ASSESSMENT OF MANGROVE FOREST MANAGEMENT EFFECTIVENESS:

A CASE STUDY IN SALEH BAY, SUMBAWA, INDONESIA

DODDY M. YUWONO
September, 2011

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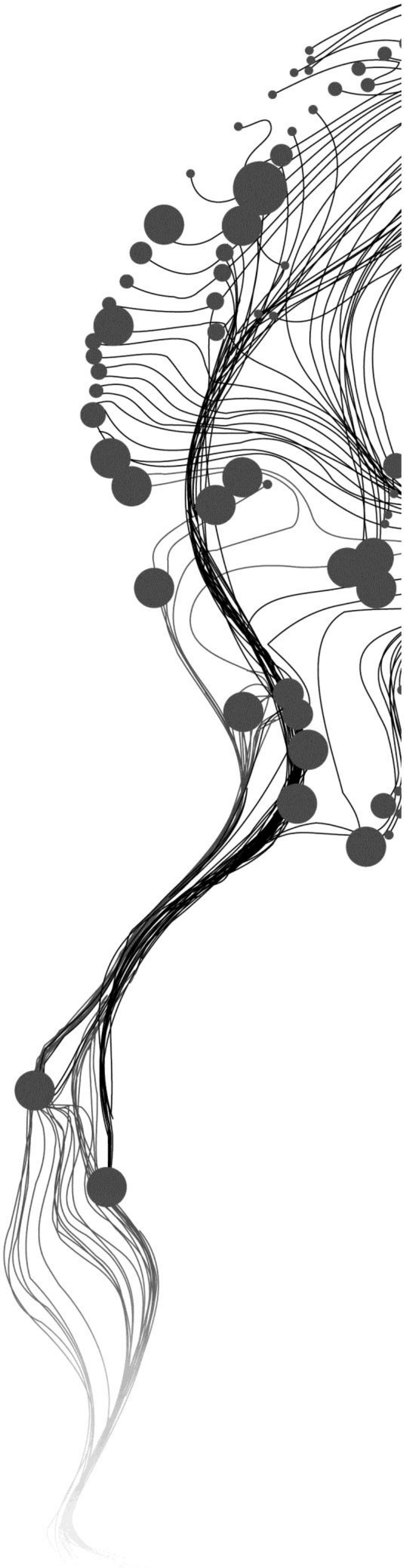

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Enschede, The Netherlands, September, 2011

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Natural Resources Management

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ABSTRACT

Mangrove forests are one of the most important ecosystems. The existence of mangrove forests is declining in the last decades. Moreover, threats on mangrove forests are mainly occurred in the developing country, including Indonesia. Saleh Bay, with its potential coastal resources, is chosen as a case study area since the issue of mangrove forests conversion and contradicting authority between national and provincial level. The enactment of Geospatial Information Law and the cost-effective technique of remote sensing combined with GIS tools contribute to the policy making and implementation regarding to spatial object, especially natural resources management.

The method used in this research is digital image classification and change detection using Landsat image data and spatial analysis (overlay and buffer analysis). Maximum likelihood used as the algorithm in supervised image classification. The classification accuracy derived from the process is 0.7068 with kappa statistic 0f 0.769. The assessment result shows that mangrove forests management more effective under the national level compared to provincial level.

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Doddy M. Yuwono
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1. INTRODUCTION

1.1. Background

Using world's population data 2003, Martinez et al. (2007) mentioned that nearly a half of the world's population or almost 2,385 million people are living along the coastline. In addition, approximately two thirds of the world's inhabitants occupy no further than 100 km from the coast within areas that are located a maximum of ten metres above sea level, the so-called Low Elevation Coastal Zone (LECZ). LECZ is a physiographic boundary defined as land area adjacent to the coastline up to a 10-meter elevation, which is assumed that foreseeable future sea-level rise is not expected to reach approximately 10 metres above the current mid-tide elevation (McGranahan et al., 2007). Historically, coastal zones attract people for local, regional, and global economic development which consequently create more urbanized types of ecosystem (UN-HABITAT, 2008). Moreover, increasing population and developments are the main drives to coastal ecosystem change.

People cultivate coastal land for agriculture and aquaculture, create settlement and infrastructure, and use it for tourism, (FAO, 2007). However, development is not always giving benefits for human and environment. In many cases, particularly in developing countries, the developments not only improve economic growth, but also give impacts to the environment, such as: mangrove forest degradation and deforestation.

Mangrove, seagrass, and coral reef are crucial coastal habitats for several coral fish species, particularly as a nursery grounds. Mangrove forests provide suitable physical condition for several economically beneficial land use activities, as mentioned above. However, beside reducing the mangrove coverage itself, disturbances could also cause degradation of adjacent ecosystems, such as seagrass and coral reef (Mumby & Hastings, 2008). Thus, "mangrove forest continuity and interdependence to riverine, estuarine, and marine environment is a biological reality for coastal fish resources" (Baran & Hambrey, 1999).

1.1.1. Factors threatening mangrove forests

Globally, mangrove forests decline at an average annual rate of 2.1 percent (Valiela et al., 2001; Wells et al., 2006; as in (UNEP, 2006)). The fastest annual change takes place in Asia with a decline of 1.01% from 2000 through 2005 and 0.56% from 2005 through 2010 (FAO, 2010) (see Figure 1.1). Nowadays, world's mangrove forests remain only 80% compared to 1980. Even much worse condition was expressed by Zhengyun et al.(2003) that world's mangrove forest area remains less than 50% and the degradation still continues. Moreover, Zhengyun et al. (2003) divided the mangrove forest degradation and deforestation factors into two main categories.

Factors causing mangrove forest degradation and destruction as pointed out by Zhengyun et al. (2003) consist of natural factors:: 1) sea level rise, and 2) fresh water supply; and human induced factors. Commonly, human induced factors to mangrove forests include reclamation of urban expansion, shrimp farming, mining activities, waste disposal and pollution from industries, and timber extraction. Furthermore, they conclude that the destruction is mainly caused by human intervention in mangrove forest conversion into shrimp pond farming (also indicated by FAO (2007)). Aquaculture development, including shrimp pond farming, occupies a large part of mangrove forests and causes habitat modification in the mostly developing countries over the world

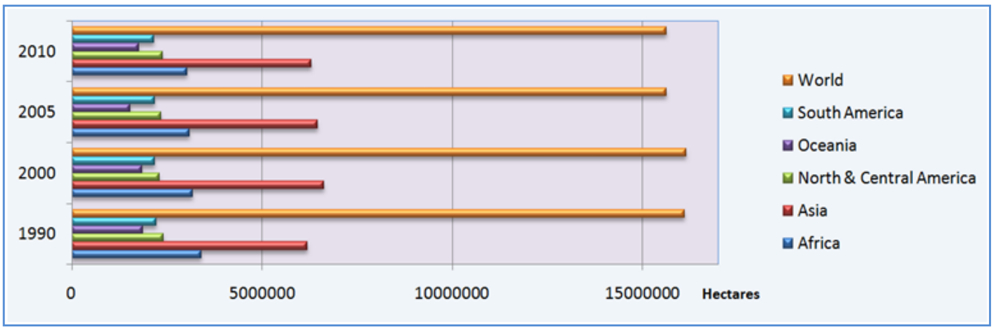


Figure 1.1 Mangrove forest trend in the world from 1990 to 2010 (FAO, 2010)

However, aquaculture is one of the important fisheries production sectors. It contributes up to 36.9 per cent of total global fish production in 2008. The global aquaculture production increases each year at annual average 8.3 per cent from 1970 through 2008. Moreover, the most increasing production is mainly occurred in Asia, especially in the developing countries (FAO, 2010). In among producer countries, the aquaculture production could increase their national and local income. Thus, aquaculture production not only significantly improves their capture fisheries production for consumption but also supports their economic growth.

Indonesia is one of the five countries with the largest net loss of mangrove between 2000 and 2010 (FAO, 2010). Indonesia's mangrove forests declines at average annual rate of 1.6% (FAO, 2007). Most of the decline is caused by urban expansion and aquaculture development, and timber extraction for building construction, charcoal, and firewood (Alikodra, 2002; Armitage, 2002). In aquaculture production, Indonesia is ranked as fourth largest in the world's aquaculture producers. Moreover, as seen in Table 1.1, the aquaculture production grows at average annual rate of 7% in the last decade (FAO, 2010). In timber extraction, Indonesia had significant charcoal production in 1998 coming from Aceh, Kalimantan Barat, and Riau Provinces. While, mangrove forests extraction for firewood is used for domestic uses which is mainly occurred in rural areas (Inoue, 1999).

Table 1.1 Aquaculture producers by quantity in 2008 (FAO, 2010)

	Production			Average annual rate of growth		
	1990	2000	2008	1990–2000	2000–2008	1990–2008
	(Thousand tonnes)			(Percentage)		
China	6 482	21 522	32 736	12.7	5.4	9.4
India	1 017	1 943	3 479	6.7	7.6	7.1
Viet Nam	160	499	2 462	12.0	22.1	16.4
Indonesia	500	789	1 690	4.7	10.0	7.0
Thailand	292	738	1 374	9.7	8.1	9.0

1.1.2. Mangrove forest management in Indonesia

Mangrove forest management in Indonesia has experienced many changes since before the independence. Previous work by Kusmana (1995) described the history of mangrove forest management in Indonesia. At first, in 1938, mangrove forest management was practiced in Segara Anakan, Cilacap, Jawa Tengah. Mangrove deforestation awareness appeared since the government in that era regulating the mangrove tree cutting, particularly in the most threatened mangrove forests, Segara Anakan. Various cutting methods and regulations were applied until 1978. They regulated the cutting periods and the number of remained primary trees. Therefore, the mangrove deforestation still cannot be avoided without exact boundary for both mangrove forest production and protection.

Then in 1978, mangrove forest management was changed and emphasized on the protected area (green belt) boundary. The boundary was defined based on the coastline and river. After more than ten years applied, the regulation had been changed by Ministry of Forestry in 1990. Finally, it was revised by the issue of the President Decree 32/1990 about Protected Area Management. The protected mangrove forests criterion is stated in the article no. 27. Until recently, this is the current regulation related to the criterion of protected mangrove forests in Indonesia. This regulation is further supported and strengthened by the Forestry Law 41/1999 (article no. 50), Spatial Planning Law 26/2007 (in the description chapter article no. 5), Coastal and Small Islands Management Law 27/2007 (article no. 31), and Government Regulation 26/2008 about National Spatial Plan (article no. 57) (see Figure 1.2).

In addition, the Government Regulation 44/2004 about Forestry Planning contains the specific guidance for forest inventory, forest area establishment, and forest management and planning. It regulates the forest area functions establishment including conservation forest, protected forest, and production forest (article no. 24). Furthermore, it explains that the forest area establishment is conducted by Forestry Minister according to the area proposed by Governor or Mayor based on the provincial or district spatial plan and forest area functions criteria (article no. 16 and 17).

1.1.3. Spatial planning in Nusa Tenggara Barat Province

An important social and economic change in 1998 has influenced to the legal and political conditions in Indonesia. One of the essential legal products is the Autonomy Law 22/1999. Based on this law, regional government got its full authority to manage their region (article no. 7). In 2004, this regulation was replaced by the Autonomy Law 32/2004. Regional government has broad authority consists of 16 development concerns including spatial planning, natural resources exploitation, and environmental control (article no. 13). In addition, this law further explains about the regional government authority on natural resources management in article no. 17 and 18. Moreover, the bigger authority has also giving broader opportunity for the regional government in producing the legal aspects which is possibly conflicting with the pre-existing central regulations (Patlis, 2005), especially in protected areas.

After experiencing a long history, Indonesia has its own spatial planning law in 1992 (Spatial Planning Law 24/1992). In addition, for the guidance of national spatial plan implementation, the Government of Indonesia issued the Government Regulation 47/1997 (National Spatial Plan). Afterwards, the Spatial Planning Law 24/1992 was finally revised with the Spatial Planning Law 26/2007 in 2007, while the Government Regulation 47/1997 was replaced by the Government Regulation 26/2008 in 2008. Until recently, the latest law is used as a general guidance or legal basis for regulating, managing, monitoring the spatial planning implementation.

In 2006, based on the related spatial planning regulations (Law 24/1992 and Government Regulation 47/1997), related forestry regulations (Forestry Law 41/1999 and Government Regulation 44/2004), and also the Autonomy Law 32/2004, Nusa Tenggara Barat Provincial Government issued the Provincial Regulation 11/2006 about Provincial Spatial Plan 2006. In this regulation, mangrove forests within Saleh Bay, Sumbawa have a specific status as a protected and tourism area. Nevertheless, the protected mangrove forests extent is different compared to the article no. 27 in the President Decree 32/1990.

As the establishment of the Forestry Minister Decree 598/2009 (the Designation of the Forest and Water Conservation Area in Nusa Tenggara Barat Province) in 2009, most of the mangrove forests status was changed into a production forest, while only in small areas still remains as a protected forest. This status was depicted on the Nusa Tenggara Barat Provincial Spatial Plan Map 2009 as well. It is issued based on the Nusa Tenggara Barat Provincial Regulation 03/2010 as a revision of the previous regulation (Provincial Regulation 11/2006) (see Figure 1.2).

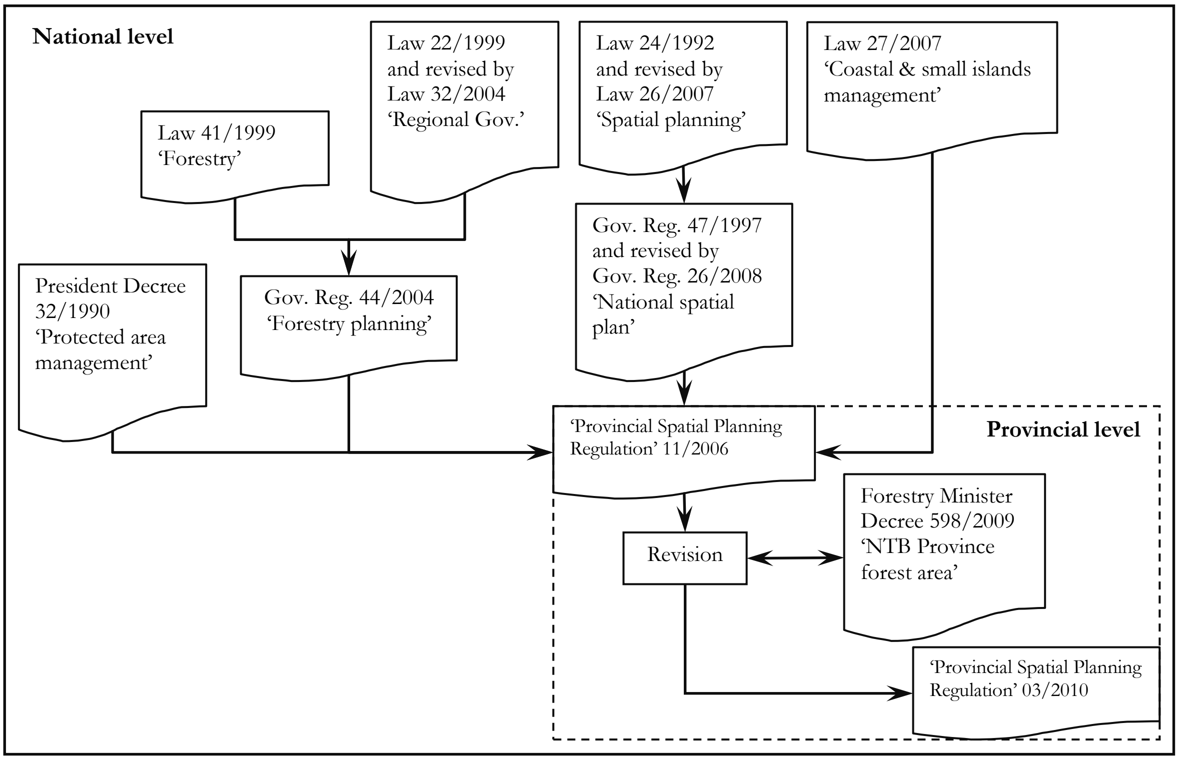


Figure 1.2 National and province level regulations related to forestry and spatial planning

1.1.4. Land tenure in Saleh Bay coastal area, Sumbawa

In general, spatial planning problem in Indonesia is related to land use management. There are three main problems according to Isa (2008): regional disparity, agriculture land conversion, inconsistent of land use management with the regional spatial planning. Furthermore, only of 68.31% land use management corresponds with regional spatial planning in Indonesia. In Nusa Tenggara Barat and Maluku Provinces, there is only of 46% land use management which is consistent to the regional spatial planning.

Land use management effectiveness particularly in the coastal protected or conservation area in Indonesia is basically related to its tenure (Adger & Luttrell, 2000). In relation to mangrove forests, the management effectiveness is depended on the tenure where the mangrove forests are located. However, many of coastal land area in Indonesia still have unclear tenure status. Particular coastal land in Indonesia is traditionally owned by individual or indigenous people. In 1982, the coastal land tenure status had been regulated based on the Forest Land Use by Consensus (TGHK/*Tata Guna Hutan Kesepakatan*) regulation and further synchronized with the regional spatial planning (Dephut, 2007). Furthermore, based on Government Regulation 16/2004 about Land Use Management article no. 3, the land tenure and land utilisation should be synchronized with the regional spatial planning.

In Basic Agrarian Law 5/1960, there are three main land categories depend on its tenure: government land (*tanah negara),* customary land tenure, and right on land (Sumarjono, 2001). Furthermore, the right on land is divided into more than seven categories (article no. 16). In Saleh Bay, there are two categories of right on land: right of ownership land (*tanah hak milik*) and right to cultivate land (*tanah hak guna usaha*). The Government of Indonesia could only manage a particular land for conservation or protected area if only the land is belonging to the government.

1.2. Research Problem

The mangrove forests in Saleh Bay have important functions both as protected and cultivated area. Protected area means that mangrove forest could preserve and protect the biodiversity and its ecosystem functions and services. However, mangrove forest in the study area also gives benefits from its land for pond cultivation and timber production (Pramudji, 2001). Even though the protected mangrove forest area designation has been indicated by the central government, which is stated in regulations and laws, the pressures on mangrove forests cannot be avoided. In addition, different regional perspective and authority on mangrove forests causes inconsistent management in the study area.

The mangrove forests conversion into ponds and other land covers are affected by the different authorities and interests between central and local government in Saleh Bay coastal area. In the beginning, based on the President Decree 32/1990 (Protected Area Management) mangrove area is categorized as protected area. This central regulation even mentions that the extent of protected mangrove forests is defined by the buffer areas which are taken into account from the coastline and river. Autonomy era causes significant political change which triggers to the economic-oriented development in regional level (Armitage, 2002). Furthermore, the establishment of the Nusa Tenggara Barat provincial spatial planning regulation 2006 indicates the different location and extent of protected mangrove forests compared to the existing central regulation. In addition, there is an inconsistent land utilisation with the regional spatial planning which is determined by the land tenure status. The three distinct land tenure statuses in Saleh Bay coastal area determine the land use/land cover management, especially in the mangrove forests.

The conflicting management policies and different land tenure statuses in Saleh Bay coastal area would give an effect to the mangrove forests condition. The absence of accurate spatial information for local/regional government in assessing the mangrove forest management exacerbates the conflicting authorities and interest between national and provincial level. In brief, it is not well understood that the mangrove forest management will be effectively implemented under different interest between the two government levels.

1.3. Research Objectives

The objective of this research is to assess and compare the mangrove forest management effectiveness of national and provincial level policy and management plan within Saleh Bay coastal area, Sumbawa, Nusa Tenggara Barat, Indonesia.

Specific Objective

1. Map the mangrove forests area in 1989, 2000, 2006, and 2009.
2. Map the mangrove forests conversion from 1989 to 2000, from 2000 to 2006 and from 2006 to 2009.
3. Prepare maps based on available national and provincial management policy and spatial planning document.
4. Assess the mangrove forest management effectiveness at national and provincial level.

1.4. Research Questions

1. What is the extent of the mangrove forests in 1989, 2000, 2006, and 2009?
2. How much mangrove forest changed between 1989-2000, 2000-2006, and 2006-2009?
3. How to map the existing mangrove forests management policy, spatial planning document, and land tenure status?
4. How effective is the national level policy?
5. How effective is the provincial level policy?
6. How effective is the provincial level policy compared to national level policy?
7. How effective is mangrove forest management on each land tenure status?

1.5. Conceptual Framework

Conceptual framework of this research explains the three key issues on the mangrove forest in study area. The first key issue is national authority which determines the mangrove forests as a protected area. The second key issue is provincial (regional) authority which determines the different protected mangrove forests area. Third, the threat and land tenure status on mangrove forests which determines the coverage changes (see Figure 1.3).

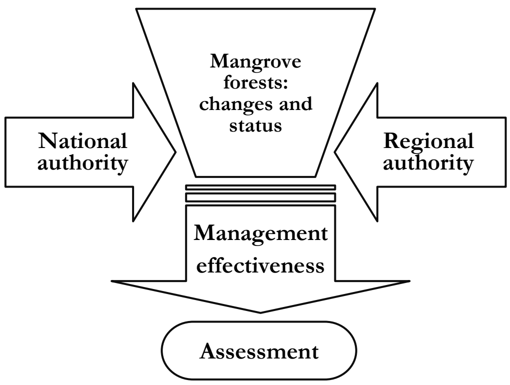


Figure 1.3 Conceptual framework of the study

By using multi-temporal images, the assessment of mangrove forests management effectiveness is done. The multi-temporal images are used for investigating the mangrove forests change within certain time period which is relevant with the management policies coming from both national and regional authorities.

2. CONCEPT AND DEFINITION

2.1. Mangrove forest area

Mangrove forest area is defined as an area on which mangroves trees or shrubs grow in tropical and subtropical tidelands, which are frequently inundated with salt water, such as estuaries and marine shorelines (Wetlands International). Meanwhile, Soerianegara (1987) define mangrove forest as trees which grow in coastal alluvial mud-plain and estuaries, and are influenced by tidal range (Noor et al., 1999). Another definition is postulated by Snedaker (1978) in Kusmana (1995); mangrove forest is trees grow in tropical and subtropical coastline associated with salt water condition and coastal landform with an-aerobe soil reaction.

Based on above various definitions, in general, the mangrove forests physical characteristics are: located in tidal area; growing along the coastline on mud, clay, sandy, or peat soil or on coral; has single crown stratum; and has typical zoning formation. Moreover, mangrove forest grows under brackish water condition which is supplied from groundwater, river, or spring for freshwater and sea for saline water (Noor, et al., 1999). Thus, mangrove forest has specific spatial distribution which is associated to those land and water characteristics.

Mangrove forest has physical, ecological and economic benefit. Physically, mangrove forest could prevent the coastal from abrasion, protect other ecosystems, trap the sediment load, and control sea water intrusion. Ecologically, mangrove forest is a place for feeding, spawning, and nursery ground for several fish species, and also as a habitat of several bird species. Economically, mangrove definitely could be extract for its timber; non-timber such as: honey, food, and medicine; and utilized for its land which potential for agriculture and aquaculture, infrastructure, industry, and recreation (Kitamura et al., 1997).

In brief, mangrove forest area is a typical coastal land cover class consist of tideland trees which give benefits physically, ecologically and economically. Moreover, the benefits of mangrove forest area strongly related to human activity. It means human could shift the mangrove forest area function to fulfil their needs.

2.2. Management effectiveness assessment

The term "management effectiveness" is commonly used in conservation or protected area management. Management effectiveness refers to how good are the existence and implementation of protected area to preserve its value and reach its objectives (Hockings et al., 2006). Additionally, Hockings et al. (2000) in the World Commission on Protected Area Guideline mentioned that there are three main elements in implementing the management effectiveness:

- design issues relating to both individual sites and to protected area systems;
- appropriateness of management systems and processes; and
- delivery of protected area objectives.

Furthermore, he explains that the design issues are referring to the protected area itself which takes into account: size and shape of the protected areas; and the existence and management of buffer zones and links between protected areas. Then, the appropriateness of the management system and process is an observation step of management implementation and its reaction to challenges. Last but not least, the protected area must achieve its objectives which comprise of both biological elements (such as the protected area extent existing or declining) and social aspects (such as supporting local people needs and tourism) (Hockings, et al., 2000).

According to Hockings et al. (2000), the word "assessment" means "the measurement or estimation of an aspect of management". Assessment is a term used to appraise the management performance compare to its objectives. Furthermore, in another definition, assessment means a "continuing process of collecting, analyzing, and reflecting on evidence to make informed and consistent measurement for management improvement" (adapted from Angelo & Cross, 1993).

2.3. Spatial planning, protected mangrove forest regulations, and land tenure status

Spatial planning is a process of planning, utilisation or implementation, and managing the space on which human and other living things interact, within their environment and among regions (Spatial Planning Law 26/2007). Based on the law, spatial planning in Indonesia is divided into three main administrative levels: national spatial plan, provincial spatial plan, and district or city spatial plan (article no. 5). The spatial planning is hierarchically implemented from national, provincial, and down to district or city level. Furthermore, based on its function, spatial planning is divided into 2 (two) main area categories: protected and cultivated. Spatial planning is implemented within 20 years, which is evaluated and revised once every 5 years.

There is a different planning unit for each spatial planning level. For national spatial planning level, the smallest planning unit is district or city (local activity centre) (Government Regulation 26/2008 article no. 1). For provincial spatial planning level, the smallest planning unit is sub-district (local service centre), while for district or city spatial planning, the smallest planning unit is village.

From its general functions, spatial planning area categories can be explained into two common definitions. First, protected area is both natural and artificial resources area which is defined by the government base on its environmental function and protection (Spatial Planning Law 26/2007 article 1 paragraph 21). The area which is considered as protected area according to President Decree 32/1990 (Protected Area Management), Government Regulation 26/2008 (National Spatial Plan), and Spatial Planning Law 26/2007 includes river and coastline buffer area, mangrove in coastal area, protected forest area, peat land area, national park and sanctuary. The main objective of protected area is to prevent the ecosystem and natural resources area from environmental damage. According to Nusa Tenggara Barat Provincial Regulation 11/2006 about Provincial Spatial Plan 2006, area categorised as protected includes forests and mangrove for protected and tourism area.

The criterion for determining protected area is different for each category (see Figure 2.1). The criterion for the river buffer is as far as 100 meter landward from the river bank. Afterwards, the criterion for the coastline buffer is determined by the area within at least 100 meter from highest tide. Meanwhile, the criterion for the protected mangrove forest is a landward area derived from multiplication of a constant value (130) with the local tidal range (President Decree 32/1990 and Government Regulation 26/2008).

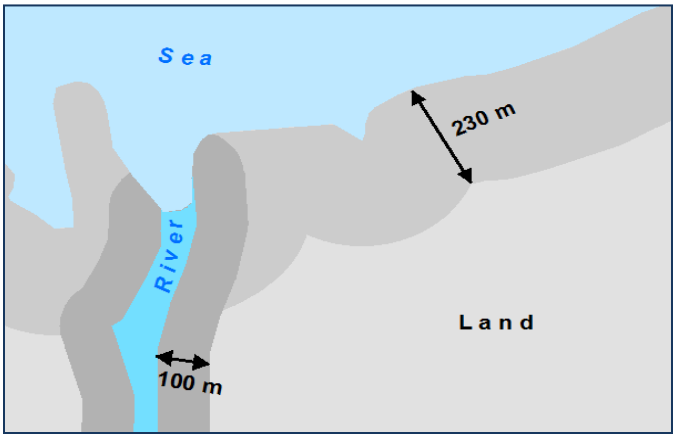


Figure 2.1 Coastal (230 m) and river (100 m) buffers defined according to the regulations

Second, cultivated area is a development area function defined by government based on its and natural, human, and artificial resources potential and condition (Spatial Planning Law 26/2007 article 1 paragraph 22). Categories included in cultivated area based on the law are production and community forest, agricultural, fishery, industry, mining, settlement, recreation, worship, education, and security and defence area uses. Moreover, production forest utilisations according to Forestry Law 41/1999 are: land area utilisation, environmental services, timber and non-timber extraction, and revenue from timber and non-timber extraction.

Land tenure status in Saleh Bay coastal area divided into three categories: right of ownership land, right to cultivate land, and government land. Based on Basic Agrarian Law 5/1960 article no. 20, right of ownership land (*tanah hak milik*) is a right on land that belongs to or owned by individual or person, right to cultivate land (*tanah hak guna usaha*) is rights on land for cultivation or other uses by person or group of persons who rent from the land owner. The third, government land (*tanah negara*), is rights on land owned by government. In relation to the mangrove forests management and protection authority, government should manage and prevent the area belongs to them and/or the area designed as protection area.

