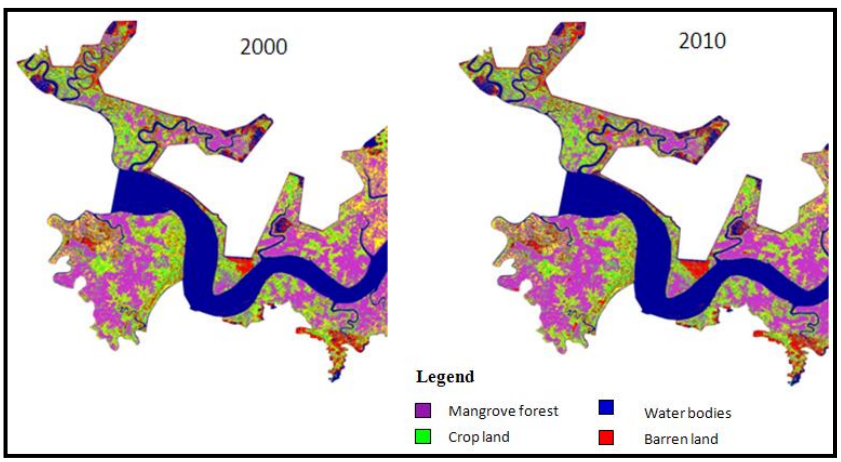

Figure 1: Image maps of ecosystem classification from unsupervised classification.

Assignment model of mangrove ecosystem service

In order to obtain ecosystem service values for each of the four land-cover categories, each category was compared with the 17 biomes identified in ecosystem service valuation model. The total value of ecosystem service represented by each land-cover category was obtained by multiplying the estimated size of each land-cover category by the coefficient value of the biome used as the proxy for that category. The principal method for assessing ecosystem service value is adopted from Costanza et al. (1997); it is shown below:

Ecosystem service value

$ESV = \sum (A_k * VC_k)$

Where, ESV is the estimated ecosystem service value, Ak the area and VCk the value coefficient (RM/ha/yr) for land use category 'k'. The change in ecosystem service value is estimated by calculating the difference between the estimated values for each land- cover category in 2000, 2010 and 2020 (predicted).

i. Ecosystem service function Value type *f (*value of services provided by individual ecosystem functions)
$ESV_f = \sum (A_k * VC_{kf})$

Where, ESVf is the estimated ecosystem service value of function, A_k = the area (ha), VC_k = the value of coefficient (RM/ha/yr), k = land-use category and VC_{kf} = the value coefficient (RM/ha/yr) for land use category *k* with ecosystem service function type *f.*

ii. Value of combined ecosystem service

$ESV_c = \sum w_f * A_k * VC_{kf}$

Where, W_f = Equivalent weight factor ecosystem services per hectare, A_k = the area (ha), and VC_{kf} = the value coefficient (RM/ha/yr) for land use category *k* with ecosystem service function type *f.*

RESULTS AND DISCUSSION

Land use changes
Land use change analysis in 2000 and 2010 were derived from digital image processing and classification on SPOT 5 imageries. Meanwhile, the values of land use change for the next 10 years (2020) have been predicted based on the area change percentages in the past 10 years; this prediction assumes that there are no major activities or development in the study area.

Based on the image analysis, ground verification and survey, the values of rate of change in land use were found to range from -2.9% to 3.5%. The most affected land use type was crop land and mangrove forest, which increased from 435 ha in 2000 to 548 ha in 2010, and decreased from 1246 ha in 2000 to 1152 ha in 2010, respectively. The other land use types also experienced changes during the 10-year period. Water bodies decreased from 1352 ha to 1243 ha, and barren land increased from 235 ha to 325 ha. By assuming that the rate of change does not vary significantly for the next 10 years, the prediction of land use in 2020 for each land use type is as follows: 661 ha for crop land, 1058 ha for forest area, 1134 ha for water bodies and 415 ha for barren land. Classified land use maps were verified by carrying out accuracy assessment exercise. The accuracy assessment for data in 2000 and 2010 recorded results of 91.55 and 91.56%, respectively. Remote sensing products offer many advantages; the most important aspect is the provision of data of actual areas on the ground. The results obtained through vegetation indexes provide an accurate land use mapping of the real situation on the ground.

Estimation of Ecosystem Service Value

The ecosystem service value (ESV) for each land use type was estimated with the ecosystem coefficient value. Ecosystem service value coefficient for different land use types are as follows: crop land is RM294.00 per/ha, forest area RM3,100.80 per/ha and water bodies RM2,500.00 per/ha. Ecosystem service value for crop land increased from RM128,064.00 in 2000 to RM161,331.20 in 2010 and is predicted to increase to RM194,598.40 in 2020. The total change in crop land ecosystem service value was about RM66,534.40 (51.9%). The value for forest area decreased from RM3,863,596.80 in 2000 to RM3,572,121.60 in 2010; its value is predicted to be RM2,049,628.80 in 2020. Meanwhile, the value for water bodies also decreased from RM3,380,000.00 in 2000 to RM3,107,500.00 in 2010; its value is predicted to be RM2,835,000.00 in 2020. The decrease in total ESV for forest area and water bodies during 2000 to 2010 was 46 and 16.1%, respectively. Barren land was not assigned any ESV since this land was unproductive; however, its actual ecological value was underestimated. The total ESV in the year 2000 was RM 7,371,660.80 and RM 6,840,952.80 in the year 2010; ESV is predicted to be RM 5,079,227.20 in 2020. On the whole, the change in ESV from 2000 to 2020 results in losses of about RM 22,292,433.60 (31%).

