A REVIEW ON ISSUES OF MANGROVE WETLANDS AND METHODS OF ASSESSING CHANGES

MAHANUM DOL
PhD Candidate, Faculty of Built Environment, Universiti Teknologi Malaysia, Skudai, Johor
(e-mail: mahanumdol@yahoo.com)

ABSTRACT :

There is no doubt on the benefits provided by mangroves. However, the mangroves are under immense threat from human activities which incrementally change and damage their ecosystem. Today, the Ramsar's site of Sungai Pulai Estuary which is the largest riverine mangrove system in the state of Johor confronting the impacts of pollution, deforestation, sedimentation and habitat lost from the human activities. The impacts gradually have caused loss and degradation of mangroves quantitatively and qualitatively. Being a wetland of international importance which focuses on biodiversity conservation, Sungai Pulai Estuary has advantages on regulatory compliance, planning and protection activities whereby any planning on development has to foresee the impacts to the site. Monitoring and managing the change and damage of its ecosystem owing to human activities within a period of time are necessary for the site. From literatures many methods have been employed for the management of wetlands/forest ecosystem changes. The paper reviews the methods that can work within Geographic Information System (GIS) environment either in a form of integration or embedded. The models reviewed are the Landscape Structure Indices Model (LSI) and Vegetation Succession Models (VSM).

Key words: Mangroves, quantitative and qualitative changes, GIS, LSI, VSMod

1.0 Introduction

Mangroves are the rainforests that live between land and sea. They are marginal ecosystem and have significant functions and values to environment and society. This amongst world's most productive environment performs many functions such as shoreline stabilization and erosion control, retention of nutrients, sediments and pollutants (ITTO 2002, Ramsar Convention Secretariat 2006 p.9-10). Mangroves also provide tremendous benefits for example fisheries, timber and other building materials and agriculture (Ramsar Convention Secretariat 2006 p.10). They are also known as the habitat for flora and fauna, weather changes mitigation area as well as the human and asset protector (ISME 2000).

As a marginal ecosystem, mangroves are very sensitive to human activities (Beck, 1994; Johnson et al. 1997, Kost 1997, Tiner 1999, Syphard 2001, Hartig et al. 2002, Qin Li 2003) and easily vulnerable to sudden or drastic changes in the environment. The disappearance of a single species of mangrove may be the start of a chain reaction that leads to inability of the ecosystem to fulfill its vital role against coastal erosion threatening for instance coconut plantations (Van Campehout 1997, Van Pottebergh 1999), human settlements (Anouk Verheyden et al 2002), and aquaculture.

Mangroves are also subject to change by both natural processes and human actions (Foulis and Tiner 1992a, 1992b, 1993a, 1993b, 1993c, 1994, Tiner et al 1994, Gerla 1999, Hunt et al 199, Morison 2002, Qin Yin 2005). Many studies have observed that human actions have produced changes on mangroves. Chua, Chou & Awang (1987) Blasco et al (2001), ITTO (2002) and MAP (2007) agreed that the degradation or depletion of mangroves could be triggered by human actions such as human settlement, aquaculture & other development activities, unsustainable logging, traditional used of mangrove resources and pollution. Blasco et al (2001) also learn that alterations of freshwater inflows by various upstream activities in catchments areas could threaten the mangrove extension. This extension is also decreasing because of the conversion of the area to other uses such as urbanization and tourism development (ITTO 2002).

Another impact brought by Kaas et al (2004) is the effects of land reclamation on hydrology whereby the activity has increased changes in water levels, inundation and drainage, salinity and sedimentation processes. These forces of changes have resulted the loss and degradation of mangrove ecosystems quantitatively and qualitatively. The quantitative changes are the actual increases and decreases in the amount of wetlands within a period of time (Qin Li 2003). Meanwhile, the qualitative changes involve changes in vegetation and/or hydrology of wetlands (Qin Li 2003) which may alter the wetland functions and affect the wetlands values.

2.0 Mangrove Wetlands Issues at Sungai Pulai Estuary

Sungai Pulai Estuary which has been gazetted as Ramsar Sites on 31 January 2003 is the largest riverine mangrove system in Johor. It also represents the best example of tropical lowland river basin consisting of inland freshwater riverine forest, intertidal mudflats, and sea grass beds. The estuary supports rich biodiversity and is home to the rare and endemic species of flora and fauna. The site fringes function as shoreline stabilization and severe flood prevention to the adjacent 38 villages. Furthermore the local population depends on the natural resources of the estuary for their livelihood.