2.4. Geospatial information for mangrove forest management

In 2011, Government of Indonesia has issued its first geo-spatial information law, namely Geospatial Information Law 4/2011. Based on this law, geospatial information is useful in policy formulation, decision making, and/or development concerning to the space. Geospatial information is a data describing the geographic location, size, shape, and characteristic of both natural and artificial objects, which can be extracted, processed, and presented in relation with the time dimension (Geospatial Information Law 4/2011 article no. 1; Folger & Service, 2010). As one of important natural resources and ecosystem, mangrove forests have to be mapped and monitored using accurate and cost effective technique in order to give quick information to the government in accordance to develop and implement the policy (Walters et al., 2008).

The combination of remote sensing and geospatial technologies is a useful tool concerning to the geospatial data gathering, manipulating, and displaying. Researchers using this combination for extracting, analysing, and monitoring the mangrove forests distribution and extent (Walters, et al., 2008). Furthermore, the combination of remote sensing and geospatial technologies, such as Geographic Information System (GIS) and spatial analysis, giving varied benefits in coastal studies: covers the large areas, cost effectively collect spatial data, provides time series data, relates to varied analysis level of studies, and provides robust framework for monitoring, analysis, and assessment of coastal ecosystems (Yang, 2009).

The use of remote sensing technology for mangrove forests management was widely demonstrated by researchers. Knudby et al. (2010) used Landsat free archive data to monitor coastal environment change by comparing the use of visual interpretation and supervised classification. In the end, the research conclude that change detection analysis using supervised classification is a superior and effective technique even though it is technically more complicated compared to visual interpretation. Geospatial data processing using GIS is also commonly used to observe and analyse the distribution and extent of the spatial objects. GIS tools, such as overlay and proximity analysis, used to detect and observe spatial change within certain boundaries. Mas (2005) demonstrated the use of buffer analysis to assess the protected area effectiveness in Mexico.

In conclusion, geospatial information derived from remote sensing and GIS analysis tools is useful in providing effective procedure of mapping, monitoring, manipulating, and presenting the spatial objects on earth. In relation to the protected mangrove forests management, information about spatial location and extent becomes important in order to assess its effectiveness compared to its objective preserving the area.

3. MATERIALS AND METHOD

3.1. Study Area

3.1.1. Location

Saleh Bay is located in Sumbawa Regency, Nusa Tenggara Barat (NTB) Province, Indonesia. Geographically, it is located between 08° 24' 17.40" and 08° 39' 22.58" South longitude, and between 117° 26' 43.25" and 118° 05' 48.71" East longitude. Administratively, Saleh Bay is located between two districts in Sumbawa Island: Sumbawa on the West side and Dompu on the East side. Essential components of coastal habitat such as: mangroves, seagrass, and coral reef are found in this area. In addition, it has potential marine culture activities, such as: seaweed and pearl cultivation.

Saleh Bay is located at the east side of Sumbawa Besar Municipality. It can be reached from Sumbawa Besar Municipality using land or sea transportation (see Figure 3.1). There are several small sea harbours in Saleh Bay that can be reached by car taking approximately 20 minutes up to 3 hours from the city. From Sumbawa Besar main harbour, Labuhan Badas, Saleh Bay is only about 2 hours travel using motor boat. Sumbawa Besar Municipality itself is accessible from Jakarta approximately in 3 hours by flight with a transit at Mataram (Capital City of Nusa Tenggara Barat Province) and continue using daily flight to Sumbawa Besar in about 25 minutes.

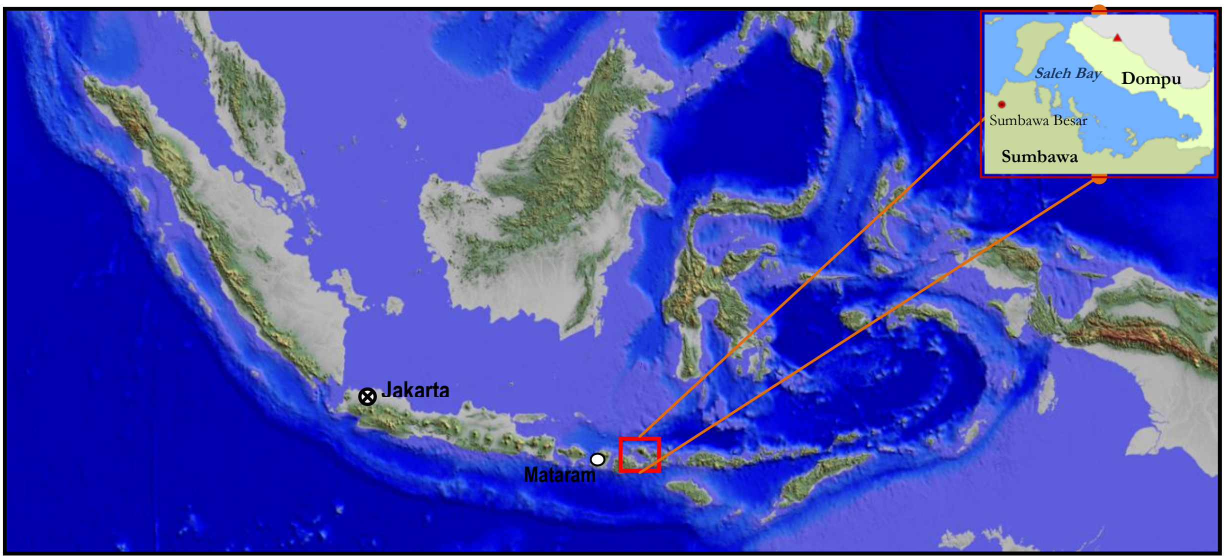


Figure 3.1 Map showing study area location

3.1.2. Topography

Saleh Bay covers 1,495 sq Km area with 282 Km coastline long. It is surrounded by a mountainous area on the West side with the highest altitude is 325 m above mean sea level and Tambora Volcano on the East side with altitude of 4,300 m above mean sea level. The slope within this area varies from 2 to 15 %.

Land forms in Sumbawa especially on the West side of Saleh Bay are mainly dominated by alluvial land consisting of accumulated sediment from the river system. In the East side of Saleh Bay, which belongs to

Dompu District, the land form is dominated by volcanic land with steeper slopes controlled by Tambora Volcano. In brief, the coastal characteristics between the West and East side of Saleh Bay are different.

Saleh Bay is an almost enclosed bay which is protected by the existence of Moyo Island on the North. For fresh water supply, Saleh Bay is influenced by several rivers, such as: Sumbawa, Beh, Sekongkang, Rea, Moyo, Lamang, Jiram, Batubulan, and Banggo. Thus, through those rivers, suspended material flows from upper land area are more intensively occurred especially in the rainy season.

3.1.3. Climate and sea condition

Saleh Bay has the same climate characteristic as other Indonesian places, dry and rainy or wet seasons. Based on Schmidt and Ferguson climate classification, Saleh Bay is dominated by class C and D, which means the climate is categorized as a moderate wet climate (BPS, 2009). Rain intensity derived from observations in 2008 shows that most of dry months occur from May through September. In addition, the rainfall intensity peak is in February. Moreover, February has the highest amount of rainy days, 19, while in August no rain occurred (see Figure 3.2).

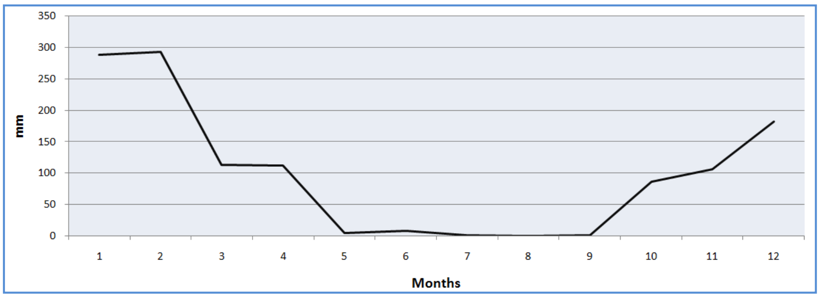


Figure 3.2 Monthly rain intensity in Saleh Bay, 2008 (BPS, 2009)

Sea bottom slope on the West side of Saleh Bay varies from 1.5% to 16%. In addition, tidal range in Saleh Bay is influenced by tidal condition from Java Sea. As seen in Table 3.1, based on the observation conducted by Hydro-oceanographic Office (Dishidros) in 1997, tidal range in Sumbawa is 1.77 meter which is calculated from Mean High Water Spring (MHWS) subtracted by Mean Low Water Neap (MLWS) (Bakosurtanal, 2009).

Table 3.1 Tide condition in Saleh Bay, Sumbawa (Bakosurtanal, 2009)

Tide		Height (cm)
High tide water spring	MHWS	166
High tide water neap	MHWN	150
Mean sea level	MSL	90
Low tide water neap	MLWN	30
Low tide water spring	MLWS	-11

3.1.4. Mangrove forest condition

The land tenure status within mangrove forest in Sumbawa is divided into three main ownerships. The first one is mangrove forest located on government land (state forest). Second, mangrove forest occurs on private land or right of ownership land (non-state forest). In addition, certain part of government land can be rented to other parties for cultivation (right to cultivate land). The condition of the mangrove forest in Saleh Bay is dominated by bad or damage condition. Furthermore, according to BPDAS Dodokan-Moyosari (2006) all of the mangrove forest is located on non-state forest area (see Table 3.2).

Table 3.2 Mangrove condition per sub-district in Sumbawa District year 2006

Sub-districts	Ha	%	Condition
Empang	478.6	45.4	bad/damage
	575.2	54.6	bad/damage
	1053.9	100.0	
Moyo Hilir	734.5	97.6	bad/damage
	18.3	2.4	good
	752.8	100.0	
Lapelopok	546.5	89.8	bad/damage
	62.0	10.2	bad/damage
	608.5	100.0	
Plampang	109.4	5.3	bad/damage
	1942.2	94.7	bad/damage
	2051.6	100.0	

3.1.5. Social and economic condition

Statistical data shows that the total population in Sumbawa District is 413.869 persons in 2008. Most of the population is distributed within the coastal area. Annual population growth in Sumbawa District from 1971 through 1980 is 2.38% and from 1990 through 2000 is 2.26%. In addition, annual population growth in each coastal sub-district can be seen in Table 3.3. In relation to land use/land cover in Sumbawa, people activities in the coastal sub-district in Sumbawa are still dominated by farming and fisheries.

Table 3.3 Coastal sub-district population based on population census (BPS, 2009)

Coastal Sub-district	Decadal Population					
	1971	1980	Growth	1990	2000	Growth
Empang	19,856	24,254	2.22%	27,876	32,544	1.40%
Lapelopok	14,350	19,202	3.25%	23,577	29,238	2.07%
Moyohilir	16,580	19,422	3.96%	24,304	27,039	2.27%
Plampang	11,508	16,387	1.75%	25,493	39,766	4.52%

There are several types of fishery cultivation in Sumbawa, such as brackish water ponds, traditional fishing, seaweed cultivation, and pearl cultivation. Seaweed cultivation and brackish water ponds are the main types of marine cultivation and aquaculture in Sumbawa. Seaweed becomes the first commodity for regional income followed by brackish water ponds. Sumbawa is one of the largest shrimp producers in Indonesia. The production increases significantly from 2005 to 2008 (as seen in Table 3.4).

Table 3.4 Shrimp commodity in Sumbawa from 2005 – 2008 (Dislutkan Sumbawa, 2008)

Commodity	Production (ton)				
	2005	2006	2007	2008	Increase
Shrimp	4,067.48	5,812.70	12,565.70	16,324.30	8.3%

3.2. Materials

3.2.1. Images and Maps

Images and maps are included in process and analysis of the effectiveness of mangrove forest management (see Table 3.5). Landsat images are primary data which are used for deriving land cover classification. ASTERGDEM is employed for defining the spatial extent based on area within 10 heights above mean sea level (Low Elevation Coastal Zone).

Table 3.5 Images data, spatial resolution, cloud cover, path/row, and source used in this research

No	Images	Acquisition date (dd-mm-yyyy)	Spatial res. (meter)	Cloud cover	Path/row (location)	Source
1	Landsat TM5	05-07-1989	30	< 10%	115/066	http://glovis.usgs.gov
2	Landsat ETM+	13-09-2000	30	< 10%	115/066	http://glovis.usgs.gov
3	Landsat TM5	22-09-2006	30	< 10%	115/066	http://glovis.usgs.gov
4	Landsat TM5	16-10-2009	30	< 10%	115/066	http://glovis.usgs.gov
5	ASTER GDEM	29-10-2008	30	0	S09 - S08, E117 - E118	www.gdem.aster.ersdac.or.jp

The reason behind image acquisition date selection, first, is related to the management issues in mangrove forest area. Second, the cloud coverage of each image should below 10% to minimize of losing important land cover information. Table 3.6 shows the specific consideration of choosing image on specific acquisition date.

Table 3.6 Images, acquisition date, cloud cover, and relation to policy regulations and laws

No	Images	Acquisition date (dd-mm-yyyy)	Policy regulations and laws
1	Landsat TM5	05-07-1989	before the enactment of President Decree 32/1990
2	Landsat ETM+	13-09-2000	the issue of first autonomy law
3	Landsat TM5	22-09-2006	the issue of RTRWP 2006
4	Landsat TM5	16-10-2009	the issue of RTRWP 2009 (revision of previous regulation)

Vector and scanned maps were used to define the administrative, spatial planning, and land tenure status boundary in relation to study area (see Table 3.7). Coastline and river system were used to define the national buffer area based on President Decree no. 32/1990. Administrative boundary was used as an attribute in defining the administrative location of mangrove forests change. Land tenure status is important to define the land authority in the study area. Provincial spatial planning or *Rencana Tata Ruang Wilayah Provinsi* (RTRWP) 2006 is the spatial planning map which was used for further assessment of mangrove forest management effectiveness at provincial level.

Table 3.7 Maps and sources used in this research

No.	Maps	Year updated	Source
1.	Coastline and river system	2007	Bakosurtanal
2.	Administrative boundary	2008	Bakosurtanal
3.	Land tenure status	2007	Bakosurtanal/BPN
4.	RTRWP (Provincial Spatial Planning)	2006	Bappeda NTB
5.	RTRWP (Provincial Spatial Planning)	2009	Bappeda NTB

3.2.2. Software

This research employed several professional software packages to assist the spatial and non-spatial data.
For spatial data:
ENVI 4.8 → image processing and analysis
ArcGIS 10 SP 2 → GIS analysis: overlay and query
For non-spatial data:
MS. Word → thesis research writing
MS. Excel → calculation

3.3. Method

Firstly, a desktop study was conducted to gain supported literature in regard to the study area, mangrove forest, data processing and analysis. Desktop study was carried out by searching and browsing from the sources which have national and international standard publications. Next, data collection, field work, data processing, change detection analysis, and assessment were performed (see in Figure 3.3).

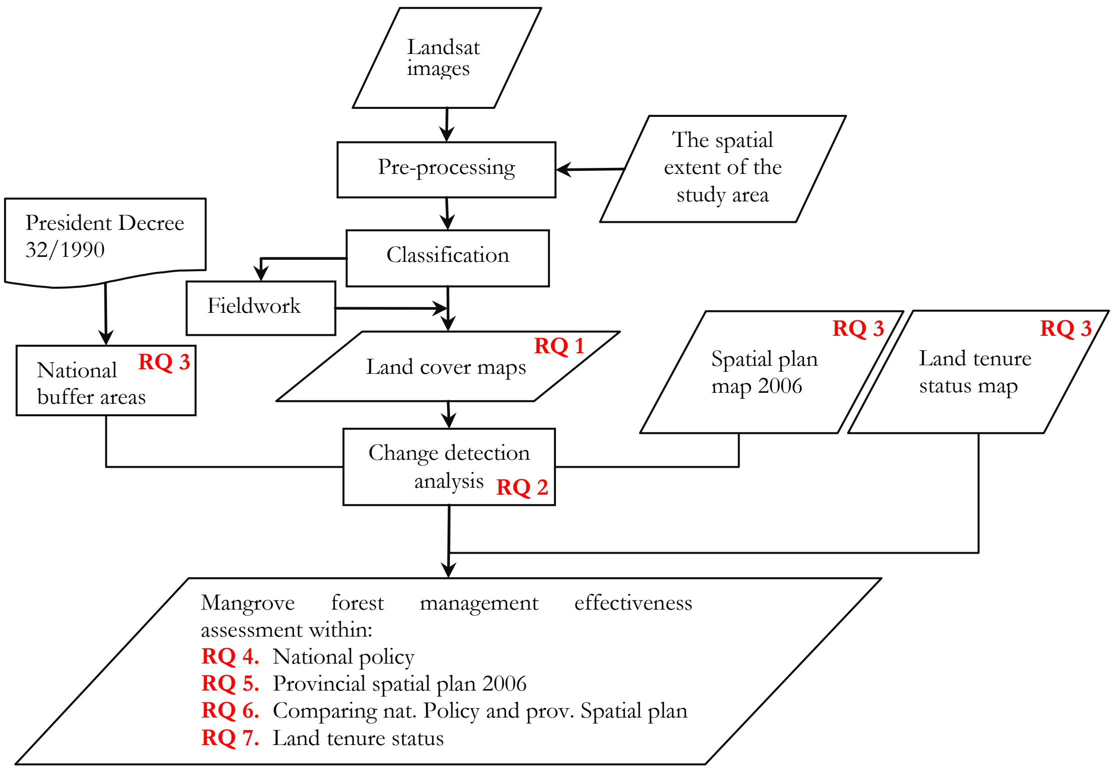


Figure 3.3 General research process

3.3.1. Data Collection

Data collection was also performed by searching and browsing from related sources through internet, library, previous research, and visiting related institutions. Whereas, maps were collected from relevant institutions in Indonesia, Bakosurtanal, and images were collected from other sources such as USGS and ERSDAC. In general, data collection consists of primary and secondary data.

3.3.2. Fieldwork

In accordance to the field work activity, image interpretation was performed beforehand, in order to investigate the existing land covers within the study area. Field work route was also defined by using topographic maps. In the field, the sample point locations were stored in Global Positioning System device. The list of ground truth coordinate points is available in ***Appendix 1***.

Field work was done in March-April 2009. As general, there will be two main activities during the fieldwork:

1) Primary data acquisition: land cover
   The objective of primary data acquisition was to verify the digital Landsat image supervised classification year 2009 by collecting ground truth points and observing the study area. Image verification was conducted by visiting pre-defined places as sample locations which were selected in advance. To record coordinate points in sample locations, a 2009 Landsat composite image was stratified into stratum based on land cover types. For each stratum, random coordinate points were selected and recorded, representative for the strata. The total of 71 sample points was selected for the whole strata. It was classified into 6 classes of land cover types which are: mangrove forest, aquaculture (pond cultivation), mixed grass and shrub, cropland, waterbody, and bareland. The land cover classification is based on Indonesian Topographic Map (*Rupa Bumi* Indonesia, Bakosurtanal) scale 1: 25,000 – 1: 50,000.
2) Secondary data acquisition
   Secondary data consists of project and scientific report related to the location and object of research which are mangrove forest and pond cultivation. This data was collected from related local institution such as: Nusa Tenggara Barat Province Planning and Development Agency (Bappeda NTB), National Statistic Bureau (BPS), and Sumbawa Regional Agency for Marine and Fisheries Affairs (*Dislutkan* Sumbawa). Basically, this step completes the data collection step.

3.3.3. Land Cover Change Analysis

a) Pre-processing

Pre-processing and image masking steps were performed before analyse the land cover change in study area. First, pre-processing step was necessary performed to minimize the image distortion. Landsat images used in this study have already radiometrically and systematic geometrically corrected (Level 1G). However, geo-referencing and atmospheric corrections are still needed to get nearly uniform image properties for time series analysis (Vicente-Serrano et al., 2008). In this pre-processing, the images were calibrated by first converted into radiance value and then converted into reflectance value. Atmospheric correction carried out to these images was linear regression using image 2009 as reference image. Landsat image 2009 was selected as a reference because it has less cloud cover than other images.

Second, another important step in image pre-processing is cloud masking. Masking was aimed to minimize noises from clouds and its shadows. That step was done in order to get the comparable classified time series digital images to be analysed with cloud-free area for all images (Wulder et al., 2008). All images used in this research have clouds and shadows coverage. Therefore, several part of land cover classes which are covered by them on the images were considered as no data.

b) Defining the spatial extent of the study

Since this research analyzed mangrove forest management effectiveness at national and provincial level, the spatial extent should cover the whole mangrove forest or its habitat in Saleh Bay, Sumbawa District. The research process in defining the spatial extent of the study area took into account the physiographic boundary and administrative boundaries (spatial planning or management unit).

Physiographic boundary

Several physical characteristics in accordance to mangrove forest habitat such as slope and elevation were examined. The assumption used in this research was that mangrove forest occur in flat areas, around 0 – 2%, and at low elevation. Low elevation was defined based on the low elevation coastal zone (LECZ). LECZ is a physical boundary, which was originally used to analyse and assess the coastal land area (including: coastal ecosystem landscape and distribution of population) in regards to potential susceptibility of sea-level rise in the future (Lichter et al., 2011). LECZ is a continuous area within 10 meter height above current mean sea level (McGranahan, et al., 2007). In this research, LECZ was defined using ASTER GDEM (with DEM accuracy of 7 m, http://www.ersdac.or.jp) data and reclassifying it using ArcGIS 10 into a specific elevation class from 0 through 10 meter height above mean sea level.

Administrative boundary

Regional spatial planning is usually based on administrative units. In relation to mangrove forest management effectiveness, administrative boundaries cover coastal villages or sub-districts, or even regency near the coastline. Based on the administrative boundary map from Bakosurtanal, this research used coastal sub-district boundaries to assess the spatial extent of the study area as well. The use of sub-district boundaries is based on the administrative unit which is used in provincial spatial planning.

Physiographic and administrative boundaries combination

The combination of physiographic and administrative boundaries was chosen as the spatial extent of the study area because it covers all mangrove forest habitat and pond cultivation in the study area. Moreover, the boundaries are connected with province spatial planning unit. The combination of physiographic and administrative boundaries explains the study area homogeneity which is mainly dominated by flat and low elevation area, and the same political stratum (sub-districts).

To combine the physiographic and administrative boundaries, LECZ map and sub-district boundaries were overlaid using intersects overlay operation in ArcGIS 10 software. The overlay operation yields a map with LECZ boundary and each sub-district boundary attributes. The spatial extent of the study area consists of sub-district names attribute, namely: Empang, Lapelopok, Moyohilir, and Plampang.

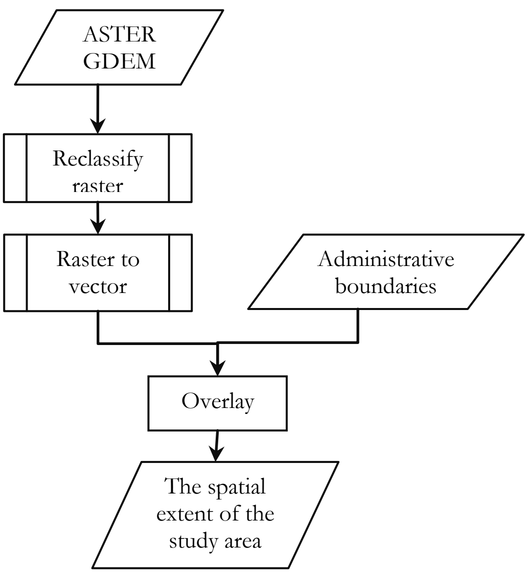


Figure 3.4 The overlay between ASTER GDEM and administrative boundaries

c) Land cover classification

This research used supervised classification method for land cover classification. Land cover classes in the study area were based on the Indonesia Topographic Map scale 1: 25,000 and 1: 50,000 (Rupa Bumi Indonesia, Bakosurtanal) classification, especially in the coastal area. The supervised classification was used in order to cluster pixels in an image into classes corresponding to user-defined training samples. Training sample process was done in order to select sample points as inputs in supervised classification process. Sampling area for training process was selected based on the spectral characteristic of the classes on the image.

The supervised classification method used in this research was maximum-likelihood classification. This algorithm is widely used for image classification because of its statistical consistency (Bayarsaikhan et al., 2009), (Deng et al., 2009), and (Abd El-Kawy et al., 2011). Furthermore, different from other supervised classification, maximum likelihood algorithm considers not only the cluster centre but also the shape, size, and orientation by using mean value and covariance matrix in statistical analysis (Jensen, 1996).

In this step, all images (1989, 2000, 2006, and 2009) were classified using maximum likelihood classification algorithm. Pixel samples were selected from all images at the nearly same location in order to keep the training samples consistency. Using ENVI 4.8 training sample selection, it is possible to select regions of interest (ROI) of all images together. Selected ROIs were distributed evenly along the image. The ROI classes were depended on the land cover classes which are: mangrove, pond, bareland, mixed grass and shrub, cropland, and waterbody. No settlement class was chosen because the rural area in the study area is considered very small area and basically settlements are mixed with other larger land cover classes, such as: cropland and mixed gardens (grass and shrub).

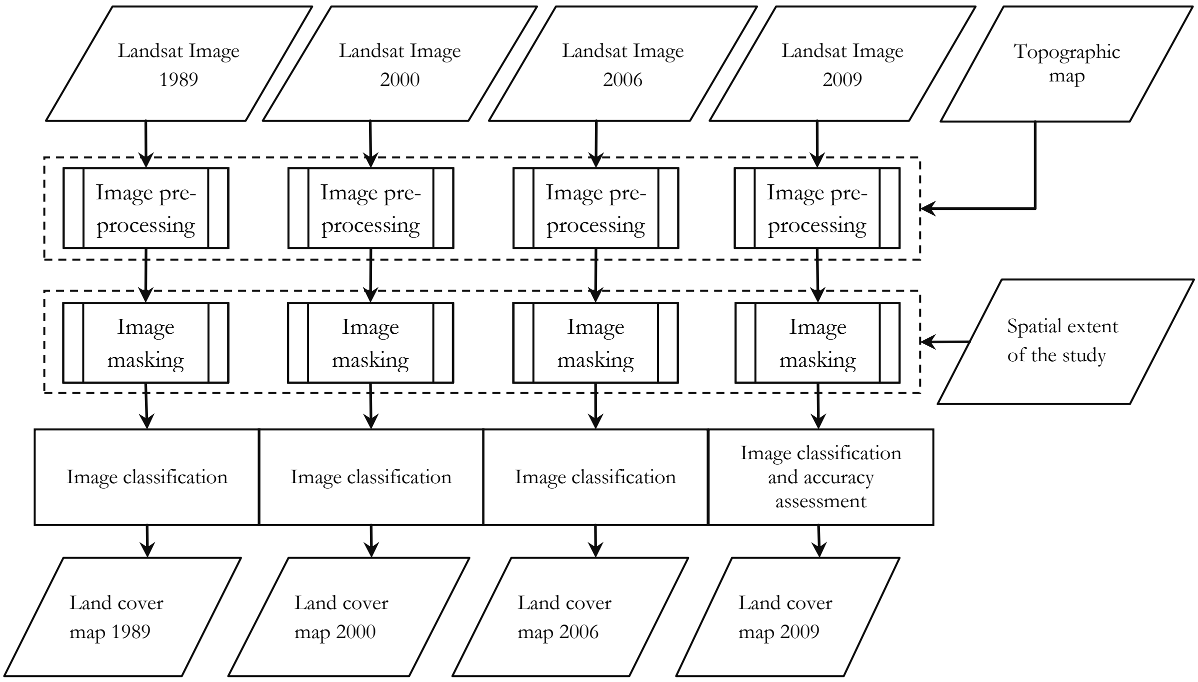


Figure 3.5 Process of land cover classification

Figure 3.4 explains the sequence of image processing and classification using maximum likelihood algorithm. This process was important because it would be used for further analysis, change detection. Image classification accuracy assessment was performed before all of the classified images used for change detection analysis. In the end of classification process, visual interpretation was done in order to refine the classification result (Abd El-Kawy, et al., 2011).

d) Accuracy assessment

Accuracy assessment was aimed to give the information about the classification accuracy using ground truth data as reference. In this research, ground truth data was derived only from field work in March-April 2009. Thus, accuracy assessment cannot be performed for the images prior to 2009. The total ground sample points used in this research is 71 points. According to these points, the accuracy assessment was done.

