WETLAND VEGETATION CHANGES AT A LANDSCAPE SCALE IN BEAUFORT AREA, SABAH USING REMOTE SENSING AND GIS TECHNIQUES

THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE

SCHOOL OF INTERNATIONAL TROPICAL FORESTRY
UNIVERSITI MALAYSIA SABAH
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DECLARATION

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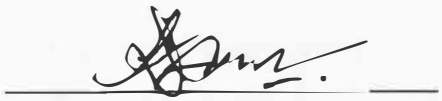

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ABSTRACT

WETLAND VEGETATION CHANGES AT A LANDSCAPE SCALE IN BEAUFORT AREA, SABAH USING REMOTE SENSING AND GIS TECHNIQUES

Wetland is a part of natural ecosystem that provides many intangible services to human. However, many of these wetlands have been destroyed and converted to other land uses. Beaufort, Sabah, consists of an extensive wetland ecosystem. This wetland ecosystem lays pieces of pristine peat swamp forest (PSF) that has been degraded due to human activities. This study aims at examining the dynamics of wetland vegetation changes in relation to anthropogenic activities in Beaufort area. Multitemporal satellite data of Landsat MSS (June 29, 1985), Landsat TM (June 14, 1991), Landsat 7 ETM+ (November 2, 1999), Landsat 7 ETM+ (Jan 14, 2003) and SPOT4-HRVIR (March 26, 2003) were used in this study. A supervised classification approach was performed to classify satellite images into ten land cover types. The overall accuracies for all classifications are more than 89%. The result from the land cover classification shows a significant changes to PSF, bareland and grassland cover type throughout the 18-year period. The PSF had drastically plummeted by about 70% from 1985 to 2003. The grassland had almost doubled from 1985 to 2003 and bareland also increased more than 100%. These changes were mainly due to fires occurred in 1998 and 2003 during El-Niño event. The El-Niño fires did not affect the mangrove. The dynamics change pattern analysis showed that the PSF area has severely degraded, leading to deforestation. The main dynamic pattern indicate that the PSF areas have changed to grassland and bareland from 1985 to 2003. Fragmentation analysis based on mean patch size and largest patch index provide the evidence that the PSF has undergone an increase of fragmentation between 1985 to March 2003. The mean nearest neighbour distance value has increased indicating that the patches of PSF have low connectivity and become more isolated. Buffering and overlay analysis showed that agriculture was the main factor contributing to deforestation in Beaufort area. Questionnaire survey discovered that El-Niño fires in 1998 and 2003 was due to land clearing for plantation using slash and burn. In short, the PSF in Beaufort area has been decreasing at an alarming rate due to uncontrolled human activities. Therefore, the authorities such as Sabah Forestry Department are suggested to take action in controlling and managing the human activities for agriculture near the PSF especially during dry season.

