

State of the Art Information on Mangrove Ecosystems in Indonesia

Muhammad Ilman, Iwan Tri Cahyo Wibisono, and I Nyoman N. Suryadiputra



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Compilation made by:

Muhammad ILMAN
Iwan Tri Cahyo Wibisono
I Nyoman N. Suryadiputra

Translated by:

Wendy Suryadiputra

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Compilation by : Muhammad ILMAN, Iwan Tri Cahyo Wibisono, and
I Nyoman N. Suryadiputra

Translated by : Wendy Suryadiputra

Design & Layout : Triana

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This report is available at:

Wetlands International – Indonesia Programme
Jl. A. Yani No. 53 Bogor 16161
Tel. 0251 8312189
Facs. 0251 8325755
E-mail: admin@wetlands.or.id
<http://www.wetlands.or.id>

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1. Status and Trends of Mangroves in Indonesia

A. GENERAL CONDITION OF MANGROVES IN INDONESIA

Indonesia is a tropical archipelago with coastlines measuring a total length of 95,181 km, making it the country with the fourth longest coastline in the world (EarthTrends WRI, 2003, and Rompas, RM.2009). All along the coast are the estuaries of rivers great and small that flow the whole year round thereby enabling mangroves to thrive, particularly on shores sheltered from the waves, such as lagoons, deltas, coral and sand bars. Currently, Indonesia's mangroves cover 30,000 square kilometres, 21% of the global total mangrove area, and contain 45 (not including introduced species) of the world's 75 species of true mangrove (Spalding *et al.*, 2010). As a result, Indonesia is known as the country possessing the most mangroves, both in terms of area and number of species.

Mangroves play an important role in the lives of Indonesia's coastal communities, because they provide habitat for fish, crustaceans and algae which form both food and a source of livelihoods. This is evident from the size of shrimp exports, which reach 1 billion dollars a year (KKP, 2009). Mangroves also fulfil other needs, such as timber for a variety of constructions, energy, dyes and medicines; their fruits can even be used to make jam, syrup and crisps for consumption. Mangrove timbers are known for their strength, which makes them suitable for construction, such as *ceriops* which is used for railway sleepers and handles for construction tools (Giesen *et al.*, 2006). Each year, around 50 thousand to 300 thousand cubic metres of mangrove logs are obtained from timber concession company activities in mangrove forests (BPS, 2009). This does not include the timber exploitation activities carried out by communities living in the vicinity of mangrove forests, for construction and charcoal production.

The enormous economic value of mangrove timber has led to massive exploitation, especially on the four largest islands: Sumatera, Java, Kalimantan and Sulawesi. Between 1980 and 2000, it is estimated that 1-1.7 million hectares of mangroves were lost. The wide diversity in the uses of mangrove makes it difficult to determine precisely which activities are the most dominant causes of mangrove destruction. Giesen (2006) estimated that 25% of mangrove loss was due to the clearing of mangroves for fish pond aquaculture (*tambak*), and 75% from a combination of: land conversion for agriculture, degradation resulting from overexploitation, and coastal erosion. Differing from Giesen, the Forestry Ministry's Analysis (2005) found that up to 2003, around 750 thousand hectares of mangrove had been cleared for aquaculture, indicating that the major single cause of mangrove loss (~50%) was in fact the construction of aquaculture ponds.

Mangrove degradation has resulted not only from human exploitation but also from natural disasters like the earthquakes and tsunami in Aceh. Analysis of satellite imagery by the National Institute for Aeronautics LAPAN (2005, in Dephut 2005) estimates that around 32,000 ha of Aceh's mangroves were devastated by the tsunami on 26 December 2004, which also destroyed parts of the mangrove ecosystems on small islands in the waters to the west of Sumatera, not just as a result of the force of the tsunami but also because the mangroves were uplifted to a height of several centimetres above sea-level and therefore dried out and died.

The rapid escalation in mangrove exploitation in Indonesia has also been influenced by the lax law enforcement and mistakes in policy implementation at lower levels, as in the spatial planning of coastal areas, even though in fact Indonesia has a range of legislation which was drawn up to protect mangroves (see the chapter on Governance of Mangrove Resources Management). Most of the large-scale exploitation of East Kalimantan's north coast, amounting to more than 300

thousand hectares in less than a decade (1995-2005), is thought to have been illegal as it was carried out in forest areas and done without any permit from the Forestry Minister. This was possible because at that time the East Kalimantan government was severely short of staff and funding to guard its 750 thousand hectare expanse of mangroves (Ilman et al, 2009).

B. ESTIMATES OF THE EXTENT OF MANGROVE COVER IN INDONESIA

Studies of the status and distribution of mangroves in Indonesia have been carried out since the beginning of the twentieth century. These have been reported by, among others, van Bodegom (1929) who reported on measurement of the mangrove area in Riau (Giesen et al. 2006). Publications on national mangrove status have been published since at least 1950. One of these states that Indonesia's mangroves, excluding Bali and Nusa Tenggara, amounted to around 2.5 million ha (Martosubroto 1950, in FAO 2007). According to an FAO inventory (2007) and investigation by WIIP, to date there have been at least 30 publications on Indonesia's mangrove status, which estimate their extent at anything from one million hectares (Directorate Forest Planning 1979) to 9.3 million ha (Dephut, 2007). A complete list of publications on the extent of Indonesia's mangroves can be seen in Appendix 1.

Despite the many publications on the distribution and status of Indonesia's mangroves, up until 2006 no proper attempt had been made to map them comprehensively on a national scale. Present information on their extent is generally in the form of compilations of results from a variety of separate surveys of land scattered along Indonesia's coastlands. Each survey may well have used different methods and definitions of mangrove, thus resulting in widely different estimates of their extent. Moreover, Giesen's research (2006) shows that even though these estimates were given by different authors (persons/institutions), several of them simply repeat content quoted from the same source of reference.

WIIP's investigation of the methodology used in various assessments of the status of Indonesia's mangroves also indicates that the differences in the estimates presented by different authors have been caused not just by changes in the actual extent of mangrove cover in the field, but also by the following factors :

- Differences in the process of interpreting satellite images: differences in the method, in the type of image, and in the time at which the satellite photographs were taken.
- Differences in the coverage of the area studied: some parts have accurate data, some others have only rough estimates.
- Differences in the definition of mangrove which forms the reference for calculating the area. Some researchers measured the area inhabited by true mangrove only, while others also included mangrove associates, and a few even included freshwater swamp forest and the ecosystems surrounding the mangroves.

One of the latest publications on the status of Indonesia's mangroves is the book *Peta Mangrove Indonesia* (Indonesian Mangrove Atlas) published by the National Survey and Mapping Coordination Agency (Bakosurtanal, 2009). The Agency is confident that the figures presented for national mangrove area in this publication are the most accurate because these estimates are based on analysis of satellite images that cover the entire coastal regions of Indonesia. Estimates of the extent of the nation's mangroves over the last 5 years are presented in Table 1 below.

Table 13. Publications during the last 5 years that discuss the extent of mangroves in Indonesia

Source and year of publication	Mangrove Estimate		Data Source
	Area (ha)	Year	
Giesen et al (2006)	2,930,000	2000	FAO (2003); Spalding et al. (1997)
FAO (2007)	2,900,000	2005	Dephut (2003) and other supporting sources
RLPS-MoF (2007)	7,758,410	2000	Peta system lahan nasional 1995 – 2000
Spalding (2010)	3,062,300	2003	MoF (2003)
Bakosurtanal (2009)	3,244,018	2009	Satellite Images Analysis

C. THE LOSS AND DEGRADATION OF MANGROVE IN INDONESIA

Widigdo's (2000) research of the literature on the extent of Indonesia's mangrove forests indicates that they shrank drastically from a total area of 5.21 million to 3.24 million hectares in the five years 1982 – 1987. This depletion continued until only 2.5 million hectares remained in 1993. Another source, Anwar and Gunawan (2006), state that the rate of mangrove destruction in Indonesia has reached an alarming 530,000 hectares a year. This is much faster than the rate of mangrove rehabilitation, which is estimated to be around 1,973 ha a year.

Mangrove destruction is still continuing. Of North Sumatera province's former 103,425 ha (1977 measurements) now only about 41,700 ha are left, a loss of about 59,68% (Onrizal, 2010). A DTE (2000) report on the East Kalimantan coast shows the same picture, where 150 thousand hectares of mangrove in the Mahakam Delta have been converted for shrimp ponds, leaving only 15 thousand ha of mangrove. As a result, several of the small mangrove islands in the delta have now disappeared (Down to Earth, 2000).

Table 14. Changes in Mangrove Area in 6 regions of Indonesia based on data from RePPPProTand Bakosurtanal

Region	Area (ha)	
	1989	Present (2009)
Sumatera	857,000	576,956
Java	170,500	34,482
Bali Nusra	39,500	34,524
Kalimantan	1,092,000	638,283
Sulawesi	242,027	150,017
Maluku	197,500	178,751
Papua	1,500,000	1,634,003
Total	4,098,527	3,247,016

Source: RePPPProT (1985-1989) cited in Giesen et al (1991); Bakosurtanal (2009)

D. KEY DRIVERS TO THE LOSS AND DEGRADATION OF MANGROVE

D.1. Aquaculture pond (*Tambak*) development

Shrimp farming is one of the most enticing businesses undertaken in mangrove areas. The felling of mangroves to make way for more and more shrimp ponds has been the biggest cause of mangrove loss in Indonesia. According to data published by the Ministry of Forestry (2005), shrimp pond expansion has been responsible for the destruction of around 750 thousand hectares of mangrove. Using a moderate estimate (1.5 million ha) of the depletion in Indonesia's mangrove cover, this means that shrimp pond expansion has contributed 50% of the mangrove loss in Indonesia.

There are many publications describing the dramatic destruction of mangroves due to shrimp pond expansion. One instance much publicised is what occurred in East Kalimantan, a province having more than 750,000 ha of mangrove (11 times the area of Singapore). Within less than one decade, 300,000 ha of this mangrove in two regions, the Mahakam Delta and Tarakan, had been converted to aquaculture ponds.

Large-scale conversion of mangrove occurred not only in areas having large expanses of mangrove, but also in places with only a little mangrove, like Banawa in Central Sulawesi. It is estimated that around 69% (391 ha) of the 536 ha mangrove there was converted to ponds during the 15 years 1985 – 2000 (Armitage, 2002).

D.2. Oil palm development and expansion

The euphoria for developing oil palm plantations has spread throughout the whole of Indonesia. This has spurred on the clearing of forests (including mangrove forest) and their conversion to oil palm plantation. Generally, mangrove forests have been cleared by groups or individuals from the community. Only very rarely have any cases been found of a company clearing mangrove forest for oil palm. To date, there is still no national data or information on mangrove clearance for oil palm. Nevertheless, a literature study by WIIP has identified at least three cases of land cover conversion from mangrove to oil palm, which are as follows:

- In North Sumatera, 2000 hectares of mangrove forest have been converted to oil palm plantation, especially in Kabupaten Langkat district. This has reportedly had an adverse impact on the local community whose livelihoods depended on the mangrove ecosystem, in particular traditional fishermen. It has also progressively restricted the area of movement for obtaining incomes from the capture of shrimp and fish in and around the mangrove forest (Lira News, 2010).
- In Bandar Pasir Mandoge (Kabupaten Asahan district), the mangrove forest along the coast has been converted to oil palm plantation both by the local people and by private companies. Unfortunately, no figures are available for the area converted (Medan Pos Online, 2010).
- In Aceh Tamiang (Nanggroe Aceh Darussalam Province), 17,000 hectares (around 85% of the total 20,000 hectares) of mangrove forest have been converted for oil palm, with each family receiving 2 hectares of palm oil plantation (Kompas, 2010).

D.3. Agricultural development

In Indonesia, it is estimated that about 200,000 hectares of mangrove were reclaimed for agriculture during 1969 – 1974 (Bird and Ongkosongo, 1980). Conversion of function from mangrove forest to agricultural land was noted in several provinces: Central Java, West Java, South Kalimantan Selatan and South Sumatera. In these provinces, the mangrove forests were completely cut down and the land used for rice paddies and horticulture (Kusmana, 2010).

Compared to the other provinces, South Sumatra has experienced the fastest rate of mangrove loss due to conversion to agriculture. About 7500 hectares or 30% of its initial mangrove forest has been lost; 1,500 ha of it on the coast of Musi Banyuasin (widely known as the MUBA region) in South Sumatra has been totally cleared and replaced by rice paddies (Ministry of Agriculture, 1982).

Mangrove conversion to agriculture has also occurred in Lampung province. Between 1933 and 1982, 4,000 ha of protected mangrove forest was completely cleared for agriculture (Lampung Agriculture Office, 1979).

Serious pressure on mangrove has also been reported in Central Java province. Needing land for agriculture, groups of local inhabitants of Cilacap district have cut down mangrove forest in their area. The local government states that around 4,000 hectares of mangrove forest in Segara Anakan have been converted to agricultural land (Perum Perhutani, 2009).

D.4. Conversion to salt pans

Although not widespread, some mangrove forest in Indonesia has also been converted to salt pans (*tambak garam*). According to various references, this conversion has been reported only on the islands of Java, Madura and Bali. However, it has also been noted to have occurred to a limited extent in several other areas, particularly those where the dry season each year is longer than the wet. Salt pans in Indonesia are estimated to cover about 36,000 hectares in the provinces of Nanggroe Aceh Darussalam, West Java, Central Java, East Java, Bali, West Nusa Tenggara (NTB), East Nusa Tenggara (NTT), South Sulawesi and Central Sulawesi. Their total national production in 2006 was estimated at 1,300,000 ton valued at about Rp 650 billion rupiah (US\$ 72 million).



Figure 2. Salt pan developed in ex-mangrove area in Lam Ujong, Aceh Besar (Photo: Ilman, 2008)

In Jepara district, salt pans are a major source of livelihood. In the villages of Panggung, Bulakbaru and Tanggul Tlare, the lives of the majority of the inhabitants depend on this activity. Generally, these *tambak* are used to produce salt only during the dry season. In the rainy season, they function as fish ponds (Pariyono, 2006).

D.5. Coastal development

Rapid population growth and economic improvement has taken place in Indonesia's coastal areas along with an increasing demand for land for housing, agriculture, fishery and industry. This coastal development has frequently involved the conversion of mangrove ecosystems, as happened on the north coast of Jakarta where the mangrove ecosystem in the Kapuk area was reclaimed for the building of luxury homes.

Lax spatial planning of coastal areas is one of the reasons why mangrove ecosystems could be sacrificed for such development projects. In Giesen's (2006) estimation, the contribution of coastal developments to mangrove ecosystem conversion for other purposes is extremely large, amounting to around 1.1 million hectares, excluding clearing for aquaculture ponds¹. This situation has been further exacerbated during the era of reformation and government decentralisation that began in 1998, as local governments acquired enormous freedom to control the development of their region. The strong desire to speed up coastal economic development in their area has prompted local governments to take short-cuts by sacrificing the mangrove ecosystems. Some examples of this are as follow :

- Conversion of mangrove ecosystem at Tanjung Api-api in South Sumatera province for an international harbour. An estimated 4,000 ha of mangrove of important ecological value for local fishery is to be altered or directly affected by the construction of an international harbour complex (Supriyatna, Y. 2010).
- Plans for the construction of a waterfront city in Serang city, Banten province. This is one of the plans currently being proposed. An investigation of relevant documents by WIIP indicates that this waterfront city is to be built on lands currently covered by mangroves and the local community's aquaculture ponds. In the plan document it can be seen that, despite being dubbed "water front city", it has actually been planned with a strong landward orientation and lacks any adequate planning regarding protection of coastal ecosystems.
- Reclamation on the north coast of Jakarta. It seems that extremely large scale reclamation is to be carried out on the Jakarta coast, extending into part of West Java province, for the construction of a water front city. This will take the form of housing, a marina resort, trade centre, office complex, recreation/tourism facilities, and a golf course, covering a total area of 8000 ha and stretching along 30km. The area to be reclaimed comprises 4,000 ha of shallow waters (maximum depth 5 metres) and 4,000 ha of aquaculture ponds and mangroves. According to Hasmonel et al (2000), the Jakarta coastal reclamation will have a direct impact on the coral reef ecosystems in the vicinity, i.e. those of Kepulauan Seribu. This is because the reclamation will cause drastic, complex changes on the north coast of Jakarta which is currently a transition ecosystem between land and sea (Ligtvoet et al, 1996).

The trend towards building water front cities in Indonesia will continue, because a large proportion of the population, businesses, trade and industry are near the coast. The water front cities described above are just a few examples of the coastal city developments causing serious damage to the coast. Nevertheless, amidst this bleak picture of sea-side city construction in Indonesia, there are some cities that have built settlements in mangrove areas but actually succeeded in creating environmentally friendly water-front cities. These success stories can be found in Balikpapan and Bontang, which have managed to transform former slums in the mangrove areas into settlements that have won awards for their continuous efforts to construct environmentally friendly housing (Pos Metro Balikpapan, 2009).