Accuracy assessment explains the degree of 'correctness' of a classification in thematic mapping from remotely sensed data (Foody, 2002). Accuracy assessment was conducted in ENVI 4.8 by using reference region of interest (ROI) from ground truth data. Accuracy assessment method used in this research is confusion matrix and kappa statistic. Confusion matrix explains the degree of image classification by expressing "a simple cross-tabulation of the mapped class label against that observed in the ground or reference data for a sample of cases at specified locations, it provides an obvious foundation for accuracy assessment" (Campbell, 1996 and Canters, 1997) in (Foody, 2002). Whereas, kappa statistic represent the agreement of the image classification data and the reference points (Jensen, 1996). The agreement showed by kappa statistics can be categorized as high reliable if it shows kappa value of > 0.8, moderate reliable is between 0.6 and 0.8, and poor or unreliable agreement is < 0.6 (Carletta, 1996; Landis, 1977).

e) Change detection

Change detection analysis was done in ArcGIS 10 software. Images derived from classification step were converted into vector layer format. Afterwards, using intersect overlay operation, land cover change detection analysis from 1989 to 2000, 2000 to 2006, and 2006 to 2009 were done. Intersect overlay operation means that all features or portions of features which overlap in all layers will be written to the output layer. Besides maps, change detection analysis also produced tables contain of the amount of area changes in each land cover class. By performing query operation, the change can be detected from one land cover to other land covers for different year.

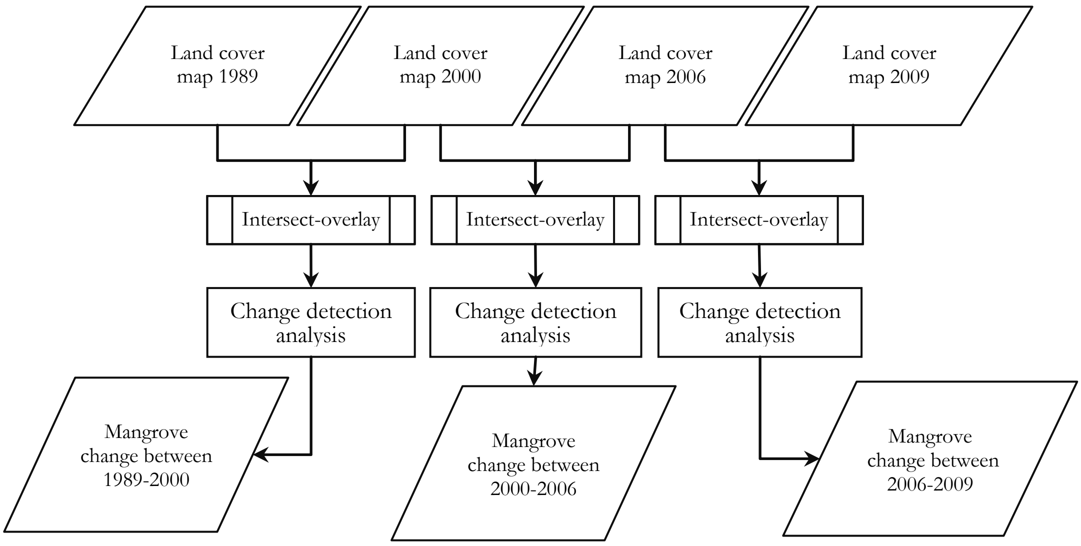


Figure 3.6 Change detection workflow

As seen in Figure 3.5, three intersect overlay operations were performed. The first operation was performed for the land cover map 1989 and 2000; second, for the land cover map 2000 and 2006; and third, for the land cover map 2006 and 2009.

The maps resulted from supervised image classification were used for direct comparability using post-classification comparison method. Post-classification comparison method was effective and easy to use in analysing changes since it can minimize problem derived from multi-temporal image and use simple comparison (Coppin, Jonckheere, Nackaerts, Muys, & Lambin, 2004; Rivera, 2005; Singh, 1989; Warner & Campagna, 2009; Zhou, Troy, & Grove, 2008) as in (Abd El-Kawy, et al., 2011). Simple mathematical formula used in post-classification comparison is:

$$\Delta = \left(\frac{A2 - A1}{A1} \times 100 \right) / (T2 - T1)$$

Where: Δ = the rate of land cover change
A1 = amount of land cover type in time1
A2 = amount of land cover type in time2

3.3.4. Mapping the existing mangrove forests management policy, spatial planning document, and land tenure status

First, mapping the existing mangrove forests management policy is based on the President Decree 32/1990 about Protected Area Management article no. 27. The protected area defined using buffer analysis from both coastline and river. As mentioned in Chapter 2, the coastline buffer area is within 230 meter with additional 3 buffer areas. For the river buffer area, it is within 100 meter with additional 4 buffer areas. The process used buffer tools in the proximity analysis in ArcGIS 10 software. Second, mapping the spatial planning map 2006 and land tenure status 2007 were done by digitizing the scanned maps (***Appendix 5*** and ***Appendix 6***). The digitizing process was conducted in ArcGIS 10 software as well.

3.3.5. Assessing the management effectiveness

The management effectiveness assessment was aimed to identify the proportion of protected mangrove forests in achieving objective to preserve the area extent. Based on the regulations concerning with mangrove forest management performed in the study area, there are two main policies were assessed (see Figure 3.6). The first one, national policy refers to President Decree 32/1990 about Protected Area Management. Second, provincial level regulation refers to Nusa Tenggara Barat Regional Regulation 11/2006 about Provincial Spatial Planning. The assessment of mangrove forest management effectiveness was supported by land tenure status map as well. Land tenure status is important in mangrove forest in the study area since it is related to the land management where mangrove forest was located. In addition, sub-district boundary was taken into account as an attribute unit in each assessment since it was used in spatial planning.

Thus, the assessment of mangrove forest management effectiveness was divided into four sections. First, assessment of mangrove forest management effectiveness for national level policy was conducted based on mangrove forest change between 1989 through 2006. Second, assessment of mangrove forest management effectiveness for province level policy was conducted based on mangrove forest change between 2006 through 2009. Third, the effect of provincial spatial planning to mangrove forest management national policy was conducted based on mangrove forest change between 2006 through 2009 as well. Finally, assessment of mangrove forest management effectiveness in each land tenure status in the study area was performed.

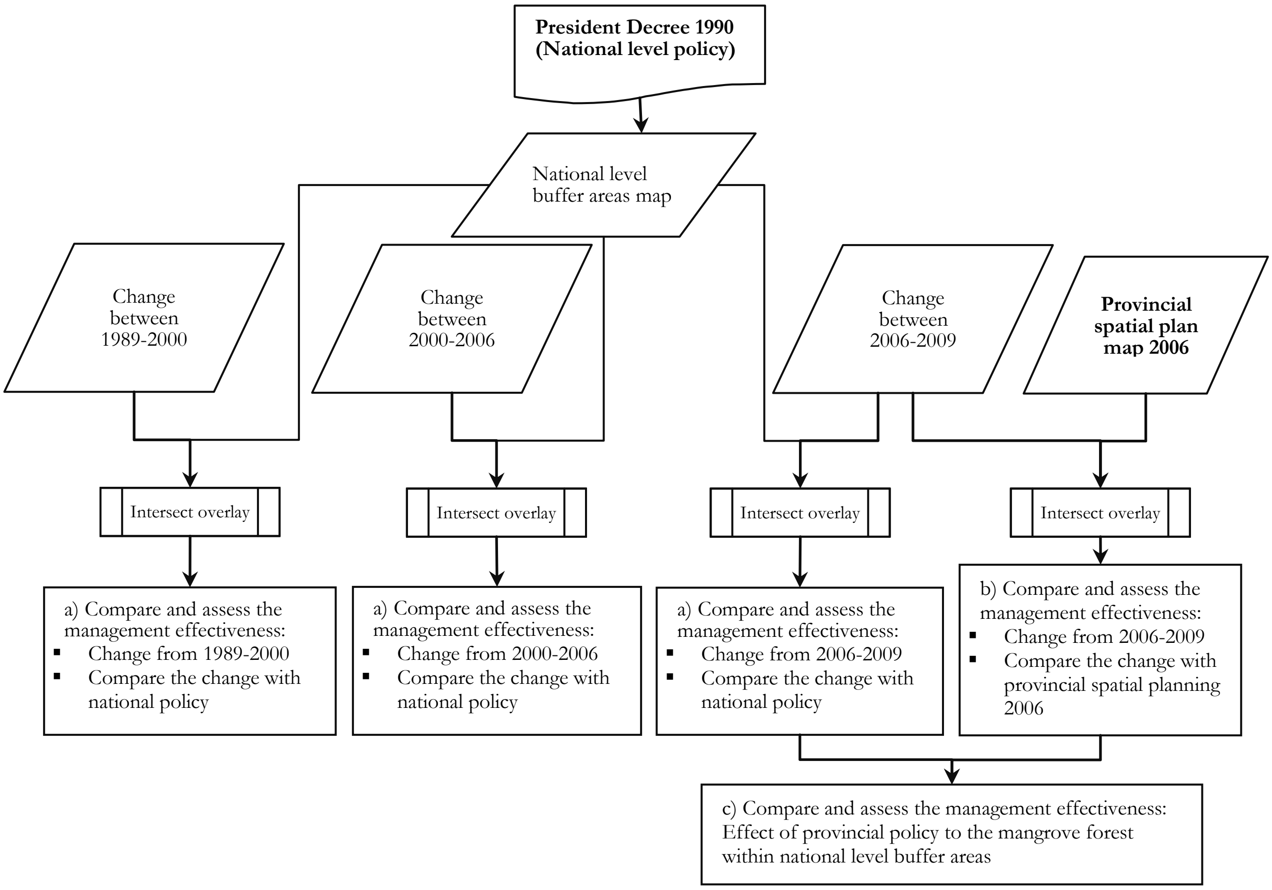


Figure 3.7 Management effectiveness analysis diagram

a) Mangrove forest management effectiveness: national level policy

President Decree 32/1990 (national level policy) stated that mangrove forest protected area is an area within 230 meter buffer area from coastline. 230 meter buffer area is calculated based on local tidal range (1.77 meter) multiplied by 130 (constant). In addition, protected area in the river bank is an area within 100 meter buffer beside the river. It means that mangrove forest conversion within those national level buffer areas is not allowed.

The operation used for making buffer area of 230 meter from the coastline and buffer area of 100 from the river was Multiple Ring Buffer in Proximity Analysis Tools in ArcGIS 10 software. To compare with the change outside of those protected areas, this research used additional 3 buffer areas of 230 meter from the coastline and 4 buffer areas of 100 meter from the river. By using additional 3 buffer areas from the coastline and 4 buffer areas from the river, all the mangrove forests can be covered. The buffer areas were overlaid with each land cover change: 1989-2000, 2000-2006, and 2006-2009 (see Figure 3.6).

The management effectiveness of national level policy was also discussed in accordance to another national level policy setting, autonomy law (2000). The assessment of mangrove forest management effectiveness of national level policy was done by comparing mangrove forest change both before and during the autonomy era (starts from year 1999/2000).

b) Mangrove forest management effectiveness: province level policy

In this section, mangrove forest management effectiveness was assessed after the enactment of Regional Regulation 03/2006 about Nusa Tenggara Barat province spatial planning year 2006. This province spatial planning describes about land use allocation or zoning from 2006 through 2020. Each land use zoning has defined area which is depicted on the spatial planning map and can be measured using ArcGIS 10.

On spatial planning map 2006, there are six different land use zonings allocated on the coastal area, they are: ponds cultivation, mangrove forests for protected area, mangrove forests for tourism area, forest (protected area), tourism area, and other land use area. Additionally, no conversion is allowed on the mangrove forests (both protected and tourism) and forest area (Government Regulation 26/2008 about National Spatial Plan).

Land cover change map between 2006 through 2009 was used for assessing mangrove forest management effectiveness on province level. By comparing land cover change map between 2006 and 2009 and spatial planning map 2006, the area and location of mangrove forests change were determined. Assessment and comparison between land cover change map 2006 – 2009 and spatial planning map 2006 were done by using intersect overlay operation in ArcGIS 10 software (see Figure 3.6).

c) Province level policy compare to national level policy

In this section, the assessment was done for mangrove forest within national level buffer areas under the spatial planning map 2006 zonings. According to spatial planning map 2006, the land use zonings for mangrove protection has been changed. This change can influence mangrove forest management within national level buffer areas. Therefore, this research assessed the mangrove forest management effectiveness of spatial planning 2006 (province level policy) by comparing to national level buffer areas (national level policy). To assess, both province level and national level policies were compared to land use change between 2006 and 2009 (see Figure 3.6). All comparison processes were done using intersects overlay operation in ArcGIS 10 software.

d) Mangrove forest management effectiveness: land tenure perspective

Mangrove forest area management is related to its land tenure status. In Sumbawa, land tenure status is divided into three categories. The first is right of ownership land (*tanah hak milik*), is rights on land that belongs to or owned by individual or person. Second, right to cultivate land (*tanah hak guna usaha*), is rights on land for cultivation or other uses by person or group of persons who rent from the land owner. The third, government land (*tanah negara*), is rights on land owned by government.

The process was used land tenure status map updated on 2007 under Geo-Spatial Marine Resources Information System (GMRIS) Project (Bakosurtanal). The mangrove forests management effectiveness was assessed by comparing land tenure status map with the land cover change between 2006 and 2009 (see Figure 3.7). To compare, the maps were overlaid using intersects overlay operation in ArcGIS 10 software.

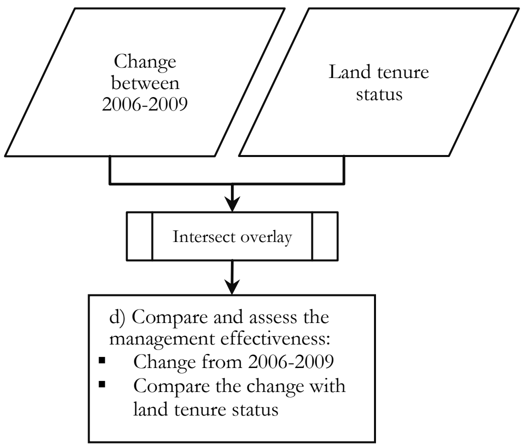


Figure 3.8 Mangrove forests management assessment and comparison within land tenure status

4. RESULTS

Based on research objectives and questions, this research produced eight result points. The result points comprise of: defining the spatial extent, mangrove forest change, existing mangrove forest management policy at national and province level, effectiveness of national and province policies, effectiveness of the province level policy compared to national level policy, and effectiveness of mangrove forest management on each land tenure status. In sequence, the results will be described below. For further analysis and discussion, the thesis research only focused on the change of mangrove forest and ponds only.

4.1. Defining spatial extent of the study area

This research part is aimed to determine the study area which covers all mangrove forests and ponds. In addition, administrative boundary is an important regional management unit which is taken into account in the regional spatial planning. The combination between physiographic and administrative boundaries covers all mangrove forests and ponds including the administrative boundary. The result shows that the study area covers homogenous flat area, low elevation area, and sub-district boundaries.

LECZ covers not only all mangrove forest and ponds but also area within 10 meter height from coastline in study area. The LECZ is straightforward since it connected to mangrove habitat general criteria. Most of the LECZ area coincides with the flat area, slope between 0 – 2%. These physical characteristics are met to mangrove forest habitat and ponds land suitability as well. Moreover, coastal sub-district boundary is useful especially related to certain planning policies or other data analysis, such as: social and economic data.

In Figure 4.1, the combination of the LECZ and sub-district boundaries is presented. The total LECZ in Saleh Bay coastal sub-districts (Moyohilir, Lapelopok, Plampang, and Empang) covers 5.0% of Sumbawa District total area. In addition, the total LECZ area subtracted by total cloud cover (8.8% of total LECZ area) in the study area is 4.5% of Sumbawa District total area or 30,073.5 hectares.

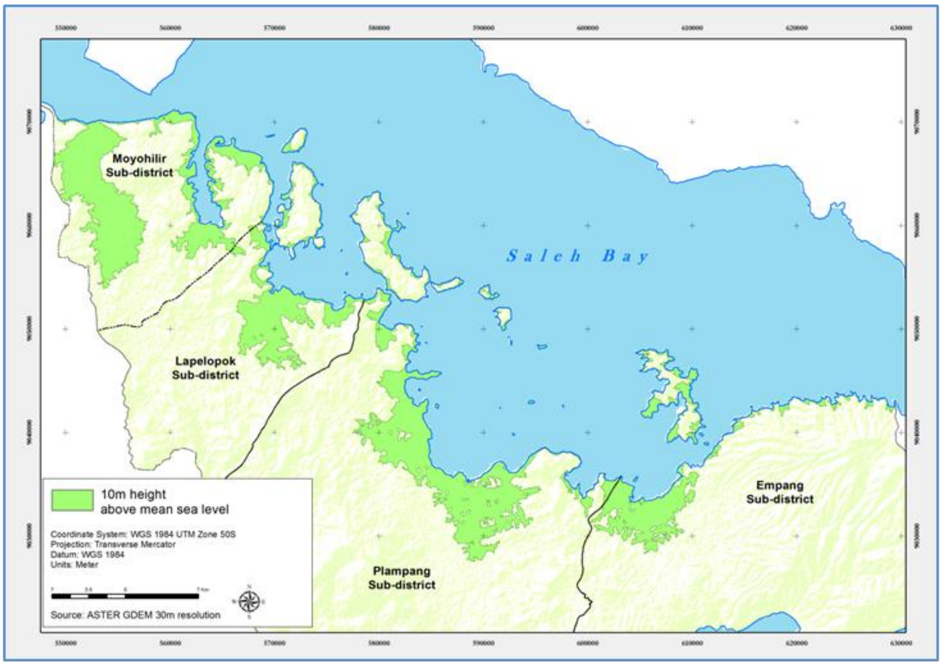
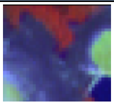
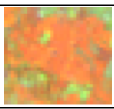
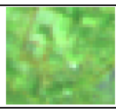
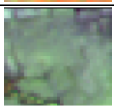


Figure 4.1 Low elevation area in coastal sub-districts in Saleh Bay, Sumbawa

4.2. Land cover classification

Land cover classification is a basic and important part of the research since it will be used for change detection and management effectiveness analysis. The land cover classification scheme is based on the Topographic Map (*Peta Rupa Bumi* Indonesia, Bakosurtanal, 2000) which shown in Table 4.1 below. Those classes were used to classify four Landsat images (1989, 2000, 2006, and 2009). The land cover classification map is divided into two sections. First, it shows land cover classification in Moyohilir and Lapelopok sub-districts. Second, it shows land cover classification in Plampang and Empang sub-districts.

Table 4.1 Land cover image classification characteristics and its description

Land cover class	View on RGB 452	Description	Land cover class	View on RGB 452	Description
Ponds		Pool or water area surrounded by linear feature made by human on coastal area for shrimp cultivation	Waterbody		Open water area, such as: tidal area and river
Cropland		Vegetated area dominated by paddy fields, maize, and cassava	Grass and shrub		Vegetated area dominated by mixed grass and shrub
Bareland		Sparsely, or non-vegetated area, could be wet or dry	Mangrove forest		Vegetation (trees) on tidal area along the coastline and tidal rivers

4.2.1. Land cover classification and mapping 1989

Figure 4.2 and Figure 4.3 display the classification result for year 1989. Based on visual inspection, there are large mangrove forests near the coastline in each sub-district. Largest mangrove areas are found in Labutunuk Bay, Plampang sub-district. Plampang sub-district is the largest low elevation area in Sumbawa coastal area. Almost all of large mangrove areas in Saleh Bay, Sumbawa are located in the mainland coastal area. The rest, small parts of mangrove areas are located in small islands, such as: Liang, Ngali, and Rakit Islands.

Based on the Figure 4.2 and Figure 4.3, larger mangrove forests are mainly distributed on larger bay and supported by large river. As seen on Figure 4.2, mangrove forests in Plampang sub-district fringes of the greater bay compare to them in other sub-districts. Moreover, river does also influence the mangrove forest distribution (Manson et al., 2003). For those located near large river, mangrove forests grow deeply into the land area up to 3.3 Km far from the coastline, such as mangrove forests located in Plampang sub-district.

Small ponds area are found along the Saleh Bay coastal area. Compare to waterbody, ponds has much less area. Ponds are only found in Moyohilir and Lapelopok sub-districts. In Moyohilir sub-district, ponds are located far from the coastline. While in Lapelopok sub-district, ponds are located near the coastline. Adjacent to mangrove forests, there are large waterbody areas. Waterbody areas are commonly located behind mangrove forests. These areas show the actual tidal influence in Saleh Bay, in 1989.

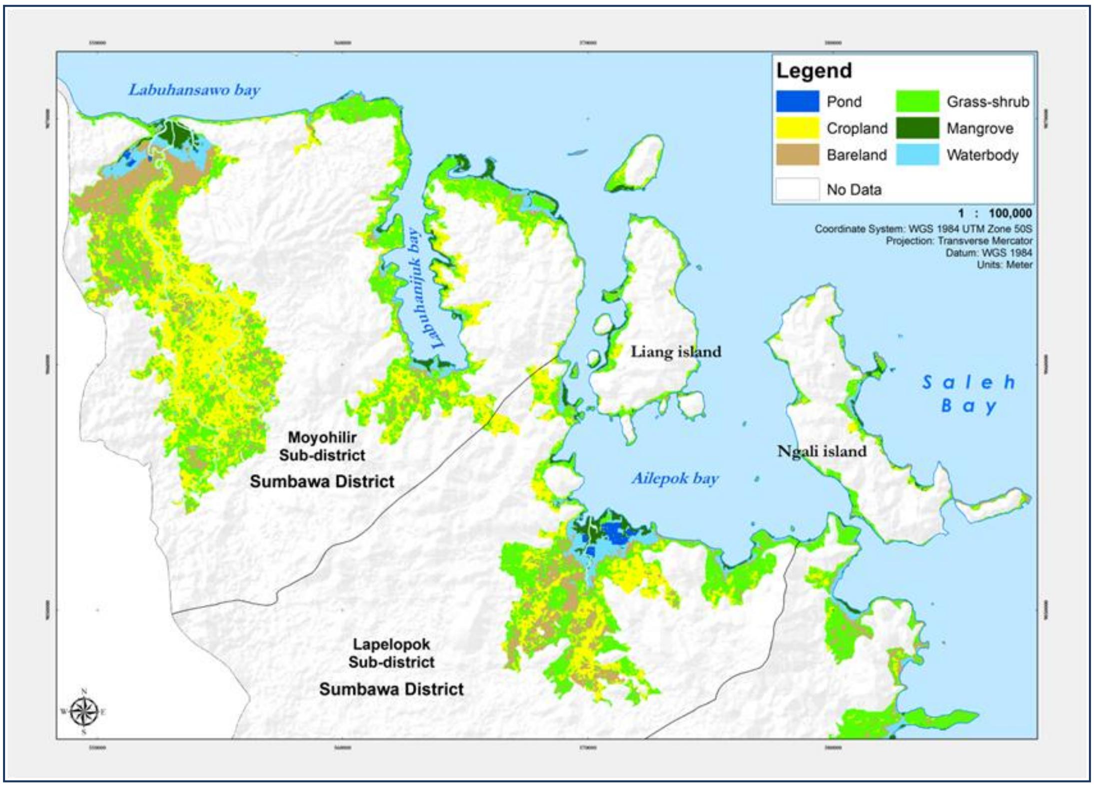


Figure 4.3 Land cover map 1989 in Plampang and Empang sub-districts

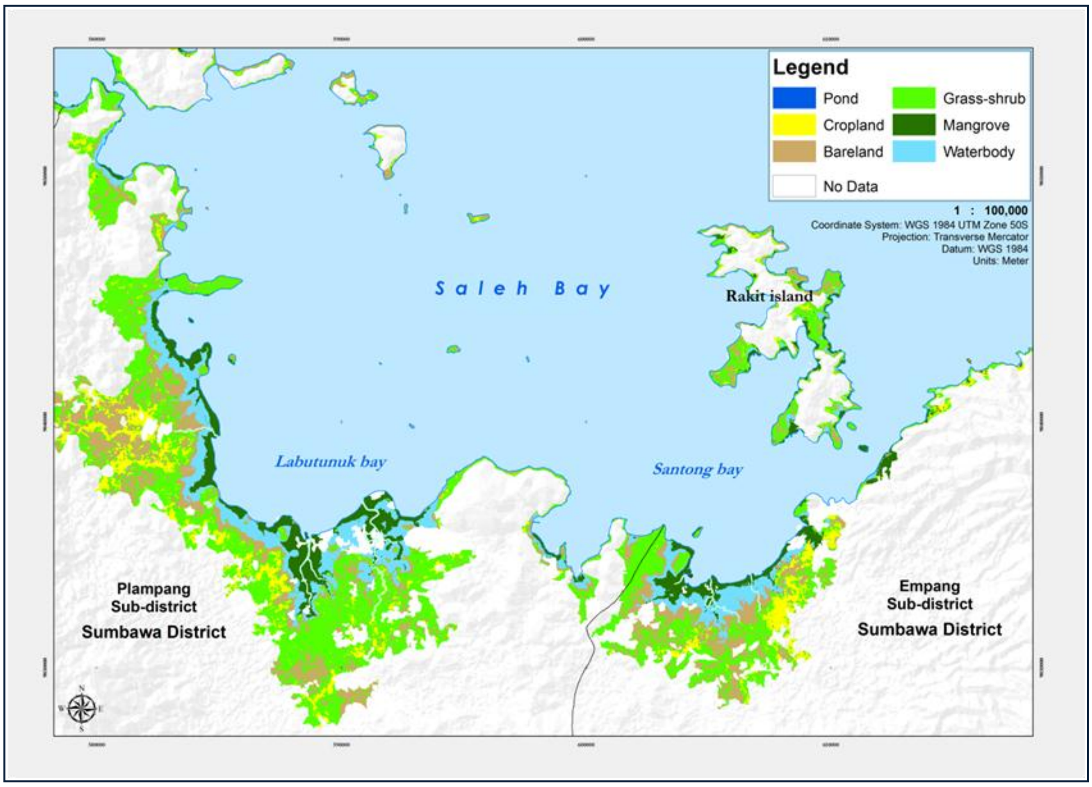


Figure 4.2 Land cover map 1989 in Moyohilir and Lapelopok sub-districts

Table 4.2 Land cover types in each sub-district year 1989

Land cover	Sub-districts (Ha)								Total	%
	Moyohilir	%	Lapelopok	%	Plampang	%	Empang	%		
Mangrove	**341.2**	**3.5**	**363.8**	**6.6**	**990.4**	**9.8**	**635.6**	**13.0**	**2,331.0**	**7.8**
Pond	**17.5**	**0.2**	**86.7**	**1.6**	**-**	**-**	**-**	**-**	**104.1**	**0.3**
Waterbody	545.7	5.7	437.9	8.0	1,350.2	13.4	605.5	12.4	2,939.3	9.8
Bareland	1,482.6	15.4	914.5	16.7	2,112.3	20.9	1,084.3	22.2	5,593.7	18.6
Cropland	3,547.6	36.8	1,337.8	24.5	912.2	9.0	562.3	11.5	6,360.0	21.1
Grass-shrub	3,695.7	38.4	2,330.2	42.6	4,725.6	46.8	1,993.9	40.8	12,745.4	42.4
Total	9,630.3		5,471.0		10,090.6		4,881.7		30,073.5	

Table 4.2 describes each land cover area within each low elevation area in coastal sub-district (year 1989). As seen in the table above, the largest mangrove forest is found in Plampang sub-district with 990.4 hectares (9.8% of its total low elevation area). While, the smallest mangrove forest (341.2 Ha) is occurred in Moyohilir sub-district. As seen in the Table 4.2 as well, ponds are found in small part and distributed only in Moyohilir (17.5 Ha) and Lapelopok (86.7 Ha) sub-districts. Overall, in 1989, Saleh Bay coastal area has 2,310.0 Ha (7.8%) of mangrove forests and 104.1 Ha (0.3%) of ponds.

4.2.2. Land cover classification and mapping 2000

Figure 4.4 and Figure 4.5 present the land cover map 2000. On the map, there are considerable ponds occurred in each sub-district. Mainly, the ponds are located behind the mangrove forests. Visually, the largest ponds are found in Plampang sub-district. On the West side of Labutunuk bay, there is large ponds increase behind the mangrove forests. In addition, the smallest ponds are found in Empang sub-district.