ABSTRAK

Hutan tanah Lembap merupakan ekosistem semulajadi yang memberi banyak kebaikan yang tak ketara kepada manusia. Bagaimanapun, kebanyakkan hutan tanah lembap ini telah dimusnahkan dan ditukar kepada guna tanah lain. Beaufort, Sabah, mempunyai ekosistem tanah lembab yang luas. Di dalam tanah lembap ini terletaknya hutan paya gambut (HPG) asli yang mengalami degradasi akibat aktiviti manusia. Kajian ini bertujuan untuk mengenalpasti dinamik perubahan vegetasi dan hubungkaitnya dengan aktiviti antropogenik di kawasan Beaufort. Data satelit multitemporal Landsat MSS (29 Jun 1985), Landsat TM (14 Jun 1991), Landsat 7 ETM+ (2 November 1999), Landsat 7 ETM+ (14 Januari 2003) and SPOT4-HRVIR (26 Mac 2003) digunakan dalam kajian ini. Dengan pendekatan pengkelasan terselia, imej satelit ini dikelaskan kepada ten jenis kelas. Keseluruhan analisis ketepatan bagi setiap pengkelasan memberi nilai lebih daripada 89%. Keputusan daripada pengkelasan litupan tanah menunjukkan perubahan signifikan untuk jenis penkelasan litup HPG, rumput dan kawasan lapang dalam tempoh 18 tahun. HPG berkurang sebanyak 70% dari tahun 1985 hingga 2003. Rumput meningkat hampir dua kali ganda dari 1985 hingga 2003 dan kawasan lapang meningkat lebih 100%. Punca utama perubahan ini adalah disebabkan berlakunya kebakaran pada tahun 1998 dan 2003 pada musim El-Niño. Kebakaran El-Niño tersebut tidak mempengaruhi hutan payah bakau. Corak perubahan dinamik HPG menunjukkan hutan ini mengalami degradasi yang serius sehingga berlakunya penyahutanan. Corak utama dinamik perubahan menunjukkan perubahan HPG kepada rumput dan kawasan lapang dari tahun 1985 hingga 2003. Analysis fragmentasi bagi kelas HPG dihitung menggunakan nilai 'mean patch size' dan 'largest patch index' menunjukkan fragmentasi di kawasan ini semakin meningkat dari tahun 1985 hingga 2003. Peningkatan 'mean nearest neighbour distance' menunjukkan 'patches' HPG mempunyai perhubungan yang rendah dan semakin terasing. Analisis penampan dan overlay menunjukkan bahawa faktor utama berlakunya penyahutanan di kawasan Beaufort ialah disebabkan faktor pertanian. Soalselidik menunjukkan bahawa amalan buka tanah menggunakan tebang dan bakar menyebabkan berlakunya kebakaran semasa musim El-Niño pada 1998 dan 2003. Kesimpulannya, HPG di Beaufort semakin berkurang di tahap yang kritikal akibat aktiviti manusia yang tidak terancang. Oleh yang demikian, pihak berkuasa seperti Jabatan Perhutanan Sabah dicadangkan untuk mengambil tindakan mengawal dan memantau aktiviti manusia berhampiran kawasan HPG untuk pertanian terutamanya pada musim kering.

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PSF	Peat Swamp Forest
BFR	Binsuluk Forest Reserve
KFR	Klias Forest Reserve
FR	Forest Reserve
HPG	Hutan Paya Gambut
UNDP/GEF	United Nations Development Program/ Global Environment Facility
ADO	Assistant District Officer
PKR	People Development Leader
JUPEM	Department of Survey and Mapping Malaysia
ENSO	El-Niño – Southern Oscillation
SPSS	Statistical Package for Social Sciences
GIS	Geographic Information System
UTM	Universal Transverse Mercator
RMS	Root Mean Square
RGB	Red, Green, Blue
LANDSAT TM	Landsat Thematic Mapper
LANDSAT ETM+	Landsat Enhanced Thematic Mapper Plus
LANDSAT MSS	Landsat Multispectral Scanner
SPOT4-HRVIR	Satellite Pour l'Observation de la Terre Four - High Resolution Visible and Infrared
NIR	Near-Infra Red
MIR	Mid-Infra Red
.img	File Format for ERDAS Imagine
FCD	Forest Canopy Density

DOS	Dark Object Substration
DN	Digital Number
dNBR	Normalized Burn Ration differencing
FRAGSTAT	Spatial Pattern Analysis Program for Categorical Maps
BP	Before Present
USD	United State Dollar
pH	Measure of the acidity or basicity of a solution
Km	Kilometers
Km^2	Square Kilometers
mm	Millimeters
m	Meters
ha	Hectares
O^o	Degree
>	More than
<	Less than

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CHAPTER 1

INTRODUCTION

1.1 Background

Wetland is a very important natural ecosystem that provides many intangible services to human. It provides the important landscape to natural ecosystems and values for human environment especially socio-economic sustainable development (Liu *et al.*, 2004). However, there are only a few remaining wetland landscapes on the face of the earth that has not been altered by human influence. The world wetland covers 6% of the earth (Safford and Maltby, 1998) and now over 50% of that total have probably been degraded or lost (Millennium Ecosystem Assessment, 2005). Mankind's existence on the earth affects the ecosystem causing changes to the natural environment of the wetland ecosystem. The pressure on land use increases, especially in developing nations, where the population increases faster. Competing demands on land use for urbanization, agriculture, forestry and recreation changes this wetland into a complex landscape. Rate of degradation also increases every year resulting from all types of land use (Ozturk *et al.*, 2002).