¹ "Moderate" level estimate of mangrove destruction i.e. 1.5 million ha.

D.6. Logging

The term “logging” refers to the felling of trees in a forest by people, motivated by various purposes, including: business interests, fulfilment of personal needs (e.g. for house building, firewood) or for additional income. Based on the system applied, logging can be categorised into three types: clear cutting, selective cutting, and strip cutting. Based on its legal status, logging can also be classified into two types: legal and illegal.

As with terrestrial forests, so too the mangrove forests are logged, both legally and illegally. Legal logging is usually carried out by timber companies that hold concessions (HPH) while illegal logging is normally done by members of the public. This has led to the deforestation and degradation of mangrove forests. Below are further details of logging for timber in mangrove forest.

a) Legal logging

In an effort to increase domestic income, the government gave the private sector the opportunity to manage forests through the granting of forestry concession permits; this included mangrove forests. The exploitation of mangrove forests under this concession scheme (HPH - *Hak Pengusahaan Hutan*) began after the Forestry Act *Undang-Undang Pokok Kehutanan (UUPK)* of 1967 came into force.

Based on scrutiny of several documents, the government granted mangrove forest concession licences to 14 companies in 1982. In 1984, the number of concession holders fell to 13. The latest data states that in 2009, only three concession holder companies were still operating in Indonesia's mangrove forests.

Table 15. Concession holders operating in mangrove forest between 1982 and 2009

Year	Number of concession holders	Total area (ha)	Location/ concession holder
1982	14	919,000	Sumatra, Kalimantan, Papua
1984	13	455,000	Sumatra, Kalimantan, Papua
2009	3	165,230	Aceh, Riau, South Sumatra, West Kalimantan, South Kalimantan, Papua PT. Bintuni Utaa Murni Indah Wood (137,000 ha) PT. Bina Ovivipari Semesta/PT.BIOS (10,100 ha) PT. Kandelia Alam (18,130 ha)

The concession holders were given the right to exploit the forest in line with the prevailing principles of conservation and sustainability. For every volume of exploited timber, the Government charges the company a forest tax (DR/reforestation fund and PSDH/forest resource provision fund) as a source of national domestic revenue. Nevertheless, to ensure forest conservation, the company is also obliged to undertake intensive, sustained rehabilitation and maintenance of the forest.

Sadly, however, the implementation of mangrove forest exploitation in the field has not been as good as envisaged by the government. In reality, there are many cases where the harvests taken by the company exceed the permitted quota, with the result that the rate of exploitation outstrips that of rehabilitation, regeneration and forest succession. In fact, in certain cases, it is not unusual to find companies that carry out clear cutting or “land clearing” without doing any planting whatsoever.

The following facts from the field have certainly been factors in exacerbating the destruction of mangrove forests in the context of forest exploitation.

1. The perpetration of illegal practices by concession holders, such as: exceeding the allowed annual cut, felling of trees with a diameter smaller than the allowed minimum, falsification of production reports, etc.
2. The illegal practices in 1 above have been exacerbated by the government's (forestry agency) lax supervision and evaluation of concession holders' activity in the field. There are many cases of government field officers having been involved in collusion with companies, and high officials having been bribed to close their eyes to the illegal practices. During the last five years, several regional heads and forestry officials have been found guilty in a court of law and sentenced to jail for violation of various prohibitions, as well as for manipulation and collusion with forestry companies, thereby causing loss to the State.
3. The complexity of mangrove ecosystems has both directly and indirectly made it difficult for the government to decide on a suitable silviculture system for managing mangrove forest, with the result that they have changed the silviculture system at least three times. The first silviculture system to be applied in mangrove forests was the "Standard Clear-Cutting Sylvicultural System". As this involved several problems regarding identification, the government replaced it with the "Stripwise-Selection-Felling-Sylvicultural System". As with the first system, the government also saw weaknesses with the second, so this was subsequently replaced by the "Seed-Tree Method" system in 1978. This last system was considered the best suited to mangrove ecosystem conditions and has therefore been applied up to the present.

b) Illegal logging

Another threat to mangrove conservation is illegal logging, which has degraded mangrove ecosystems, reducing their function and productivity and, in certain places, causing a reduction in the area covered by mangrove forest.

Illegal logging has been defined by the government as a "national problem" because it happens in almost all of Indonesia's provinces and has clearly led to environmental degradation and national loss. The rate and intensity of illegal logging differs from one area to another, depending on a number of factors like the mangrove forest's potential, the number of inhabitants, the community's economic level, the local demand for timber, the availability of a timber market, the level of regional government policy, the intensity of law enforcement, etc.

In the Cilacap district of Central Java province, the local inhabitants willingly cut down mangrove (*Rhizophora apiculata*, *R. mucronata*, and *Bruguiera gymnorhiza*) in the Segara Anakan area. According to local government records, the volume of mangrove timber cut throughout 2007 was estimated at an average of 14.23 m³ a day (Sastranegara *et al.*, 2007).

Illegal logging also occurred in the Sei Kepayang subdistrict of Asahan district in North Sumatra province in 2010. Investigations by local NGOs reported that illegal logging had been responsible for the loss of 100 ha of mangrove forest there. It was also reported that most of the trees cut down had been *Rhizophora Mucronata* with a diameter of 10-15 inches. It is strongly suspected that this was due to a market demand for timber of this size.



*Figure 2. Mangrove forest heavily logged by illegal loggers in Pasangkayu
(Photo: Iwan TCW, 2010)*

Forest Watch Indonesia reported that illegal logging practices (of various types of timber, not just mangrove) cost the State losses of Rp. 45 trillion (US\$ 4 Billion) in 2004. In the latest reports, Indonesia Corruption Watch (ICW) and Sawit Watch Indonesia (SWI) have estimated the potential loss to the State due to illegal logging in 2010 to be Rp. 14.13 trillion or US\$ 1.6 Billion (Jakarta Post, 2010).

D.7. Mining

Information on mining activity in Indonesia's mangrove ecosystems is extremely limited. The following is information gathered on a few of these activities.

In Bangka Belitung province, tin mining activity in 2009/2010 seriously degraded around 70 percent of the total 122,000 hectares of mangrove. Mining operations not only destroyed mangrove forest but also had a detrimental impact on other coastal ecosystems in the area (Kompas, 2010).

In 2007, four coal mining companies operating in South Kalimantan province (PT BCMP, PT Borneo Inter Nusa, CV Antara, CV Rahma and PT Adibara Pelsus) were reported to have destroyed mangrove forest on the coast of Serongga, Kabupaten Kotabaru district. Unfortunately, the exact area of mangrove forest affected by the mining activities is not known. It is reported that these coal mining activities also left behind them chemicals harmful to mangrove forest and to the other ecosystems in the area (Kabupaten Kota Baru, 2007).

Mangrove forest on Batam island (off the east coast of Sumatera) is also reported to have been badly degraded as a result of sand quarrying. Investigations by a local NGO in 2009 reported large numbers of dead trees, with the remaining trees experiencing severe stress and thus being in extremely worrying condition. Unfortunately, the precise area of mangrove forest lost and degraded as a result of the sand quarrying is not known. Many researchers are certain that this quarrying has altered the coastal hydrology which will, it is feared, endanger the future survival of the mangrove forest (Batam Pos, 2010).

D.8. Natural disasters

Situated in the volcanologically active “ring of fire”, Indonesia is known to be a country highly prone to disasters. Natural disasters hitting Indonesia during the last ten years have increased in frequency compared against the previous years. Recorded national disasters include: flash floods in 2003 in Bukit Lawang village (North Sumatra province), tsunami in 2004 in Nanggroe Aceh Darussalam province, flash floods in 2010 in Wasior (West Papua), tsunami in 2010 in the Mentawai Islands (West Sumatra province), and the recent eruption of Mt Merapi in Yogyakarta towards the end of 2010.

Natural disasters in Indonesia have claimed huge numbers of lives and caused incalculable amounts of damage and loss. They have also been responsible for damage to various types of ecosystem, which leads to a decline in environmental quality. Of the disasters mentioned above, tsunami poses the biggest threat to coastal ecosystems, including mangrove forest.

The Tsunami that hit Nanggroe Aceh Darussalam province in 2004 devastated most of the province’s coastal areas (west, north and east coasts, and several islands to the west) as well as those of Nias island in North Sumatra province. BAPPENAS (National Development Planning Agency) reported that mangrove forest destroyed by the Tsunami amounted to 25,000 ha (Indriatmoko, et al. 2006). A different figure is reported by LAPAN (National Institute for Aeronautics), who state that the area of mangrove forest destroyed by the Tsunami was as much as 32,000 ha, most of it on the north and east coasts of Aceh (Dephut, 2005).



Figure 3. Mangrove swept away by Tsunami in Aceh Besar (Photo: Iwan TCW, 2005)

Recently, tsunami also hit the Mentawai Islands (West Sumatra province) in November 2010. This disaster is also reported to have caused destruction along the whole of the west coast, including the mangrove forests. Unfortunately, the exact area of mangrove forests destroyed there is as yet unknown.

2. Mangrove services and their economic value

Mangrove is one of the most productive ecosystems, which is why millions of people living in coastal areas depend heavily on mangrove forests to fulfil their needs for goods and services, as well as cultural attributes (Saenger, 2002). This dependence includes fishery products, wildlife, medicines, gums, tannins, honey and fruits. Mangrove also plays an important role in protecting the coastline from erosion and flooding, providing shelter against storm, and acts as a carbon sink and nutrient store. For these reasons, mangrove is usually considered as the backbone of tropical coastlines.

A comprehensive assessment of the beneficial services provided by mangrove ecosystems in Indonesia from ecological, economic and social viewpoints began about two decades ago when Ruitenbeek published his findings on the economic value of the mangroves in Teluk Bintuni in 1992. However, comprehensive study of mangrove's economic value was then relatively inactive until 1998 when Kusumastanto *et al* (1998) published their findings on the economic value of mangroves in an area prone to oil spills in the Malaka Straits. Since then, dozens of research projects, Master's theses and Doctoral dissertations have assessed the economic value of mangrove ecosystems in Indonesia's coastal areas, including studies by Bangda and IPB (2000) and Gonner (2002) which published their findings on the economic value of mangrove ecosystems in Segara Anakan (Central Java) and Sembilang National Park (South Sumatera).

A. PROVISIONING SERVICES

The mangrove forest ecosystem is known as the ecosystem which has the highest productivity and possesses above-ground biomass ranging from 5.4 to 18.4 kg/m² (Hutchings and Saenger, 1987). Its high productivity, according to Duarte and Cebrian (1996), is mainly (90%) derived from leaf-fall. About half of the fallen leaves remain in the mangrove ecosystem because they decompose in the water (40%) or are stored in the soil sediment (10%) while much of the remainder are carried away by water to other nearby ecosystems (30%) (Duarte and Cebrian, 1996). Hamilton (1984) found that the total weight of the fallen mangrove leaves ranged from 10 to 14 ton dry-weight/ha/year.

The results from many studies show that, although the figures for the economic value of environmental services differ from one place to another, they always show very high economic value for mangrove ecosystems, reaching trillions of rupiah per region. An assessment carried out by the Environment Ministry and PKSPL of Institut Pertanian Bogor (Bogor Agricultural University) and published by Gatra magazine (Majalah Gatra, 2002) describes the Total Economic Value of mangroves in various parts of Indonesia, which are : Madura island Rp 49 trillion (US\$ 5.4 billion), Papua Rp 329 trillion (US\$ 36.5 billion), East Kalimantan Rp 178 trillion (US\$ 19.7 billion), West Java Rp 1.357 trillion (US\$ 151 million), and for the whole of Indonesia around Rp 820 trillion (US\$ 91 billion).

More detailed research by Ruitenbeek (1992) in Bintuni Bay where the mangrove ecosystem covers about 300,000 ha shows that traditional use/utilisation by the local community has an annual economic value of around Rp 100 billion (US\$ 11 million), fisheries Rp 350 billion (US\$ 39 million) per annum and logging around Rp. 200 billion (US\$ 22 million).

A.1. Fishery

Mangrove plays a very important role in supporting fishery in Indonesia. This is because mangrove shelters aquatic organisms from the sun, its fallen leaves make the waters more fertile, and the complexity of its root systems in the water column makes mangrove swamp a comfortable place for various aquatic biota to take refuge, spawn and feed. Such conditions make fishery productivity (including shrimps, crabs and molluscs) in mangrove waters very high, thus providing an important source of food for the community. Currently, fisheries, especially *tambak* pond aquaculture, have become the activity with the highest economic value that utilises the mangrove ecosystems in Indonesia. This is because almost all these aquaculture farms are in or near mangrove ecosystems.

The average annual value of *tambak* aquaculture based fishery production in Indonesia over the last five years (2005-2009) was Rp 16 trillion or around US\$ 1.8 billion (DKP, 2009). This shows a continuing upward trend from year to year (DKP, 2009). A primary aquacultural fishery commodity is shrimps, most of which are produced for export. The annual volume of shrimp exports during the last five years was around 163 thousand MT (metric ton) with a value of about US\$ 1 billion (Figure 4).

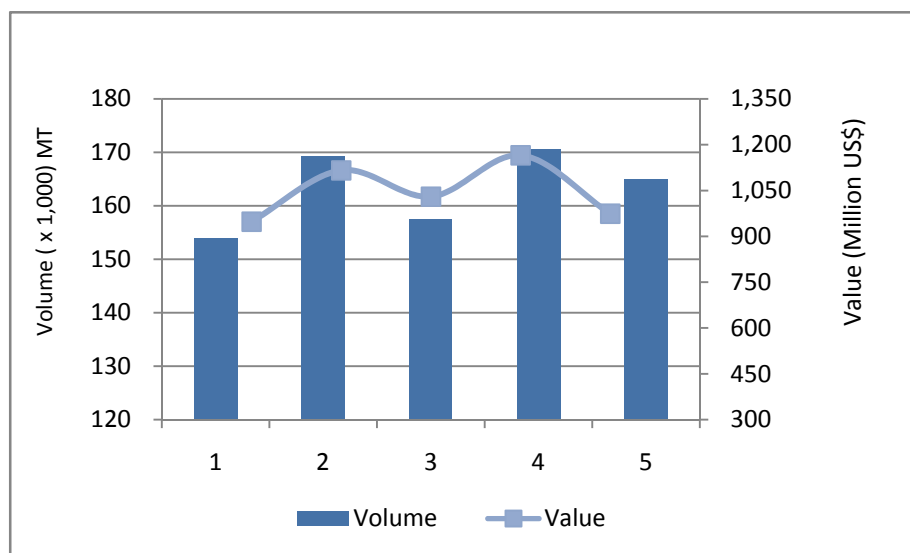


Figure 4. Volume and value of Indonesia's shrimp export between 2005 – 2009.
Graphic generated from Ministry of Marine Affairs and Fishery/ MMAF (2009)

Another type of fishery is fish capture in and around the mangrove ecosystems. The fish targeted (including shrimps, molluscs and crabs) depend for part or all of their life cycle on the mangrove ecosystem. One of the main products of capture fishery in or around mangrove ecosystems is crabs. Total annual crab export from Indonesia (both captured and cultivated) is around US\$ 180 million.

The mangrove ecosystem is a nursery ground for a range of fish and shrimps, and during the 1980s was one of the sources of natural shrimp larvae for the aquaculture industry. As the numbers of larvae in the wild have become much diminished (due to degradation of their natural ecosystem) and therefore inadequate to stock the ponds, harvesting of larvae from the wild is now much less common. Instead, larvae are produced in hatcheries.

Shrimp hatcheries are currently limited to certain species, in particular the Blacktiger (*Penaeus Monodon*), Pacific white (*Litopenaeus vannamei*), and a small number produce Banana shrimp (*Fenneropenaeus merguensis*). Other commercial shrimps like the Black pink (*Metapenaeus monoceros*), which is farmed in ponds in Sulawesi and East Kalimantan, still depend entirely on wild stocks in mangrove ecosystems.

Production of Black pink from the north coast of East Kalimantan (Tarakan and surrounding area) is around 2,000 MT/annum (PT. MMA 2009). To achieve this amount requires at least ¼ billion Black pink shrimp larvae, all of which come from the wild. This shows that the function of the Tarakan coastal mangrove ecosystems as a nursery ground for Black pink shrimp larvae alone has an economic value of over US\$ 130 thousand a year or around US\$ 1.3 per ha². This value will rise substantially if the economic value of the other crab, shrimp and fish larvae obtained directly from East Kalimantan's north coast mangrove waters are also included in the calculations.