The ponds distribution is largely occurred near to the coastline. Different from others, ponds in Labuhansawo bay in Moyohilir sub-district are located closer to the river than the coastline (see Figure 4.4). That condition is caused by the narrow low elevation area characteristics on the estuary. The ponds development in that area is mainly depended by the main river water condition.

Table 4.3 below provides the land cover classification in each sub-district year 2000. The largest mangrove forests area found in Plampang sub-district (965.1 Ha). There are large ponds increase in Plampang sub-district as well. In 2000, this sub-district has become the largest ponds developer with areas of 150.4 Ha. With 120.2 Ha areas, Empang sub-district has the smallest ponds in Saleh Bay coastal sub-districts. Overall, there are 2,200.6 Ha (7.3%) mangrove forests and 563.5 Ha (1.9%) ponds in Saleh Bay coastal sub-districts in 2000.

Table 4.3 Land cover types in each sub-district year 2000

Land cover	Sub-districts (Ha)								Total	%
	Moyohilir	%	Lapelopok	%	Plampang	%	Empang	%		
Mangrove	**316.2**	**3.3**	**327.4**	**6.0**	**965.1**	**9.6**	**592.0**	**12.1**	**2,200.6**	**7.3**
Pond	**163.6**	**1.7**	**129.3**	**2.4**	**150.4**	**1.5**	**120.2**	**2.5**	**563.5**	**1.9**
Waterbody	80.5	0.8	82.9	1.5	245.1	2.4	34.4	0.7	442.9	1.5
Bareland	5,091.9	52.9	2,115.7	38.7	3,442.5	34.1	1,209.6	24.8	11,859.7	39.4
Cropland	2,629.8	27.3	1,742.9	31.9	2,021.0	20.0	1,533.7	31.4	7,927.4	26.4
Grass-shrub	1,348.2	14.0	1,072.9	19.6	3,266.5	32.4	1,391.7	28.5	7,079.4	23.5
Total	9,630.3		5,471.0		10,090.6		4,881.7		30,073.5	

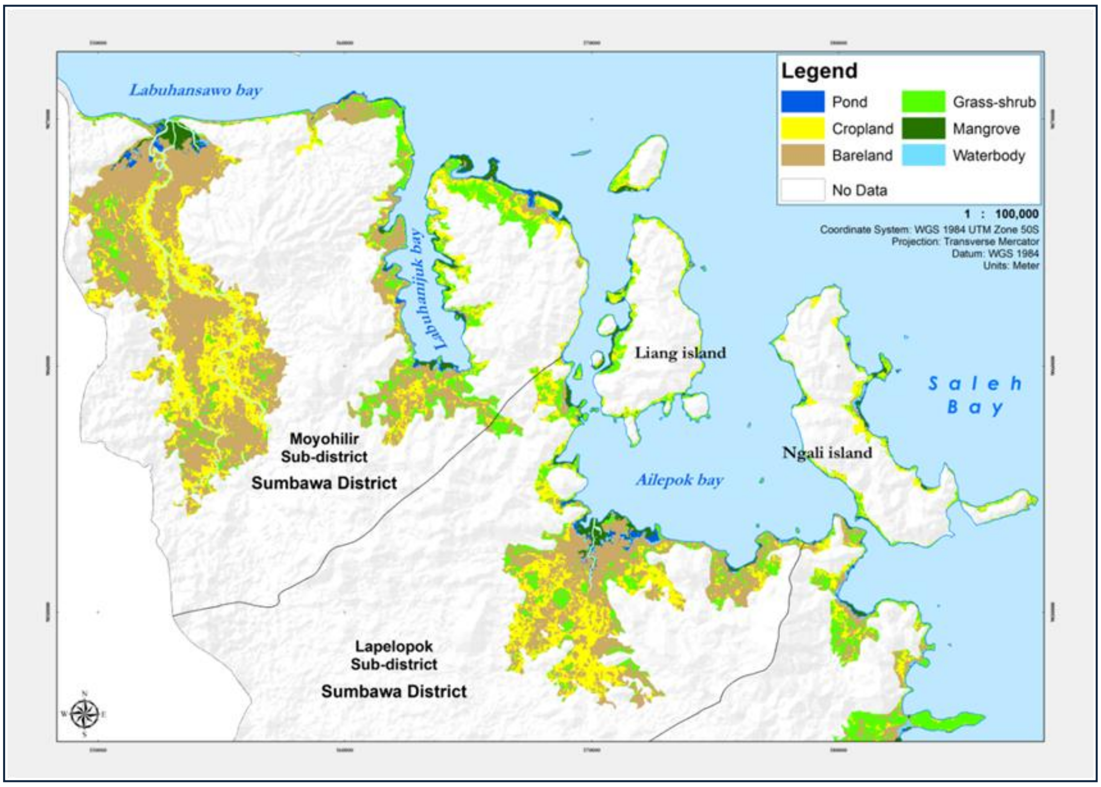


Figure 4.4 Land cover map 2000 in Moyohilir and Lapelopok sub-districts

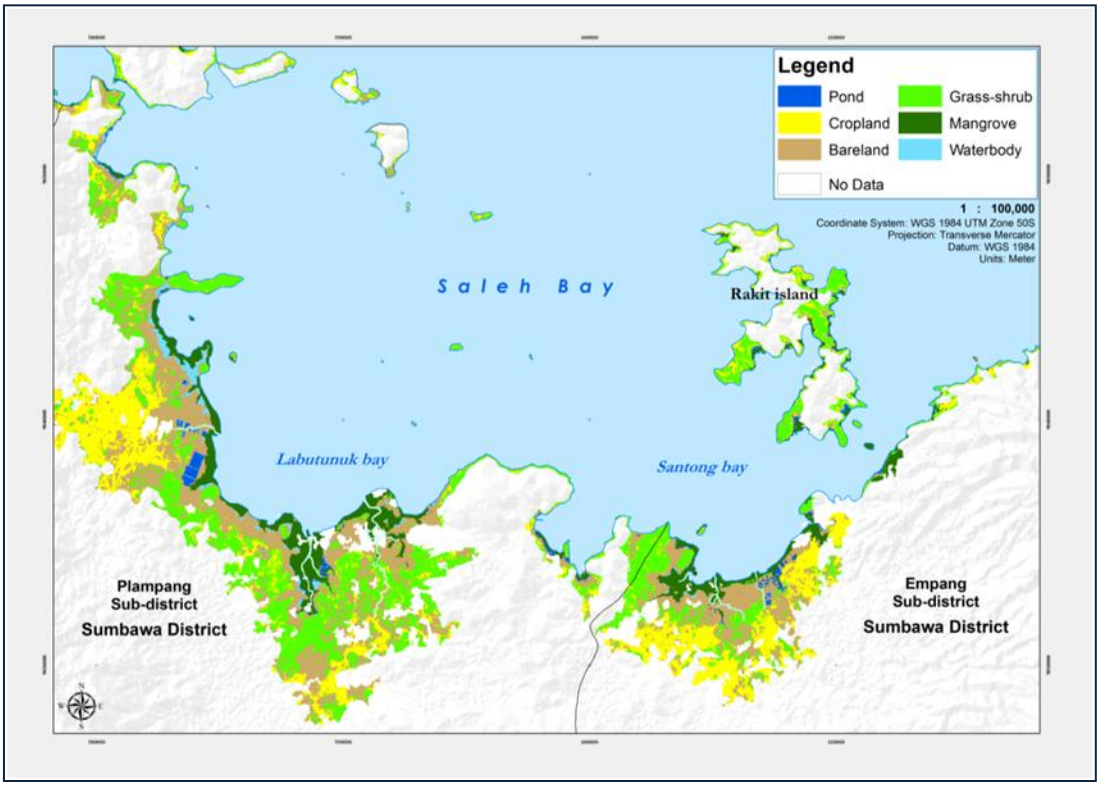


Figure 4.5 Land cover map 2000 in Plampang and Empang sub-districts

4.2.3. Land cover classification and mapping 2006

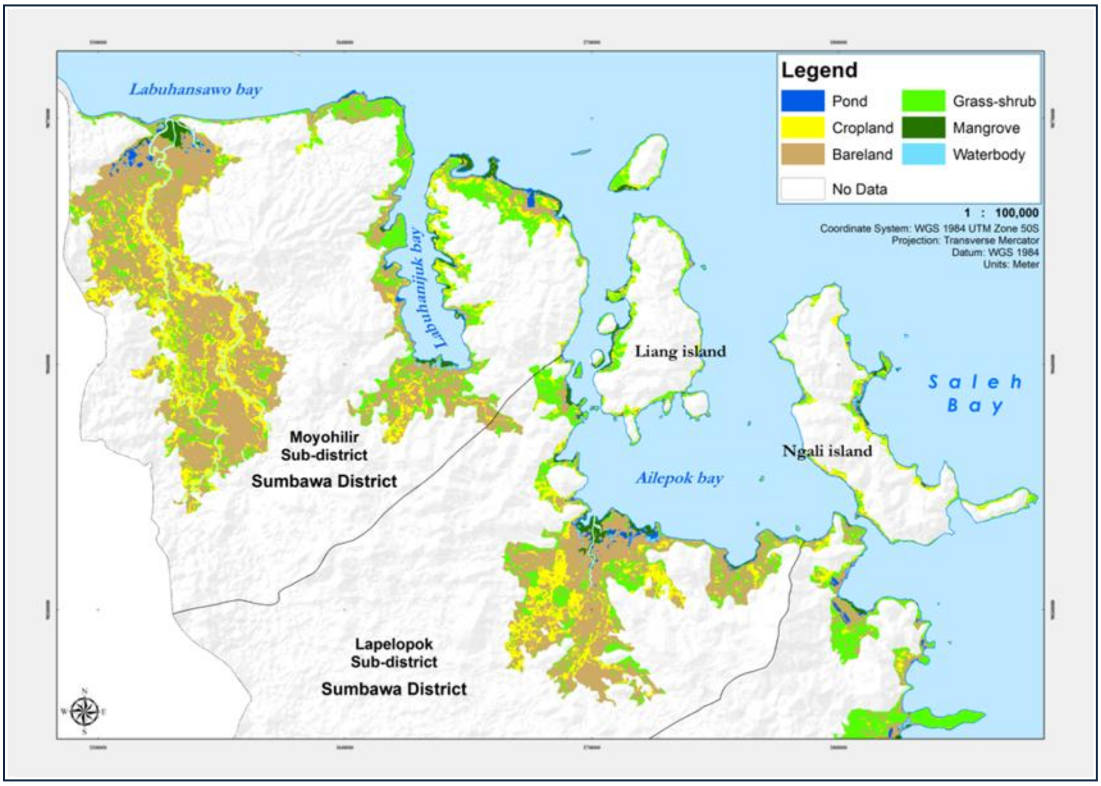


Figure 4.6 Land cover map 2006 in Moyohilir and Lapelopok sub-districts

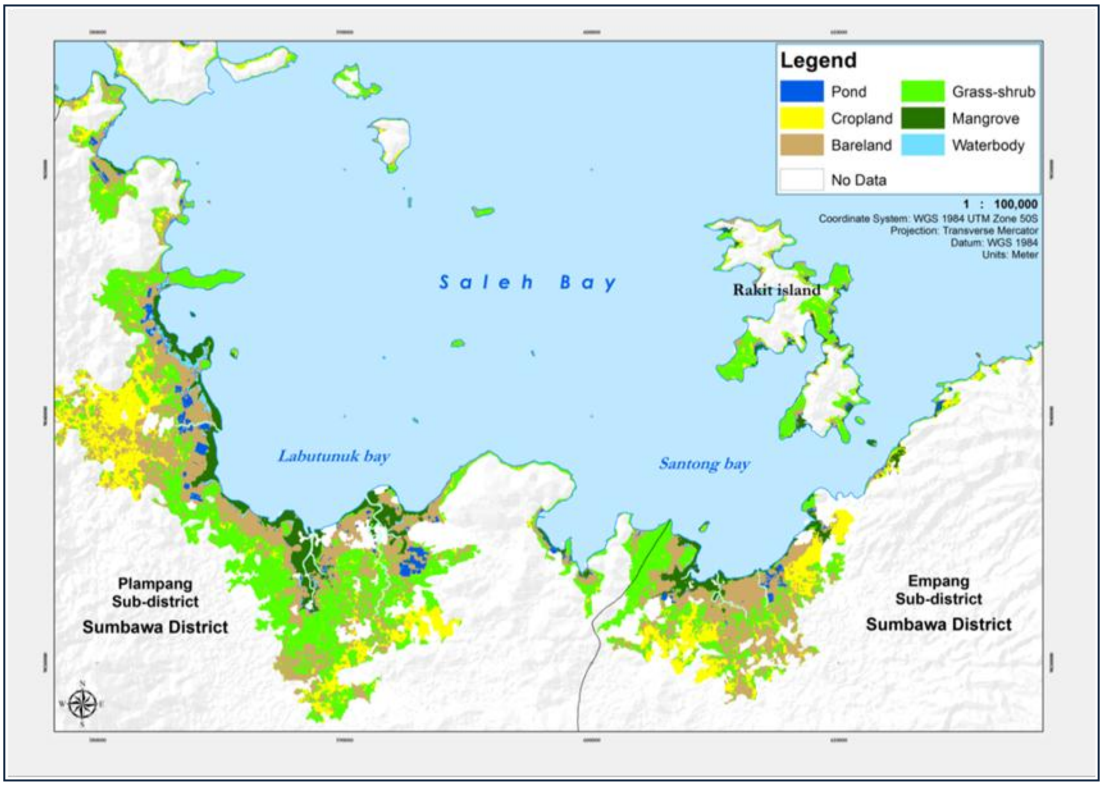


Figure 4.7 Land cover map 2006 in Plampang and Empang sub-districts

Figure 4.6 and Figure 4.7 show the distribution of mangrove forests and ponds in 2006. The ponds are distributed evenly in four Saleh Bay coastal sub-districts. The ponds are mainly located behind the mangrove forest. On the West side of Labutunuk bay, ponds are located just behind the mangrove forests and waterbodies. However, far from the South side of Labutunuk bay, there are considerable ponds. Those ponds are associated with the existence of the main river in that location.

Based on the Table 4.4 below, the largest mangrove forests are occurred in Plampang sub-district (851.2 Ha). While, the least mangrove forests are occurred in Moyohilir sub-district. Nevertheless, Moyohilir sub-district has the second largest of ponds (124.6 Ha) after Plampang sub-district (310.9 Ha). In general, total mangrove forest and ponds respectively in Saleh Bay coastal area is 1,808.9 Ha (6.0%) and 644.8 Ha (2.1%) in 2006.

Table 4.4 Land cover types in each sub-district year 2006

Land cover	Sub-districts (Ha)								Total	%
	Moyohilir	%	Lapelopok	%	Plampang	%	Empang	%		
Mangrove	**248.9**	**2.6**	**263.2**	**4.8**	**851.2**	**8.4**	**445.6**	**9.1**	**1,808.9**	**6.0**
Pond	**124.6**	**1.3**	**94.3**	**1.7**	**310.9**	**3.1**	**114.9**	**2.4**	**644.8**	**2.1**
Waterbody	85.2	0.9	67.2	1.2	161.7	1.6	19.8	0.4	334.0	1.1
Bareland	5,311.1	55.2	2,642.6	48.3	3,426.1	34.0	1,678.0	34.4	13,057.9	43.4
Cropland	2,076.3	21.6	1,132.3	20.7	1,494.8	14.8	1,005.3	20.6	5,708.8	19.0
Grass-shrub	1,784.1	18.5	1,271.3	23.2	3,845.8	38.1	1,618.0	33.1	8,519.2	28.3
Total	9,630.3		5,471.0		10,090.6		4,881.7		30,073.5	

4.2.4. Land cover classification and mapping 2009

The last land cover classification map (year 2009) in this research is explained by Figure 4.8 and Figure 4.9 below. As seen in both land cover classification maps 2009, large amount of ponds are established in Moyohilir and Empang sub-districts. There is a ponds location difference between these two sub-districts. In Moyohilir sub-district, ponds are mainly developed far from the coastline. They are developed by using the brackish water supply through the main river existence. On the other hand, ponds in Empang sub-district are mainly supported by the brackish water supply through adjacent sea water.

The mangrove forest and ponds amounts in each sub-district in 2009 are shown in Table 4.5 below. In Moyohilir sub-district, the ponds (178.6 Ha) exceed the mangrove forests (171.5 Ha) in amount. While, the leading mangrove forests (772.9 Ha) and ponds (288.2 Ha) are located in Plampang sub-district. On the whole, mangrove forests place 1,503.4 Ha areas or 5.0% of total low elevation area in coastal sub-districts in Saleh Bay in 2009.

Table 4.5 Land cover types in each sub-district year 2006

Land cover	Sub-districts (Ha)								Total	%
	Moyohilir	%	Lapelopok	%	Plampang	%	Empang	%		
Mangrove	**171.5**	**1.8**	**198.3**	**3.6**	**772.9**	**7.7**	**360.7**	**7.4**	**1,503.4**	**5.0**
Pond	**178.6**	**1.9**	**109.6**	**2.0**	**288.2**	**2.9**	**141.6**	**2.9**	**718.0**	**2.4**
Waterbody	202.2	2.1	171.0	3.1	310.9	3.1	155.6	3.2	839.7	2.8
Bareland	4,358.9	45.3	2,967.9	54.2	4,025.9	39.9	1,477.3	30.3	12,830.0	42.7
Cropland	2,999.1	31.1	541.5	9.9	802.7	8.0	1,028.1	21.1	5,371.4	17.9
Grass-shrub	1,720.0	17.9	1,482.7	27.1	3,890.0	38.6	1,718.4	35.2	8,811.1	29.3
Total	9,630.3		5,471.0		10,090.6		4,881.7		30,073.5	

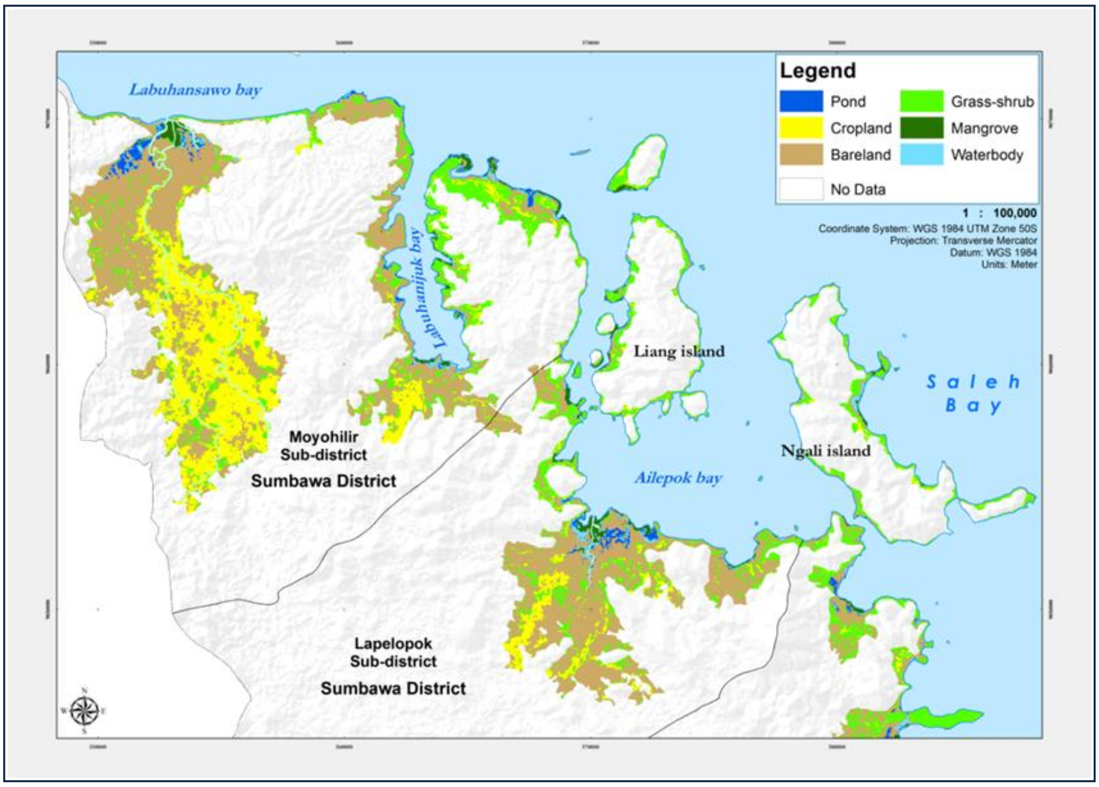


Figure 4.9 Land cover map 2009 in Moyohilir and Lapelopok sub-districts

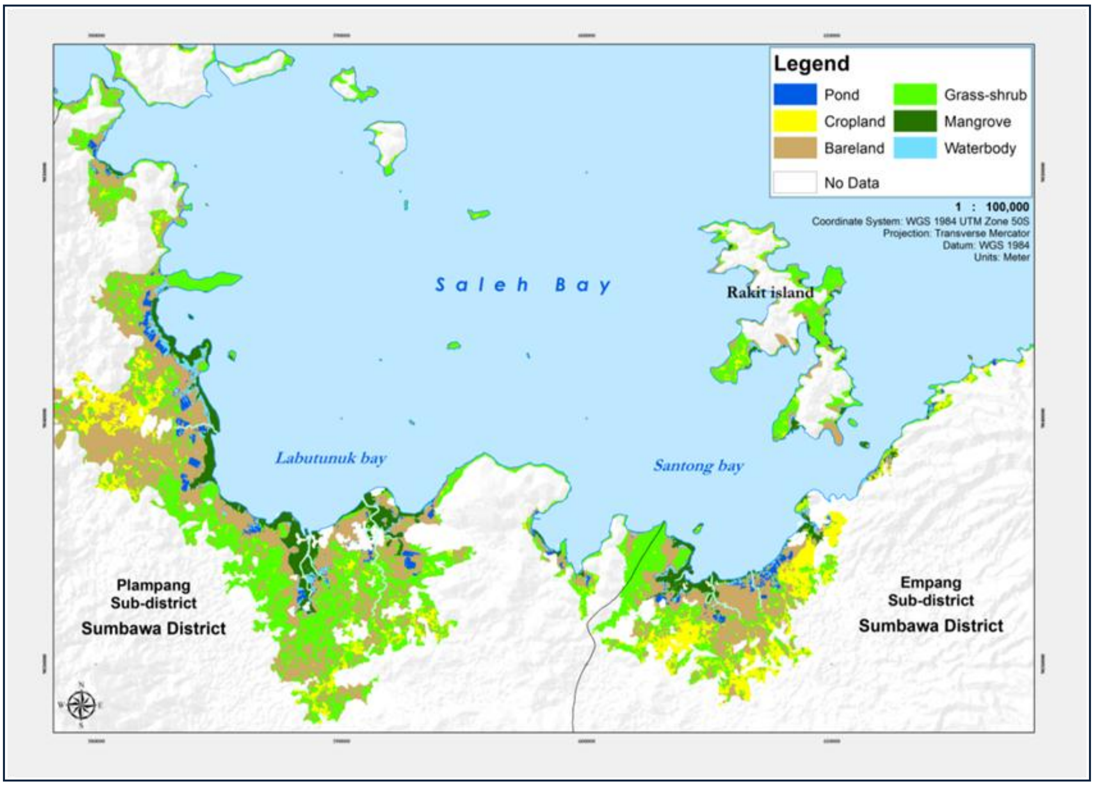


Figure 4.8 Land cover map 2009 in Plampang and Empang sub-districts

4.2.5. Summary of land cover map

Table 4.6 explain the mangrove forest and ponds in each year. Mangrove forests area amount decrease considerably from 1989 through 2009. There is annual 0.5% area decrease from 2,331.0 Ha in 1989 to 2,200.6 Ha in 2000. Nonetheless, the ponds have experienced high annual increase (40.1%) from 104.1 Ha in 1989 to 563.4 Ha in 2000.

Furthermore, from 2000 through 2006, the mangrove forests annual change rate is -3.0%. This rate is slightly faster than the ponds increase (2.4%). In 2006 to 2009 period, mangrove forest decrease turn out faster than previous period (2000-2006). The change is occurred from 1,808.9 Ha in 2006 to 1,503.4 Ha in 2009 (-5.6% annual change rate). While, ponds increase as much as 3.8% from 644.8 Ha in 2006 to 718.0 Ha in 2009. According to Table 4.7, the largest mangrove forests remains is located in Plampang sub-district. All the mangrove area within each sub-district declined from 1989 to 2009, whereas the ponds area increased. The area of bareland increased from 1989 to 2009 as well. In the contrary, the area of waterbody decrease significantly from 1989 to 2006, especially in Plampang sub-district. From 2006 to 2009, the waterbody area tended to increase.

Interesting result showed by cropland area which only increased in year 2000 for all sub-district. After 2000, the area continued to decrease until 2009. The extent of mixed grass and shrub decreased from 1989 to 2009 in all sub-district.

Table 4.6 Land cover area and change rate per year

Land cover	Area (Ha) and change rate/Δ (%)						
	1989	Δ1	2000	Δ2	2006	Δ3	2009
Mangrove	**2,331.0**	**-0.5**	**2,200.6**	**-3.0**	**1,808.9**	**-5.6**	**1,503.4**
Ponds	**104.1**	**40.1**	**563.5**	**2.4**	**644.8**	**3.8**	**718.0**
Waterbody	2,939.3	-7.7	442.9	-4.1	334.0	50.5	839.7
Bareland	5,593.7	10.2	11,859.7	1.7	13,057.9	-0.6	12,830.0
Grass-shrub	12,745.4	-4.0	7,079.4	3.4	8,519.2	1.1	8,811.1
Cropland	6,360.0	2.2	7,927.4	-4.7	5,708.8	-2.0	5,371.4
Total	30,073.5		30,073.5		30,073.5		30,073.5

Table 4.7 Area of each land cover type from 1989 to 2009 per sub-district

Land cover	Sub-districts (Ha)															
	Moyohilir				Lapelopok				Plampang				Empang			
	1989	2000	2006	2009	1989	2000	2006	2009	1989	2000	2006	2009	1989	2000	2006	2009
Mangrove	341.2	316.2	248.9	171.5	363.8	327.4	263.2	198.3	990.4	965.1	851.2	772.9	635.6	592.0	445.6	360.7
Pond	17.5	163.6	124.6	178.6	86.7	129.3	94.3	109.6	0	150.4	310.9	288.2	0	120.2	114.9	141.6
Waterbody	545.7	80.5	85.2	202.2	437.9	82.9	67.2	171.0	1,350.2	245.1	161.7	310.9	605.5	34.4	19.8	155.6
Bareland	1,482.6	5,091.9	5,311.1	4,358.9	914.5	2,115.7	2,642.6	2,967.9	2,112.3	3,442.5	3,426.1	4,025.9	1,084.3	1,209.6	1,678.0	1,477.3
Cropland	3,547.6	2,629.8	2,076.3	2,999.1	1,337.8	1,742.9	1,132.3	541.5	912.2	2,021.0	1,494.8	802.7	562.3	1,533.7	1,005.3	1,028.1
Grass-shrub	3,695.7	1,348.2	1,784.1	1,720.0	2,330.2	1,072.9	1,271.3	1,482.7	4,725.6	3,266.5	3,845.8	3,890.0	1,993.9	1,391.7	1,618.0	1,718.4
Total	9,630.3	9,630.3	9,630.3	9,630.3	5,471.0	5,471.0	5,471.0	5,471.0	10,090.6	10,090.6	10,090.6	10,090.6	4,881.7	4,881.7	4,881.7	4,881.7

4.3. Accuracy assessment

Error matrix was used for assessing the accuracy of image classification. Image classification overall accuracy for year 2009 is 76.06 % with Kappa statistic of 0.7068. Detail error matrix and complete accuracy report are shown n Table 4.7.