The global concern about anthropogenic alteration on wetland in the form of fragmentation caused by over exploitation of natural resources will also increase the potential of natural disaster such as forest fire. It was recorded that in the early 90's, the total wetland of a peat swamp forest (PSF) in Malaysia was 2.7 million hectares (ha) (Wong, 1991) compared to recent data which shows that the area had decreased to 1.5 million ha (UNDP/GEF, 2006). This proves that almost half of the pristine wetland had been destroyed within a decade. The reduction of PSF in Southeast Asia is mostly by fire (Stuebing *et al.*, 2006). The question is why fire frequently occurs in this particular area? Although fire is regarded as an ecological factor, intended fires either for land clearing, hunting activities or human habits such as indiscriminately throwing cigarette butts can be destructive due to lack of conservation awareness (Pianzin, 2004).

Remote sensing and Geographic Information System (GIS) are the most widely used tools for identifying environmental causes and changes in wetland ecosystem. This is due to the difficulty of monitoring the inner part of the wetland where it is sometimes impossible to access. Therefore, remote sensing is one of the most cost effective tools for monitoring land cover change (Wang *et al.*, 2004; Wenting *et al.*, 2004; Wilson and Sader, 2002) especially when it concerns a large area. It provides spatial information for wetland change monitoring. Change detection is one of the important uses of remote sensing that identifies differences in the state of an object by observing it at different times or periods (Singh, 1989). Change detection of wetland provides a better understanding between human and natural phenomenon to manage the resources. It can involve multitemporal datasets to quantify the changes of a wetland in time series. As for GIS, it is an important tool in the management of natural resources. GIS in combination with remote sensing has been increasingly used in all aspects of wildland fire management (Setiawan, 2004). GIS can be instrumental for identifying the factors that are causing changes in an area.

Change can be a quantitatively characterized as landscape patterns which link the change to ecological process in the landscape. According to Frohn (1998), landscape metrics are necessary for use by researchers to detect the pattern of change that is not readily visible to the human eye or easily detectable by human analysis. Landscape metrics are employed to generate quantitative measures of spatial patterns found on remote sensing images. Assessing the landscape structure using satellite remote sensing has also become the essence in landscape fragmentation studies (Kepner *et al.*, 2000).

Therefore, the combination of remote sensing products and GIS tools is very important to provide the understanding of the current changes caused by human alteration to generate scenarios for the future modification of the wetland and the surrounding area. As verified by Kaishaigili *et al.* (2006), a scientific community needs quantitative and spatially explicit data on how the land cover has been changed for future prediction. Without proper control of land use practices, deforestation leading to further fragmentation will destroy the remnants of wetland.

1.2 Problem Statement

During the past decade, forest fire occurring in the wetland areas has increased at an alarming pace. Fire is recognized as one of the major threats to the remaining wetland. This catastrophe is becoming more of a concern by the fact that certain areas have been burned constantly. As a result, it is causing a great number of losses to the economy of the affected country. Economists estimated that the damages to the economy due to smoke alone in 1997 was more than 1.4 billion USD (Siegert and Hoffman, 2000). Imagine how much it will cost for the loss of a pristine forest?

The wetland in Beaufort area is also facing the same problem. Forest fire had repetitively occurred in certain part of the wetland and adjacent area. It was reported to occur in 1983, 1998 and again in 2003 during the El-Niño event destroying 85% of Binsuluk Forest Reserve (BFR) (UNDP/GEF, 2006). The Klias Forest Reserve (KFR) remains in a relatively good condition but is under threat. Only a few studies have been conducted on peat fire especially in the tropics (Lailan and Ahmad Ainuddin, 2004). Hence, the integrated study on peat fire is important in resource management and biodiversity conservation. Efforts to compile data pertaining the burned areas using medium resolution satellite data should also be conducted over the past El-Niño event (Phua, 2007). Resource managers need remote sensing data to make decisions about landscape patch size as a necessity for land use planning. The ability to identify landscape structure especially fragmentation is prerequisite to determine landscape function and change (McGarigal and Marks, 1995). The need in discovering the changes in landscape pattern are to identify how degraded the forest area is.