In general, mangroves are naturally resilient; however, they have still been classified by many governments and industries alike as wastelands or useless swamps (MAP, 2007). Thus, these mangroves are exploited for unsustainable developments causing mangrove losses and degradation. The discussion on mangroves issues at Sungai Pulai Estuary shall focus on two major issues that are (1) mangrove loss and degradation and (2) wetlands of international importance or Ramsar Sites.

2.1 Mangroves Loss and Degradation

Human action is one of the forces that causing both gains and losses in mangroves acreage as well as changes in the functional values of mangroves areas. In general, the overall effect at Sungai Pulai Estuary has been loss and degradation of mangroves. Overview of loss and degradation is discussed in terms of quantitative and qualitative changes of the mangrove areas.

2.1.1 Quantitative Changes

As reported by Ramakrishna (2001), the mangroves area at Sungai Pulai Estuary in 1960 was about 9,150 hectares (Ramakrishna et al 2001). Currently, the area of the reserve is 9,126 hectares which 7,636 hectares of mangrove forest and 1,490 hectares of water body (including Sungai Pulai and its tributaries) (Ramakrhisna et al 2001, Kaas et al 2004). These quantitative changes of mangrove forests are the result of excision activities to make way to agriculture, pond culture (Ramakrishna et al 2001), port, coal-fired power plant, power transmission line and petrochemical and maritime industries.

i) Port of Tanjung Pelepas (PTP)

Study by Kaas et al (2004) on the ecological assessment of Tuas extension view and Pulau Tekong reclamation has shown that in 2000 the mangrove area of Sungai Pulai Estuary has disappeared 6.7 percent (6.4 square kilometers). The loss is mainly associated with development of Port of Tanjung Pelepas (PTP) whereby 210 hectares of mangrove was cleared for PTP Phase I. Between 2000 and 2004, there has also been direct mangrove clearance at north of PTP (Kaas et al 2004). However, the degraded mangrove between Tanjung Piai (part of the Ramsar Sites) and Sungai Pendas has decreased from 12.3 square kilometers (in 2000) to 7.5 square kilometers (in 2004). Serious erosion at Ramsar site of Tanjung Piai occurs due to the nearness of ship route to PTP with the river mouth of Sungai Pulai as well as the dredging activities (Bernama 2007). As a result, Tanjung Piai is facing depletion of mangrove forests and areas.

ii) Coal-Fired Power Plant (CFPP) and Petrochemical and Maritime Industries (PMI) at Tanjung Bin

The CFPP was developed on mangrove area of Tanjung Bin. Though the area is not within the Ramsar site, the development continues to bring impacts to mangrove within the catchments. As recorded by Kaas et al (2004), dredging activities took place in 2003 involving the volume of 2,300,000 cubic meter of soft to firm clay soil which then filled with 6,300,000 cubic meter of dredged sand from Teluk Ramunia. The reclamation is to improve the soil quality for the CFPP development but not to the mangroves and its ecosystem.

Under the Pontian District Plan 2002 to 2015 page 32, Tanjung Bin is designated as the industrial center for development of petrochemical and maritime industry (MNRE 2007). The development which will house heavy industries producing plastic, paints, pesticides and chemical products, shall clear out 913 hectares of mangrove areas. The development will include dredging the waterfront area along Sungai Pulai and reclamation of 15 hectares of land under water along Sungai Pulai and branches of rivers. Part of the development will seize 91 square kilometers of Ramsar site (R.Sittamparam 2007). From the construction to the operation and maintenance stages (see Comprehensive Environmental Impact Assessment for detail), the development is not only removing 913 hectares of mangrove forests but also shall claim more than that. The pre-construction stage activities have already destroyed the mangrove forests to make way to the development area.

iii) Aquaculture

Chan (1989) and Ramakhrisna (2001) reported that the seafront mangrove was cleared out and the buffer was reduced from 300 meter to 50 meter in width owing to a marine shrimp farm at Tanjung Bin. Obviously the clearance has caused depletion of mangrove forests quantitatively.

iv) Illegal Harvesting and Power Transmission Line

An illegal harvesting of mangroves involving 526 hectares (Ramakhrisna et al 2001) and development and maintenance of Power Transmission Lines are also contributed to the loss of mangroves forests and their biodiversity.