Table 4.8 Error matrix of land cover classification year 2009

Class	Bareland	Cropland	Grass and shrub	Mangrove	Waterbody	Pond	Total
Bareland	11	1	1	0	0	10	23
Cropland	0	6	1	0	0	0	7
Grass and shrub	0	0	9	1	0	0	10
Mangrove	0	0	0	17	1	0	18
Waterbody	1	0	0	0	4	0	5
Pond	0	0	0	0	1	0	8
Total	12	7	11	18	6	7	71

Table 4.9 Accuracy assessment of land cover classification year 2009

Class	Number Correct	Number Classified	Reference Total	Commission %	Omission %	Prod. Accuracy %	User Accuracy %
Bareland	17	18	18	52.17	8.33	91.67	47.83
Cropland	6	7	7	14.29	14.29	85.71	85.71
Grass and shrub	9	10	11	10	18.18	81.82	90
Mangrove	4	5	6	5.56	5.56	94.44	94.44
Waterbody	11	23	12	20	33.33	66.67	80
Pond	7	8	17	12.5	58.82	41.18	87.5
Total	54	71	71				
Overall Accuracy	76.06 %						

According to the accuracy assessment shown in Table 4.8, highest producer accuracy is shown by mangrove forest class (94.44%). Producer accuracy means the accuracy produce by calculating number of correct divided by the reference in specific class. It implies that mangrove forest area has the highest probability of a reference being correctly classified. Mangrove forest area has the highest user accuracy as well (94.44%). User accuracy means that number of correct divided by number of classified in specific class. It implies that mangrove forest area has the highest probability that a pixel on the map actually represents that category on the ground. Whereas, the lowest producer accuracy is pond and the lowest user accuracy is bareland.

4.4. Mangrove forests change analysis

4.4.1. Mangrove forests change 1989 - 2000

Figure 4.11 and Figure 4.12 show land cover change map from year 1989 through 2000 in the study area. On the map, the distribution of mangrove forest conversion into pond and other land cover are located in all sub-districts. On Figure 4.11, large part of other land cover converted into ponds is found in Lapelopok sub-district. Whereas, pond developments from other land covers are found in all sub-districts as well. A large pond development is found on the West side of Labutunuk bay, Plampang sub-district.

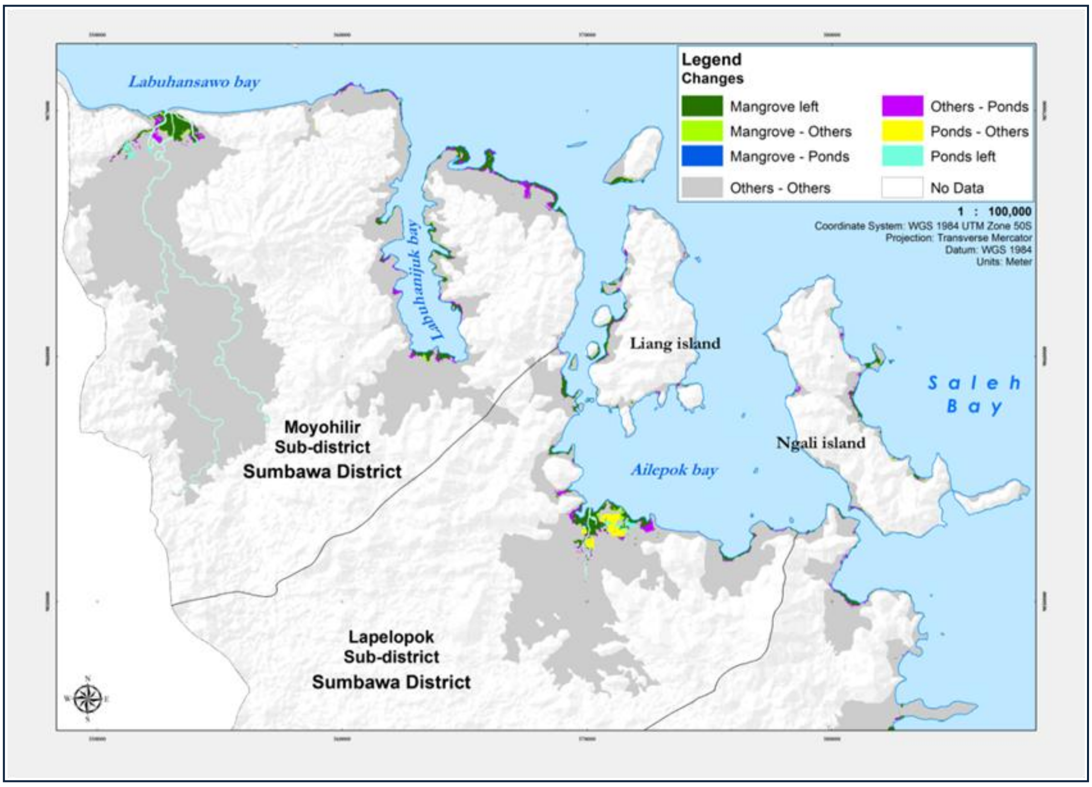


Figure 4.11 Land cover change 1989-2000 in Moyohilir and Lapelopok sub-districts

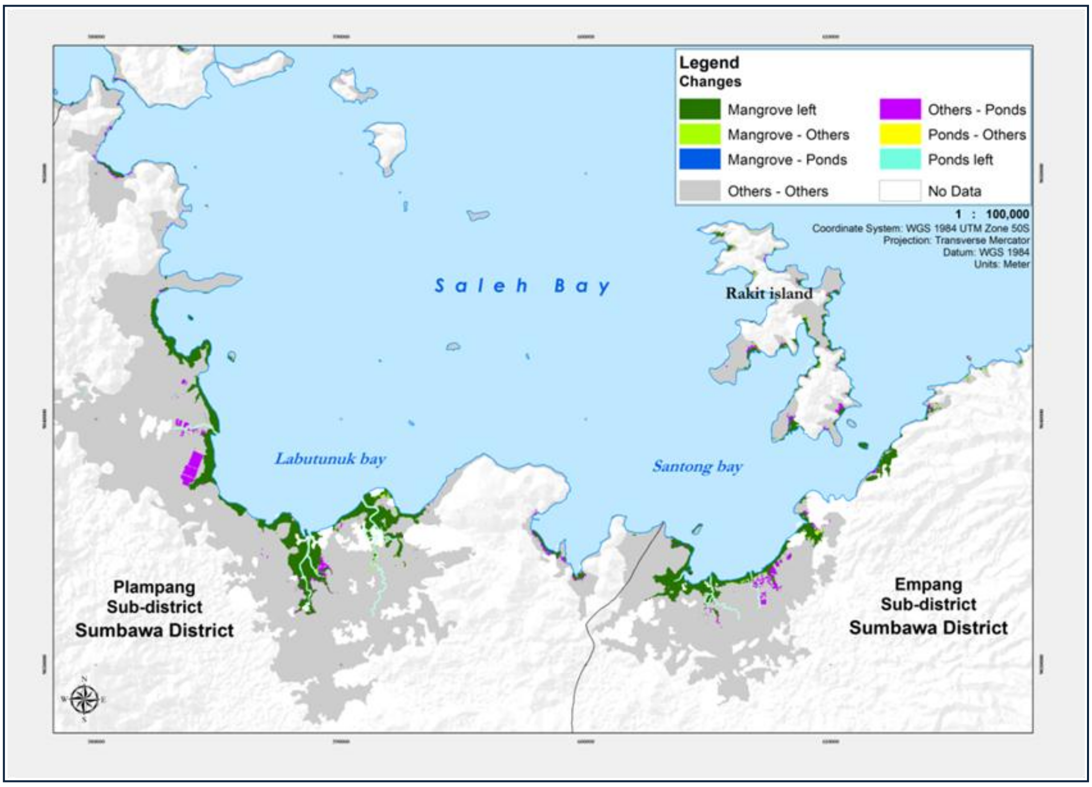


Figure 4.10 Land cover change 1989-2000 in Plampang and Empang sub-districts

According to the Table 4.9, the total mangrove forest remaining is 2,200.6 Ha or 94.4% of total mangrove forest in 1989. Furthermore, total mangrove forests conversion into ponds is 13.5 Ha (0.6%) with mainly occurred in Plampang sub-district (4.1 Ha or 0.4%). However, from 1989 to 2000, mangrove forest decrease is more caused by conversion into other land cover types rather than by ponds development. The total pond development comes from remained ponds (38 Ha or 6.9%), mangrove forests conversion (13.5 Ha or 0.6%), and other land cover types conversion (515 Ha 93.1%). The largest ponds development is occurred in Plampang sub-district with 147.8 Ha areas increase from no ponds existed before. Furthermore, the ponds development is intensively occurred in all sub-districts between 1989 and 2000.

Table 4.10 Mangrove forests change between 1989and 2000 per sub-district

Change	Area and percentage in each sub-district between 1989 and 2000									
	Moyohilir	**%**	**Lapelopok**	**%**	**Plampang**	**%**	**Empang**	**%**	**Total**	**%**
Mangrove left	316.2	92.7	327.4	90.0	965.1	97.4	592.0	93.1	2,200.6	94.4
Mangrove - Others	**22.8**	**6.7**	**32.5**	**8.9**	**21.1**	**2.1**	**40.4**	**6.3**	**116.8**	**5.0**
Mangrove - Ponds	**2.2**	**0.6**	**3.9**	**1.1**	**4.1**	**0.4**	**3.2**	**0.5**	**13.5**	**0.6**
TOTAL A	341.2	100.0	363.8	100.0	990.4	100.0	635.6	100.0	2,331.0	100.0
Others	9,126.7	98.4	4,915.4	97.9	8,952.4	98.4	4,129.0	97.2	27,123.5	98.1
Others - Ponds	144.9	1.6	105.1	2.1	147.8	1.6	117.1	2.8	515.0	1.9
TOTAL B	9,271.6	100.0	5,020.5	100.0	9,100.3	100.0	4,246.1	100.0	27,638.4	100.0
Ponds - Others	0.0	0.0	66.1	76.3	0.0	0.0	0.0	0.0	66.1	63.5
Ponds	17.5	100.0	20.5	23.7	0.0	0.0	0.0	0.0	38.0	36.5
TOTAL C	17.5	100.0	86.7	100.0	0.0	0.0	0.0	0.0	104.1	100.0
TOTAL A+B+C	9,630.3		5,471.0		10,090.6		4,881.7		30,073.5	

4.4.2. Mangrove forests change 2000 – 2006

The land cover change map between 2000 and 2006 is shown on the Figure 4.13 and Figure 4.14. The distribution of mangrove forest change occurred evenly in all four sub-districts Based on visual inspection, mangrove forest conversion into other land cover types (light green colour) is seen in small patches mainly located in Empang sub-district. On the other hand, ponds development from other land cover types (magenta) is easily found in Plampang sub-district.

The mangrove forest and ponds conversion amounts vary in each sub-district (see Table 4.10). The largest mangrove forest conversion is occurred in Plampang sub-district which is converted into other land cover types (133 Ha). The minimum area of mangrove conversion is happened in Lapelopok sub-district which is converted into ponds (11.2 Ha). The ponds development is intensively occurred in Plampang sub-district as well. The development take place in 257.7 Ha areas converted from other land cover types, 18.4 Ha areas converted from mangrove forest, and 50.1 Ha areas remained. Overall, the mangrove forests remain 1,808.2 Ha or 82.1% of the total study area, while ponds remain 292.6 Ha (42%) and they are developed from other land cover types 391.1 Ha (57.2%) and from mangrove forest 62.3 Ha (2.8%).

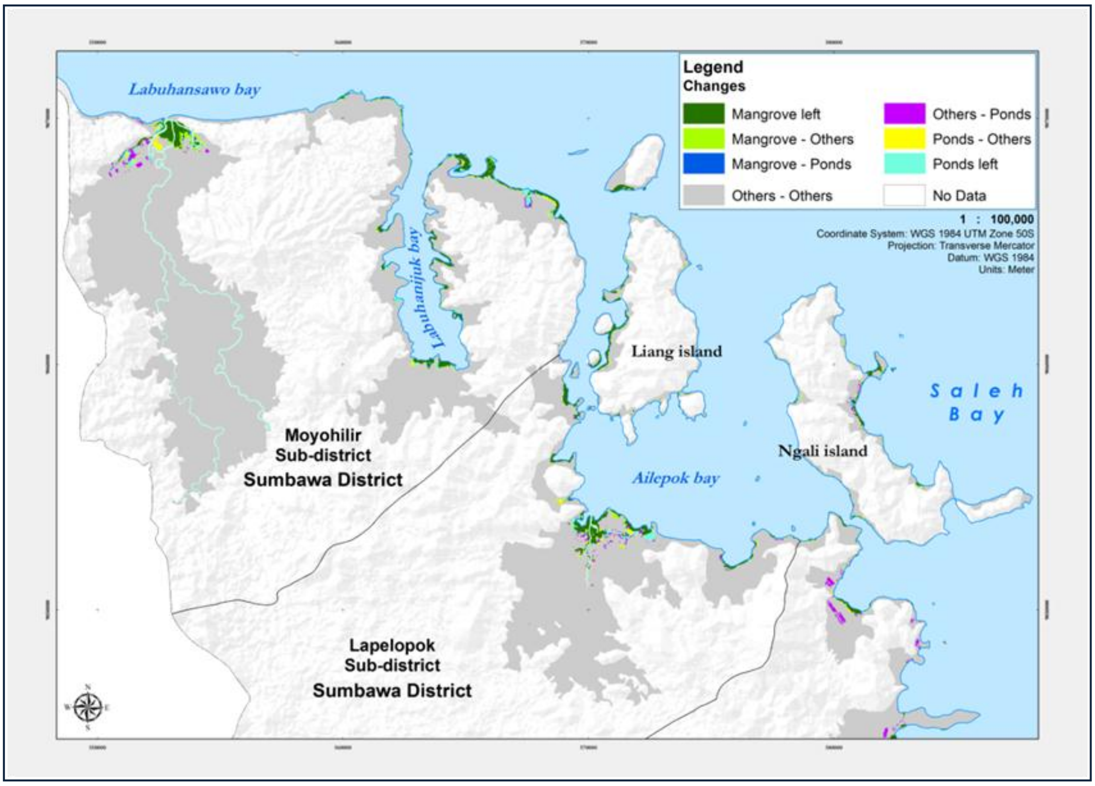


Figure 4.12 Land cover change map 2000-2006 in Moyohilir and Lapelopok sub-districts

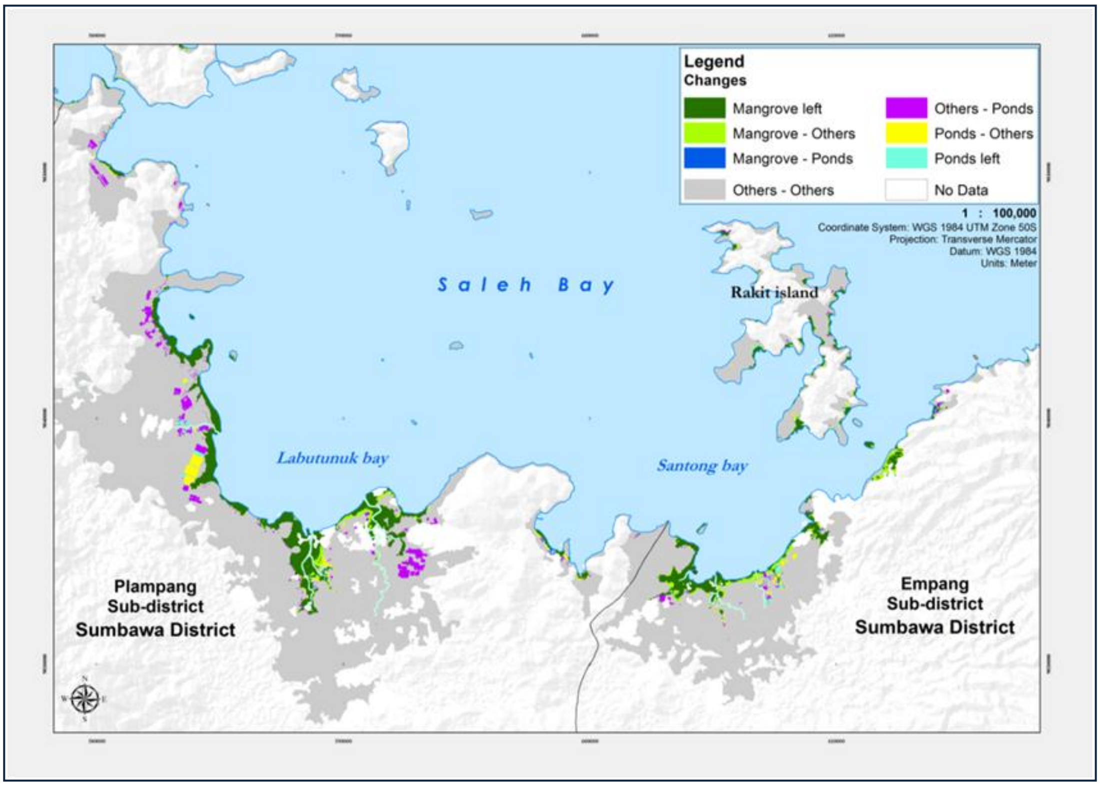


Figure 4.13 Land cover change 2000-2006 in Plampang and Empang sub-districts

Table 4.11 Mangrove forests change between 2000 and 2006 in each sub-district

Changes	Area and percentage in each sub-ditrict between 2000 and 2006									
	Moyohilir	**%**	**Lapelopok**	**%**	**Plampang**	**%**	**Empang**	**%**	**Total**	**%**
Mangrove left	248.7	78.5	262.7	80.3	851.2	88.1	445.6	75.2	1,808.2	82.1
Mangrove - Others	**49.2**	**15.5**	**53.2**	**16.3**	**96.4**	**10.0**	**133.0**	**22.5**	**331.8**	**15.1**
Mangrove - Ponds	**19.0**	**6.0**	**11.2**	**3.4**	**18.4**	**1.9**	**13.7**	**2.3**	**62.3**	**2.8**
TOTAL A	316.9	100.0	327.1	100.0	966.0	100.0	592.4	100.0	2,202.4	100.0
Others	9,107.1	99.6	4,977.6	99.2	8,717.0	97.1	4,111.6	98.6	26,913.3	98.6
Others - Ponds	38.5	0.4	37.8	0.8	257.7	2.9	57.1	1.4	391.1	1.4
TOTAL B	9,145.6	100.0	5,015.4	100.0	8,974.7	100.0	4,168.7	100.0	27,304.4	100.0
Ponds - Others	56.8	33.9	49.9	38.8	99.8	66.6	67.7	56.1	274.2	48.4
Ponds	110.9	66.1	78.6	61.2	50.1	33.4	52.9	43.9	292.6	51.6
TOTAL C	167.8	100.0	128.5	100.0	149.9	100.0	120.6	100.0	566.8	100.0
TOTAL A+B+C	9,630.3		5,471.0		10,090.6		4,881.7		30,073.5	

4.4.3. Mangrove forests change 2006 - 2009

Land cover change map between 2006 and 2009 is shown in Figure 4.15 and Figure 4.16. Based on the map, mangrove forest change into ponds (dark blue colour) is shown in small patches which are located in all four sub-districts. The pond development polygons are also commonly seen on the map. The pond development polygons are distributed evenly in each sub-district. These polygons are divided into three: pond remained (cyan), ponds developed from other land cover types (magenta), and ponds developed from mangrove forest (dark blue). These three colour combination is mainly seen in Plampang sub-district.

Table 4.11 describes the mangrove forest and pond land cover change area amount. From 2006 to 2009, total mangrove forest converted into other land cover type is 119.8 Ha or6.6% of the total mangrove forest existed in 2006, and converted into ponds is 185.7 Ha or 10.3% of the total mangrove forest existed in 2006. Moreover, the mangrove forest conversion is mainly occurred in Moyohilir sub-district. Of 24% mangrove forest in 2006 is converted into ponds. In general, from 2006 to 2009, mangrove forests remain 1,503.4 Ha or 16.9% of mangrove lost.

Between 2006 and 2009, total ponds development comes from conversion from other land cover types as much as 426.8 Ha or 50.6% of its initial area in 2006, remained ponds as much as 416.8 Ha or 49.4% of its initial area in 2006, and conversion from mangrove forest as already mentioned above.

Table 4.12 Mangrove forests change between 2006 and 2009 in each sub-district

Changes	Area and percentage in each sub-ditrict between 2006 and 2009									
	Moyohilir	**%**	**Lapelopok**	**%**	**Plampang**	**%**	**Empang**	**%**	**Total**	**%**
Mangrove left	171.5	68.9	198.3	75.3	772.9	90.8	360.7	80.9	1,503.4	83.1
Mangrove - Others	**17.7**	**7.1**	**23.2**	**8.8**	**29.4**	**3.5**	**49.5**	**11.1**	**119.8**	**6.6**
Mangrove - Ponds	**59.6**	**24.0**	**41.8**	**15.9**	**48.9**	**5.7**	**35.4**	**8.0**	**185.7**	**10.3**
TOTAL A	248.9	100.0	263.2	100.0	851.2	100.0	445.6	100.0	1,808.9	100.0
Others	9,154.6	98.9	5,046.1	98.7	8,758.9	98.1	4,233.4	98.0	27,193.0	98.5
Others - Ponds	102.1	1.1	67.3	1.3	169.6	1.9	87.7	2.0	426.8	1.5
TOTAL B	9,256.8	100.0	5,113.4	100.0	8,928.5	100.0	4,321.1	100.0	27,619.8	100.0
Ponds - Others	22.3	17.9	25.3	26.8	144.0	46.3	36.4	31.7	227.9	35.4
Ponds	102.4	82.1	69.0	73.2	166.9	53.7	78.5	68.3	416.8	64.6
TOTAL C	124.6	100.0	94.3	100.0	310.9	100.0	114.9	100.0	644.8	100.0
TOTAL A+B+C	9,630.3		5,471.0		10,090.6		4,881.7		30,073.5	

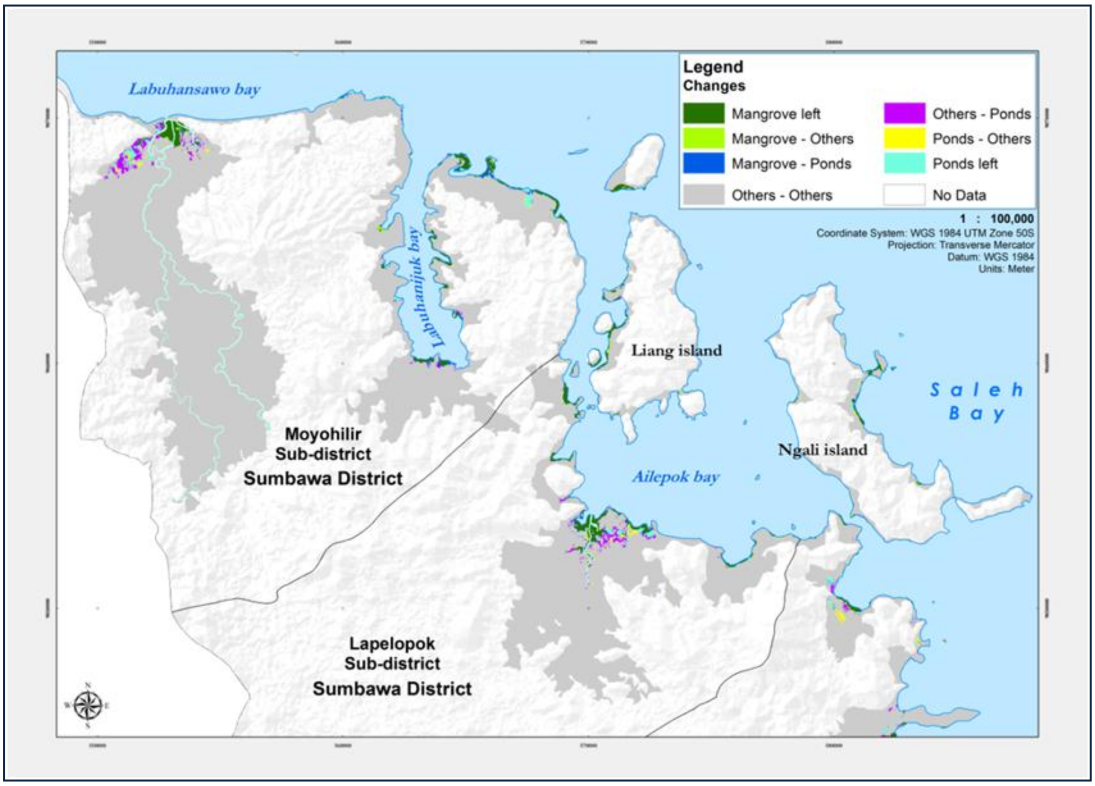


Figure 4.14 Land cover change 2000-2006 in Plampang and Empang sub-districts

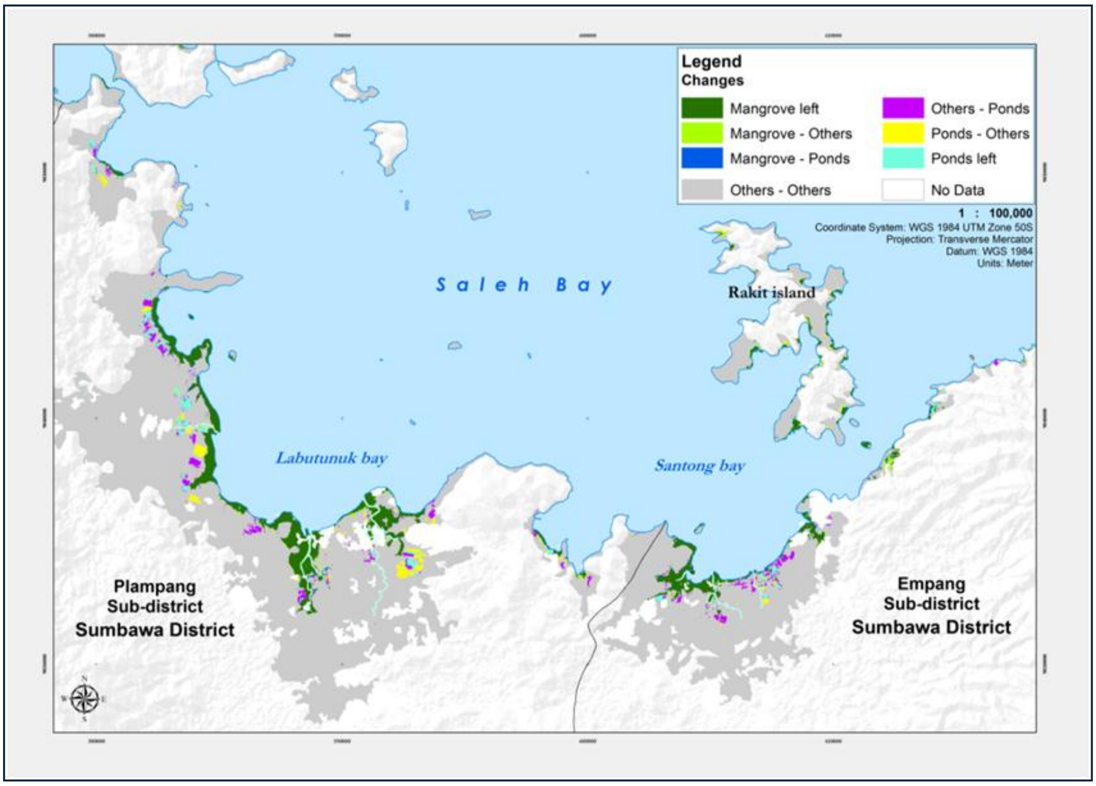


Figure 4.15 Land cover change map 2000-2006 in Moyohilir and Lapelopok sub-districts

4.4.4. Summary of mangrove forests change

Based on the Table 4.13, the largest mangrove forests change was occurred in between 2006 and 2009. The mangrove forests remained 83.1%. In the period 1989 to 2000, mangrove forests remained at 94.4%. This percentage was larger than the mangrove forests in between 2000 and 2006. The mangrove forests conversion into other land cover types is larger comparing to mangrove forests conversion into ponds from 1989 to 2006. In 2006 to 2009, the mangrove conversion into ponds exceed in percentage of mangrove forests conversion into other land cover types. The largest mangrove forests conversion into ponds was occurred in Moyohilir sub-district in between 2006 and 2009.