Assessment of the economic value of fishery in mangrove ecosystems elsewhere has also been done, specifically in Batu Ampar (West Kalimantan) in 2001, Segara Anakan (Central Java), and Subang (West Java). Annual value of fishery utilisation in Batu Ampar was around Rp 13 billion per annum (US\$ 1.4 million) from the capture and cultivation of fish, shrimps and crabs (see Table 4 below). The assessment also gives more detailed information about annual mangrove productivity per hectare values, which are : Rp 500,000/ha/year (US\$ 56) for shrimps, Rp 150,000/ha/year (US\$ 17) for crabs, and Rp 74,000/ha/year (US\$ 8.2) for fish. These economic values are relatively small if compared the annual productivity values for fishery in Segara Anakan which reach Rp 922,647/ha/year (US\$ 103) and in Subang which the figure is about Rp 848,148/ha/year (US\$ 94). This difference is due partly to the differences in the local shrimp prices in each place.

Table 16. Direct benefit of fishery activities in Batu Ampar Mangrove Ecosystem – West Kalimantan. (Salmah et al., 2001).

Type of benefit	Benefit value (Rp/yr)	Cost (Rp/yr)	%	Nett benefit (Rp/yr)	%
Fish	1,534,309,800	498,050,900	32	1,036,258,900	68
Shrimps	8,486,116,800	784,210,200	9	7,701,906,600	91
Crabs	2,920,904,300	829,454,700	28	2,091,449,600	72

² Assumption: harvest weight of Black pink 14 gram, survival rate 60%, larvae price Rp 5 each, total mangrove area around Tarakan 100 thousand ha.

Box 1. The role of mangroves in sustaining aquaculture production

Healthy mangrove ecosystems support sustainable aquaculture fishery by protecting it from natural hazards through a variety of mechanisms, which include controlling the rate of erosion and providing protection from flooding and storms. These ecological services have values that differ from place to place depending on the fishery site's level of fragility in respect to various natural disturbances. For this reason, the existence of mangrove ecosystems in the form of a relatively wide green belt in an area should possibly be a basic requirement for aquaculture ponds, while in other places it is needed simply to provide better water quality.

One function of mangrove ecosystems which is vital in the management of aquaculture pond water quality is to control/absorb waste nutrients from the ponds. According to Robertson and Phillips (1995) mangrove forest covering 22 ha is capable of filtering/absorbing waste nitrogen and phosphorous from 1 ha of intensive aquaculture.

The high productivity of mangrove forest ecosystems constitutes a food supply for the fish farming system. Organic material and nutrients from the mangrove can be carried in the form of nutrient-rich water to the open waters nearby for use by shellfish being cultured there or by shrimps and fish being raised in terrestrial ponds. Larsson et al (1994) estimate that the bacteria and fungal layer on mangrove leaf detritus contribute about 30% of shrimp food in the wild. Fish and other aquatic organisms living in the mangrove ecosystem can also function as food, both directly as "trash fish" or as a component of manufactured pellets.

A.2. Timber and non timber products as direct benefit

A.2.1. Timber products

Mangrove forest has fairly high timber potential. However, in terms of volume, timber production from mangrove forests is less than that from other types of forest. Not only do mangrove forests cover a smaller area, but the number of commercial tree species growing there is much fewer than in terrestrial tropical forest.

Timber products obtained from mangrove forests are : (a) chips, especially from *Rhizophora spp* and *Bruguiera spp*, (b) wooden planks or plywood from *Bruguiera spp* and *Heritiera littoralis*, (c) "scaffold" specifically from *Rhizophora apiculata*, *Bruguiera spp* and *Ceriops spp*, and (d) charcoal specifically from *Rhizophora spp* (Watson, 1928, cited by Saenger, 2002). A study by Soemodihardjo et al (1993) reports that mangrove forest in South Kalimantan has high timber potential with an average volume of 135 m³/ha, while timber potential of mangroves in Papua is much lower at only 40 m³/ha. (Soemodihardjo et al., 1993)

It is known that timber potential from mangroves has been utilised by the local community since long ago but the literature does not say when this first began. Win (1924) reported that organised large scale exploitation of mangrove forest only started in 1923. Generally, harvesting has been directed towards *Rhizophora mucronata* which is widely used as a building material, poles and firewood.



Figure 5. *Bruguiera* and *Rhizophora* poles taken from Bulungan mangrove forest, East Kalimantan, for construction works (Photo: Ilman, 2009)

A report on log production in the forestry sector published by the Bureau of Statistics (BPS) notes that mangrove log production in 2004 was 290,474 m³. This subsequently decreased. In 2008, it was reported to be 55,558 m³ (see graph below). (BPS, 2009)

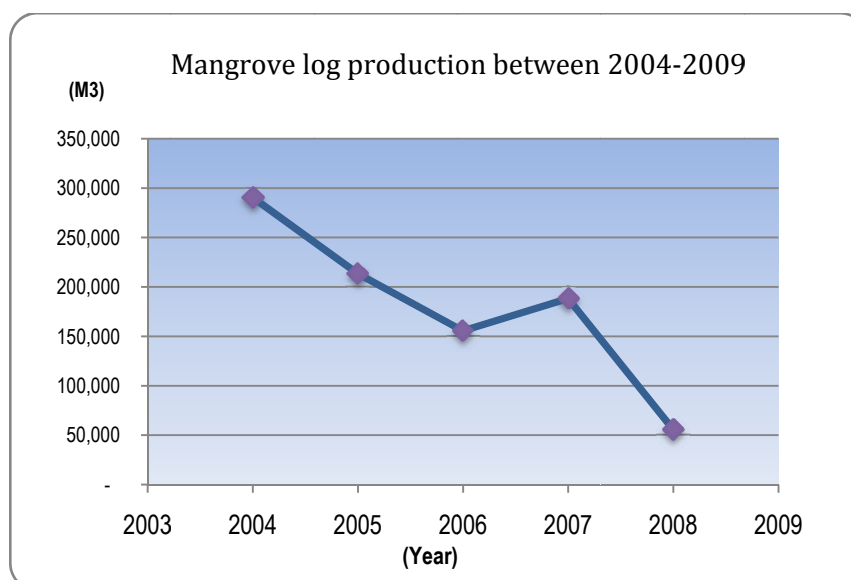


Figure 6. Mangrove log production between 2004-2008 (Source, BPS, 2009)

In addition to logs, mangrove forests are also well known as a source of high quality charcoal. Citing Alrasjid (1989) in Dahuri *et al.*, (1995), one hectare of mangrove forest is capable of producing an average of 9m³ of charcoal a year. Meanwhile, an economic evaluation of mangrove by Salmah *et al.* (2001) in Batu Ampar (West Kalimantan province) in 2001 found the total net benefit from charcoal to be Rp. 855,141,900 a year (US\$ 95,000).

A.2.2. Non timber forest products

In addition to timber products, mangrove forest also contains “non-timber forest product” potential. This term refers to all products and services other than timber that can be obtained or utilised from the forest. Non-timber products include fruit, vegetables, fish capture, medicinal plants, resin, other aromatic products, bark, fibre, and other non-timber plants such as bamboo and rattan, if present. The table below summarises the species of mangrove traditionally known and used by the community to meet their daily needs and earn additional income.

Table 17. Timber and Non-timber forest products from various species of mangrove (Kusmana, 2010).

No.	Species	Use
1.	<i>Acanthus ilicifolius</i>	Fruit crushed in water can be used to help stop bleeding from a wound and to treat snake bites.
2.	<i>Acrostichum aureum</i>	Parts of the young plant can be eaten raw or cooked as a vegetable.
3.	<i>Aegiceras corniculatum</i>	Bark and seeds used to make fish poison.
4.	<i>Avicennia alba</i>	Young leaves used for livestock fodder, seeds can be eaten if boiled, bark is used for traditional medicine as an astringent, a secreted resin-like substance is used as a contraceptive, an ointment made mixed with the seeds of this plant is very effective in treating pox blisters – the seeds are highly toxic so great care must be taken when using them.
5.	<i>Avicennia marina</i>	Young leaves can be eaten as a vegetable, pollen from the flowers can attract honeybee colonies, ash from the wood is an excellent ingredient in soap-making.
6.	<i>Avicennia officinalis</i>	Seeds can be eaten after they have been washed and boiled.
7.	<i>Bruguiera gymnorhiza</i>	The wood is excellent for charcoal-making, firewood and tannin, bark from the young trunk can be used in cooking to flavour fresh fish, <i>pneumarhophoranya</i> can be used as seedlings for mangrove reforestation.
8.	<i>Bruguiera parviflora</i>	Wood for charcoal and firewood.
9.	<i>Bruguiera sexangula</i>	Young leaves, fruit embryo, root hairs can be eaten as a vegetable, the leaves contain alkaloid that can be used to treat skin tumours, roots can be used for making incense, fruit for mixing traditional eyewash.
10.	<i>Ceriops tagal</i>	Bark is excellent for colouring, for preserving/strengthening fish nets and for the batik industry; the wood is good for the plywood industry; bark is used for traditional remedies.
11.	<i>Excoecaria agallocha</i>	The sap is toxic and can be used to poison fish.
12.	<i>Heritiera littoralis</i>	Wood is good for the plank industry, the fruit's juice is toxic and can poison fish.
13.	<i>Lumnitzera racemosa</i>	Boiled leaves can be used to treat mouth ulcers.
14.	<i>Oncosperma tigillaria</i>	Trunks used for house stilts/poles, soft shoots as a vegetable, flowers to flavour rice.
15.	<i>Rhizophora mucronata</i>	Wood for charcoal/firewood and chips; fruit juice and skin of young shoots can be used to repel mosquitoes from the body.
16.	<i>Rhizophora apiculata</i>	Wood for firewood, charcoal, chips and construction timber.
17.	<i>Sonneratia caseolaris</i>	Fruit are edible, the fruit juice can be used to soften the skin, the leaves for goat fodder, can produce pectin.
18.	<i>Xylocarpus woluccensis</i>	Wood is very good for planks; roots can be used as a basic material for handicraft making (wall decorations, etc); bark for traditional remedy to treat diarrhoea; fruit exude oil that can be used as a traditional hair oil.
19.	<i>Nipa fruticans</i>	Leaves for house roofs, walls, hats, raw material for making paper, baskets and to wrap cigarettes; the fermented sap (nira) for drinks and alcohol, seeds for jelly and consumption as ‘kolang-kaling’; and the leaf sheaths which are burnt to produce salt.

An economic evaluation of mangrove forest in 2001 (Salmah, et al., 2001) in Batu Ampar (West Kalimantan province) identified the total net benefit from Non-Timber Forest Products obtained from the utilisation of nipah leaves at Rp.81,330,832 (US\$ 9,000) and that from the sale of mangrove seedlings at Rp.855,141,900 per annum (US\$ 95,000).

In addition, the use of mangrove for foodstuffs has long been part of the coastal communities' lives. This takes the form of staple foods, edible fruit, and as a main or minor ingredient in the making of various traditional cakes. Mangrove fruits commonly consumed by the community include *Bruguiera*, *Rhizophora*, *Acrostichum*, *Avicennia*, and *Sonneratia* (Santoso et al., 2004). Coastal inhabitants in Sulawesi have been using mangrove in their diets since the 16th century (Santoso et al., 2005).



Figure 7. *Sonneratia* fruit commonly consumed by Buginese living in coastal area of Sulawesi and Kalimantan.

Today, the use of mangrove fruits for food is still very limited. Besides the tendency to select fruits that are generally familiar to them, the general public are also wary because the fruits of some mangrove species contain toxic substances such as HCN. In fact, these substances can be easily removed through washing, thus making the fruit safe to eat. There are now at least two books containing various recipes for preparing food from mangrove ingredients, safely and healthily, written by Santoso et al (2005) and Priyono et al (2010) respectively.

Several research studies have been done at IPB with the primary aim of determining the nutrient content of mangrove fruit and at the same time to explore methods of using mangrove for human consumption. From this research, it can be stated that the energy content of mangrove fruit is equivalent to 371 kilocalories per each 100 grams. This is much higher than that of rice (360 kilocalories/100 grams) and corn (307 kilocalories/ 100 grams).

As quoted by Tempo Interactive magazine (2005), the carbohydrate content of mangrove fruit is estimated to reach as much as 85.1 grams per 100 grams of fruit. This is significantly higher than for boiled rice (78.9 gram/100 gram) and corn (63.6 gram/100 gram). Thus it can be concluded that mangrove fruit have great potential as a foodstuff and can at the same time provide an alternative when facing food shortages.

B. REGULATING SERVICES

Mangrove play an important role in providing natural physical protection against coastal abrasion, tsunami, tidal waves and storm. The threat of sea-level rise is worrying for small islands and coastal areas (IPCC 2007).

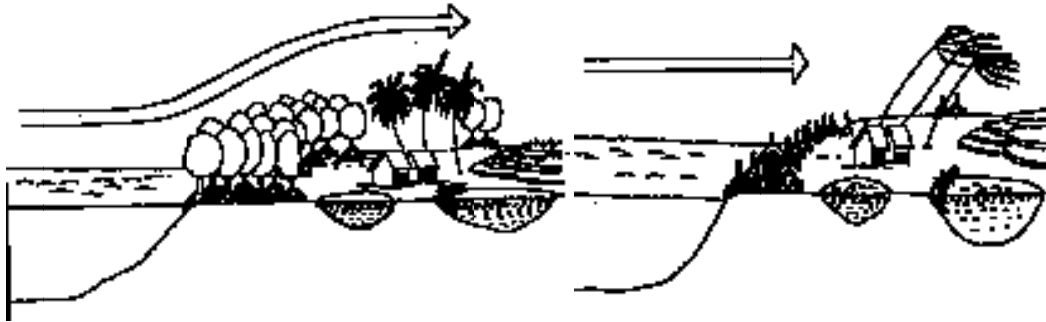


Figure 8. Simple illustration depicts the role of mangrove in protecting coastal area from strong wind (source: wiip doc)

B.1. Micro climate regulation

Mangrove ecosystems also play an important role in stabilising micro climates. A dense mangrove forest stand can create conditions in which daytime temperatures are relatively cool and night-time relatively warm. Besides this, air humidity under a mangrove canopy is higher than outside in the open. Evapotranspiration occurring from the natural mangrove forest affects a rise in humidity and cloud density on a regional scale, thus having an influence on regional rainfall patterns (Kusmana, 2010).



Figure 9. Boating under canopy of *Avicennia* in Mahakam Delta (Photo: Ilman, 2009)

From another perspective, mangrove ecosystems also possess the capability to sequester carbon dioxide (CO₂) which is a greenhouse gas, by converting it to organic carbon (C) through photosynthesis, and then storing it in its biomass. If mangrove forests increase, so more greenhouse gases will be sequestered. Conversely, however, if the area of mangrove forests continues to decline, less CO₂ will be sequestered. Moreover, when mangrove forests are logged, this releases CO₂ thus increasing the concentration of CO₂ gas in the atmosphere. This mechanism is strong evidence of the role of mangrove in the issue of climate change.

Ong (1993) estimated above ground biomass at 100-200 ton C per hectare, with annual productivity between 9 to 12 ton C/ha. Although the accumulation of below ground carbon by root systems is very difficult to measure, it is estimated to be capable of reaching 700 t C per 1m soil thickness per hectare, by estimating a carbon sequestration rate of 1.5 t C/ha/year (Ong, 1993).

Several measurements of carbon stock have been done specifically on mangrove forest in the last three years. That done by WIIP in Kabupaten Pasangkayu district (West Sulawesi province) in 2010 found that dense mangrove forest could store 382.8 ton carbon per hectare, while sparse mangrove forest could have a carbon stock of 261.9 ton/ha (Wibisono *et al.*, 2010). Measurements by CERINDO in 2009 in Sembilang National Park (South Sumatra province) confirmed that primary mangrove forest possesses a carbon stock of 241 ton /ha, whereas that of degraded forest is much smaller at 128 ton/ha (Boer, 2009). Besides storing carbon in its biomass, mangrove forest also accumulates large quantities of carbon in the soil (carbon soil). In a 20 year old stand of mangrove, this carbon stock could reach 11.6 kg/m² with an accumulation rate of 580 g/m²/year (Fugimoto, 2000).

Under certain conditions, mangrove is capable of altering the natural landscape, topography and bathymetry of an area through sedimentation. This reduces the land's vulnerability to threats of flooding resulting from a rise in sea-level.

B.2. Pollution control

Another role of mangrove forest is its capacity for controlling pollution. Besides filtering natural waste which can prevent various forms of pollutants, mangrove forest is also capable of absorbing pollutants rapidly and effectively, thus minimising the extent of pollution (Robertson and Phillips, 2005).