2.1.2 Qualitative Changes

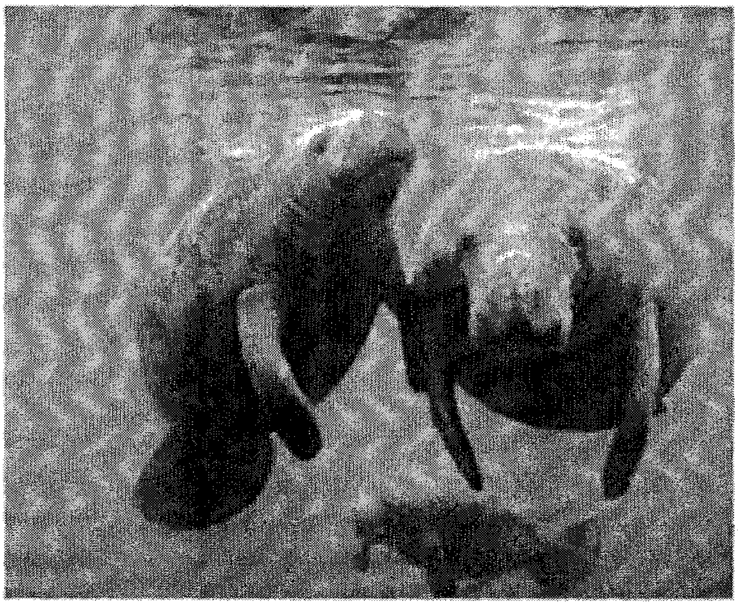
Mangroves ecosystem is sensitive to human actions. The disappearance of single species may affect the overall food chains and the health of ecosystem. Thus, the loss of mangrove areas at Sungai Pulai Estuary have affected the function values as nutrients retention and habitat for aquatic species such fishes, prawns etc. The impacts continue to affect the threatened and endangered aquatic species as well as the people who depending on aquatic resources for their livelihood.

i) Sedimentation

It is recorded that the development of CFPP and PTP have resulted in heavy silting (Kaas et al 2004) which led to heavy growth of seaweed (Ulva reticulata). These seaweed blocked sunlight filtering down to the sea grass beds, reducing the amount of food that was available to fish, prawns, dugong (NST 2007) and seahorse. This indirect impact disturbs the food chains in the ecosystem. This can be seen from the total of inshore fish landings on West Johor whereby the amounts are decreasing from 7,324 metric tones in 1993 to 2,998 metric tones in 2002 (Kaas et al 2004).

ii) Habitat Loss

Seahorse and dugong are example of species indicator to a healthy ecosystem. Perbadanan Taman Negara Johor (2001) has identified the Sungai Pulai Estuary as dugong and seahorse spot areas. Declining of seahorse population at Sungai Pulai Estuary owing to habitat loss and degradation is one of the indirect impacts of mangrove loss and degradation. The clearing of mangrove forest to make way for development, agriculture, aquaculture and logging has created pollutants that endanger the life of sea grasses which are the habitat of spotted sea horse, dugong and other aquatic species. Despite the fact that the habitat is beyond the periphery of Ramsar site and the developments, the threats have created changes to the population of aquatic species.



Dugong or Sea cow found off the Sungai Pulai Estuary
Source: Kaas et al (2004)

According to Comprehensive Environmental Impacts Assessment Report (NRE 2005), the pre-land clearing for the PMI development will clog canals and pollute the water leading to reduce oxygenation. This situation affects the locals fishing spots and traditional fishing ground (NST 2007). Moreover, the permanent destruction of mangrove forests at the area will disturb the protected (in Malaysia), vulnerable and near threaten (IUCN Red List) species as well as will reduce the nesting and hunting place of birds (MNER, 2007).

Meanwhile the PTP development threatens to change the dynamics of the river's hydrology and alter the riverine ecosystem, thus removing the intrinsic values that earned it a place on the Ramsar list (Chiew 2003).

In addition, the illegal and sustainable harvesting are not only destroying the mangrove areas but also fragmenting the vegetation composition and configuration which influence the flora and fauna existence.