Table 4.13 Mangrove forests change in three different series per sub-district

Changes	Change between 1989 and 2000						Change between 2000 and 2006						Change between 2006 and 2009					
	1	2	3	4	Total	%	1	2	3	4	Total	%	1	2	3	4	Total	%
Mangrove left	592.0	327.4	316.2	965.1	2,200.6	94.4	445.6	262.7	248.7	851.2	1,808.2	82.1	360.7	198.3	171.5	772.9	1,503.4	83.1
Mangrove - Others	**40.4**	**32.5**	**22.8**	**21.1**	**116.8**	**5.0**	**133.0**	**53.2**	**49.2**	**96.4**	**331.8**	**15.1**	**49.5**	**23.2**	**17.7**	**29.4**	**119.8**	**6.6**
Mangrove - Ponds	**3.2**	**3.9**	**2.2**	**4.1**	**13.5**	**0.6**	**13.7**	**11.2**	**19.0**	**18.4**	**62.3**	**2.8**	**35.4**	**41.8**	**59.6**	**48.9**	**185.7**	**10.3**
TOTAL A	635.6	363.8	341.2	990.4	2,331.0	100.0	592.4	327.1	316.9	966.0	2,202.4	100.0	445.6	263.2	248.9	851.2	1,808.9	100.0
Others	4,129.0	4,915.4	9,126.7	8,952.4	27,123.5	98.1	4,111.6	4,977.6	9,107.1	8,717.0	26,913.3	98.6	4,233.4	5,046.1	9,154.6	8,758.9	27,193.0	98.5
Others - Ponds	117.1	105.1	144.9	147.8	515.0	1.9	57.1	37.8	38.5	257.7	391.1	1.4	87.7	67.3	102.1	169.6	426.8	1.5
TOTAL B	4,246.1	5,020.5	9,271.6	9,100.3	27,638.4	100.0	4,168.7	5,015.4	9,145.6	8,974.7	27,304.4	100.0	4,321.1	5,113.4	9,256.8	8,928.5	27,619.8	100.0
Ponds - Others	0.0	66.1	0.0	0.0	66.1	63.5	67.7	49.9	56.8	99.8	274.2	48.4	36.4	25.3	22.3	144.0	227.9	35.4
Ponds left	0.0	20.5	17.5	0.0	38.0	36.5	52.9	78.6	110.9	50.1	292.6	51.6	78.5	69.0	102.4	166.9	416.8	64.6
TOTAL C	0.0	86.7	17.5	0.0	104.1	100.0	120.6	128.5	167.8	149.9	566.8	100.0	114.9	94.3	124.6	310.9	644.8	100.0
TOTAL A+B+C	4,881.7	5,471.0	9,630.3	10,090.6	30,073.5		4,881.7	5,471.0	9,630.3	10,090.6	30,073.5		4,881.7	5,471.0	9,630.3	10,090.6	30,073.5	

1: Empang 2: Lapelopok 3: Moyohilir 4: Plampang

4.5. Mangrove forest management effectiveness

4.5.1. Management effectiveness: national level policy

4.5.1.1. Coastline buffer area

a) 1989 – 2000

First, mangrove forest area management effectiveness is assessed for period 1989 through 2000. This period determines the implementation of President Decree 32/1990 (national level policy) until the issue of autonomy law in 1999. Figure 4.16 presents the mangrove forests and pond land cover areas diagram in each buffer area between 1989 and 2000. Based on this figure, mangrove forests decrease respectively from 230 m buffer area through 690-920 m buffer area. On the contrary, ponds increase respectively from 230 m buffer area through 690-920 m buffer area.

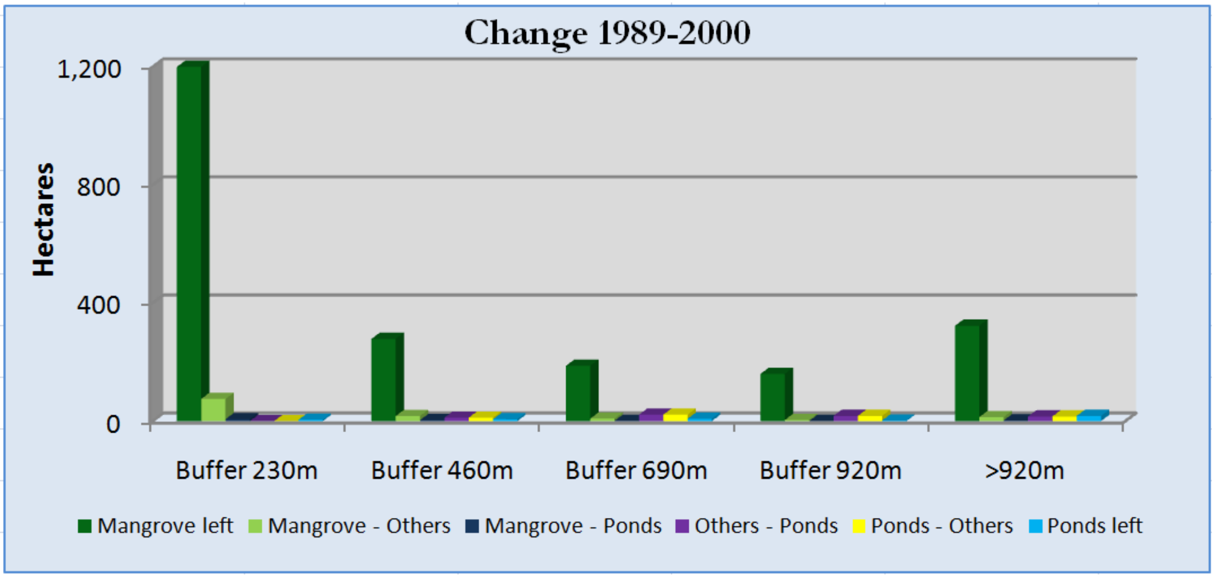


Figure 4.16 Mangrove forests change between 1989 and 2000 within coastline buffer areas

Table 4.14 Mangrove forests change area between 1989 and 2000 within coastal buffer areas

Changes	Ring of buffer area (ha & %)									
	0-230	%	230-460	%	460-690	%	690-920	%	> 920	%
Mangrove left	1,314.9	94.2	278.4	93.1	187.3	95.2	159.8	97.6	323.1	95.3
Mangrove - Others	**74.8**	**5.4**	**17.2**	**5.8**	**8.3**	**4.2**	**3.7**	**2.3**	**13.5**	**4.0**
Mangrove - Ponds	**6.4**	**0.5**	**3.4**	**1.1**	**1.2**	**0.6**	**0.3**	**0.2**	**2.3**	**0.7**
Total A	1,396.2	100.0	299.0	100.0	196.9	100.0	163.8	100.0	339.0	100.0
Others	3,711.1	92.8	2,067.1	96.9	1,450.5	97.7	1,217.5	96.3	18,748.6	99.4
Others - Ponds	286.7	7.2	66.4	3.1	34.4	2.3	46.3	3.7	113.6	0.6
Total B	3,997.8	100.0	2,133.6	100.0	1,484.8	100.0	1,263.8	100.0	18,862.2	100.0
Ponds - Others	0.0	0.0	11.6	65.2	21.5	73.1	17.5	89.3	15.5	47.1
Ponds	4.3	100.0	6.2	34.8	7.9	26.9	2.1	10.7	17.5	52.9
Total C	4.3	100.0	17.8	100.0	29.4	100.0	19.6	100.0	33.0	100.0
Total A+B+C	5,398.3		2,450.3		1,711.1		1,447.2		19,234.2	

Table 4.14 above explains the mangrove forest and pond land cover areas in each buffer area between 1989 and 2000. Remained mangrove forests respectively from 230 m to >920 m buffer area is 1,314.9 Ha, 278.4 Ha, 187.3 Ha, 159.8 Ha, and 323.1 Ha. There is large difference between mangrove forests in 230 m and 230-460 m buffer area. This is because the mangrove forests existence in 230 m buffer area is much larger than other buffer areas. The same condition is occurred to mangrove forests conversion into ponds as well. Mangrove forests conversion into ponds (6.4 Ha) and into other land cover types (74.8 Ha) are mainly occurred in 230 m buffer area, and then they decrease respectively as they go far from coastline.

b) 2000 - 2006

Second, mangrove forest area management effectiveness is assessed for period 2000 through 2006. Basically, this period designates the issue of autonomy law through the issue of province spatial planning regulation (province level policy). The result shows in the Figure 4.17. According to the Figure 4.18 below, the land cover change is largely occurred in 230 m national buffer area. As it goes far behind the coastline, the land cover change is getting less and less. The different condition is occurred to >920 m buffer area because the area extent is much different than the other buffer areas.

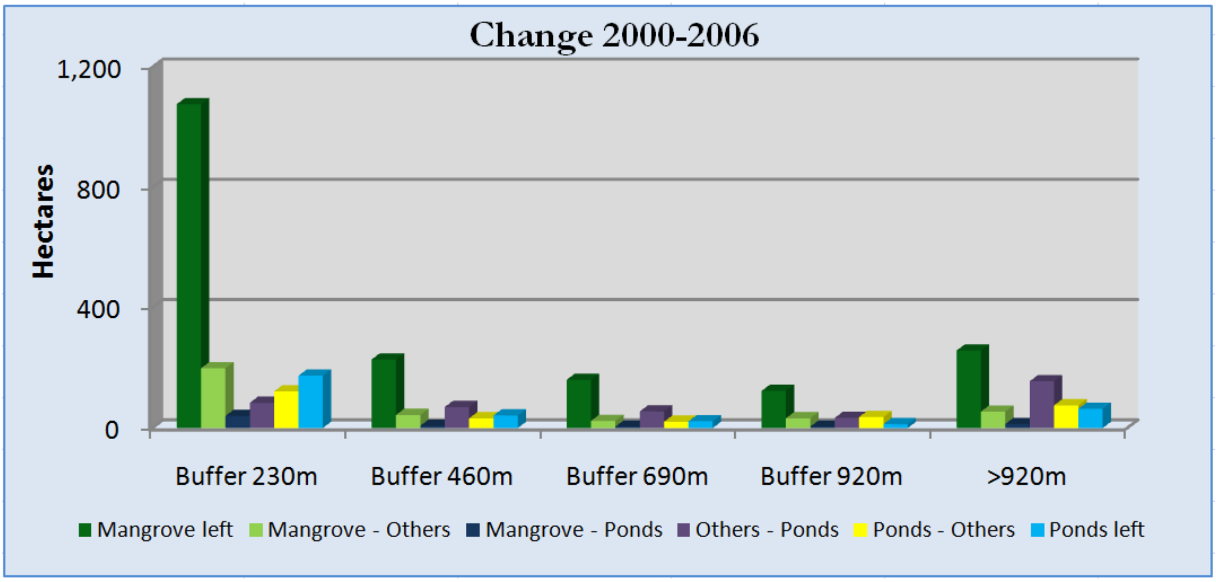


Figure 4.17 Mangrove forests change between 2000 and 2006 within coastline buffer areas

According to the Table 4.15 above, all land cover conversion, especially mangrove forests that are occurred from largest area within 230 m buffer area into smallest area within 690-920 m buffer area respectively. Mangrove forests conversion into other land cover types (198.4 Ha or 3.7%) and ponds (39.8 Ha or 0.7%) are mainly occurred within 230 m national buffer area. Similar to mangrove conversion, remained ponds (173.9 Ha or 3.2%) is mainly located within 230 m national buffer area as well. On the contrary, other land cover types conversion into ponds is largely occurred in the >920 m buffer area (155.1 Ha).

Table 4.15 Mangrove forests change area between 2000 and 2006 within coastal buffer areas

Changes	Ring of buffer area (ha & %)									
	0-230	%	230-460	%	460-690	%	690-920	%	> 920	%
Mangrove left	1,076.7	81.9	227.7	81.8	160.0	85.3	123.3	77.1	257.2	79.3
Mangrove - Others	**198.4**	**15.1**	**43.2**	**15.5**	**23.4**	**12.5**	**32.1**	**20.1**	**54.3**	**16.7**
Mangrove - Ponds	**39.8**	**3.0**	**7.5**	**2.7**	**4.3**	**2.3**	**4.5**	**2.8**	**13.0**	**4.0**
Total A	1,314.9	100.0	278.4	100.0	187.6	100.0	159.9	100.0	324.5	100.0
Others	3,704.1	97.8	2,028.6	96.7	1,425.9	96.3	1,205.1	97.3	18,616.2	99.2
Others - Ponds	83.6	2.2	69.6	3.3	54.7	3.7	33.4	2.7	155.1	0.8
Total B	3,787.7	100.0	2,098.2	100.0	1,480.7	100.0	1,238.5	100.0	18,771.3	100.0
Ponds - Others	121.7	41.2	32.1	43.6	20.8	48.5	36.3	74.3	75.1	54.3
Ponds	173.9	58.8	41.6	56.4	22.0	51.5	12.5	25.7	63.3	45.7
Total C	295.7	100.0	73.7	100.0	42.8	100.0	48.8	100.0	138.4	100.0
Total A+B+C	5,398.3		2,450.3		1,711.1		1,447.2		19,234.2	

c) 2006 – 2009

At last, mangrove forest management effectiveness is analysed by using buffer area which is drawn from President Decree 32/1990 as well for land cover change from 2006 through 2009. Furthermore, from the map overlay result, the Figure 4.18 and Table 4.16 show the land cover change within each buffer area. As seen on the Figure 4.18, the land cover change is mainly happened within 230 m buffer area, such as: mangrove forests conversion and ponds development.

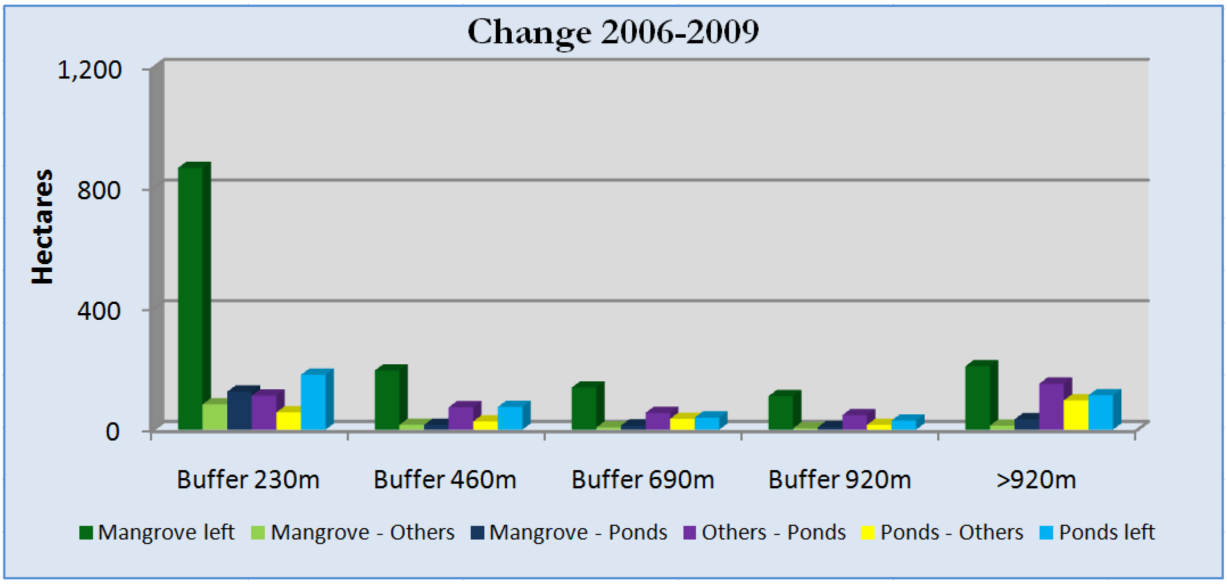


Figure 4.18 Mangrove forests change between 2006 and 2009 within coastline buffer areas

Based on Table 4.16, mangrove forests remain from 230 m to >920 m buffer area respectively is 867.6 Ha, 196.2 Ha, 139.5 Ha, 110.9 Ha, and 210.1 Ha. Mangrove forest conversion into pond (125.6 Ha) is dominantly occurred within 230 meter buffer area. Mangrove forests conversion into ponds amount decreases respectively from 230 m national buffer area (125.6 Ha) through 690-920 m buffer area (8.2 Ha). In addition, it is known that larger ponds comes from other land cover type conversion (112.7 Ha) and remained ponds (181.8 Ha) are located within this national level policy buffer area as well. The total ponds in national level policy buffer area are 420.1 Ha.

Table 4.16 Mangrove forests change between 2006 and 2009 within coastal buffer area

Changes	Ring of buffer area (ha & %)									
	0-230	%	230-460	%	460-690	%	690-920	%	> 920	%
Mangrove left	867.6	80.6	196.2	86.2	139.5	87.2	110.9	89.9	210.1	81.5
Mangrove - Others	**83.7**	**7.8**	**15.8**	**6.9**	**7.1**	**4.5**	**4.2**	**3.4**	**13.2**	**5.1**
Mangrove - Ponds	**125.6**	**11.7**	**15.7**	**6.9**	**13.4**	**8.4**	**8.2**	**6.7**	**34.4**	**13.4**
Total A	1,076.9	100.0	227.7	100.0	160.0	100.0	123.3	100.0	257.8	100.0
Others	3,969.8	97.2	2,045.7	96.5	1,419.8	96.2	1,230.0	96.2	18,613.9	99.2
Others - Ponds	112.7	2.8	74.1	3.5	55.6	3.8	48.0	3.8	152.0	0.8
Total B	4,082.5	100.0	2,119.8	100.0	1,475.4	100.0	1,278.1	100.0	18,765.9	100.0
Ponds - Others	57.1	23.9	27.4	26.7	35.8	47.3	15.8	34.3	96.7	45.9
Ponds	181.8	76.1	75.4	73.3	39.9	52.7	30.2	65.7	113.8	54.1
Total C	238.9	100.0	102.8	100.0	75.8	100.0	45.9	100.0	210.5	100.0
Total A+B+C	5,398.3		2,450.3		1,711.1		1,447.2		19,234.2	

4.5.1.2. River buffer area

a) 1989 - 2000

River buffer area analysis is included in the implementation of President Decree 32/1990 (national level policy) as well. This analysis is used Main River as reference for building buffer areas. Figure 4.19 explain the mangrove forests and pond land cover areas diagram in each river buffer area between 1989 and 2000. Based on this figure, mangrove forests decrease respectively from 100 m buffer area through 400-500 m buffer area. Similar to mangrove forests, ponds converted from other land cover types decrease respectively from 100 m buffer area through 400-500 m buffer area as well.

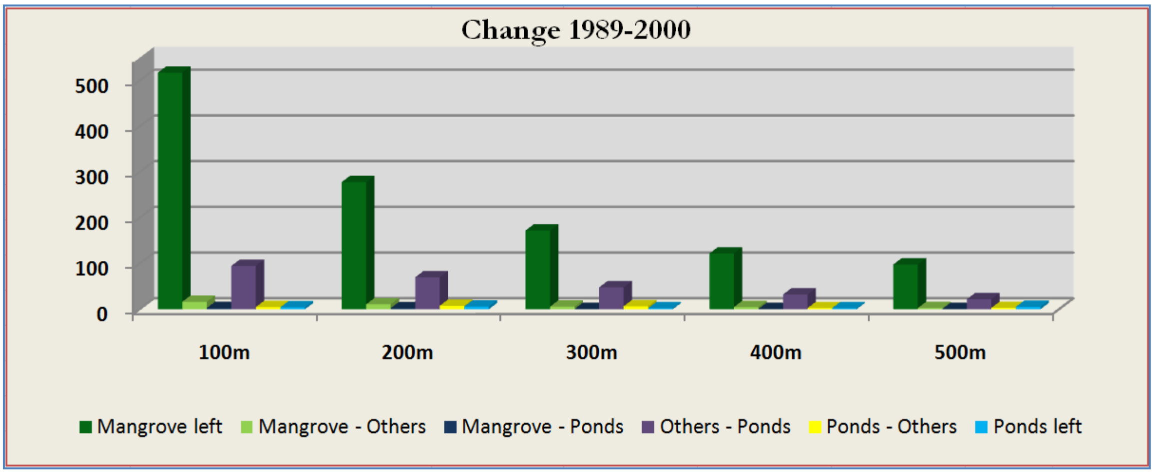


Figure 4.19 Mangrove forests change between 1989 and 2000 within river buffer areas

Table 4.17 explains the mangrove forest and pond land cover areas in each buffer area between 1989 and 2000. Remained mangrove forests respectively from 100 m to 400-500 m buffer area is 517.9 Ha, 278.4 Ha, 172.5 Ha, 122.2 Ha, and 98.1 Ha. There is large difference between mangrove forests in 100 m and 500 m buffer area. This is because of the remained mangrove forests in 100 m buffer area is much larger than other buffer areas. The same condition is occurred to mangrove forests conversion into ponds as well. Mangrove forests conversion into ponds (2.9Ha) and into other land cover types (16.5 Ha) are mainly occurred in 100 m buffer area, and then they decrease respectively as they go far from river.

Table 4.17 Mangrove forests change area between 1989 and 2000 within river buffer areas

Change	Ring of buffer area (Ha & %)									
	0-100m	**%**	**100-200m**	**%**	**200-300m**	**%**	**300-400m**	**%**	**400-500m**	**%**
Mangrove left	517.9	96.4	278.4	95.4	172.5	96.3	122.2	95.5	98.1	96.7
Mangrove - Others	**16.5**	**3.1**	**10.9**	**3.7**	**5.9**	**3.3**	**4.9**	**3.8**	**2.7**	**2.6**
Mangrove - Ponds	**2.9**	**0.5**	**2.5**	**0.9**	**0.8**	**0.4**	**0.8**	**0.7**	**0.7**	**0.7**
Total A	537.3	100.0	291.8	100.0	179.2	100.0	127.9	100.0	101.5	100.0
Others	3,097.5	97.0	2,635.4	97.4	2,305.9	98.0	2,007.5	98.4	1,721.3	98.7
Others - Ponds	95.0	3.0	70.1	2.6	48.0	2.0	32.3	1.6	22.1	1.3
Total B	3,192.5	100.0	2,705.5	100.0	2,353.8	100.0	2,039.8	100.0	1,743.4	100.0
Ponds - Others	4.9	53.8	7.7	55.9	6.6	74.2	2.6	52.2	3.1	36.6
Ponds left	4.2	46.2	6.0	44.1	2.3	25.8	2.3	47.8	5.4	63.4
Total C	9.2	100.0	13.7	100.0	8.9	100.0	4.9	100.0	8.6	100.0
Total A+B+C	3,739.0		3,011.0		2,541.9		2,172.6		1,853.5	

b) 2000 - 2006

Mangrove forest area management effectiveness is assessed for period 2000 through 2006 as well. The result shows in the Figure 4.20. According to the Figure 4.20, the land cover change is largely occurred in 100 m national river buffer area. As it goes far from the river side, the land cover change is getting less and less. This condition is happened in almost all of land cover change types, except for pond conversion from other land use types. On the graphic, other land use types change into ponds in 100-200m buffer area is higher than in 100 m buffer area.

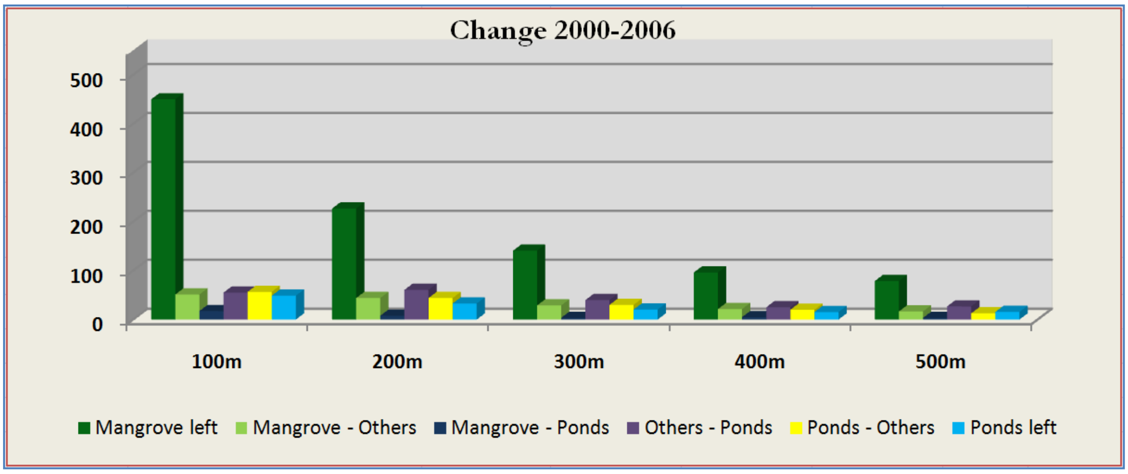


Figure 4.20 Mangrove forests change between 2000 and 2006 within river buffer areas

According to the Table 4.18, all land cover conversion, especially mangrove forests change are occurred from largest area within 100 m buffer area into smallest area within 500 m buffer area respectively. Mangrove forests conversion into other land cover types (51 Ha or 1.4%) and ponds (17.3 Ha or 0.5%) are mainly occurred within 100 m national buffer area. Similar to mangrove conversion, remained ponds (48.8 Ha or 1.3%) is mainly located within 100 m national buffer area as well.

Table 4.18 Mangrove forests change area between 2000 and 2006 within river buffer areas

Change	Ring of buffer area (Ha & %)									
	0-100m	%	100-200m	%	200-300m	%	300-400m	%	400-500m	%
Mangrove left	450.0	86.8	226.8	81.4	140.6	81.4	96.2	78.6	78.6	80.0
Mangrove - Others	**51.0**	**9.8**	**43.9**	**15.8**	**28.8**	**16.6**	**21.3**	**17.4**	**16.4**	**16.7**
Mangrove - Ponds	**17.3**	**3.3**	**7.8**	**2.8**	**3.5**	**2.0**	**4.9**	**4.0**	**3.2**	**3.3**
Total A	518.4	100.0	278.5	100.0	172.8	100.0	122.4	100.0	98.2	100.0
Others	3,060.4	98.2	2,595.3	97.7	2,279.4	98.3	1,989.9	98.8	1,700.4	98.5
Others - Ponds	55.0	1.8	60.5	2.3	39.6	1.7	25.0	1.2	26.8	1.5
Total B	3,115.3	100.0	2,655.8	100.0	2,319.0	100.0	2,014.9	100.0	1,727.2	100.0
Ponds - Others	56.5	53.7	43.9	57.2	29.8	59.4	19.9	56.5	12.6	45.0
Ponds left	48.8	46.3	32.8	42.8	20.3	40.6	15.3	43.5	15.5	55.0
Total C	105.3	100.0	76.7	100.0	50.1	100.0	35.3	100.0	28.1	100.0
Total A+B+C	3,739.0		3,011.0		2,541.9		2,172.6		1,853.5	

c) 2006 - 2009

At last, mangrove forest management effectiveness is analysed by using river buffer area for land cover change from 2006 through 2009 as well. Furthermore, from the map overlay result, the Figure 4.21 and Table 4.19 below explain the land cover change within each buffer area. As seen on the Figure 4.21, the land cover change is mainly happened within 100 m buffer area, such as: mangrove forests conversion and ponds development.

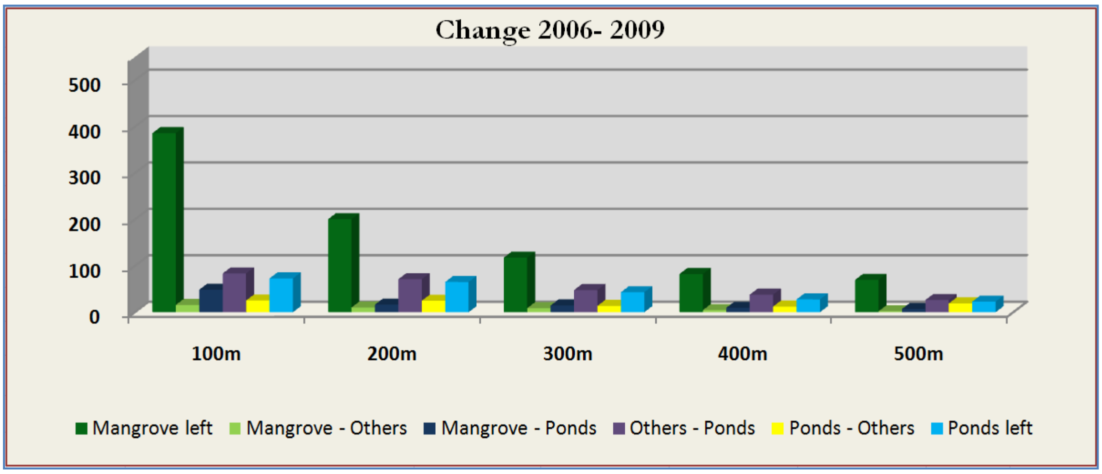


Figure 4.21 Mangrove forests change between 2006 and 2009 within river buffer areas

Based on Table 4.19, mangrove forests remain from 100 m to 400-500 m buffer area respectively is 385.9 Ha, 200.5 Ha, 117.6 Ha, 82.3 Ha, and 69.7 Ha. Mangrove forest conversion into pond (58.5 Ha) is dominantly occurred within 100 meter buffer area. Mangrove forests conversion into ponds amount decreases respectively from 100 m national buffer area (48.5 Ha) through 400-500 m buffer area (7.0 Ha). In addition, larger ponds coming from other land cover type conversion (83.5 Ha) and remained ponds (72.8 Ha) are located within this national level policy buffer area as well. The total ponds in the national level policy buffer area are 204.8 Ha.