Maintaining mangrove forest around an aquacultural area is one of the best ways of controlling and eliminating pollutants, considering that aquaculture tends to use manufactured food pellets and various kinds of chemicals, both as pesticides and for other purposes. This has been confirmed by research carried out by Kusumastuti (2009) in Kabupaten Sidoarjo district, which concluded that mangrove forest succeeded in neutralizing various pollutants, in particular those originating from pond aquaculture. Some of the important findings from this research are as follow:

- Mangrove is known to be effective in overcoming water pollution; i.e. it is capable of reducing water turbidity and lowers the values for BOD (Biological Oxygen Demand), nitrate, phosphate, cadmium (Cd) and lead (Pb) in water.
- Muddy sediment on the floor of mangrove forest stores large amounts of pollutants such as lead (Pb) and copper (Cu). This is evidenced by the high concentrations of these substances in the sediment layer.
- Mangrove deals with pollutants in three ways : 1) it absorbs the pollutants and stores them in its roots, stems and leaves, 2) it stabilizes the sediment which is vital for mangrove root systems, and 3) indirectly, mangrove is a habitat for various waste decomposer microorganisms.

B.3. Natural defence in disaster adaptation

Mangrove forest is at the front line of a natural defence system which is of great significance to disaster risk reduction. This is extremely important for Indonesia considering that the majority of her population (65% of a total 235 million) live in coastal areas. Mangrove plays a role in preventing or reducing erosion by catching and depositing sediment. This process is very important in relation to the issue of rising sea levels. Mangrove stands are also capable of arresting, absorbing and reducing the force of waves through their exceedingly dense root system.

As a terrestrial natural defence system, mangrove forest is capable of sheltering the coast from a range of possible hazards coming from the sea, such as tidal waves, hurricane, storms, and even tsunami. However, the extent to which it can be effective depends on a number of factors, including : the type of hazard, its force, the thickness and density of the mangrove, the species composition of the mangrove, etc. Under certain conditions, mangrove forest really can prevent damage by disasters from the sea. At other levels, however, it is at least able to reduce the amount of damage caused by the disaster.

B.3.1. Natural defence against tidal waves and tsunami

In his report, Aksomkoae (1993) emphasizes that mangrove play an important role in mitigating the impact of tidal waves and tsunamis. The structure of mangrove forest stands enables them to withstand strong waves and helps to spread the force of the wave. An analytical model developed by Hirashi and Harada (2003) indicates that a mangrove stand of 30 trees per 0.01 hectare with a depth of 100 m can reduce the destructive force of a tsunami by up to 90%. In Indonesia, several studies have been done that look specifically at how mangrove forest plays a role in reducing the impact of tidal waves and tsunamis. The results of some of these are given below:

- Pratikto *et al* (2002) conducted research at Teluk Grajagan, Kabupaten Banyuwangi district (East Java province) which indicated that the mangroves growing along the shore had significantly reduced the force of tidal waves by 0.7340 joule.
- A study by Utomo (2003) also confirmed that mangrove forest with an average height of 5 metres and thickness of 50 metres could minimize wave height and reduce wave force to between 25% and 38%.
- From another point of view, Istiyanto *et al* (2003) in their research stated that mangrove stand formation situated/growing in an alternating manner with mixed species would increase the mangrove's ability to reduce the energy of a tsunami. In this formation, the mangrove would reflect, absorb and transmit part of the tsunami's energy more effectively.
- Suryana (1998) in his study confirmed that mangrove forest with a width of 100m inhabiting the shore had the potential to reduce the initial extent of the wave to 60%.

Mangrove's function as a coastal defence against tsunami was proven during the disaster that hit Nanggroe Aceh Darussalam province in December 2004. Field findings identified a correlation between the presence of mangrove and the degree of damage done. In places that still possessed dense mangrove forest, the level of damage was far lighter compared with those areas where the mangrove had been removed or badly degraded (Onrizal, 2005).



Figure 10. Mangrove's role in protecting coastal area from tsunami
(source: Mangrove Action Project)

B.3.2 Abrasion control

Abrasion (coastal erosion) can damage the coast (including the infrastructure and buildings on it), disrupt people's livelihoods, and trigger conflict over coastal land ownership.

With its zonation patterns and root systems, the mangrove forest ecosystem plays an important role in controlling coastal erosion. As is known, several mangrove species, particularly those growing in the front zone like *Sonneratia* spp, possess extremely firm root systems that can protect the shoreline from the assault of the waves.

Mangroves control abrasion by breaking the kinetic energy of the ocean waves and reducing the extent of their penetration onto land. This has been proven in a study by Suryana (1998) on the north coast of Java. This study confirmed that abrasion does not occur on beaches having a 100m (minimum) thick mangrove forest.

On the coast of Tongke-tongke village (kabupaten Sinjai district) in South Sulawesi, a 200-300 metre wide belt of mangrove (*Rhizophora* spp) planted from the edge of the shore into the sea (planted 0.5 x 0.5 m apart) has succeeded in protecting the village from storm and waves. This mangrove forest now extends out far into the sea as a result of the shallowing caused by sedimentation of mud from the nearby river.

B.3.3. Flood control

Mangrove can also reduce the impact/damage caused by water currents during flooding. The root system and sturdy trunks of mangrove trees can reduce the velocity of water flow when heavy rain/flooding occurs. This corresponds with a report by Hossain et al. (2009) which states that the level of flood damage will be smaller if there is mangrove forest nearby.

Another mechanism by which mangrove mitigates flood hazard is through the ability of its substrate to absorb water and maximise the ecosystem's water storage capacity function. Excess water from heavy rain or overflow from another area can be well absorbed by the substrate, while the remainder can be stored in the form of pools on surface of the substrate without run-off to other places.



Figure 11. Mangrove at Tongke-tongke, south Sulawesi, protects the village and boat access to the village is made in between mangrove trees (left). Planting mangrove near the seashore (right). (Photo: Nyoman Suryadiputra, 2010)

B.3.4. Hydrological regulator and intrusion control

Mangrove plays an important role in controlling the water cycle and preventing intrusion of seawater into the land. Suryana et al (1998) state that mangrove performs this function in two ways: a) by maintaining terrestrial fresh groundwater levels, and b) preventing tidal waves from reaching rivers. The presence of mangrove will also protect the aquifer stock which makes it possible to reduce/prevent seawater intrusion into land. More detailed explanation is given by Kusmana (2010), who explains that intrusion control by the mangrove ecosystem occurs through four mechanisms: a) the inhibition of CaCO_3 deposition by substances in root exudates; b) the reduction of salinity by organic material resulting from the decomposition of litter/detritus; c) the physical role of the mangrove root structure that restricts the landward reach of high tides, and d) the improvement of the soil's physical and chemical characteristics through the decomposition of litter.

Mangrove is capable of surviving in highly saline environments where other species cannot. Where salinity is high, mangrove adapts by absorbing salt into its roots and leaves. It is this mechanism that enables it to adapt to highly saline environments; and directly it will play a role in preventing seawater intrusion or reducing soil and water salinity (Climate Avenue, 2010).

Research by Sukresno and Anwar (1999) into the quality of well-water along the Java North Coast proved that there is a strong correlation between water quality and the presence of mangrove. According to this study, well-water 1 km from the coastline in Pemalang and Jepara remained fresh because the mangroves at these two sites were still in good condition. In contrast, well-water at the same distance from the coastline (1km) in Semarang and Pekalongan had become saline as much of the mangrove forest there had become degraded and parts of it completely destroyed for conversion to *tambak* aquaculture ponds. (Our Note: Maybe the loss of mangrove is only one factor. As Semarang and Pekalongan more densely populated than Pemalang and Jepara. So, the higher rate of groundwater extraction for human use in densely populated area would also be a major cause of saltwater intrusion.)

C. CULTURAL SERVICES

C.1. Ecotourism

Indonesia possesses the largest total area of mangrove ecosystem in the world, with an extremely rich biodiversity. Sadly, the use of this ecosystem for the purposes of recreation and tourism has not yet been well managed whether by government, the community, or the private sector,

especially if compared with the management of mangrove ecosystem based tourism in Malaysia and Singapore. Malaysia, for example, has at least ten professionally managed mangrove ecosystem tourist sites. One of these is the Langkawi mangrove ecosystem, which is managed as a recreational wilderness. Visitors can take a 6 hour boat tour through the mangrove forest for RM 140 or about 45 USD (VirtuaMalaysia.com).

In Indonesia, only a very few mangroves have been developed and then professionally managed as a tourist venue charging an entrance fee. These include the Mangrove Information Centre (Pusat Kajian Mangrove) at Suwung Bali, Tarakan Urban Protection Forest (Hutan Lindung Kota Tarakan) in East Kalimantan, and the Angke Kapuk Ecotourism Park in Jakarta. The Tarakan Urban Protection Forest is a 9 hectare mangrove ecosystem located next to the commercial centre of Tarakan city. Although this forest is managed as a multifunctional site, its functions encompassing education, research, green belt, *bekantan* (Proboscis monkey) conservation, and as the town's "lungs", it is better known as a recreational forest. Each month, about 2,500 local and foreign visitors visit this mangrove forest, paying an entrance fee of Rp 2,000 or 0.22 US (local visitors) and Rp 10,000 or US\$ 1.1 (foreign visitors). Thus, this mangrove ecotourism brings in a total of around Rp 5,000,000 (US\$ 556) a month from entrance fees alone.

In fact, a lot of mangrove ecosystems have been developed for commercial ecotourism. Some even have expensive infrastructure built by the local government. Sadly, most of these sites, although already in operation, have not been developed to their full envisaged potential because of a lack of management skills on the part of the local community, the private sector and the government. These sites include recreational mangroves at Wonorejo (East Java), Bontang Kuala (East Kalimantan), Hutan Mangrove Mojo (Pemalang in Central Java), and Kuala Langsa (Aceh). Income obtained by the community from managing the ecotourism at these sites does not come from a system of payment for the ecosystem's services, such as from an entrance fee or the provision of well organised tourist services, but more from indirect, supporting services like parking and restaurants, or occasionally from disorganised boat rental which is not well managed.

C.2. Education

There are also a few mangrove ecosystems in Indonesia where good facilities have been constructed to accommodate visitors. The problem is that these have been aimed more towards education and research, so recreational activities are just an extra addition. Examples of this type of mangrove ecosystem management can be seen at the Mangrove Information Centre Bali, the Environmental Education Centre (PPLH) at Puntondo South Sulawesi, and the Lebah Foundation Mangrove Research Centre (Pusat Penelitian Mangrove Yayasan Lebah) in Aceh.



Figure 12. Board walk in mangrove Center in Suwung village, Bali (left); and cottages within mangrove forest in Jakarta (right). (Photo: Nyoman Suryadiputra, 2010)

D. SUPPORTING SERVICES

D.1. Nutrition cycle

Mangrove forest is a starting point in the food web because a mangrove ecosystem (on the forest floor) contains large quantities of detritus capable of feeding many types of microorganism. The high decomposition rate and the continuous operation of the nutrition cycle are reasons why the mangrove ecosystem is known as the most productive of the wetland ecosystems.

Mangrove forest is widely known for its role in the food chain cycle, both within the mangrove ecosystem itself and in the waters around it. Mangrove leaf debris on the forest floor is an important food for many forms of life in the mangrove ecosystem. The presence of decomposer organisms not only turns the leaves into detritus that finally becomes food for the aquatic creatures around it (like worms, crustaceans, fish, molluscs and other fauna), it also releases nutrients (nitrogen and phosphate) needed by primary producers (like phytoplankton) to photosynthesise.

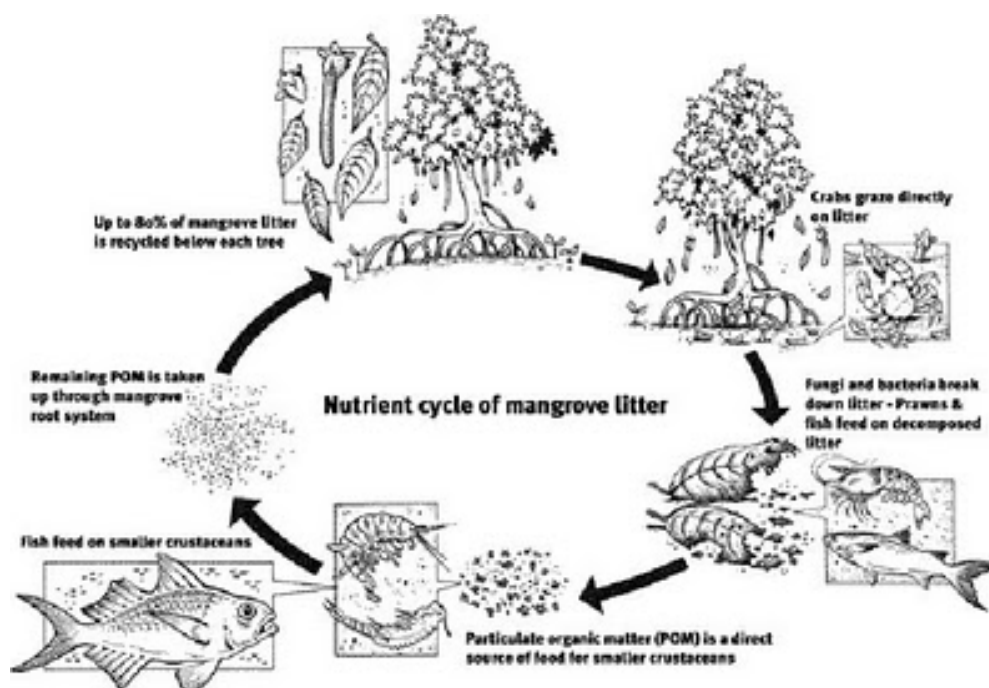


Figure 13. Simple illustration of nutrition cycle of mangrove litter³

Mangrove ecosystems contribute directly to the maintenance of fish stocks in the waters both within the mangrove ecosystem and outside it, by supplying nutrients and providing a perfect habitat for spawning. With this rich fish resource, mangroves are considered to play a vital role in the livelihoods and food security of millions of people, in particular those who live in Indonesia's coastal regions.

A study carried out by Martosubroto and N. Naamin (1997) proved that there is a positive correlation between the presence of mangrove ecosystems and increased catches of fish and shrimps by the community. In addition, Hemminga *et al* (1994) state that seaweed plays a role as a buffer zone between mangrove and coral reef, where the seaweed can effectively trap nutrients produced by the decomposition of organic materials originating from mangrove litter.

³source: http://1.bp.blogspot.com/_002C7n3paGI/S3NuuBQf-SI/AAAAAAAAAgc/XDE6nL70DHg/s400/mangrove+nutrient+life+cycle.JPG

From a study by Kusmana (1995) in the area of Talidandang Besar (Riau province), it is known that litter production from a stand of *Bruguiera parviflora* is 1267 g/m²/year. For *B. sexangula* and mixed communities of *B. sexangula-Nypa fruticans* respectively, the figures are 1269 g/m²/year and 1096 g/m²/year.

Meanwhile, observations by Sukardjo (1995) show that the abundance of litter in mangrove forest can reach 13.08 ton/ha/year. This figure is equivalent to a mangrove phosphate contribution of 2 kg/ha/year and Nitrogen (N) 148 kg/ha/year. This is highly important as a significant contribution from mangrove in the form of nutrition enrichment that is vital to the plants and animals that inhabit mangrove forest.

D.2. Role of mangrove as a biodiversity pool

Mangrove is a unique ecosystem that forms a home for a wide variety of flora and fauna. This ecosystem is composed of a whole range of vegetation components, from trees, shrubs, palms, bushes, undergrowth, grass, epiphytes, etc. It is also an ideal habitat for many species of fauna, both permanent inhabitants and transient.

D.2.1. Diversity of Flora

Noor *et al* (1999) note that at least 202 plant species have been found living in mangrove ecosystems in Indonesia, comprising 89 species of tree, 5 species of palm, 19 species of creeper, 44 species of herb, 44 species of epiphyte and 1 species of fern. Of all these, 43 species are categorised as true mangrove, while the other 159 are known as mangrove associates. At least 14 of the mangrove species in Indonesia are categorised as rare; these are:

- Five (5) locally common species categorised as rare globally. These are *Ceriops decandra*, *Scyphiphora hydrophyllacea*, *Quassia indica*, *Sonneratia ovata*, *Rhododendron brookeanum*. All five have 'vulnerable' status and require special attention in their management.
- Five (5) species categorised as 'rare' in Indonesia but which are common elsewhere. These are *Eleocharis parvula*, *Fimbristylis sieberiana*, *Sporobolus virginicus*, *Eleocharis spiralis* and *Scirpus litoralis*. These do not require special management globally.
- Four (4) species categorised as rare globally, which therefore require special management to ensure their survival. These are *Amyema anisomeres*, *Oberonia rhizophoreti*, *Kandelia candel* and *Nephrolepis acutifolia*.