There are many factors that can cause the ignition of fire. Anthropogenic activities especially the ongoing conversion for agricultural purposes is becoming a major threat to this area (Phua *et al.*, 2007). It contributes to the increase of fragmentation to the forest area. Habitat fragmentation, the unique transport of flammable plants and ubiquitous overlay of human impacts on fire regimes demand a new level of understanding for the peaceful coexistence with the fire occurrences (Bond and Keeley, 2005). The changes are not only caused by various natural

impacts but is also caused by human impacts where both forces induce complex processes with very great effects on the environment (Kalis *et al.*, 2002). Recent evidence proved that the major contributor of forest fragmentation in Malaysia is agricultural activities especially the cultivation of oil palm and rubber (Abdullah *et al.*, 2006). Many studies had shown that repeated fire is caused by the nearby human activities. Most of it is due to the traditional land clearance for agriculture using slash and burn technique. This is the easiest and cost-effective way to clear a land especially a large area. However, fire is a major threat of vegetation extinction and fragmentation in tropical wetland (IFFN, 2001). If fragmentation increases, it will initiate an extreme degraded forest. Therefore, it is important to study the extent of fragmentation and what causes it to happen

It is also a necessity to see the human dimension that is causing the landscape alteration of the wetland in Beaufort area. According to the information obtained from Beaufort District Office, Mohd Shaid (2008), the increment of total population in the area is 3.5% each year with the total population in year 2000 was 64,756 people. There are 127 villages in Beaufort and half of them are located near the wetland area. It also stated that 70% of the economic production is dependent on agricultural sector. Therefore, it is important to identify the factor from agricultural practices to social activities that maybe causing the fire to constantly happen in the areas near the wetland of Beaufort area. In view of the above, observing the changes of vegetation in detail and spatially can describe the interaction between human activities and environment and thus highlight the driving forces of vegetation changes (Petit *et al.*, 2001). Ecosystem management needs a better understanding of how the human disturbances influence ecosystem dynamics and how focal ecosystem interacts with adjacent areas (Liu *et al.*, 1999). The impact of massive vegetation changes on biodiversity is profound and has been of concern in the environment ecosystem. The immediate effect of changes of vegetation can be significant and it is important to be understood to create a better management system for the effected area.

In Beaufort area there is lack of empirical proof and studies yet to be done to assess the nature and causes of wetland vegetation change. The level of fragmentation in this area had also never been quantified in multitemporal period. The cause of forest fire during the prolonged drought by the El-Niño in 1998 and 2003 in Beaufort are still not clear. It predicted that the causes of this event were due to human interference on the wetland area. For instance land use activities such as forest clearance, cooking, use of fire in hunting activities and social practices such as slash and burn agriculture, careless throwing of cigarettes butts and match sticks, open burning of forest clearance and domestic waste, and even deliberately burning the forest (Painzin, 2004). It is therefore necessary for a study such as this to be carried out in the wetland of Beaufort area to prevent more destruction of the pristine wetlands.

1.3 Objectives

The main objective of this study is to examine the dynamics of wetland vegetation changes in relation to anthropogenic activities in Beaufort area, Sabah. Specifically, this study intends to;

a) Quantify the wetland vegetation changes using supervised classification of multitemporal satellite data

b) Examine the dynamics of peat swamp forest in a land cover change context

c) Examine the multitemporal fragmentation pattern of PSF based on landscape pattern indices

d) Identify the anthropogenic factors influencing PSF vegetation changes using GIS and socio-economic survey techniques

1.4 Scope of Study

In this study five sets of remotely sensed data were used to analyze the wetland vegetation change of the study area. The temporal vegetation change only takes into account of the changes from year 1985-1991, 1991-1999, 1999-January 2003

and January 2003- March 2003. The land cover classification includes ten types of classes which comprise PSF, mangrove, shrubland, grassland, bareland, oil palm plantation, rubber tree plantation, water, cloud and shadow. Even though there are various time of fire occurrences in Beaufort area it was not possible to find image satellite of the earliest dates covering the whole study area. In this case, this study will only focus on two episodes of fire occurrences during the El-Niño event, the 1998 and 2003 fire. Due to shortage of time, the GIS data for buffering and overlaying analysis with the change area will only include three type of factor; agricultural, road and settlement. The socio-economic survey also includes only ten villages with three different distances due to time shortage and village accessibility. The socio-economic data analyzed is mainly based on the livelihood of the respondents, especially the agricultural aspects.