Table 4.19 Mangrove forests change area between 2006 and 2009 within river buffer areas

Change	Ring of buffer area (Ha & %)									
	0-100m	%	100-200m	%	200-300m	%	300-400m	%	400-500m	%
Mangrove left	517.9	96.4	278.4	95.4	172.5	96.3	122.2	95.5	98.1	96.7
Mangrove - Others	**16.5**	**3.1**	**10.9**	**3.7**	**5.9**	**3.3**	**4.9**	**3.8**	**2.7**	**2.6**
Mangrove - Ponds	**2.9**	**0.5**	**2.5**	**0.9**	**0.8**	**0.4**	**0.8**	**0.7**	**0.7**	**0.7**
Total A	537.3	100.0	291.8	100.0	179.2	100.0	127.9	100.0	101.5	100.0
Others	3,097.5	97.0	2,635.4	97.4	2,305.9	98.0	2,007.5	98.4	1,721.3	98.7
Others - Ponds	95.0	3.0	70.1	2.6	48.0	2.0	32.3	1.6	22.1	1.3
Total B	3,192.5	100.0	2,705.5	100.0	2,353.8	100.0	2,039.8	100.0	1,743.4	100.0
Ponds - Others	4.9	53.8	7.7	55.9	6.6	74.2	2.6	52.2	3.1	36.6
Ponds left	4.2	46.2	6.0	44.1	2.3	25.8	2.3	47.8	5.4	63.4
Total C	9.2	100.0	13.7	100.0	8.9	100.0	4.9	100.0	8.6	100.0
Total A+B+C	3,739.0		3,011.0		2,541.9		2,172.6		1,853.5	

4.5.1.3. Summary of national policy management effectiveness

From the Table 4.20 and Table 4.21, the mangrove forests decreased from 1989 to 2009 in both coastline and river buffer areas. In between 1989 to 2000, mangrove forests area within coastal buffer area effectively prevent at 94%. The percentage decreased in between 2000 and 2006 with the percentage at only 82.7%. Finally in between 2006 and 2009, the remained mangrove forests percentage was 81.2%. The condition was better in the river buffer area. Mangrove forests remained in between 1989 and 2000 was 96.4%.

Table 4.20 Area within national level coastal buffer area

Changes	Area within 230 m buffer between 1989 and 2000						Area within 230 m buffer between 2000 and 2006						Area within 230 m buffer between 2006 and 2009					
	1	2	3	4	Total	%	1	2	3	4	Total	%	1	2	3	4	Total	%
Mangrove left	369.9	263.0	193.5	443.7	1,270.0	**94.0**	282.4	209.6	160.4	397.7	1,050.2	**82.7**	226.2	158.2	103.9	364.6	852.9	**81.2**
Mangrove - Others	**29.3**	**23.9**	**11.7**	**9.2**	**74.1**	**5.5**	**79.2**	**44.2**	**23.7**	**37.7**	**184.8**	**14.5**	**32.6**	**21.5**	**12.1**	**14.2**	**80.4**	**7.7**
Mangrove - Ponds	**1.8**	**1.2**	**0.6**	**2.8**	**6.3**	**0.5**	**8.3**	**9.2**	**9.3**	**8.3**	**35.1**	**2.8**	**23.6**	**29.9**	**44.6**	**18.9**	**117.0**	**11.1**
Total A	401.0	288.0	205.8	455.6	1,350.4	100.0	369.9	263.0	193.5	443.7	1,270.0	100.0	282.4	209.6	160.6	397.7	1,050.3	100.0
Others	849.9	1,040.6	890.6	892.7	3,673.9	93.3	854.8	1,047.2	895.2	872.8	3,670.0	97.9	940.5	1,126.6	950.6	904.2	3,921.9	97.5
Others - Ponds	57.3	73.9	95.0	36.5	262.7	6.7	24.5	17.5	7.4	30.4	79.8	2.1	30.4	18.5	20.0	32.5	101.4	2.5
Total B	907.2	1,114.5	985.7	929.2	3,936.6	100.0	879.2	1,064.7	902.6	903.2	3,749.8	100.0	970.9	1,145.1	970.6	936.7	4,023.4	100.0
Ponds - Others	0.0	0.0	0.0	0.0	0.0	0.0	31.5	33.3	28.2	20.0	113.1	41.6	18.1	13.4	8.0	14.1	53.6	24.6
Ponds left	0.0	4.3	0.0	0.0	4.3	100.0	27.5	45.9	67.2	17.9	158.5	58.4	36.8	38.8	52.2	36.3	164.0	75.4
Total C	0.0	4.3	0.0	0.0	4.3	100.0	59.1	79.2	95.4	37.9	271.5	100.0	54.9	52.1	60.2	50.4	217.6	100.0
Total A+B+C	1,308.2	1,406.9	1,191.4	1,384.8	5,291.3		1,308.2	1,406.9	1,191.4	1,384.8	5,291.3		1,308.2	1,406.9	1,191.4	1,384.8	5,291.3	

1: Empang 2: Lapelopok 3: Moyohilir 4: Plampang

Table 4.21 Area within national level river buffer area

Changes	Area within 100 m buffer between 1989 and 2000						Area within 100 m buffer between 2000 and 2006						Area within 100 m buffer between 2006 and 2009					
	1	2	3	4	Total	%	1	2	3	4	Total	%	1	2	3	4	Total	%
Mangrove	113.0	56.9	83.9	261.8	515.5	**96.4**	90.0	52.0	67.7	238.7	448.5	**86.9**	79.2	43.2	51.3	211.2	384.9	**85.8**
Mangrove - Others	**4.5**	**0.5**	**4.2**	**7.3**	**16.5**	**3.1**	**19.4**	**3.6**	**9.6**	**18.1**	**50.7**	**9.8**	**4.0**	**0.5**	**3.7**	**7.4**	**15.6**	**3.5**
Mangrove - Ponds	**0.0**	**0.4**	**1.1**	**1.4**	**2.9**	**0.5**	**3.7**	**1.2**	**6.5**	**5.3**	**16.7**	**3.2**	**6.8**	**8.3**	**12.6**	**20.2**	**48.0**	**10.7**
Total A	117.5	57.7	89.2	270.5	534.9	100.0	113.1	56.9	83.9	262.1	515.9	100.0	90.0	52.0	67.7	238.7	448.5	100.0
Others	587.1	293.0	986.3	1,229.5	3,095.9	97.1	579.2	294.8	980.9	1,203.9	3,058.8	98.2	599.0	300.8	985.9	1,220.0	3,105.7	97.4
Others - Ponds	26.8	14.1	22.7	30.0	93.7	2.9	12.1	3.1	6.4	33.1	54.8	1.8	18.6	8.7	29.0	27.0	83.2	2.6
Total B	613.9	307.1	1,009.0	1,259.5	3,189.5	100.0	591.3	297.8	987.4	1,237.1	3,113.5	100.0	617.6	309.4	1,014.8	1,246.9	3,188.8	100.0
Ponds - Others	0.0	4.9	4.2	0.0	9.1	99.3	17.2	6.8	11.5	21.0	56.5	54.3	7.0	2.0	1.7	14.3	25.1	26.0
Ponds left	0.0	0.1	0.0	0.0	0.1	0.7	9.9	8.4	19.6	9.8	47.6	45.7	16.8	6.3	18.1	30.0	71.2	74.0
Total C	0.0	5.0	4.2	0.0	9.2	100.0	27.1	15.2	31.1	30.8	104.1	100.0	23.8	8.4	19.8	44.3	96.3	100.0
Total A+B+C	731.5	369.8	1,102.3	1,530.0	3,733.6		731.5	369.8	1,102.3	1,530.0	3,733.6		731.5	369.8	1,102.3	1,530.0	3,733.6	

1: Empang 2: Lapelopok 3: Moyohilir 4: Plampang

4.5.2. Management effectiveness: provincial level policy

At the provincial level policy, mangrove forest area management effectiveness was assessed using the spatial planning map 2006 and land cover change map 2006 – 2009. As it is known before that provincial spatial planning map 2006 was revised in 2009, thus its active period is only from 2006 through 2009. The maps presented the land cover change map between 2006 and 2009 which is overlaid with the spatial planning map of 2006 (***Appendix 5***). The maps help to investigate visually the mangrove forest conversion location. On the map, mangrove forests conversion within mangrove protected area (striped red polygons) is occurred in all four sub-districts. The largest area is found in Plampang sub-district.

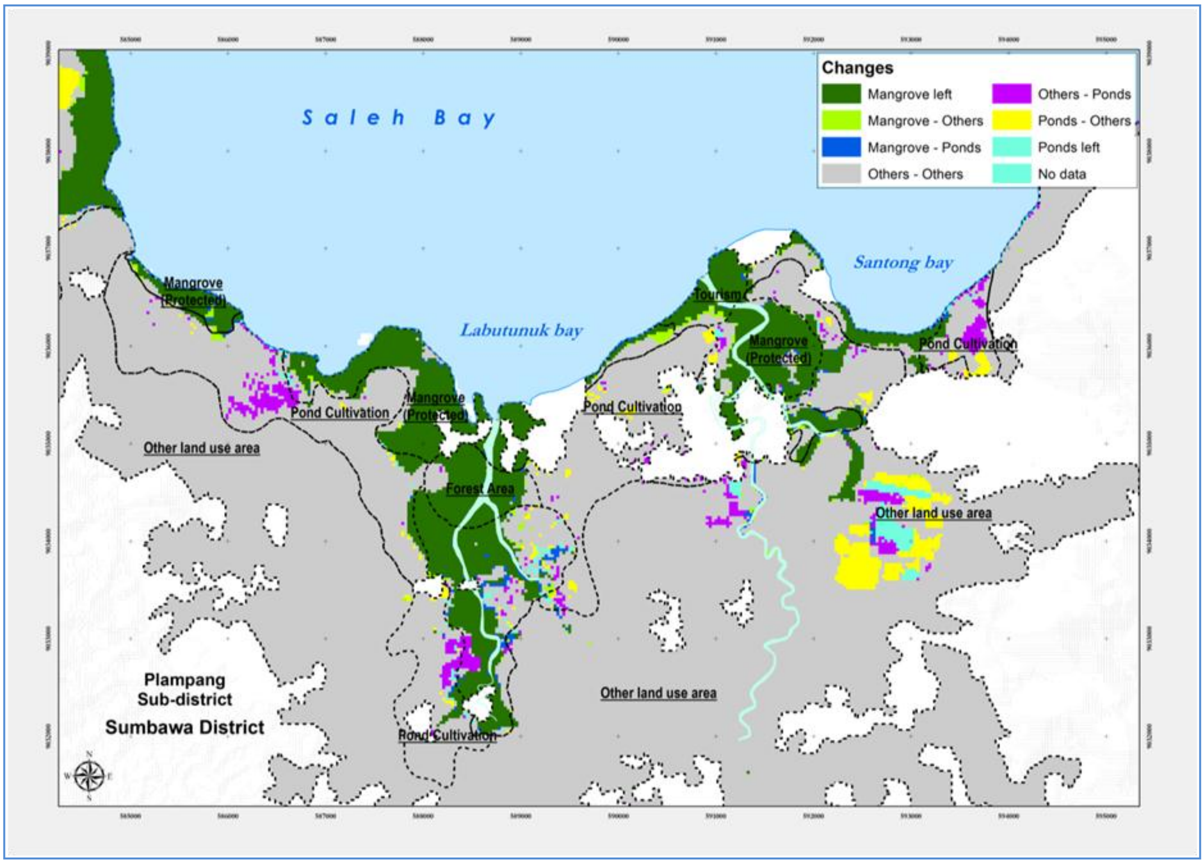


Figure 4.22 Mangrove forests change 2006-2009 within spatial planning 2006 map in the part of Plampang sub-districts

According to the Table 4.22, mangrove forests conversion occurred within mangrove protected area noticed is composed of mangrove forests conversion into ponds (58.6 Ha or 6.6%) and into other land cover types (23.2 Ha or 2.6%). Whereas, of 278.8 Ha mangrove forests remain in 2009 are categorized as pond cultivation in province spatial planning 2006. Overall, between 2006 and 2009, mangrove forests remain within mangrove protected area in spatial planning are 809.9 Ha or 90.8% of the total area, in 2009. As much as 319 Ha within mangrove protected area is occupied by other land cover types and from ponds conversion into other land cover types (9.4 Ha). On the other side, ponds occupy 53.4 Ha of mangrove protected area coming from pond development from other land cover types (24.9 Ha) and from remained ponds (28.5 Ha).

Table 4.22 Mangrove forests change within spatial planning 2006 categories

Change	Spatial Plan 2006																	
	Forested area								Non-forested area									
	Mangrove (Protected)		Mangrove (Tourism)		Forest		Total		Tourism		Pond Cultivation		Other land use		Total	%	Total	%
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%				
Mangrove left	809.9	**90.8**	29.3	**93.9**	52.5	**98.2**	891.7	**91.3**	177.9	**72.5**	278.8	**80.6**	155.0	**64.3**	611.6	**73.5**	1,503.4	**83.1**
Mangrove - Others	**23.2**	**2.6**	**1.0**	**3.2**	**0.2**	**0.4**	**24.4**	**2.5**	**41.3**	**16.8**	**14.9**	**4.3**	**39.1**	**16.2**	**95.4**	**11.5**	**119.8**	**6.6**
Mangrove - Ponds	**58.6**	**6.6**	**0.9**	**2.8**	**0.8**	**1.4**	**60.3**	**6.2**	**26.3**	**10.7**	**52.2**	**15.1**	**47.0**	**19.5**	**125.4**	**15.1**	**185.7**	**10.3**
Total A	891.7	100.0	31.2	100.0	53.5	100.0	976.5	100.0	245.4	100.0	346.0	100.0	241.1	100.0	832.5	100.0	1,808.9	100.0
Others - Others	319.0	92.7	9.4	100.0	12.4	98.6	340.7	93.1	1,978.6	99.2	3,167.6	91.0	21,706.2	99.7	26,852.3	98.5	27,193.0	98.5
Others - Ponds	24.9	7.3	0.0	0.0	0.2	1.4	25.1	6.9	15.3	0.8	314.2	9.0	72.2	0.3	401.7	1.5	426.8	1.5
Total B	343.9	100.0	9.4	100.0	12.6	100.0	365.8	100.0	1,993.8	100.0	3,481.7	100.0	21,778.4	100.0	27,254.0	100.0	27,619.8	100.0
Ponds - Others	9.4	24.8	0.2	23.7	0.1	100.0	9.7	24.9	23.7	45.3	110.6	31.3	83.9	42.0	218.3	36.0	227.9	35.4
Ponds left	28.5	75.2	0.7	76.3	0.0	0.0	29.2	75.1	28.6	54.7	243.2	68.7	115.9	58.0	387.7	64.0	416.8	64.6
Total C	37.9	100.0	0.9	100.0	0.1	100.0	38.8	100.0	52.3	100.0	353.8	100.0	199.8	100.0	605.9	100.0	644.8	100.0
Total A+B+C	1,273.5		41.5		66.1		1,381.1		2,291.5		4,181.5		22,219.3		28,692.4		30,073.5	

Table 4.23 Province level and national level policy comparison area

Change 2006-2009	Spatial planning 2006 within national level buffer area (combined 230 and 100 m)																	
	Forested area								Non-forested area									
	Mangrove (Protected)	%	Mangrove (Tourism)	%	Forest	%	Total	%	Tourism	%	Ponds	%	Other land use	%	Total	%	Total	%
Mangrove left	597.1	**90.1**	26.2	**94.6**	20.3	**97.4**	643.7	**90.5**	169.8	**100.0**	207.1	**100.0**	126.5	**100.0**	503.4	**100.0**	1,147.0	**94.4**
Mangrove--Others	**64.3**	**9.7**	**1.5**	**5.4**	**0.5**	**2.6**	**66.3**	**9.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**66.3**	**5.5**
Mangrove--Pond	**1.3**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**1.3**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.3**	**0.1**
Total A	662.8	100.0	27.7	100.0	20.9	100.0	711.3	100.0	169.8	100.0	207.1	100.0	126.5	100.0	503.4	100.0	1,214.7	100.0
Others	209.3	93.2	8.9	100.0	2.0	100.0	220.1	93.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	220.1	93.5
Others--Ponds	15.3	6.8	0.0	0.0	0.0	0.0	15.3	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.3	6.5
Total B	224.6	100.0	8.9	100.0	2.0	100.0	235.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	235.5	100.0
Ponds--Others	17.1	64.0	0.2	90.9	0.0	0.0	17.3	64.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.3	64.3
Ponds left	9.6	36.0	0.0	9.1	0.0	0.0	9.6	35.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	35.7
Total C	26.7	100.0	0.2	100.0	0.0	0.0	27.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0	100.0
Total A+B+C	914.1		36.8		22.9		973.8		169.8		207.1		126.5		503.4		1,477.2	94.4

4.5.3. Provincial level policy compare to national level policy

Table 4.23 describes the provincial level and national level policy comparison. As seen in the table, there are total mangrove forests conversions within protected area in provincial spatial planning map into other land cover types at 64.3Ha or 9.7% and conversion into ponds at 1.3 Ha or 0.2%. The total remained mangrove forests within protected, tourism, and forest area in provincial spatial planning map showed that the management effectively prevent the mangrove forests at 90.5% or 643.7 Ha. Comparing to the national level policy, total remained mangrove forests was 94.4% with larger area (1,147.0 Ha remained mangrove forests). However, the total mangrove conversion in the national level buffer areas was larger compared to the provincial level spatial planning map. The same condition was occurred for mangrove forests conversion into other land cover types (66.3 Ha or 5.5%) and into ponds (1.3 Ha or 0.1%) for both national and provincial level policy..

4.5.4. Management effectiveness: land tenure perspective

Table 4.24 described the land cover change area per land tenure status between 2006 and 2009. By comparing the mangrove forests conversion among land tenure categories between 2006 and 2009, it is found that mangrove forests change is mainly occurred in government land. The mangrove forest conversion in government land between 2006 and 2009 comprise of mangrove forest conversion into other land cover types (120.6 Ha) and mangrove forest conversion into ponds (168.9 Ha). The map of comparison between spatial planning map 2006, land cover change between 2006 and 2009, and land tenure status is available in ***Appendix 6***.

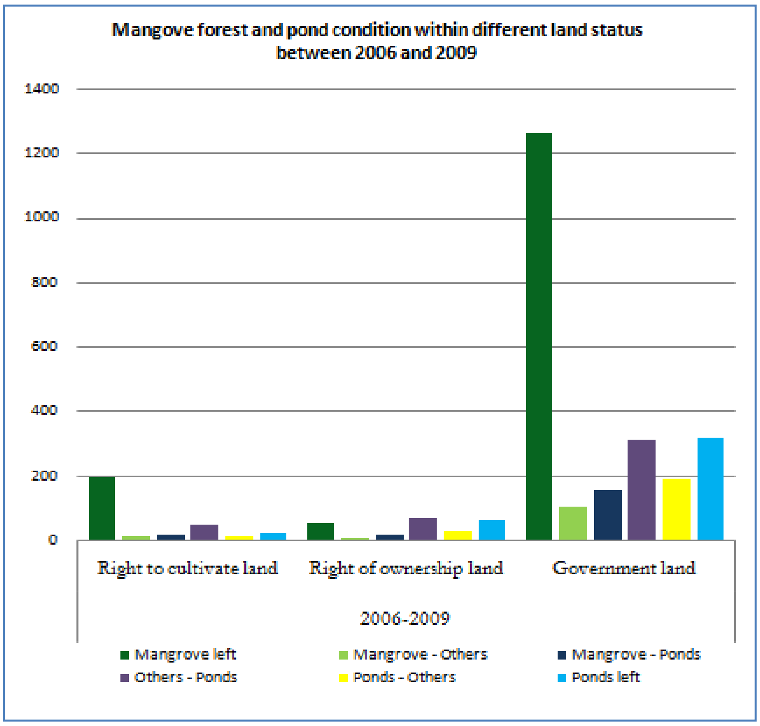


Figure 4.23 Land cover change within land tenure status

Table 4.24 Mangrove forest change area per land tenure status between 2006 and 2009

Changes	**2006-2009**					
	Right to cultivate land	**%**	**Right of ownership land**	**%**	**Govt. Land**	**%**
Mangrove left	192.1	**87.6**	50.8	**70.2**	1,277.7	**81.5**
Mangrove - Others	**11.3**	**5.2**	**4.9**	**6.7**	**120.6**	**7.7**
Mangrove - Ponds	**15.8**	**7.2**	**16.8**	**23.1**	**168.9**	**10.8**
Total A	219.1	100.0	72.5	100.0	1,567.2	100.0
Others	1,177.4	96.3	11,800.8	99.4	14,137.3	97.7
Others - Ponds	45.5	3.7	66.9	0.6	326.8	2.3
Total B	1,222.9	100.0	11,867.7	100.0	14,464.1	100.0
Ponds - Others	11.8	37.1	27.0	29.8	204.2	38.0
Ponds left	20.0	62.9	63.6	70.2	333.4	62.0
Total C	31.9	100.0	90.6	100.0	537.6	100.0
Total A+B+C	1,473.9		12,030.7		16,568.9	

5. DISCUSSION

5.1. Land cover mapping and mangrove forests change

The overall accuracy for the classification of the Landsat image 2009 is 76.06 % with kappa statistic of 0.7068. The accuracy explains that of 23.94% of the classification does not match with the reference data. Moreover, kappa statistic explains that 70.69% of the whole classification is reliable in accordance to the reference data (Carletta, 1996; Landis, 1977). Challenges come from change detection images. In this research, the accuracy assessment was only done for image year 2009 because no available reference data for image prior to 2009. For images prior to 2009, the classification accuracy assessment cannot be performed, thus no information about classification agreement to the reference data

In the classification result, the classification problem occurred between land cover types with similar spectral characteristic. Mangrove forests have similar characteristic with mixed wet cropland and shrub area. To deal with this situation, visual interpretation was done in the end of the classification process. This refinement process is useful in increasing classification accuracy (Yuan et al., 2005). The refinement process was also used to fix the strange class in change detection analysis. In this research, it is found that ponds change into mangrove or mixed grass and shrub into mangrove. For this problem, refinement process using visual interpretation was used to correct the missed classification in each image.

Based on the result, mangrove forests within study area have kept steady decreasing over past three decades. The mangrove forests decrease is evidently indicated by GIS analysis resulted from this research. In the table is shown that the mangrove forests change at annual average is steadily decreasing at 0.5% between 1989 and 2000, at 3.0% between 2000 and 2006, and at 5.6% between 2006 and 2009. The mangrove decrease is not only converted into ponds but also into other land cover types, mostly bareland. It indicates that mangrove forests are not only used for its land but also for its timber.

The change detection analysis is useful in monitoring and assessing the mangrove forests conversion related to management policy. Geospatial information for supporting mangrove forests change analysis which is derived from multispectral and multitemporal remote sensing helps in the decision making process and implementation.

5.2. Assessment of mangrove forest management effectiveness

President Decree 32/1990, the basic legal framework for environmental protection in Indonesia, state that ecosystems and species should be utilized in a manner protective of ecosystem processes, flora, and fauna. Moreover, this law stipulates that mangrove forest protection is designed for coastal preservation from abrasion and of cultivated area behind.

Between 1989 and 2000, the mangrove forests management purely refers to President Decree 32/1990. This is a national level policy which regulates mangrove forests protected area within 230 m coastal buffer area and 100 m river buffer area. In 2000 to 2006, the issue of Law 22/1999 and Law 32/2004 give full authority to regional government to take over the natural resources management. Related to that issue, this research finds that the mangrove forests conversion tends to increase between 2000 and 2006 compare to 1989 to 2000. From 2006 to 2009 the mangrove forest conversion within national buffer area is continuously decreasing with annual conversion rate of -6.5%.

The mangrove forests decrease within those buffer areas indicates that local government has less concern to mangrove forests protection. Local government tend to prepare their own law which is not consistent with pre-existing central law. The result indications are consistent with the (Patlis, 2005) who conducted a research in Bunaken National Marine Park in Indonesia. Economic orientation However, this research produces distinct condition.

In the national level coastal buffer area, the mangrove forests remained area decrease apparently from 1989 to 2009. Remained mangrove forests between 1989 and 2000 are 94% or 1.270.0 Ha. It means that, in that time the national level policy effectively prevent the mangrove forests at 94%. In between 2000 and 2006, the area and percentage was decreasing. Remained mangrove forests between 2000 and 2006 are 82.7 or 1,050.2 Ha. There was a political change started in 2000 which could lead to the environmental change. In that time was the autonomy era started. The autonomy era lead to the more economically oriented in the regional government level (Armitage, 2002). However, the data showed that the mangrove forests conversion into ponds (35.1 Ha or 2.8%) were smaller than mangrove forests conversion into other land cover types (184.8 Ha or 14.5%). In the contrary, between 2006 and 2009 the mangrove forests conversion into ponds (117.0 Ha or 11.1%) exceeded the mangrove forests conversion into other land covers types (80.4 Ha or 7.7%). In that time was the beginning of the provincial spatial plan implementation. The similar condition was occurred in the river buffer area as well. The remained mangrove forests decreased from 1989 to 2009. Moreover, the mangrove forests conversion into ponds also exceeded the mangrove forests conversion into other land cover types between 2006 and 2009. Overall, the mangrove forests management effectiveness in the national level policy prevent above 80% of the protected area.

In provincial level policy, the mangrove forests area within defined protected area between 2006 and 2009 remained 891.7 Ha or 91.3%. However, there are 611.6 Ha mangrove forests which are not included in the protected area in spatial planning 2006. It means that the provincial level spatial planning is effectively preventing the mangrove forest area at 91.3%. Furthermore, the comparison of national level buffer area with provincial level spatial planning map within the area of 230 m from coastline and 100 m from river, showed that remained mangrove forests is 643.7 Ha or 90.5% within the provincial spatial planning map. For the national level buffer areas, there are 1,147.0 Ha or 94.4% of remained mangrove forests between 2006 and 2009. It means that the mangrove forests within the national level buffer area are more effective prevent the mangrove forest extent and location.

Finally, the land tenure status comparison with mangrove forests change result in distinct area and percentage. The largest mangrove forests conversion is occurred in the government land, which comes from conversion into other land cover types (120.6 Ha or 7.7%) and conversion into ponds (168.0 Ha or 10.8%).

6. CONCLUSSIONS AND RECOMENDATIONS

6.1. CONCLUSIONS

1. Supervised classification using maximum likelihood is effectively producing reliable land cover map. In this research, the classification accuracy is 70.68 % with 0kappa statistic of 0.7069
2. The mangrove forests management is effectively prevent under the national level policy. The results shows highest mangrove forests percentage and area prevented under the national level policy.
3. The mangrove forests management in different land tenure status results in different effectiveness. However, the government land has the largest mangrove loss comparing to other land tenure status.