Figure 14. Mangrove species found in Teluk Belukar, Nias island (Indonesia)

D.2.2. Diversity of Fauna

Mangrove is an ideal habitat for many species of wildlife. Generally, fauna that live in mangrove forests can be divided into the following two groups:

- Terrestrial fauna. This group includes all animals that generally carry out their activities in mangrove trees, including snakes, primates and birds.
- Aquatic fauna, of two types :
 - Creatures that live in the water. These include the various species of fish and shrimp.
 - Creatures that live in the substrate, in particular crabs, shellfish and other invertebrate species (Irwanto, 2006)

As stated by Aksornkoae (1993), many fish species use mangrove as a place for spawning, permanent habitat or nursery. As a spawning ground, mangrove plays an important role in providing refuge and reducing stress from predators. Mangrove forest also provides food in the form of organic material from fallen leaves. As a breeding ground and nursery, mangrove provides a perfect environment for raising baby fish.

According to Erftemeijer *et al* (1989), fish species commonly found in mangrove include *Tetraodon erythraenia*, *Pilonobutis microns*, *Butis butis*, *Liza subviridis*, and *Ambasis buruensis*. Meanwhile, in his research at Pulau Panaitan island (Ujung Kulon National Park in West Java province), Burhanuddin (1993) noted at least 62 species of fish found living in the mangrove area.

Crabs are an important inhabitant of mangroves. According to Macintosh (1984), 10 - 70 individual crabs were found per square metre, comprising the genus *Cleistocoeloma*, *Macrophthalmus*, *Metaplex*, *Ilyoplax*, *Sesarma* and *Uca*. Meanwhile, Delsman (1972) in Noor *et al* (1999) also identified the crab *Scylla serrata* which is known for its high economic value. At the mangrove centre at Suwung in Bali, no fewer than 36 species of crab have been found in the area.

Mangrove is also an important habitat for many species of shrimp of important commercial value. During a survey in Jambi province in 1991, Giesen (1991) recorded at least 14 shrimp species in the mangrove forest, including the genus *Macrobrachium* (8 species), *Metapeneus* (2 species) and *Palaemonetes* (2 species).

Mangrove forest is also an ideal habitat for many reptile species. Giesen (1993) identified the most common species found in mangrove forest, i.e. saltwater crocodile (*Crocodylus porosus*), water monitor (*Varanus salvator*), water snakes (*Enhydrys enhydryis*), mangrove snakes (*Boiga dendrophila*), dog-faced water snake (*Cerberus rhynchops*), Waglers pit viper *Trimeresurus wagleri* and *T. purpureomaculatus*.

Mangrove forest is also a suitable habitat for water fowl. Those easily found in mangrove forests include egrets (*Egretta spp*), storks (*Ciconiidae*) and cormorants (*Phalacrocoracidae*). These birds normally build their nests in mangrove forest, where disturbance from predators is relatively minimal. Mangrove is, moreover, an ideal habitat for birds that are now rare or threatened with extinction, including: Milky stork (*Mycteria cinerea* - *Ciconiidae*), Sunda coucal (*Centropus nigrorufus* - *Cuculidae*), Lesser adjutant (*Leptoptilos javanicus* - *Ciconiidae*).

Mammals commonly found in mangrove habitats include wild boar (*Sus scrofa*), mouse deer (*Tragulus spp.*), bats (*Pteropus spp.*) otters (*Lutra perspicillata* and *Amblyonyx cinerea*), lutung/langur (*Trachypithecus aurata*), proboscis monkeys (*Nasalis larvatus*; endemic to Kalimantan) and mangrove cat (*Felis viverrina*) (Melisch *et al* 1993). Danielsen & Verheugt (1989) even reported that the Sumatran tiger (*Panthera tigris sumatranus*) was still seen in the mangroves of South Sumatera, which border directly onto the Berbak National Park (Jambi province).

Within the area of the Pulau Dua Mangrove Nature Reserve (total area 30 ha) in the Teluk Banten bay, Noor (2004) reported that no fewer than 108 bird species from 39 families have been observed. This constitutes 7% of all bird species in Indonesia, and 20% of all bird species in Java. Of these 108 species, 57 are water birds (30% of all water bird species in Indonesia, 50% of all water bird species in Java), of which at least ten species birds breed there. Apart from birds, this area is also reported by Syarief (2006) as habitat for 7 reptile species, 4 mammal species, 1 amphibian species, 5 fish species, 3 crustacean species and 1 gastropod species.

E. GENERAL VIEW OF ECONOMIC BENEFIT SUMMARIZED FROM VARIOUS SOURCES

The economic value of mangrove varies considerably from one place to another and also depends on the time when the assessment is carried out; it also covers not only tangible values, which can be calculated, but also intangible values which are much more difficult to measure. Tangible values, such as those of timber, fishery production and tourism, are relatively easy to calculate. However, intangible environmental services like biodiversity, flood reduction, and sea water intrusion prevention are difficult to determine with any degree of accuracy. The following table lists the values of mangroves in several places in Indonesia, but as the figures for each site do not give complete information, it is difficult to say whether a site has higher values than the others.

Table 18. Summary of economic value (US\$/ha/year) of mangrove ecosystem.

Ecosystem Services	Subang	Segara Anakan	Batu Ampar	Selat Malaka	Teluk Bintuni	Sembilang
Provisioning						
Timber and forest products						
Construction wood	138.93	11.59	18.92	18.92		-
Fire wood	3.00					-
Chips					975.61	-
Charcoal		1.14	7.50			-
Material for badminton shuttle cocks		15.24				-
Vegetables	0.34					-
Thatch		27.44	2.07			-
Nipah sugar		5.28				-
Mangrove seeds			0.70			-
Sago					0.55	-
Food for cattle		0.78				-
Fishery						
Captured fish	0.97	94.83	9.09	256.19	34.47	126.86
Captured shrimps	112.52	103.43	67.57			35.72
Crabs	3.12	44.41	18.35			18.20
Molluscs	1.78	21.26				0.08
Eels	0.28					
Extensive shrimp farm	158.99			163.71		
Intensive shrimp farm		687.22				

Ecosystem Services	Subang	Segara Anakan	Batu Ampar	Selat Malaka	Teluk Bintuni	Sembilang
Wildlife (animals)						
Birds	0.13	3.27				-
Mammals	5.11			2.33	6.98	-
Reptiles	0.70	0.23				-
Regulating						
Erosion control	426.83		466.14	221.42	2.04	5.68
Protecting from sea water intrusion			32.30			
Carbon sink and sequestration	-	-	-	-	-	2,803.48
Cultural						
Recreation		252.60				2.80
Education	-	-	-	-	-	-
Supporting (optional and/or existence)						
Biodiversity	4.39		15.09	4.57	4.57	73.73
Habitat	767.20		678.02	767.20		-

Sources:

1. Compiled by Santoso et al (2004) from various sources: Bangda and IPB (2000) for Segara Anakan, Ruitenbeek (1991) for Bintuni, Aprilati (2001) for Batu Ampar, Kusumastanto (1998) for Selat Malaka, Fahrudin (1996) for Subang.
2. Gonner (2002) for Sembilang.

3. Some Direct Impacts of Economic Development in (Former) Mangrove Ecosystems in Indonesia

Economic development in coastal regions can have a positive impact because it plays a major role in improving the community's welfare. On the other hand, it can also have a detrimental impact on the community if the development is carried out in a way that degrades the mangrove ecosystem on which life depends. Clearing away the mangrove is one such activity that can lead to disaster for the community. However, it is difficult to know for certain which kinds of economic development in mangrove will cause what scale of loss. Below are some examples of developments in mangrove areas in Indonesia which have eventually had a negative impact both on the community and on the development itself.

A. CONVERSION OF MANGROVE FOR SETTLEMENTS & INFRASTRUCTURE, CAUSING FLOODING

Conversion of mangrove ecosystems for the purposes of building settlements or infrastructure facilities is one of the most extreme forms of conversion as it entails a drastic change from an aquatic ecosystem to a terrestrial one. Mangrove lands that had previously been capable of storing millions of cubic metres of excess water from rainfall or high tides, can no longer perform this function. As a result, floods cover the low-lying areas around the site of mangrove ecosystems that have been converted to 'dry' land.

One example of a case that reflects this process can be seen in the luxury housing development of Pantai Indah Kapuk (Jakarta) for which the mangroves and aquaculture ponds of Muara Angke were converted to dry land. This conversion is strongly suspected of having caused an increase in the frequency of flooding along the toll road to Jakarta's airport, with the result that the Indonesian Government subsequently raised the level of this toll road by about 1.2 m. However, several other experts state controversially that the floods along the airport toll road are the result of extended rains and degradation of the upper reaches of the water catchment area.

Another example that received much media attention was the construction of urban infrastructure to promote/encourage/stimulate economic growth on the north coast of Java by clearing mangrove forests, which is considered to be one of the main causes of *Rhob* flooding (when sea water washes a long way inland during high tides and heavy rain). Unfortunately, no fully credible studies have yet been found that indicate a direct correlation between the occurrence of *Rhob* floods and the mangrove degradation caused by the construction of urban infrastructure on the coast.



Figure 15. The toll road to the Soekarno-Hatta Air port in Jakarta has been raised up to 1.2 meter (left due to 'rhob' flood hits northern Jakarta more frequently after mangrove have been cleared (Photo: Ita Sualia, 2010)

B. MANGROVE CONVERSION TO SHRIMP PONDS CAUSES SEA WATER INTRUSION

One detrimental impact believed certainly to have resulted from economic development where mangrove ecosystems were cleared or degraded to make way for large expanses of aquaculture ponds, is the intrusion by sea water that has contaminated the community's sources of drinking water. Measurements carried out by WIIP in the dry season of 2010 indicated that mangrove degradation (about 511ha had been converted to aquaculture ponds) in desa Sawah Luhur in the Banten Bay has caused sea water intrusion as a result of which the ground water has become saline to as far as 4km inland from the coast. A similar occurrence has been experienced by the citizens of Samarinda, which is 50km from the sea coast/ Mahakam Delta. Before 1990, the mangroves in the Mahakam Delta were still relatively intact, but after a surge in public interest in the shrimp business in this area (1990-2000), vast areas of mangrove were cut down to make way for ponds. As a result of this huge reduction in mangroves in the Mahakam Delta, in the dry season of 2003, Samarinda inhabitants found that their well water had turned saline. It is widely believed that the sea water intrusion up to 50 km inland to Samarinda happened as a result of this degradation of 80% of all the mangroves in the Mahakam Delta. The illustration below shows the fresh water boundary retreating further inland, which is an indication of sea water intrusion in the Mahakam Delta.

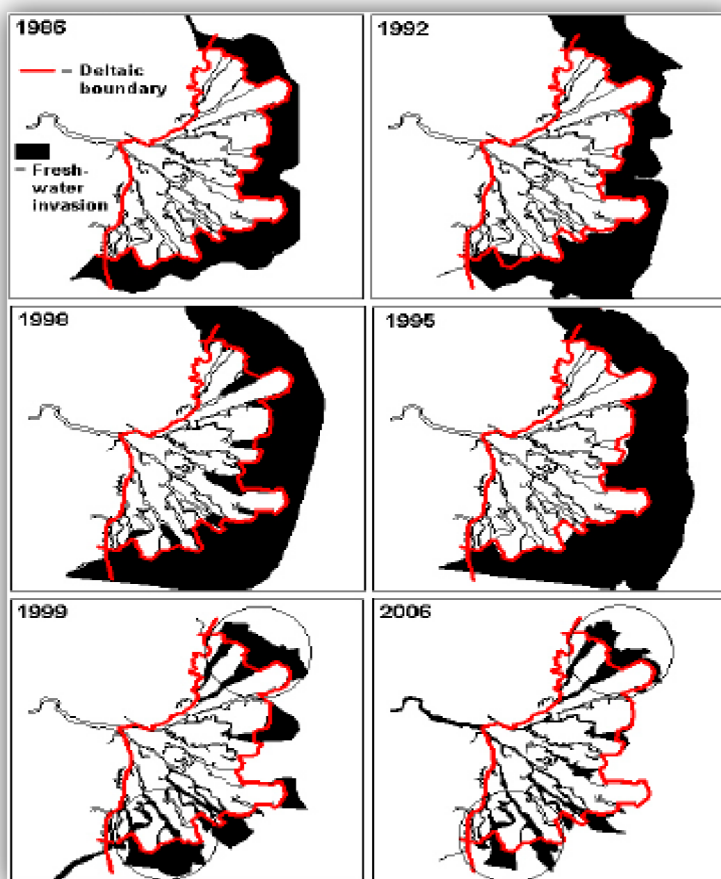


Figure 16. Diminishing freshwater flow in the Mahakam Delta from 1996 to 2006 (Sidik, 2009)



Figure 17. Mangrove clearing in Delta Mahakam for shrimp pond
(Photo: Nyoman Suryadiputra, 2001)

C. MANGROVES DECLINE, EPIDEMICS INCREASE

Some of the development activities carried out in mangrove ecosystems impact not only on the physical environment but also on human health. Research undertaken in Flores NTT between 1970 and 1990 showed strong indications that malaria outbreak was closely related to the reduction in mangrove cover (Bangs and Atmosoejo, 1990). The same conclusion was reached by Jung, R.K (1984), who found that a drastic rise in malaria cases in Cilacap (Central Java) was closely related to the cutting down of mangroves to make way for aquaculture and paddyfields. Both these cases are highly likely to have occurred because the clearing of mangrove allowed the sun's rays to penetrate directly into pools of brackish water and warm them. Such conditions are thought to be favourable to the *Anopheles* mosquito that carries malaria.

The construction of coastal infrastructure through the clearing of mangrove ecosystems, which is strongly suspected of causing increased frequency of '*Rhob*' floods, is also often accompanied by the emergence of disease. Interviews by WIIP (2010) with medical staff at several public health centres (*puskesmas*) in coastal villages in Pemalang indicated that *Rhob* floods caused a significant rise in the number of cases of dengue fever, chikunguya, and itching.

D. MANGROVE LOST, FISH PRODUCTION FALLS

The conversion of mangrove to aquaculture ponds with the aim of increasing production is not altogether correct. In the case of the Mahakam Delta, the opening of new ponds did increase overall shrimp production, but this was out of all proportion to the size of the mangrove area cleared. Shrimp production graphs presented by Bourgeois et al (2002) showed that in 1996 the area of mangrove opened up in the Mahakam Delta for shrimp ponds was 15,000 ha with a total production of 6,000 ton per annum. In other words, annual productivity of the shrimp ponds in the Mahakam Delta at that time was 400 kg/ha/year. Following the jump in shrimp prices during the Asian monetary crisis in 1998, there was large scale opening up of shrimp ponds in 1998, and by 2001 the area covered by ponds had quadrupled to 60,000 ha. In 2001, shrimp production levels in the Mahakam Delta rose to 10,000 ton/year or 1.7 times the production level of 1996. This indicates that the clearing of mangrove to increase pond area from 15,000 to 60,000 hectares in fact led to a drop in pond production levels from 400 kg/ha/year to only 167 kg/ha/year.

4. Governance of mangrove resources management

A. POLICY AND MANAGEMENT

A.1. Brief history of mangrove exploitation policy

Government policy related to mangrove exploitation and development was initially directed towards exploitation; this policy began in the 1930s, as evidenced by a Dutch colonial government document that designated all the mangrove forest ecosystems in Sumatera as production forest. This designation was subsequently continued by the Indonesian government with regulations on ways of exploiting mangrove forest timber (Santoso, 2007). Mangrove forest management, which was then already relatively advanced, can be seen in documents on forest exploitation planning drawn up by the State forestry company Perusahaan Hutan Negara in Central Java that projected average cutting rates of 200 ha per annum over the period 1930 – 1949. For West Java, formal mangrove ecosystem management policy by the Dutch colonial government is thought to have started in about 1937. At that time, mangrove management policy was relatively strict in that only trees of a certain specified diameter set by a government official were allowed to be cut down. Members of the community who wanted to cut mangrove were obliged to get prior permission by purchasing a ticket from the local official. Nevertheless, in some places policy from the previous years allowed a very large number of trees to be felled leaving only 60-100 trees per hectare to act as a source of wildlings. This policy, only just short of clear-cutting, obviously caused problems because most of the wildlings from these remaining trees could not grow as the degraded mangrove lands had rapidly been covered by bushy types of mangrove. To address this failure in natural mangrove regeneration, from 1932 Perusahaan Hutan Negara is known to have undertaken experiments in rehabilitation (De Jong, 1934 cited by Wirjodarmodjo, 1982).

Apart from the mistakes of the ‘almost clear-cutting’ approach to mangrove management in some places in Java in the early 1930s, the strict management policy during 1937-1942 succeeded in maintaining survival of mangrove ecosystems in Java. Conditions changed drastically when the Japanese invaded Indonesia during World War II. During the war, management by government authority was almost non-existent throughout the whole of Indonesia’s mangrove areas, due to political instability and lack of security. Mangrove exploitation became uncontrolled especially when aimed at meeting the need for energy, which was in drastically short supply during the Japanese occupation. In addition, mangrove was cleared by members of the community in order to claim ownership to the land, and also for housing. Such conditions continued uncontrolled, even when the new Indonesian government was formed following the Japanese departure from Indonesia, especially in areas that had originally been State forest.