2.2 Wetlands of International Importance

Sungai Pulai Estuary, Tanjung Piai and Pulau Kukup have been gazetted as as Ramsar Sites on 31 January 2003 with the aim of conserving the biodiversity of the wetlands. The treaty made between Malaysian government with Ramsar Convention on Sungai Pulai, Tanjung Piai and Pulau Kukup is a good effort and news to the conservation of mangrove areas in Malaysia. It is an advantage to the conservation effort with the allocation of international policies and guidelines on wetlands. For instance in Resolution VII.20, the Conference of Contracting Parties (COP) urges Contracting Parties to compile comprehensive wetlands inventories according to the Framework for Wetlands Inventory developed by the Scientific and Technical Review Panel (STRP). It is also suggested that remote sensing and low-cost and user-friendly geographic information systems to be used for the wetlands inventory and data management (Ramsar Secretariat 2006, p.51). Thereby the collection and management of wetlands data are improved from hardcopy format and perhaps out-dated data to updated digital data. Furthermore, the contents of digital wetlands data can be publicized to educate public and authorities on the important of wetlands to livelihood and environment in a more convincing manner.

Other than inventory the COP is required to monitor the ecological character in any wetlands over a period of time. The monitoring methods include:

i. Simple field observations,
ii. Remote sensing,
iii. Quantitative sampling techniques such as the gathering of wetlands plant material, and
iv. Participatory observation where changes in social values and uses are concerned (Ramsar Secretariat 2006, p. 51-52).

Monitoring the ecological character of wetlands over period of time by field observation, remote sensing, quantitative sampling techniques and participatory observation is important. This is to identify the status and trends of changes whether the changes threaten the mangroves ecosystem, succession process etc. Therefore, the Contracting Parties have to make sure that the job of monitoring take place effectively.

Ramsar Covention is also come up with the Integrated Framework for wetland inventory, monitoring, and assessment which adopted in Resolution IX.1 Annex E. This integrated framework is prepared to make sure that the delivery of conservation and wise use of wetlands in line with the commitments embodied in the Ramsar Covention (Ramsar Secretariat 2006, p. 52).

Having gazetted Ramsar Sites within or close proximity to a proposed development has required the Contracting Parties to take all necessary measures prior to development approval. This matter arises at the Iskandar Development Region (IDR) whereby the development has to come up with strategies to fulfill the Ramsar Covention Guidelines. This including ensuring the natural forest reserve, mangrove, animal sanctuary and water catchments areas are protected and gazetted (Khazanah Nasional 2006). Moreover the Ramsar Sites should be protected and control measures enforcement is required at the areas around the PTP and Tanjung Bin power plant. In addition, a 500 meters protection zone all around the Ramsar Sites is also imposed to all land use activities. To reinforce further, the aquaculture activities in Sungai Pulai are to be limited and controlled.

As Ramsar Sites, Sungai Pulai Estuary has advantage of being the focal of international importance with many guidelines and framework for protection and mitigation. The threats of losing the mangroves, at least within the Ramsar Sites, are insignificant as compared to degradation. This degradation of mangroves and ecosystem emerge due to the impacts of human actions from the surroundings of Ramsar Sites.

3.0 An Overview of Methods

The overview of methods will briefly look at models that can be integrated with Geographic Information System (GIS). The basis of taking GIS because of it is a tool to provide and manage information (Samat 2005). GIS is defined as a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information Esri (2007). It can also be thought of as spatial database (Lang 1998).

Generally, GIS is associated with maps. This tool is capable to solve problem in analysis, assessment, management and decision makings. However, GIS analytical capabilities have been criticized as being limited to manipulation digital map (Carver 1991, Samat 2002, Samat 2005). To enhance its analytical capabilities, this technology needs to be coupled with spatial models (Samat 2005). The models can be from a theory, a law, an equation, a hypothesis or even a structured idea.

The selected models are from the research undertaken by Cheng and Jan (2000) and DeAngelis et al (2001). They are the landscape structure indices, and vegetation succession model. These models are applied in the study of changes in landscape owing to human actions which resulting impacts to the environment. The overview will look at three components of model that are objective, description, and reliability.

3.1 Landscape Structure Indices (LSI)

3.1.1 Objective

The LSI have been developed to measure three aspects of landscape structure that are the composition of the landscape, the configuration of the landscape, and the shapes of patches in the landscapes (CGIS ____).