Ecosystem service function for different land use types

There are eight different ecosystem service function (ESF) parameters that have been assigned to the study area: gas regulation; climate regulation; water supply; soil formation and retention; water treatment; biodiversity protection; raw material; and recreation and culture. The value for each ecosystem service function for different land use type (RM/ha/year) was based on literature review and adapted to suit the Malaysian ecosystem for each ecosystem service function. The value of ecosystem service function for different land use type is presented in Table 1. Meanwhile, the change in the ecosystem service function from 2000 to 2020 for each land use type is presented in Table 2.

The value of the ecosystem service function for crop land in 2000 was RM1,476,571.62, and the value increased to RM1,786,227.92 in 2010; it is predicted to be about RM2,154,555.94 in 2020.The change in ESF is valued at RM677,984.32 (45%) for the 20-year period covering the years 2000 to 2020. For the forest area, the value of the ecosystem service function has decreased from RM12,841,824.24 in 2000 to RM11,873,018.88 in 2010; it is predicted to be about RM10,904,213.52 in 2020. This amounts to a loss of approximately RM1,937,610.72 (15%). The ESF of water bodies also decreased from RM29,316,430.00 in 2000 to RM26,952,901.25 in 2010 and is predicted at RM24,589,372.50 in 2020. On the other hand, the ESF for barren land increased from RM46,598.15 in 2000 to RM64,444.25 in 2010 and is predicted at RM82,290.35 in 2020. The total change in the ecosystem service function for all land use types decreased from RM43,681,424.01 in 2000 to RM40,676,592.30 in 2010 and is predicted to further decrease to RM37,730,432.31 in 2020. The decrease is expected to be about RM5,950,991.70 or 13% within 20 years.

Table 1: Value for each ecosystem service function for different land use types.

Ecosystem service function	Cropland/ha	Forest/ha	Water bodies/ha	Barren land/ha
Gas regulation	RM235.90	RM1,650.92	RM -	RM -
Climate regulation	RM419.80	RM1,273.57	RM216.98	RM -
Water supply	RM283.05	RM1,509.41	RM9,613.10	RM14.20
Soil formation and retention	RM688.67	RM1,839.60	RM4.72	RM9.43
Waste treatment	RM773.58	RM617.90	RM8,575.37	RM4.76
Total	**RM3,259.54**	**RM10,306.44**	**RM21,683.75**	**RM198.29**

Table 2: Change in the ecosystem service function (ESF).

Land use type	2000 (RM)	2010 (RM)	2020 (RM)	Changes from 2000–2020	
				RM	%
Crop land	1,476,571.62	1,786,227.92	2,154,555.94	677,984.32	45.9
Mangrove forest	12,841,824.24	11,873,018.88	10,904,213.52	-1,937,610.72	-15.1
Water bodies	29,316,430.00	26,952,901.25	24,589,372.50	-4,727,057.50	-16.1
Barren land	46,598.15	64,444.25	82,290.35	35,692.20	76
Total	**43,681,424.01**	**40,676,592.30**	**37,730,432.31**	**-5,950,991.70**	**-13.6**

Note: (+) ESF increased, (-) ESF decreased

Value of combined ecosystem service function

The combination of ecosystem service function in the same land use type with the equivalent weight factor is calculated based on the function for each parameter for each land use type; the top three or the higher rate of weight factor is then calculated for each land use category. The contributions of combined ecosystem service function to overall value were ranked based on their estimated ESV_f in 2000, 2010 and 2010. The combined ESV for the study area in 2000 is RM172, 849.26 for cropland, RM1, 024,492.88 for forest area, RM696, 806.33 for water bodies and RM30, 828.04 for barren land. In terms of ecosystem service function, cropland and barren land types show increasing value, while the values for forest and water bodies seem to be decreasing. Thus, the total change in the combined ESV for each land use type from 2000 to 2020 have the following values: RM89,802.14 (increased) for cropland, RM154,578.38(decreased) for forest, RM112,354.87(decreased) for water bodies and RM23,612.97(increased) for barren land.

CONCLUSIONS

There is a huge and growing interest as well as awareness and need in Malaysia for ecosystem service valuation and ecological economics studies. This study showed that satellite data are very useful and inexpensive for estimating changes in different ecosystem types and for valuing ecosystem services at the local level. In many cases, remotely sensed data may be the only economically feasible way to gather regular land cover and land use information with high spatial, spectral, and temporal resolution over large areas. Results revealed that the potential income from one hectare of mangroves over a 20-year period is expected to decrease at a rate of 15%, ranging between RM85,374.40 and RM72, 492.87 per month.

The decrease in the economic value of mangroves was largely influenced by the decrease of 2.9% of this cover types from 2000 to 2010. This study has demonstrated the role of interdisciplinary practices in addressing natural resource valuation. In particular, data sources from socioeconomic as well as geospatial data were integrated to estimate the economic value of the mangroves in the Sungai Merbok's forest reserve. It is recommended that for future studies, ESV should be applied to a large number of sites around the country in support of ESV systems, carbon trading and national accounting in collaboration with local agencies. This strategy will make ESV a widely used, trusted, and evolutionary system for ecosystem service modelling and evaluation. Integrated knowledge base and policy formulation towards ecosystem service valuation for local condition should be developed in order to obtain more meaningful coefficient values that affect land uses.

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