As the Indonesian government structure strengthened, in 1952, State forestry companies, whose official name was changed to PERHUTANI, gradually took back management of mangrove forests belonging to the State. They applied a systematic management plan design in the form of a combination of exploitation and rehabilitation developed by Versteegh (1952, cited by Wirjodarmodjo 1982). This new management design was then adopted by the Indonesian government and designated as the official guidelines for mangrove forest management in Indonesia (by Directorate General for Forestry decree SK No 60 of the year 1978). It is still valid today as a major guide for mangrove forest management in Indonesia.

Indonesia's rapid economic growth and development during the 1960s – 1970s posed a new threat to the survival of mangrove ecosystems due to the drastic escalation in the demand for timber, charcoal, and new land for agriculture and fishery. Ironically, one government policy that contributed greatly to the large-scale conversion of mangrove came from a policy issued in 1980 that was intended to conserve coastal ecosystems. This was Presidential Decree No 39 of 1980 concerning the prohibition of trawl nets because they damaged the coastal aquatic ecosystems. These trawl nets were used to catch shrimp, but being unselective their by-catch was much greater in quantity (but of low value), consisting of aquatic biota caught along the length of the trawl path traversed, compared to the shrimps that were actually the target of the catch.

The prohibition of trawl nets directly hit the livelihoods of those members of the coastal community who depended on catching shrimps from the sea. This policy was followed by a decline in shrimp exports so many shrimp processing industries collapsed. To compensate for the losses, the government issued a series of policies to stimulate shrimp production through aquaculture. This was done by clearing mangroves to construct new ponds, intensifying aquaculture production by providing a scheme for financial and technical assistance, and by transmigrating trained fish farmers to newly opened aquaculture areas (Widigdo, 2000 cited by Sualia, et al, 2009). This policy caused a drastic increase in the area of mangrove ecosystem converted to aquaculture in Indonesia, from 185,000 ha in 1980 to more than 300,000 ha in 1990 (Suwito, 1982 and Naamin 1990). In subsequent years, mangrove ecosystems continued to be converted, reaching a peak during 1998–2005 when around 300,000 ha of mangrove ecosystem were cleared in East Kalimantan alone (Ilman et al 2009). The total *tambak* aquaculture area in Indonesia is currently about 612,000 ha. Unlike the 1980–1990 period, the very rapid clearing of mangrove ecosystems for aquaculture at the end of 1990s was stimulated by the incentive of rocketing shrimp prices as a result of the Asian monetary crisis and weak law enforcement.

A.2. Preservation oriented policy

As a result of the systematic exploitation of mangrove from the early 1920s onwards (Wind, 1924), the width of the mangrove green belt on parts of Indonesia's coast has been shrinking. To prevent further mangrove loss, especially on coasts where this belt is relatively thin, the relevant government sectors all agreed that it was necessary to retain parts of the mangrove to function as green belt. However, they did not agree on how wide this belt should be. Indicative of this is the differences in the policies on green belt width issued by the forestry sector and the fisheries sector, as described below :

1. The Directorate General for Fisheries issued instruction no H.1/4/2/18/1975 to protect mangrove as green belt up to a width of 400 m parallel to the shoreline.
2. The Directorate General for Forestry issued decree (*Surat Keputusan*) no 60/Kpts/DJ/II/1978 on guidelines for brackish water forest silviculture, stipulating that the width of mangrove forest that must be protected as green belt is 50 m along the coast and 10 m along river banks, water courses and roads.

This difference in policies gave rise to confusion in their implementation, especially for regional governments. Soewito (1982) reported that neither policy could be applied in the regions because of the lack of coordination of information and the differences in perception between the forestry and fisheries sectors concerning this policy.

To overcome this policy difference, these two government sectors finally issued Joint Decree (*Surat Keputusan Bersama*) SKB No 550/246/Kpts/4/1984 and Decree (*Surat Keputusan*) no 082/Kpts-II/1984 on the regulation of land for agricultural development. This joint decree stipulated that mangrove green belt must be protected along a width of 200 metres from the shoreline. The figure of 200 metres was not based on scientific argument but on consensus between the two sectors (Soerianegara 1986). This was because at that time there was as yet no scientific study on how wide a green belt should be maintained in order to support human activities in coastal areas.

Efforts to put an end to the protracted differences in opinion over the width of mangrove green belt in Indonesia finally succeeded in 1986 when the Indonesian Institute of Sciences LIPI (*Lembaga Ilmu Pengetahuan Indonesia*) as the State's scientific authority issued recommendations for calculating the width of mangrove green belt. The formula for this is:

Width of mangrove green belt = 130 x average difference between highest and lowest tides in a year.

This formula was adopted into official legislation by the government with the publication of Presidential Decree (*Keputusan Presiden*) No 32 of year 1990 concerning the management of protected areas. Despite prolonged debate as to the appropriacy of this formula for all parts of Indonesia's very complex coastal areas, this Presidential Decree is still the primary reference for policy makers developing strategies for mangrove ecosystem protection.

A.3. Legal basis for current mangrove management policy

Currently, there are at least 6 laws with strong relevance to the protection and use of mangrove ecosystems. These are :

1. Law No 5 year 1990 regarding Conservation of Natural Resources and their Ecosystems.
2. Law No 41 year 1999 concerning Forestry, then revised in Law No 19 year 2004
3. Law No 32 year 2004 concerning Local Government
4. Law No 26 Year 2007 concerning Spatial Planning
5. Law No 27 year 2008 regarding Management of Coasts and Small Islands
6. Law No 32 Year 2009 regarding Protection and Management of Environment

Each law is usually led by a particular government sector (ministry) with the biggest responsibility for implementing or coordinating that law. Although these six laws have extremely strong relevance to mangrove ecosystem management, not one of them contains any specific regulation on mangrove ecosystem management and only two of them actually mention the word "mangrove". These six laws and their relevance to mangrove management are described in Table 7.

In addition to these six laws, there are several other laws that are related to mangrove management because they regulate sectors having activities in mangrove ecosystems, such as laws on estate crops, fisheries, and oil & gas. These laws also have a particular leading government sector with primary responsibility for their implementation. In practice, however, due to the complex social and economic conditions in mangrove areas plus the lack of clear boundaries, there is a certain amount of overlap in the implementation of these laws, both between the laws themselves and also between the government sectors as regards their responsibility for work and their area of work. One of the reasons for this is that each sector will prioritize the interests of its own sector (National Strategy and Action Plan for Mangrove Management, 1997). The complexity of implementing these laws based on their area of cover can be seen in the following diagram.

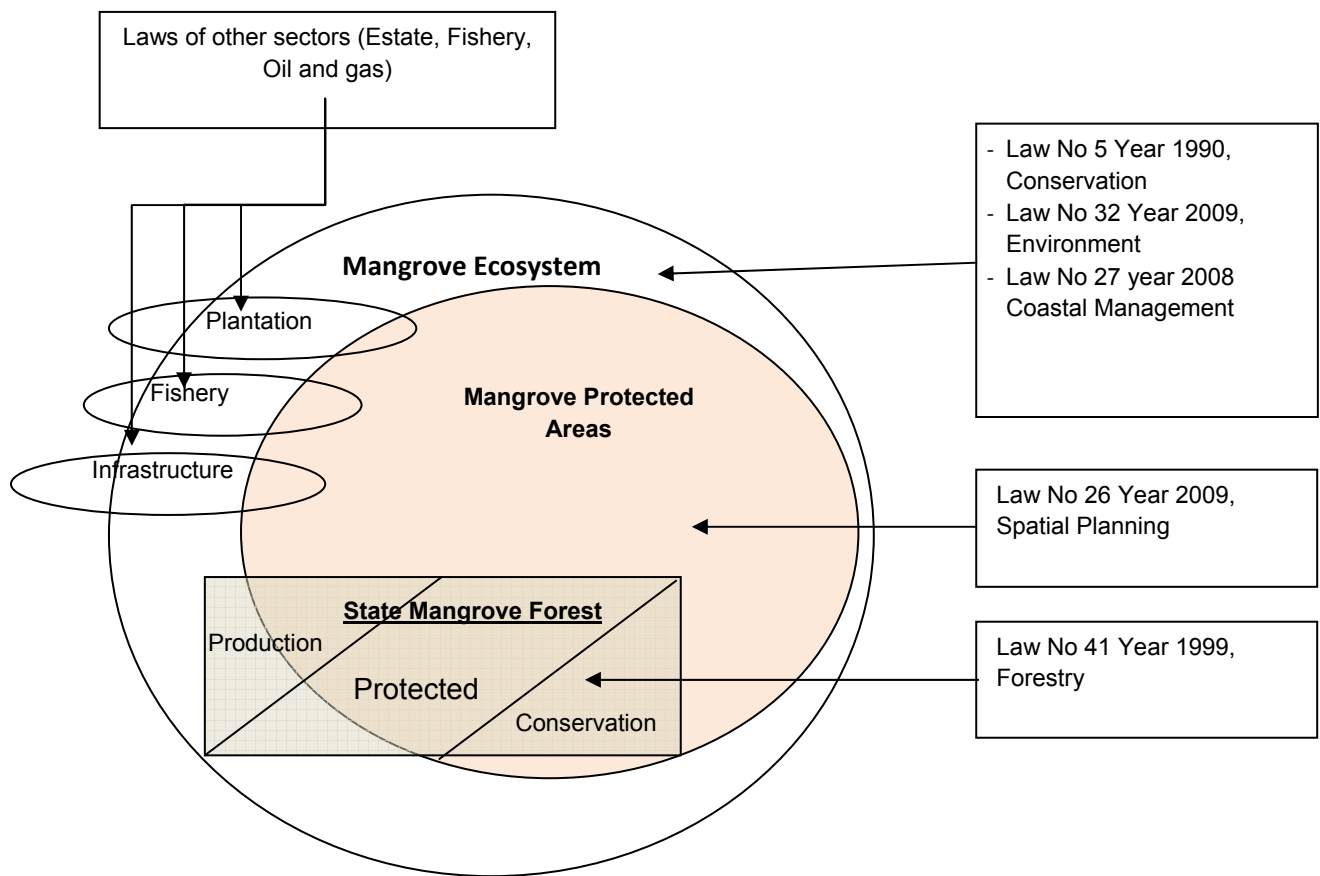


Figure 18. Areas of implementation of Laws relevant to management of mangrove ecosystems.
Portion of areas above is only to indicate boundary of Laws, not scale of areas.

Table 19. Laws relevant to mangrove ecosystem management

Law	Relevance to Mangrove Ecosystem	Main Government Sector	Potential Conflict
Law No 5 year 1990 regarding Conservation of Natural Resources and their Ecosystems.	This Law is based on establishment of conservation areas and species protection in Indonesia. More than a million ha mangrove areas have been designated as conservation areas in Indonesia.	Ministry of Forestry and Ministry of Marine Affairs and Fishery	- With mining sector laws: Currently, mining is possible in conservation areas. Example: Plans for mining in Bogani Nani Wartabone National Park - With regional government legislation: Conflict in the setting of government administrative boundaries. Example: the boundaries of Wakatobi National Park are the same as those of the <i>Kabupaten</i> Wakatobi. district
Law No 41 year 1999 concerning Forestry, partially revised from Law No 19 year 2004	The Law is aimed at management of Indonesian Forest, including mangrove forest. It provides opportunity for utilizing socio-economic value of mangrove through various licensing mechanisms like Forest Concessionaire for Timber, and Forest Concession for Environmental Service. However, timber exploitation in mangrove areas is relatively difficult as this Law adopts Presidential Decree No 32 Year 1990 that prohibits exploitation in green belt zone along sea coast, swamp and river side.	Ministry of Forestry	- Same as with Conservation Law, conflict with mining sector laws: mining is possible in conservation areas - With regional government legislation: Conflict in the setting of government administrative boundaries. Much mangrove land in the regions still has the status of forest whose management comes under Central Government (ministry of forestry) although administratively it comes under the local regional government. Example: the Mahakam Delta mangroves still "belong" to central government but the governments of the villages in this delta come under the authority of the regional government.
Law No 32 year 2004 concerning Local Government	Mangrove is not specified in this Law. However, this Law is the main reference on sharing management of natural resources that stretch beyond the administrative boundary of provincial governments, and Regency/City Governments. Mangrove is one such type of natural resource.	Provincial and Regency Government	Many cases of conflict with Conservation Law and Forestry Law in the management of mangroves, as explained above.
Law No 26 Year 2007 concerning Spatial Planning	This Law is the basis for the establishment of various categories of protected areas. Mangrove is not specifically mentioned in this Law, but one of the protected area categories in this Law corresponds to the features of mangrove ecosystems.	Development of Spatial Planning is led by Ministry of Public Works	The setting of zones based on Spatial Planning Law is relatively late. Many of the permits already granted by various government sectors (based on the Laws for their own sector) for development in mangrove ecosystems in fact contravene spatial planning criteria.

Law	Relevance to Mangrove Ecosystem	Main Government Sector	Potential Conflict
Law No 27 year 2008 regarding Management of Coasts and Small Islands	This Law is relatively new, thus many of its directives are still not applicable due to the absence of detailed regulations that should have been issued under a lower level of legislation. This Law will provide opportunity for granting permits/licenses for the exploitation of mangrove ecosystems as Fishery Resources Concession. However, this Law also provides many strict limitations to ensure sustainability and equality of fishery utilization.	Ministry of Marine Affairs and Fishery	The main conflict is with Forestry law. This is because both the Forestry Ministry (under Forestry law) and the Marine Affairs and Fishery Ministry (under Sea Coast Law) claim mangroves as an area that they must manage.
Law No 32 Year 2009 regarding Protection and Management of Environment	This Law is the basis for the implementation of environmental impact assessment (EIA), and environmental management of all activities potentially damaging to mangrove ecosystems.	Ministry of Environment	

Since the publication of Law no 5 of 1990 on the Conservation of Natural Resources and their Ecosystems, until the enactment of a new law on environmental management (Law No 32 of 2009), there had been no policy or regulation concerning integrated cross-sectoral management of mangrove ecosystems at either Government Regulation (*Peraturan Pemerintah*) level or Presidential Regulation (*Peraturan Presiden*) level. As a result, government institutions, or regional governments who were in the process of developing their own individual policies on mangrove ecosystem management, always had to extract and compile regulations from a variety of legal sources so as to form a basis for creating their own policy. This was necessary in order to avoid conflict between the policy they were developing and other legislation related to mangrove ecosystem management.

Noor *et al* (2006) identified at least 10 Government Regulations (*Peraturan Pemerintah*) and Presidential Regulations/Decrees (*Peraturan/Keputusan Presiden*) related to mangrove management. However, the legislation most used as reference in mangrove management and policy is Presidential Decree no 32 of 1990 concerning the Management of Protected Areas (*Keputusan Presiden no 32 tahun 1990 mengenai Pengelolaan Kawasan Lindung*). This decree has been adopted into almost all policy concerned with natural resources management in Indonesia, especially as related to land use and spatial planning.

Even though policy and/or legislation related to mangrove management in Indonesia has existed since the early twentieth century, nevertheless Indonesia (in an extreme estimate) has lost around 4-5 million ha of mangrove ecosystem as a result of conversion for housing, infrastructure, agriculture and fishery. In the last two decades, most of the conversion and over-exploitation has occurred not because of any lack of or conflict between policies/legislation, like the case of the policy to boost farmed shrimp production after the trawl ban of 1980, but simply because of the weakness (or absence) of law enforcement. This can be seen in the case of East Kalimantan where around 300,000 ha of mangrove were converted to shrimp ponds from late 1990 to early 2000 as a result of the regional government's inadequate capacity to protect their vast expanse of mangrove ecosystem. Another example can be seen in the Puhuwatu district of Gorontalo province, where around 70% of the 25,000 ha of mangrove was degraded, converted to shrimp ponds or exploited for its bark. This destruction was possible because of weak law enforcement and absence of supervision from the government (Gorontalo Post, 21 October 2010).