3.1.2 Description

Landscape structures are always distinguished by landscape composition and landscape configuration. Composition refers to the number and occurrence of different types of landscape elements, while configuration encompasses the physical distribution or spatial character within a landscape (McGarigal et al 1994, Eiden et al _____). Landscape composition can be characterized using landscape diversity, patch richness and landscape evenness. Landscape diversity is often represented by three indices which include Shannon diversity index (SHDI), Simpson diversity index (SIDI), and modified Simpson index (MSIDI) (Cheng and Jan 2000). Meanwhile the landscape configuration always uses Interspersion and Juxtaposition Index (IJI).

Nevertheless, only SHDI and IJI are discussed because of its suitability and widely applied in landscape changes analysis study.

Shannon Diversity Index (SHDI)

SHDI quantifies the diversity of the landscape based on two components that are the number of different patch types (patch richness) and the proportional area distribution among patch types (landscape evenness).

$$SHDI = -\sum_{i=1}^{m}(Pi * \ln Pi)$$

where,

m = number of patches types;

Pi = proportion of area covered by patch type (land cover class) i

SHDI increases as the number of different patch type's increases and/or the proportional distribution of the area among patch types becomes more equitable ((Eiden et al______).

Interspersion and Juxtaposition Index (IJI)
IJI is used in landscape configuration in order to illustrate the distribution characteristics of the landscape patches. It is the only measurement which explicitly takes the spatial configuration of patch types into account (Eiden et al______). IJI also considers the neighborhood relations between patches where each patch is analyzed for adjacency with all other patch types and measures the extent to which patch types are interspersed (Eiden et al______). Similar strategy as SHDI calculation, except the IJI has to add denominator representing the standardized for the number of classes.

$$IJI = \frac{-\sum_{i=1}^{m}\sum_{k=i+1}^{m}[(E_{ik})*\ln(E_{ik})]}{\ln\left(\frac{m(m-1)}{2}\right)}$$

where,

m = number of classes,
E_{ik} = length of edge between class i and class k.

3.1.3 Reliability
The LSI has been used widely in various studies. Examples are the determination of diversity patterns in bird species (Elliot 1969), the quantification of habitat fragmentation (CGIS ____), the analysis of landscape structure changes (Cheng and Jan 2000), and the assessment of urban ecological networks (Cook 2002).

3.2 Vegetation Succession Model (VSMod)

The VSMod is one out of three vegetation models integrated in the program of Across Trophic Level Simulation System which is developed by South Florida/Caribbean Ecosystem Research Group 1994. The other two models are the Seasonal Vegetation Dynamic Model and the Disturbance Model.

3.2.1 Objective
The model is to predict how species distributions, including the rare and exotic species, are likely to change in response to natural and human-caused environmental change. It is also to determine how the overall patterns of biodiversity will respond to water manipulation and other management activities.

3.2.2 Description
The model is developed by Duke-Sylvester to simulate the pattern of spatial and temporal changes in the distribution of vegetation in the Greater Everglades landscape. The VSMod addresses the changes in the abundance of particular plant species in response to changing environmental conditions or as a result of successional change under relatively constant conditions (DeAngelis et al 1997). It projects the spatial distribution of vegetation on a yearly basis (Sylvester 2005).

The spatial domain addressed in VSMod is mostly natural areas. The model is not based on specific vegetation types or classification but it will be based on the natural types present in the map used. The model incorporates the effects of hydrology, fires, nutrients as well as information of vegetation types respond to these factors to create projections of succession.

According to Sylvester (2005), the VSMod is a stochastic cellular automata (SCA) model. It incorporates a spatially explicit, stochastic cellular automata model to simulate vegetation succession.

3.2.3 Reliability

Relatively, the model is useful for specific management applications where interspecific interactions are important for endangered species or exotic species (DeAngelis et al 1997). The model is integrated in the ATLSS program for the restoration of South Florida Everglades.

4.0 Discussion

As have been discussed in the issues, the unsustainable developments by human actions are really threatened the environment. The Ramsar Sites management at Sungai Pulai Estuary and Tanjung Piai has to deal with the changes occurred at catchments in order to conserve the biodiversity of the area. The unsupportive EIA result to the major coastal developments within the mangrove areas is a challenge to the Ramsar management. Showing the qualitative and quantitative changes of biotic and abiotic factors in the Ramsar Sites and the buffer zones is vital. Therefore, the appropriate methods/models need to be engaged the management to ensure the healthiness of mangrove ecosystem of the sites and surroundings.

The models discussed are not sufficient to be judged as the appropriate model. However, those two models could be tested for their appropriateness for the study of changes at mangrove estuary of Sungai Pulai.

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