6.2. RECOMENDATIONS

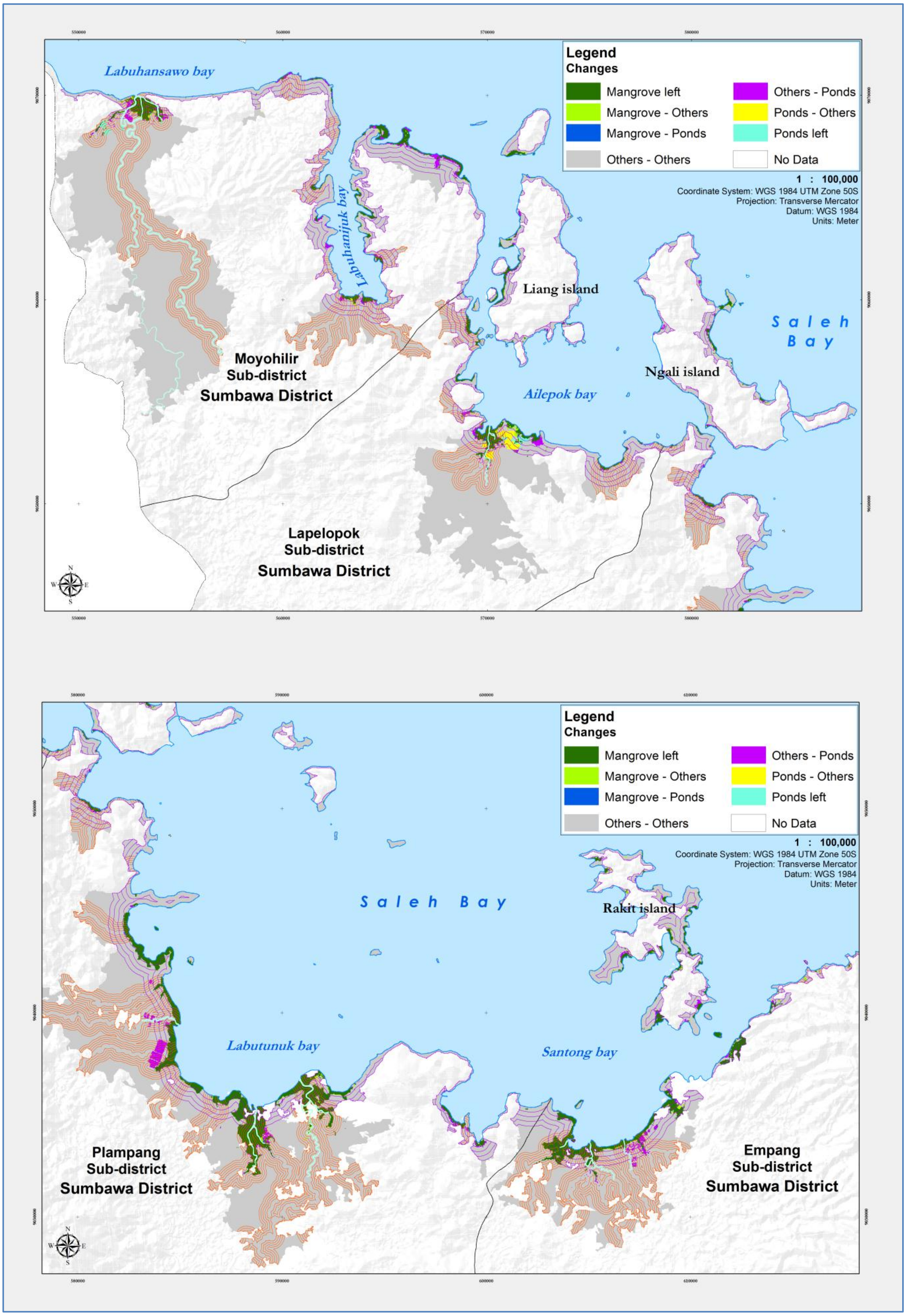
1. The assessment within sub-district should be done in order to get deep analysis regarding to the smaller scale of policy level.

APPENDICES

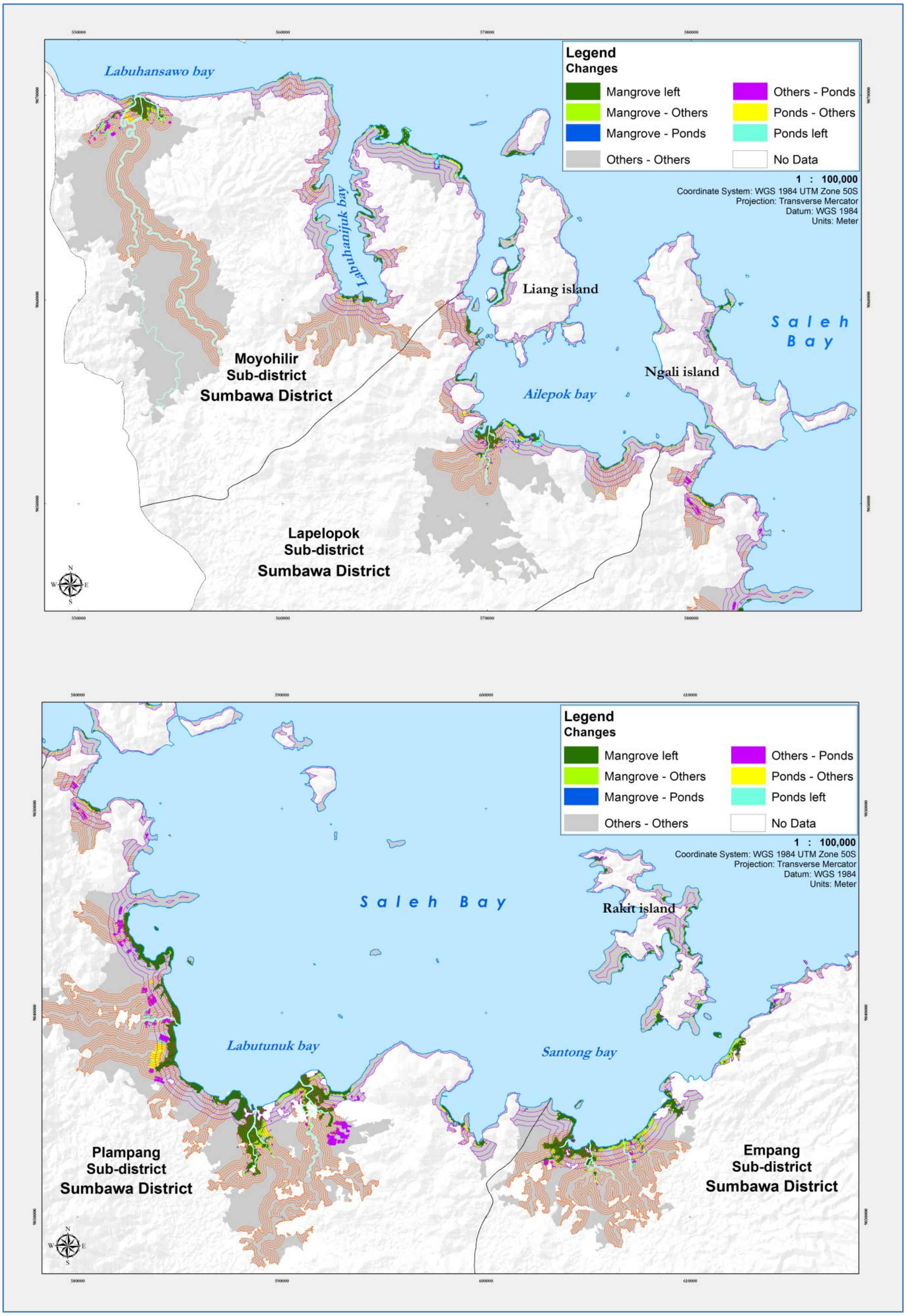
Appendix 1. Ground control points derived from fieldwork March-April 2009

No	POINT_X	POINT_Y	Land cover	No	POINT_X	POINT_Y	Land cover
1	550853.4008	9066675.621	Bareland	36	582273.67	9044285.3	Mangrove
2	550940.5801	9066414.852	Bareland	37	582316.49	9044190.9	Mangrove
3	552658.0065	9069085.174	Bareland	38	584711.18	9038237.8	Mangrove
4	553883.7652	9067385.335	Bareland	39	584712.28	9038456.3	Mangrove
5	563058.0315	9059983.126	Bareland	40	585339.11	9036564.4	Mangrove
6	570106.1865	9051399.603	Bareland	41	585616.18	9036423	Mangrove
7	571057.4051	9053417.949	Bareland	42	588839.43	9034566.3	Mangrove
8	571753.8341	9053098.183	Bareland	43	597944.73	9035351.3	Mangrove
9	584999.6748	9036470.419	Bareland	44	598037.6	9035262.5	Mangrove
10	586815.4053	9035246.897	Bareland	45	598878.41	9034530.3	Mangrove
11	589092.0436	9034740.748	Bareland	46	604123	9033183.7	Mangrove
12	603866.7028	9032513.206	Bareland	47	604317.57	9033228.4	Mangrove
13	551861.8396	9063501.277	Cropland	48	606840.63	9033688	Mangrove
14	553658.6902	9062585.488	Cropland	49	550803.67	9068115	Ponds
15	562284.8738	9058377.106	Cropland	50	551029.03	9068342.4	Ponds
16	568115.8391	9050537.387	Cropland	51	552040.93	9069077.4	Ponds
17	572218.3691	9051646.449	Cropland	52	569433.4	9053071	Ponds
18	579620.0244	9041593.523	Cropland	53	582079.34	9044190.9	Ponds
19	580622.1517	9040972.531	Cropland	54	584212.22	9038630.9	Ponds
20	552038.2436	9069597.06	Grass-shrub	55	586571.35	9035451.2	Ponds
21	553110.2842	9070001.235	Grass-shrub	56	589441.1	9034400.6	Ponds
22	562465.1215	9059345.317	Grass-shrub	57	590127.1	9035260.4	Ponds
23	570595.5216	9050692.57	Grass-shrub	58	597846.06	9035263.4	Ponds
24	581130.5827	9041159.845	Grass-shrub	59	598340.2	9034565.8	Ponds
25	581824.4727	9043539.349	Grass-shrub	60	599441.66	9033480.2	Ponds
26	581913.9486	9044216.517	Grass-shrub	61	599714.71	9033404	Ponds
27	583244.6898	9038834.013	Grass-shrub	62	604019.71	9032814.2	Ponds
28	590169.4291	9034413.723	Grass-shrub	63	607091.74	9033478.5	Ponds
29	599012.0993	9034809.217	Grass-shrub	64	607362.17	9033220.7	Ponds
30	599239.4297	9034010.651	Grass-shrub	65	607729.63	9032830.7	Ponds
31	552928.9953	9069850.476	Mangrove	66	552150.94	9068977.3	Waterbody
32	553126.4934	9069831.352	Mangrove	67	552332.84	9068831.8	Waterbody
33	569683.5327	9053306.038	Mangrove	68	552779.37	9069881.9	Waterbody
34	570298.2829	9053593.045	Mangrove	69	570267.58	9053646.3	Waterbody
35	572298.3457	9053369.281	Mangrove	70	583346.78	9042292.8	Waterbody
				71	588661.37	9034579.3	Waterbody

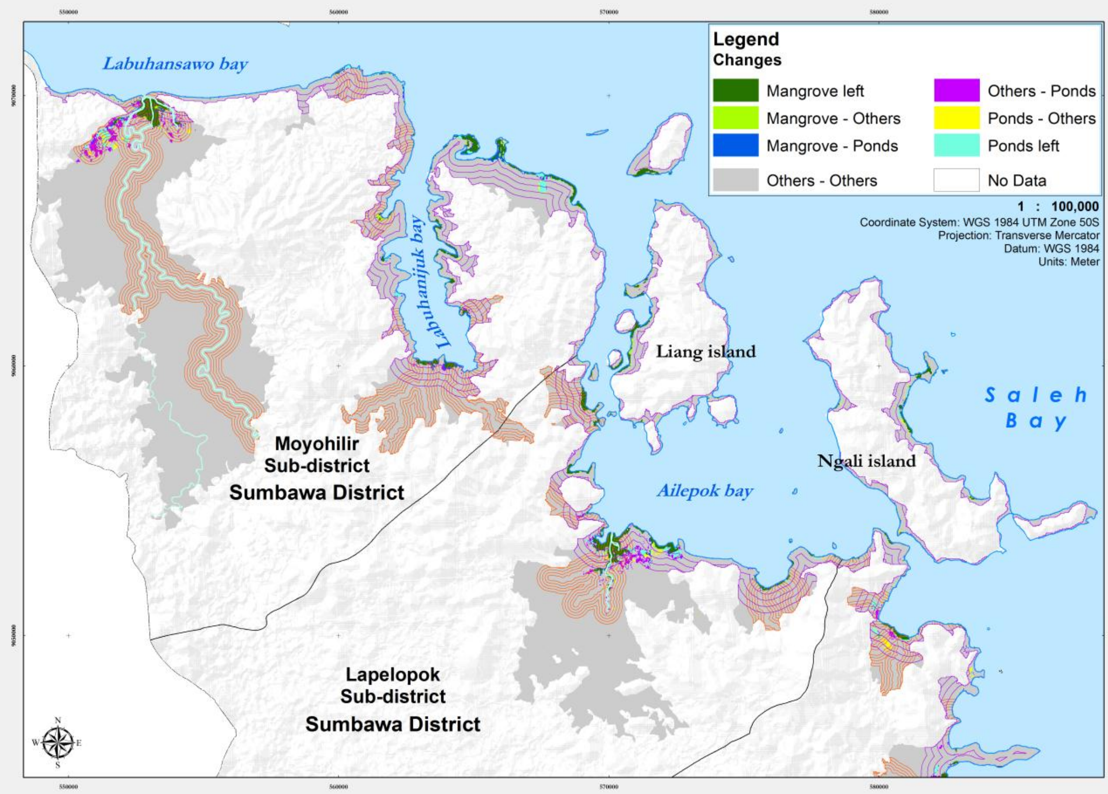
Appendix 2. Mangrove forests change within national level multiple buffer areas between 1989 and 2000

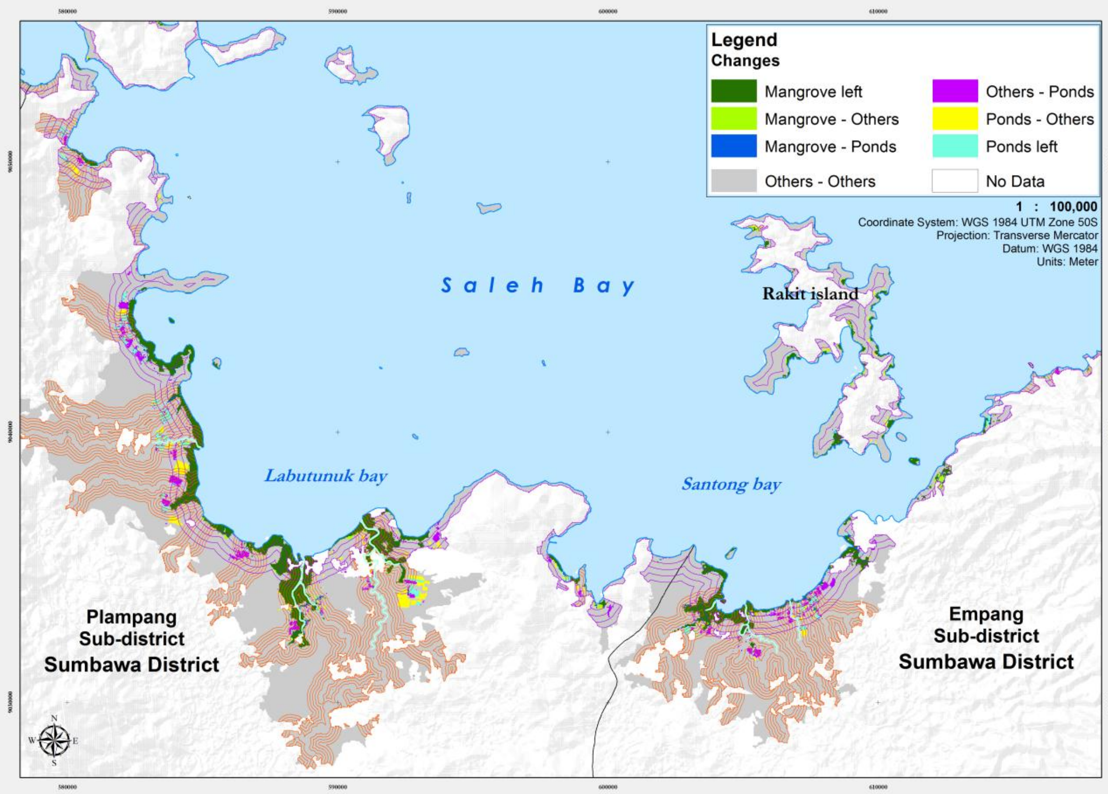


Appendix 3. Mangrove forests change within national level multiple buffer areas between 2000 and 2006

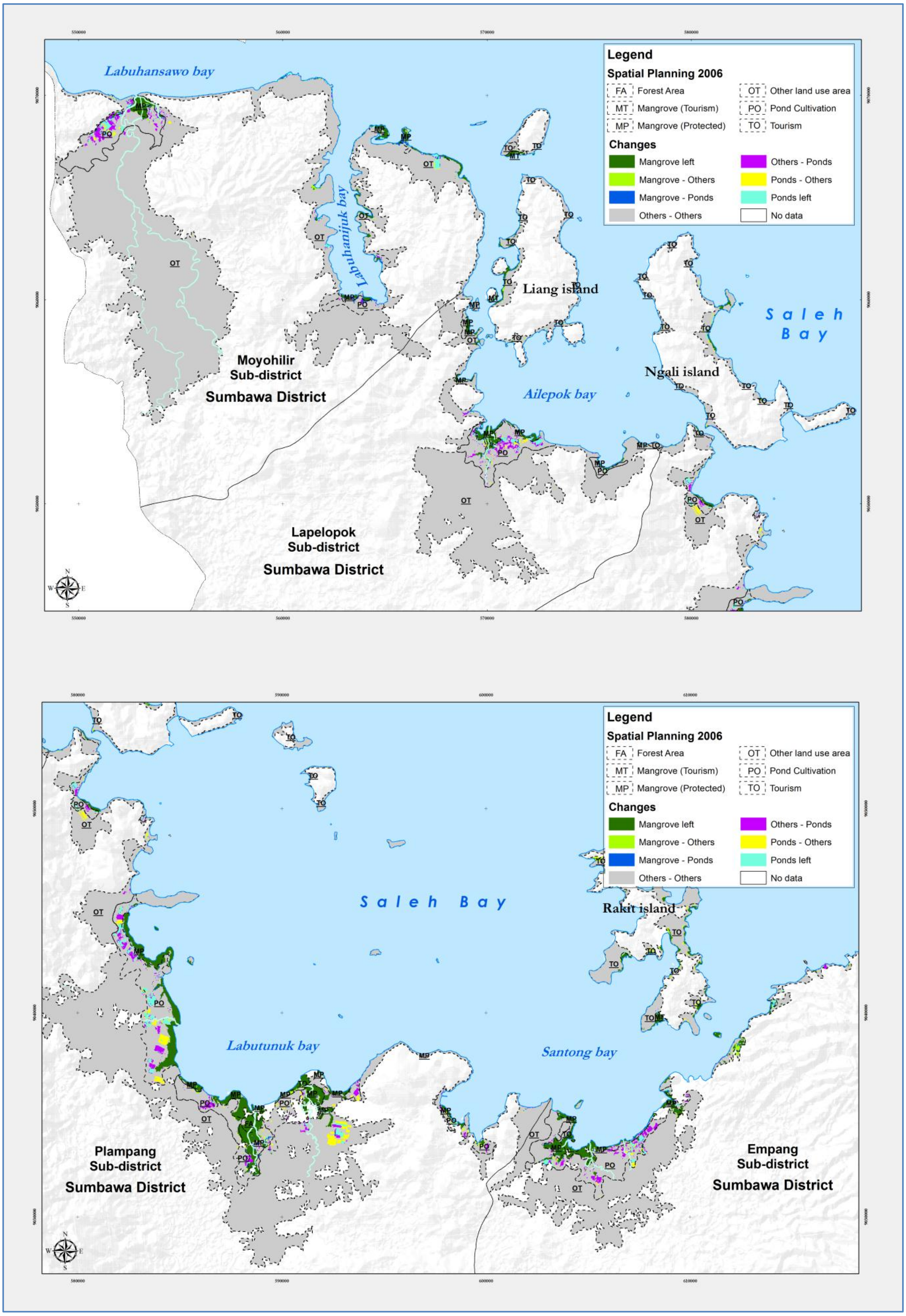


Appendix 4. Mangrove forests change within national level multiple buffer areas between 2006 and 2009

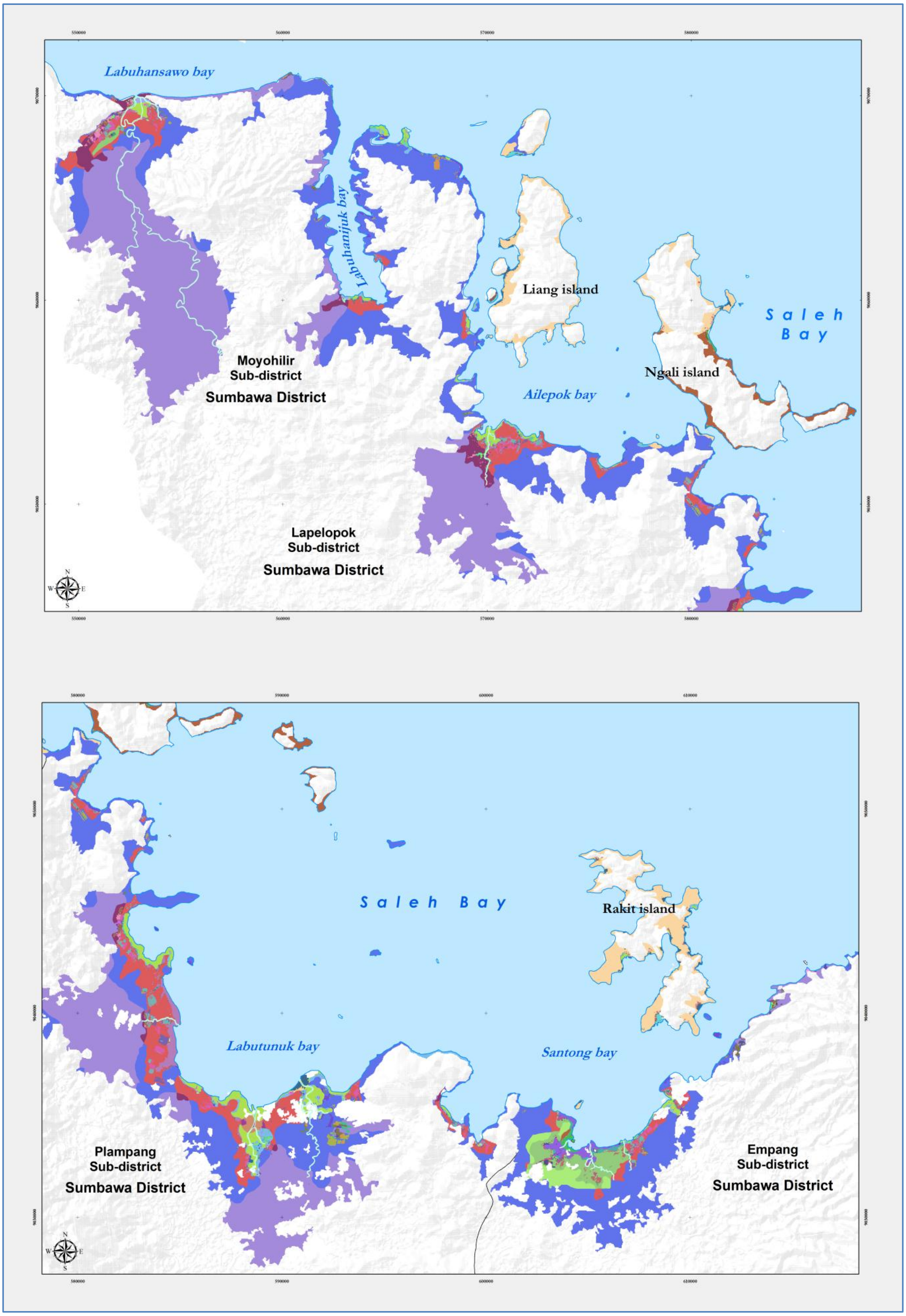




Appendix 5. **Mangrove forests change between 2006 and 2009 within provincial spatial planning map 2006**



Appendix 6. Comparison of mangrove forests change between 2006 and 2009, provincial spatial planning map 2006, and land tenure status map



Appendix 7. Comparison legend of mangrove forests change between 2006 and 2009, provincial spatial planning map 2006, and land tenure status map

Appendix 8. Comparison table of mangrove forests change between 2006 and 2009, provincial spatial planning map 2006, and land tenure status map

Forest Area	Tenure	Ha	%	Mangrove (Protected)	Tenure	Ha	%
Mangrove left	Government land	52.5	**98.2**	Mangrove left	Government land	660.2	**74.3**
Mangrove - Others	**Government land**	**0.2**	**0.4**	Mangrove left	Right of ownership land	23.8	**2.7**
Mangrove - Ponds	**Government land**	**0.8**	**1.4**	Mangrove left	Right to cultivate land	123.7	**13.9**
Total		53.5	100.0	**Mangrove - Others**	**Government land**	**19.8**	**2.2**
Others	Government land	12.4	98.6	**Mangrove - Others**	**Right of ownership land**	**0.3**	**0.0**
Others - Ponds	Government land	0.2	1.4	**Mangrove - Others**	**Right to cultivate land**	**3.1**	**0.3**
Total		12.6	100.0	**Mangrove - Ponds**	**Government land**	**49.6**	**5.6**
Ponds - Others	Government land	0.1	100.0	**Mangrove - Ponds**	**Right of ownership land**	**1.4**	**0.2**
Total		0.1	100.0	**Mangrove - Ponds**	**Right to cultivate land**	**7.2**	**0.8**
TOTAL		53.6		Total		889.1	100.0
Mangrove (Tourism)	**Tenure**	**Ha**	**%**	Others	Government land	271.9	79.7
Mangrove left	Government land	29.2	**94.1**	Others	Right of ownership land	8.4	2.5
Mangrove - Others	**Government land**	**1.0**	**3.2**	Others	Right to cultivate land	36.1	10.6
Mangrove - Ponds	**Government land**	**0.8**	**2.7**	Others - Ponds	Government land	20.0	5.9
Total		31.1	100.0	Others - Ponds	Right of ownership land	0.4	0.1
Others	Government land	9.4	100.0	Others - Ponds	Right to cultivate land	4.1	1.2
Total		9.4	100.0	Total		341.0	100.0
Ponds - Others	Government land	0.2	24.3	Ponds - Others	Government land	8.2	22.7
Ponds left	Government land	0.6	75.7	Ponds - Others	Right of ownership land	0.2	0.5
Total		0.9	100.0	Ponds - Others	Right to cultivate land	0.3	0.9
TOTAL		41.3		Ponds left	Government land	25.7	71.3
				Ponds left	Right of ownership land	0.3	1.0
				Ponds left	Right to cultivate land	1.3	3.7
				Total		36.1	100.0
				TOTAL		244.1	
Other land use area	**Tenure**	**Ha**	**%**	**Ponds Cultivation**	**Tenure**	**Ha**	**%**
Mangrove left	Government land	139.5	**58.6**	Mangrove left	Government land	238.0	**68.8**
Mangrove left	Right of ownership land	14.3	**6.0**	Mangrove left	Right of ownership land	12.7	**3.7**
Mangrove - Others	**Government land**	**35.5**	**14.9**	Mangrove left	Right to cultivate land	28.1	**8.1**
Mangrove - Others	**Right of ownership land**	**3.3**	**1.4**	**Mangrove - Others**	**Government land**	**11.7**	**3.4**
Mangrove - Ponds	**Government land**	**39.8**	**16.7**	**Mangrove - Others**	**Right of ownership land**	**1.2**	**0.3**
Mangrove - Ponds	**Right of ownership land**	**5.5**	**2.3**	**Mangrove - Others**	**Right to cultivate land**	**2.1**	**0.6**
Total		238.0	100.0	**Mangrove - Ponds**	**Government land**	**39.8**	**11.5**
Tourism	**Tenure**	**Ha**	**%**	**Mangrove - Ponds**	**Right of ownership land**	**9.7**	**2.8**
Mangrove left	Government land	137.5	**56.3**	**Mangrove - Ponds**	**Right to cultivate land**	**2.5**	**0.7**
Mangrove left	Right to cultivate land	39.9	**16.3**	Total		345.7	100.0
Mangrove - Others	**Government land**	**35.0**	**14.3**				
Mangrove - Others	**Right of ownership land**	**0.1**	**0.0**				
Mangrove - Others	**Right to cultivate land**	**6.1**	**2.5**				
Mangrove - Ponds	**Government land**	**19.5**	**8.0**				
Mangrove - Ponds	**Right of ownership land**	**0.1**	**0.0**				
Mangrove - Ponds	**Right to cultivate land**	**6.1**	**2.5**				
Total		244.1	100.0				

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