B. NATIONAL STAKEHOLDERS ENGAGED IN MANGROVE ECOSYSTEM MANAGEMENT

B.1. Government Sectors

Indonesia's National Mangrove Management Strategy (*Strategi Nasional Pengelolaan Mangrove Indonesia*) of 1997 identified at least 16 government institutions at ministerial level that are related to mangrove ecosystem management. However, only three ministerial level institutions had activities directly in the field that were related to mangrove ecosystems. Ministries and their work units handling mangrove ecosystem management in the field include the following:

Table 20. List of Ministries managing mangrove ecosystems, and their work units directly handling mangrove management

Ministry	Management Office	Tasks and Responsibilities
1. Ministry of Forestry (MoF or Kemenhut) Ministry with largest working unit dealing with mangrove ecosystem management in the field	Office of Watershed Management <i>(Balai Pengelolaan Daerah Aliran Sungai, BP DAS)</i>	The BP DAS has an office in every province, responsible for providing guidance, coordinating and monitoring watershed management activities. The BP DAS is well-known in provinces as “planting trees” has become a national issue and BP DAS is one institution coordinating forest rehabilitation (including mangrove) involving a wide range of stakeholders.
	Office of Mangrove Forest Management <i>(Balai Pengelolaan Hutan Mangrove, BPHM)</i>	BPHM has two management offices, in Medan (Region II) and Denpasar (Region I). The BPHM is responsible for coordinating mangrove management activities in its own region. Region I covers Java, Bali, Nusa Tenggara, Sulawesi, Maluku and Papua, while Region II covers Sumatera and Kalimantan.
	Office of Natural Resources Conservation and Office of National Parks <i>(Balai Konservasi Sumberdaya Alam, BKSDA, Balai Taman Nasional)</i>	These offices are present in almost all provinces. The two offices are responsible for managing conservation and protected areas, some of which are mangrove ecosystems.
2. Ministry of Marine Affairs and Fishery (MMAF or KKP) MMAF is a relatively new ministry responsible for managing coastal and marine resources. Therefore, MMAF does not yet have sufficient working units in the field to manage mangrove ecosystems like MoF.	Office of Coastal and Marine Resources Management <i>(Balai Pengelolaan Sumberdaya Pesisir dan Laut, BPSPL)</i>	BPHM has 4 offices throughout Indonesia namely: Pontianak, Padang, Denpasar, and Makassar. The BPSPL is responsible for carrying out management of coastal and marine ecosystems, including protection and utilization of mangrove.
3. Ministry of Environment (MoE or KLH)	-	MoE has no special working units in the field that deal with management of mangrove ecosystems. The work of MoE is mostly in the development of regulations and monitoring the impact of developments on ecosystems. However, in certain coastal areas that have suffered or are prone to environmental hazards/disasters, MoE normally has direct intervention activities, including mangrove rehabilitation and coastal cleanup.

Besides these three ministerial level institutions above, there are several other institutions at ministerial level that are related directly or indirectly to mangrove ecosystem management. These ministries and their relevant work units are as follow:

Table 21. List of Ministerial level institutions that have indirect activities related to mangrove management

Ministry	Most Relevant Working Unit	Relation to Mangrove Management
1. National Development Planning Body, (BAPPENAS)	Directorate of Coastal and Marine Affairs	Coordinating national government planning and budgeting on mangrove management
2. Ministry of Home Affairs (MoHA, Kemendagri)	Directorate of Facilitation of Spatial Planning and Environment	Assisting local governments in managing issues related to mangrove ecosystem management, in terms of governance and government management.
3. Ministry for the Development of Disadvantaged Areas (KPDT)	Deputy Assistant for Environmental Affairs	Assisting and developing special activities, including mangrove management, in the least developed regencies and national border areas.
4. Ministry of Public Works (Kementerian PU).	Directorate of National Spatial Planning	Coordinating spatial plan activities which will provide space for mangrove ecosystems.
5. Land Survey Coordination Bakosurtanal (BPN)	Centre for Marine Natural Resources Survey	Coordinating surveys of the status and distribution of mangroves
6. National Land Office (BPN)	Directorate of Coastal Areas and Small Islands	Managing coastal and marine resources
7. State Police (Polri)	Directorate of Special Crimes	Law enforcement on mangrove management.

B.2. Researchers and Academics

There are several academic and research institutions in Indonesia that have research units working on mangrove ecosystem issues. Unfortunately, these institutions have no special channel to enable their findings to be easily adopted by practitioners or policy makers. Some of these research centres are:

1. Research Centre for Oceanography, Indonesian Institute of Sciences (P2O LIPI). P2O LIPI is Indonesia's scientific authority, has various research activities regarding mangrove biota and coastal dynamics.
2. Agency for the Assessment and Implementation of Technology, Deputy for Natural Resources Development Technology (BPPT). The work of BPPT seems similar to that of P2O LIPI. However, their focus is on assessing the use of new technology in managing mangrove ecosystems.
3. Centre for Coastal and Marine Resources Study, Bogor Agricultural University. The centre has various studies on the management and governance aspect of mangrove ecosystems.

In addition to the research centres above, every sectoral ministry normally has a research unit that occasionally carries out research regarding mangrove ecosystems.

Indonesia also has 6 state universities mandated by the government to support the national development of coastal and marine science. Each university has its own study specialty related to coastal and marine management, including mangrove ecosystems. The 6 state universities are:

1. Riau University, Riau Province
2. Bogor Agricultural University, West Java
3. Hasanuddin University, South Sulawesi
4. Diponegoro University, Central Java
5. Sam Ratulangi University, North Sulawesi
6. Pattimura University, Maluku

B.3. Civil Society, Non Government Organizations

Mangrove ecosystem management has its own particular difficulties especially because the sites are often difficult to reach and the management issues very complex, so their management needs to be extremely dynamic in character so as to respond to continual change. For this reason, institutions with large bureaucratic structures like government institutions often find it very difficult to work effectively in managing such mangrove ecosystems. In contrast, in cases like this, local NGOs have many strengths as they are small and pragmatic, and therefore find it easy to be more flexible in responding to the complex management dynamics, so mangrove management becomes much more effective and efficient. This is why local NGOs currently play a vital role in mangrove ecosystem management in Indonesia.

The management activities being carried out by local NGOs are very varied, covering the issues of income enhancement, mangrove conservation, and policy advocacy. Some of the national NGOs working in the management of mangrove issues are listed in the Table below.

Table 22. List of some national level NGOs working on mangrove issues in Indonesia

Non Government Organization	Home base, main activity and coverage
Yayasan Mangrove Also known as Indonesia Mangrove Research and Development; www.imred.or.id	Bogor, field implementation, policy development, national coverage. Have extensive experience in Batu Ampar West Kalimantan, Muara Angke, Riau
Wetlands International Indonesia; www.wetlands.or.id	Bogor, National coverage. Extensive and long experience in mangrove rehabilitation in Aceh, Jambi, South Sumatera, Banten, Pemalang (Central Java), East Nusatenggara/NTT and Sulawesi. One of the main references for mangrove data and information in Indonesia.
Wahana Lingkungan Hidup; www.walhi.or.id	Jakarta, policy advocacy, has branches in almost all provinces.
Perkumpulan Telapak: www.telapak.org	Bogor, policy advocacy, national coverage. Develops various environmentally friendly business enterprises related to forest and coastal resources.
Jaringan Pendidikan Lingkungan (Environmental Education Network, JPL); www.jpl.or.id	Bogor, education, national coverage. JPL is a network of more than 200 individual and organization members working on the issues of environmental education.

Non Government Organization	Home base, main activity and coverage
World Conservation Society (WCS); www.wcs.or.id	Bogor, research and field implementation, national coverage. WCS has extensive working on coastal issues in Sabang (Aceh), Karimun Java (Central Java).
The Nature Conservancy	Jakarta, research, field implementation, national coverage Not specifically working on mangrove ecosystems but on broad range of coastal ecosystems. Have extensive working in East Kalimantan, South East Sulawesi
WWF Indonesia: www.wwf.or.id	Jakarta, policy, campaign, field implementation, national coverage. Have offices in provinces dealing with coastal management issues, including Aceh, Berau East Kalimantan, Papua, and South East Sulawesi.

B.4. Private sector

There are at least three types of private sector whose work involves mangrove ecosystems in Indonesia.

1. Companies working “inside or outside” mangrove ecosystems to tap mangrove provisioning services like forest and fishery services. Example: forest concession companies, shrimp farms and shrimp processing industries, tourism operators. Currently, the most active of these are the shrimp farms almost all of which cleared land in or behind mangrove ecosystems. The biggest shrimp farm in Indonesia is under the auspices of a company called CP Prima (Central Proteinaprima) Group, which produces 30-40% of the total national shrimp production. The ponds belonging to the CP Prima Group are concentrated on the east coast of Sumatera in the provinces of Lampung and South Sumatera. Nowadays, the aquaculture companies, including CP Prima, have begun to carry out rehabilitation of the mangroves in their area. This is intended, among other things, to meet the criteria set by the shrimp production standards now required by the importing countries, one of which is the stipulation that there must be green belt protection. PT Minanusa Aurora at Tarakan in East Kalimantan is also actively engaged in mangrove rehabilitation, but directed more towards environmental improvement to ensure sustainable supplies of shrimps from the farms to PT Minanusa Aurora .
2. Companies working inside or near mangrove ecosystems for other activities not directly related to mangrove. Example: Oil & gas companies, shipping companies and various types of business close to mangrove areas. The second biggest oil & gas company after PERTAMINA to work in mangrove areas is Total E&P Indonesia, which manages the Mahakam Delta Block. This company estimates that drilling and the construction of supporting facilities have contributed to the clearing of about 2% of the mangrove area in the Mahakam Delta. To compensate for this, TOTAL E&P Indonesia claims to have planted more than 5 million mangrove seedlings in the last 10years, rehabilitating about 1,300 ha of mangrove ecosystems in the Mahakam Delta.



Figure 19. TOTAL E&P oil and gas exploitation activities inside mangrove ecosystems in Mahakam Delta (Photo: Ilman, 2008)

3. Companies working outside the mangrove area and having no business activities related to mangrove ecosystems but supporting mangrove protection and rehabilitation. This type of company normally utilizes corporate social responsibility (CSR) funds for the purposes of mangrove rehabilitation. One example is the Standard Chartered Bank in Jakarta which works with Yayasan Mangrove to rehabilitate mangrove in Muara Angke, Jakarta. The company Newmont, which is active in the field of mining (outside mangroves) has also worked with Conservation International on coastal mangrove rehabilitation in Aceh.

B.5. Multi stakeholder coordination

There are a multitude of actors having a role in mangrove management and having many different interests, as described above. In view of this, there are now at least two stakeholder coordination bodies made up of representatives of government institutions, researchers, and local NGOs concerned with mangrove ecosystem management. These two bodies are:

1. National Committee for Wetlands Management or *Komite Nasional Pengelolaan Ekosistem Lahan Basah (Komnas Lahan Basah)*, led collectively by the Ministry of Forestry and Ministry of Environment. At present there is no *Komnas Lahan Basah* at local level.
2. National Working Group for Mangrove Management or *Kelompok Kerja Mangrove Nasional (KKMN)*. This group consists of members from various stakeholders (government, non government and private sectors) and its leading agency is changed every year. During 2010, the KKMN was led by the Ministry of Marine Affairs and Fishery and in 2011 it will be led by the Ministry of Forestry. In some provinces and districts, the KKMN is represented by a Provincial and District Level Working Group (also known as Regional Mangrove Working Group or KKMD). The web site of KKMN is www.kkmn.org. Wetlands International Indonesia has been a member of *Komnas Lahan Basah* since 1994 and a member of KKMN since 2009 and has actively participated in wetlands related events (workshops, seminars, training sessions) both at national and regional level and provided technical input to the development of the National Wetlands Strategy.

The involvement of a wide variety of stakeholders and the presence of senior officials as representatives from each institution in both the Komnas Lahan Basah and the KKMN does not make these two coordinating bodies more influential in mangrove ecosystem management. One reason for this is that neither Komnas Lahan Basah nor KKMN has an adequate basis in law; another is that they lack the resources to unravel the intricacies of complex government institutional structure together with the overlappings of responsibilities and duplication of tasks among different government institutions. As a result, policy recommendations produced by Komnas Lahan Basah or KKMN cannot be spontaneously put into effect by each of its members. As coordinating bodies, Komnas Lahan Basah and KKMN have attempted to overcome the various challenges of coordinating mangrove ecosystem management through the exchange of information, coordination meetings, and workshops. One example of this was when in December 2010 the leading agency for KKMN for 2010 (Ministry of Marine Affairs and Fishery) got the members of KKMN and KKMD (about 100 persons) to sit together in a National Workshop on mangrove management. This workshop was aimed at updating members on any activities other members had done related to mangrove management in certain parts of Indonesia and the problems they had faced. The workshop finished with a visit to (and explanation about) a mangrove planting demo-site in a barren aquaculture area in Desa Sawah Luhur, Teluk Banten bay, managed by WIIP.

5. Economic valuation research and mangrove management

Indonesia's rapid rate of economic development supported by decentralisation of government has caused a very significant increase in land clearance (including mangroves) and the exploitation of natural resources. Mangrove ecosystems are very fragile lands which are often exploited or converted to other forms of land because they are considered as "sleeping land" (in many provinces of Indonesia) where the economic value of the timber is lower than that of terrestrial forest timber. To address this, academics have developed a "mangrove resources economic valuation" approach that will help policy and decision makers to comprehend the true economic value of mangroves. Unfortunately, despite much research and many publications on the economic value of mangroves in certain areas, the findings of these academics and researchers have not fully become the basis for policy and decision making regarding the conversion of mangrove ecosystems into land for other economic developments.

There are several factors that make policy makers reluctant to use economic valuation research findings in formulating policies related to mangrove management. One is a tendency for mangrove economic benefit valuation to be focused on the benefits of the mangroves only, the economic value of which is very abstract, without giving information about the benefits in monetary terms if the mangroves are developed sustainably. Such research results are inadequate for policy makers to formulate policies or plans for the long term. Another reason why it is difficult to use mangrove economic valuation research findings in formulating policies is the difficulty of accessing them. Many research findings are not published in a way that is easy for stakeholders to understand the conclusions.

One interesting research result on the economic value of mangrove, which presents recommendations for choices in mangrove development, was done by Ruitenbeek (1992). His research supplied three choices for mangrove development, which are: selective cutting, clear cutting, and a cutting ban. His results showed that selective cutting (80%) held the lowest risk with the highest present value.

Ruitenbeek's research was done in Teluk Bintun, Papua, but his findings form a general pattern that can also happen in other parts of Indonesia. Unfortunately, research like this on the economic value of choices in mangrove management is rarely done, especially if the choices include other types of development (non-mangrove) such as agriculture and tourism.

The table below presents examples of results from research in different locations, concerning the economic value of various alternatives in mangrove ecosystem management.

Table 23. Valuation of selected mangrove benefits (modified from Spurgeon 1998)

Benefit	Value (USD\$/ha/yr)	Value (USD\$/ha/50 yr)	Source	Location
On-site sustainable fisheries	126	6,300	Ruitenbeek (1992)	Irian Jaya
On-site crustacean and mollusc harvests	126	6,300	Nielson (1998)	Vietnam
On-site sustainable harvest, all products	500*	12,500	Cabahug (1986)	Philippines
Off-site fisheries	189	9,500	Christensen (1982)	Asia
Off-site fisheries (managed)	147***	7,350***	Sathirathai (1998)	Thailand
Off-site fisheries (open)	92***	4,600***	Sathirathai (1998)	Thailand
Other products (e.g. fruits, thatch)	435	21,750	"	"
Charcoal	378***	18,900***	Sathirathai (1998)	Thailand
Biodiversity (captured)	20	1,000	Ruitenbeek (1992)	Irian Jaya
Total direct use value	2,505****	125,250****	Sathirathai (1998)	Thailand

- 1) * Page 453 in Cabahug (1986)
- 2) **Derived from Table 62-III in Cabahug (1986)(p. 455)
- 3) *** Assuming a conversion rate of 38 baht/ \$USD 1
- 4) **** Mean value assuming a conversion rate as above

Table 12. Examples of economic assessments of some regulating ecosystem services supported by mangroves (Bradley, 2008)

Regulating service	Values and benefits	Reference
Water quality maintenance (bio filter function)	US\$ 5820 ha ₋₁ year ₋₁ US\$ 1193 ha ₋₁ year ₋₁ 7.4 and 21.6 ha of mangroves needed to remove nitrate and phosphorous, respectively, in effluents per ha of intensive shrimp pond 1.8–5.4 ha of mangroves needed to remove nitrate in effluents per ha of shrimp pond	Lal, 1990 Cabrera et al., 1998 Robertson and Phillips, 1995 Primavera et al., 2007
Environmental disturbance prevention (storm, flood and erosion control)	US\$ 4700 ha ₋₁ US\$ 3679 ha ₋₁ US\$ 120 per household	Costanza et al., 1989 Sathirathai and Barbier, 2001 Badola and Hussain, 2005
Carbon sink	155 kg C ha ₋₁ day ₋₁ 1500 kg C ha ₋₁	Clough et al., 1997 Ong, 1993

The overview illustrates the trend in mangrove valuations for both the *type of products* and *functions* taken into account, and the *type of prices* used.

Table 13. Benefits and opportunity costs of mangrove preservation (Spaninks and Beukering, 1997)

	Christensen, (Chantabury, Thailand) in US\$/ha.	Bennet & Reynolds (Sarawak, Malaysia) in US\$/ha.	Lal (Fiji) in US\$/ha.	Ruitenbeek (Papua, Indonesia) in US\$/ha.
Forestry	30	14	6	- 67
Fisheries	130	2418	100	117
Agriculture	- 165	-	-52	-
Aquaculture	- 2106	-	-	-
Erosion	-	-	-	3
Biodiversity	-	-	-	15
Local uses	230	-	-	33
Tourism	-	424	-	-
Purification	-	-	5820	-

6. Key Knowledge Gaps and Information Needs

The discussion in the preceding chapters indicates that developments in mangrove areas by various parties have led to problems like flooding, seawater intrusion, decline in fishery production, even the occurrence of epidemics. One of the reasons these problems arise is because there are still many characteristics of mangrove ecosystems that are not yet properly understood. In fact, mangrove management measures have often had a detrimental impact because they are not based on the findings of adequate research on mangrove ecosystems.

Based on the issues discussed in the preceding chapters, the table below gives recommendations for research topics where further studies are urgently required to inform sustainable development by the identified focal sectors working in (former) mangrove areas.

Table 244. List of research needed for mangrove ecosystem management

Research Topics	Possible Research Institution
Policy	
- Effectiveness of National Mangrove Working Group (KKMN) in coordinating mangrove ecosystem management in Indonesia. - Policy and stakeholder analysis on national mangrove management, history and effectiveness.	- PKSPL – IPB - Pusat Studi Kebijakan dan Pembangunan IPB
Physical Process	
- Role of mangrove forest in coastal dynamics, especially in reducing coastal erosion, Indonesia case - Review literature regarding the role of mangrove forest in reducing impact of tsunami.	- P2O LIPI - School of Natural Science ITB
Biochemical	
- Study on the role of mangrove forest in reducing pollution from domestic waste - Effectiveness of mangrove pool as water reservoir/quarantine to reduce pollution in shrimp farms.	- Faculty of fisheries IPB - MMAF's research centre on coastal aquaculture
Fishery	
- Correlation between shrimp productivity and mangrove (vegetation) cover in Silvofishery pond. - Study on best species options for polyculture in silvofishery development. - Study on biology of Blackpink shrimp (<i>udang bintik</i>) of East Kalimantan and its opportunity to be commercially hatched.	- Faculty of fisheries IPB - MMAF's research centre on coastal aquaculture - Faculty of fisheries, Mulawarman University, Samarinda
Climate Change	
- Study on the carbon sequestration capacity of different mangrove species. - Study on GHG/carbon budget on different types of shrimp aquaculture.	- Faculty of Forestry, IPB. - Research Centre for Soil and Agrilimatology.
Economic Valuation	
- Study on the economic value of different types of development options in mangrove ecosystems - Study on the economic value of the regulating services of mangrove ecosystems	- PKSPL – IPB - MoF's social research centre

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(<http://osdir.com/ml/culture.region.indonesia.ppi-india/2005-01/msg00480.html>) Original
source and year of publication untraced

Annex 1. Extent of mangrove in Indonesia from various sources (1950-2010)⁴

	Year	Area (ha)	Source	Remarks
1	1950	2,501,825	Martosubroto, P. & Naamin, N. 1977. Relationship between tidal forests (mangroves) and commercial shrimp production in Indonesia. <i>Marine Resources Indonesia</i> 18: 81-86.	Map analysis. This figure excludes Bali and Nusa Tenggara and provides a low estimate for Irian Jaya.
2	1973	3,807,100	Directorate of Forestry Planning. 1981. <i>Report on the Forest of Indonesia</i> . Publication No. 18, 1981	Cited in: Sutter, H., Ministry of Forestry, Government of Indonesia, FAO. 1989. <i>Forest Resources and Land Use in Indonesia</i> .
3	1977	9,500,000	Martosubroto, P. & Naamin, N. 1977. Relationship between tidal forests (mangroves) and commercial shrimp production in Indonesia. <i>Marine Resources Indonesia</i> 18: 81-86.	
4	1978	1,000,000	Directorate of Forest Planning. 1979. <i>Forestry in Indonesia 1978</i> . Bogor	Cited in: FAO, UNEP. 1981. <i>Tropical Forest Resources Assessment Project, Forest Resources of Tropical Asia</i> . FAO, UNEP, 475 pp. According to the authors this figure has to be considered as on the high side.
5	1978	3,600,000	Soemodihardjo, S. 1978. <i>Utilization and management of mangrove resources in Indonesia</i> .	Cited in: Snedaker, S.C. 1984. The Mangroves of Asia and Oceania: Status and Research Planning. In: <i>proceedings of the Asian Symposium on Mangrove Environment Research and Management</i> , p 5-15 Kuala Lumpur, August 25-29, 1980. Edited by E. Soepadmo, A.N. Rao and D.J. MacIntosh. 1984
6	1978	3,627,119	Wiroatmodjo, P. and Judi, D.M. 1978. <i>Pengelolaan hutan payau di Indonesia / Management of brackish-water forests in Indonesia</i> . Presented at Seminar on Mangrove Ecosystem, 27 February - 1 March 1978, Jakarta.	Cited in: FAO. 1982. <i>Management and utilization of mangroves in Asia and the Pacific</i> . FAO environment paper 3. 160 pp.
7	1978	3,707,119	Knox, G. and Miyabara, T. 1984. <i>Coastal Zone Resource Development and Conservation in Southeast Asia with special reference to Indonesia</i> . UNESCO East-West Centre, Jakarta Pusat, Indonesia, 182 pp.	Based on: Burbridge, P. R., Koesoebiono. 1980. <i>Management of Mangrove exploitation in Indonesia</i> ; Wiroatmodjo, P. and Judi, D.M. 1978. <i>Pengelolaan hutan payau di Indonesia / Management of brackish-water forests in Indonesia</i> . Presented at Seminar on Mangrove Ecosystem, 27 February - 1 March 1978, Jakarta
8	1980	2,171,300	Sutter, H. 1989. <i>Forest Resources and Land Use in Indonesia</i> . Forestry studies: I-1. MOF - FAO.	Vegetation map of Outer Islands at the scale of 1:2 750 000, source date 1972; Java and Bali at scale 1: 1 000 000.
9	1982	3,177,200	Sutter, H., Ministry of Forestry, Government of Indonesia, FAO. 1989. <i>Forest Resources and Land Use in Indonesia</i> . Forestry studies: I-1. MOF - FAO.	Bina Programme 1982 & FAO 1981 and 1982 edited from Asian Wetland Bureau, quoted in article in The Jakarta Post of 27 March 1989 by Information Officer at AKEPHI, the Network for Forest Conservation in Indonesia.
10	1982	4,251,011	FAO. 1985. <i>Mangrove management in Thailand, Malaysia, and Indonesia</i> . FAO Environment Paper (FAO), no. 4. FAO, Rome, 62 pp.	BINA program - Directorate of Forest Planning

⁴ Status and trends in mangrove area extent worldwide . FAO
(<http://www.fao.org/docrep/007/j1533e/j1533e46.htm>)

	Year	Area (ha)	Source	Remarks
11	1982	4,254,312	Forestry Department. 1982	Cited in: Soemodihardjo, S., Wiroatmodjo, P., Abdullah, A. Tantra, I.G.M. and Soegiarto, A. 1993. Condition, socio-economic values and environmental significance of mangrove areas. In: Clough, B.F. 1993. <i>The Economic and environmental values of mangrove forests and their present state of conservation in the South-East Asia/Pacific Region</i> . p. 17-38 Mangrove Ecosystems Technical Reports vol.3 ITTO/ISME/JIAM Project PD71/89. Rev. 1(F) Okinawa, Japan, ISME. 202 pp.
12	1983	2,176,300	Saenger, P., Hegerl E.J. and J.D.S., Davie. 1983. <i>Global status of mangrove ecosystems</i> . Commission on Ecology Papers No.3. IUCN. Gland, Switzerland. 88 pp.	Secondary reference, no primary source provided. The "Year" is the publication year. The figure is very similar to the one cited in Sutter, <i>et al.</i> 1989 (see above) It could refer to the same source, the difference in the figure could be due to a different conversion factor used.
13	1984	4,250,000	Darsidi, A. 1984. Mangrove forest management in Indonesia. In: Soemodihardjo, S. et al (eds) <i>Proceedings of the Seminar on the Mangrove Ecosystem II</i> , Baturaden, 1982. LIPI : 19-26	Cited in: Soegiarto, A. 2000. Research and conservation of Mangrove ecosystem in Indonesia. In: <i>Proceedings of the International Workshop 26-30 March, 2000, Okinawa, Japan - Asia-Pacific cooperation on Research for conservation of Mangroves</i> . This figure could refer to For. Dep. 1982. (see above)
14	1984	4,345,116	Soegiarto and Sukardjo. 1984.	Cited in: Cholik, F. and A. Poernomo. 1986. Development of aquaculture in mangrove areas and its relationship to the mangrove ecosystem. In: Mephram, R.H. 1986. <i>Papers contributed to the workshop on strategies for the management of fisheries and aquaculture in mangrove ecosystems</i> . p. 93-104. Bangkok, Thailand, 23 June 1986. The "Year" is the publication year.
15	1985	3,737,340	National Forest – Inventory. 1993. <i>INTAGM Dep. Kehutanan using Landsat data from early and mid -1980's</i>	Remote sensing.
16	1988	4,542,100	Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. <i>World Mangrove Atlas</i> . The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp.	Map analysis. Scale 1:2 500 000. According to the authors, the estimate by Soemodihardjo, S. et al., 1993 (see above, ref. year 1982) is likely to be more accurate.
17	1988	3,493,110	Ibid.	Combined national level mangrove estimate based on the following remote sensing studies. The reference year is the area weighted average: Bali: Forestry Department. 1982 (cited in Soemodihardjo, S., Wiroatmodjo, P., Abdullah, A. Tantra, I.G.M. and Soegiarto, A., 1993). (Ref. Year: 1982). Irian Jaya: National Forest - Inventory, INTAGM Dep. 1993. (by Hatari, H. pers comm 2002). (Ref. Year: 1985). Java: Regional Physical Planning Programme for Transmigration (RePPProT mid 1980's (1985-89) (cited in The World Bank, 2001). (Ref Year: 1985). Kalimantan: National Forest - Inventory, INTAGM Dep., 1993. (by Hatari, H. pers comm 2002). (Ref. Year: 1985) Maluku: National Forest - Inventory, INTAGM Dep. 1993 (by Hatari, H. pers comm 2002) (Ref Year: 1985) Nusa Tenggara, Sulawesi: FAO, Directorate General of Forest Inventory and Land Use Planning. 1995. (Ref Year 1989). Sumatera: Aizpuru, M., Blasco, F. 2000 Reference Year: 2000.

	Year	Area (ha)	Source	Remarks
18	1989	3,743,500	FAO, Directorate General of Forest Inventory and Land Use Planning. 1995. <i>Second Interim Forest Resources Statistics Indonesia</i> . UTF/INS/066/INS	Remote sensing. Same figures as in Nat. For. Inv., 1985 (see above) except for Sulawesi.
19	1992	3,515,471	Selamat Datang di Situs- Departemen Kehutan Republik Indonesia. n.d. <i>Peta Fungsi Kawasan Hutan</i> (Peta Tata Guna Hutan Kesepakatan).	Remote sensing imagery (Landsat)
20	1993	2,490,185	Giesen, W. 1993. <i>Indonesia's mangroves: an update on remaining area and main management issues</i> . Presented at the international seminar on coastal zone management of small island ecosystems. Ambon 7 - 10 April 1993. AWB Indonesia. 10 pp	Calculation on remaining mangrove areas based on RePPProT's (1985-1989) series and Land-system maps plus remote sensing information for some of the islands.
21	1996	3,533,600	Kitamura, S., Anwar, C., Chaniago, A., Baba, S. 1997. <i>Handbook of mangroves in Indonesia - Bali & Lombok</i> - JICA, ISME, Japan, p.119.	Secondary reference, no primary source is provided.
22	2000	4,000,000	Aizpuru, M., Achard, F., and Blasco, F. 2000. Global Assessment of Cover Change of the Mangrove Forests using satellite imagery at medium to high resolution. In <i>EEC Research project n 15017-1999-05 FIED ISP FR – Joint Research Centre, Ispra</i> .	National level estimate extrapolated from a remote case study (Java) plus literature review.
23	2000	2,423,700	World Resources Institute. 2000. <i>World resources 2000-2001: people and ecosystem—the fraying web of life</i> . Washington, DC., UNDP. 400 pp.	
24	2003	3,062,300	Rekalkulasi Penutupan Lahan Indonesia, 2003. <i>Indonesia Forest Coverage Reassessment, 2003</i> . Unpublished. www.dephut.go.id	Cited in: Kusumawardhani, L. 2004. Information provided for the Global Forest Resources Assessment (GFRA) 2005 thematic study on mangroves. Unpublished.
25	2005	9,361,957	Legal data of Potential area of Mangrove Forest in Indonesia based on Inventory and Identification by Directorate of Watershed Management and Land Rehabilitation, Directorate General of Land Rehabilitation and Social Forestry, Ministry of Forestry – Indonesia	The calculation is based on land system where mangrove grows and was conducted in 1995/1996 – 2000. Cited in: Wahyu Suryatanuwidjaya. 2005. Information provided for the Global Forest Resources Assessment (FRA) 2005 thematic study on mangroves. Unpublished.
26	2006	2,930,000	Land system map, FAO (2003); Spalding et al (1997)	
27	2007	2,900,000	FAO (2007)	Calculated from Dephut (2003) and various sources
28	2009	7,758,410	RLPS. 2007. Kemenhut RI	
29	2010	3,190,000	Spalding et al, 2010. Atlas Worlds Mangrove ISME.	
30	2009	3,244,019	BAKOSURTANAL. 2009. Peta Mangroves Indonesia	

Mission:

To sustain and restore wetlands, their resources and biodiversity for future generations

Indonesia is a tropical archipelago and the country with the fourth longest coastline in the world. All along the coast are the estuaries of rivers great and small that flow the whole year round thereby enabling mangroves to thrive. Currently, Indonesia's mangroves contributed to 21% of the global total mangrove area, and are known as the country possessing the most mangroves, both in terms of area and number of species. Mangroves play an important role in the lives of Indonesia's coastal communities, because they provide habitat for aquatic biota, timber for a variety of constructions, energy, medicines, which form both food and a source of livelihoods. This is evident from the size of shrimp exports, which reach 1 billion dollars a year.

The enormous economic value of mangrove ecosystems has led to massive exploitation. Between 1980 and 2000, it is estimated that 1-1.7 million hectares of mangroves were lost. Mangrove degradation also resulted from natural disasters like earthquake and tsunami in Sumatera where around 32,000 ha of Aceh's mangroves were devastated on 26 December 2004 and many mangroves ecosystems were uplifted to a height of several centimetres above sea-level and therefore dried out and died. The rapid escalation in mangrove exploitation in Indonesia has also been influenced by the lax law enforcement and mistakes in policy implementation, even though in fact Indonesia has a range of legislation which was drawn up to protect mangroves. In East Kalimantan, due to the government severely short of staff and funding, more than 300 thousand hectares mangrove in less than a decade is thought to have been cleared illegally.

The loss and degradation of mangrove that drove by economic development have a positive impact as it plays a significant role in improving the coastal community's welfare. On the other hand, it can also have a detrimental impact on the community if the development is carried out in a way that degrades the mangrove ecosystem on which life depends. Some of the impact that believed to be caused by the loss and degradation of mangroves are flooding, sea water intrusion, declining of fish production and increasing of epidemic.

Nevertheless, amidst this bleak picture of mangrove management in Indonesia, there are some good developments underway. Cities like Balikpapan and Bontang have succeeded to transform former slums in the mangrove areas into environmentally friendly water-front cities. Many actors (private sector, NGO, government, individual) are also known to be actively participating in the efforts to combat the loss and degradation of mangroves everywhere in Indonesia. However, given the fact that Indonesia's mangroves cover very vast areas with very complex management issues, the rate of the loss and degradation of Indonesia's mangrove is still perching on the worrying level.

For further information please
visit our website or contact our office

Wetlands International – Headquarters

PO Box 471
6700 AL Wageningen
The Netherlands
Tel: +31 318 660910
Fax: +31 318 660950
E-mail: post@wetlands.org
Website: www.wetlands.org

Wetlands International – Indonesia Programme

PO Box 254/BOO, Bogor 16002
Jl. A. Yani No. 53, Bogor 16161
Jawa Barat, INDONESIA
Tel: +62 251 8312189
Fax: +62 251 8325755
E-mail: admin@wetlands.or.id
Website: www.wetlands.or.id

