Case Studies

REMOTE SENSING TECHNOLOGY FOR MARINE AND LAND RESOURCE PLANNING IN INDONESIA: A SUSTAINABLE APPROACH[1]

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Abstract: Concepts, theory and practical applications on conducting development tasks in sustainable ways are being assessed and implements in Indonesia. These include the socio-economic conditions, natural resource conditions, biodiversity and physical development drives.

Two programs related to marine and land resource planning are being implemented in this world's largest archipelagic state 17508 islands rich in natural resources and abundant in flora & fauna species. Several means of methods and technologies, including the geographic information system (GIS) and remote sensing technology are also being implemented to support this program.

Indonesia possesses one of the richest tropical forest, having 89% of the known forest types and covering about 10% of the world's tropical forest resources. From the interpretation of Landsat MSS images (acquisitions between 1986 to 1991) for the first stage of NFI forest land use estimations, it is indicated that more than 120 million hectares (or 63 %) of Indonesia land area is forest cover. Irian Jaya possess the most forest cover, i.e. 84.71 % of its land area, followed closely by Maluku, i.e. 82.47 , whereas Java and Bali have the least, i.e. only 22.04 %.

The marine resource evaluation and planning (MREP) program covers 10 marine and coastal management areas of 44,200 square kilometer land areas and 82,100 square kilometer marine areas with three main objectives: The development of Coastal Environmental Map in the MREP area, The development of GIS database The development of GIS analytical procedures for marine and coastal evaluation and planning.

National development with sustainable approach is being implemented extensively in Indonesia.

1. Introduction

Following the United Nations Conference on Environment and Development (UNCED) held at Rio de Janeiro in 1992, the need to understand sustainable development, particularly for land use and land cover change and its implementation, are increasing day by day. Concepts, theory and practical applications on conducting development tasks in sustainable ways are being assessed and implements in many countries.

There are many ways to interpret sustainable development based on resource capabilities, however, there is a "rule of thumb" theory proposed by Murai (1994) which may be used to identify sustainable development, as follow:

The sustainable development is accomplished if the following conditions have been met:
1) If the country's population growth reaching 1 %,
2) If more than 30% of the country's area is covered by forest,
3) If there is no massive logging,

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4) If at least 1 % of the fragile watershed areas are protected,
5) If the ratio between the productive forest and the protective forest is, at least, 1 : 2,
6) If the reforested areas are not covered by a single species trees,
7) If all of the country's big projects have flood control systems,
8) If most of the country's forests are covered by broadleaf trees instead of conifer type trees,
9) If the country imposed a stiff pollution control program,
10) If the country consumed small chemical and pesticide substances.

Republic of Indonesia is the world largest archipelagic state with the total of 17508 islands stretching 5100 kilometer from West to East at the equator (Figure 1). Indonesia's populations of reaching over 186 millions in 1992, with the average annual population growth of 1.7 % and enjoying GDP of more than 6 % annually in the last 25 years, has positioned itself as one of the strong contributor to the fastest growing region of the world. By the year 2000, Indonesia will be occupy by approximately 212 millions inhabitants, with the estimated average income per capita of $1000/year (Table 1). Efforts in managing resources, both natural and human resources, in sustainable ways are one of the major government of Indonesia's tasks.

In order to develop the country in sustainable ways, several physical and socio-economic parameters are being identified. The implementations of various theories and methods are also underway. Including in this activity is the launching of national program for the evaluation and planning of land resources and marine resources. Several means of methods and technologies, including the geographic information system (GIS) and remote sensing technology are also being implemented to support this program.

2. Program in Land and Marine Resources Evaluation and Planning

In order to be able of exploiting and, at the same time, managing its resources in sustainable ways, programs are underway to make inventory of Indonesia's natural resources for better planning and development. The inventory of the country's physical parameters and socio-economic parameters includes: the geologic conditions, climate, hydrology, physiography, soil, land cover, environmental hazard and its forest conditions. While parameters for the socio-economic conditions, includes population and the regional economic conditions.

The geological conditions of Indonesia reflect from its position between two continents, the Asia and Australia, and two oceans, the Indian Ocean and the Pacific. Three tectonic plate margins, the Indo-Australian plate, the Pacific plate and the Eurasian plate are met and collided within the Indonesian archipelago. This condition may reflects on the country's natural hazard environment, including the earthquake prone conditions, landslides, floods and also on the distribution of Quaternary active volcanoes. There 600 volcanoes in Indonesia, 129 of them are active. These geologic and tectonic conditions have also brought a very positive impact on the country's resource potentials. It will bring richness in soil, a fertile soil, for forest and agriculture. It bears potential resources for minerals, including tin, nickel, copper, lead, zinc, bauxite, chromite, manganese, iron sand, gold, silver and energy such as oil and gas, coal and peat (Table 2).

Most of Indonesia enjoys a moist tropical climate, with abundant rain and high temperatures. With the exception of rainfall, climatic variables at a particular place change little during the course of the year. This also bring soil moisture and bring impacts to the plant growth.

The geologic, climatic and hydrologic conditions of the country bring forest of Indonesia as the country's most valuable natural resource asset and still cover two-thirds of the land area. The total forest coverage is 120 million hectares, consist of conserved forests and production forests. In doing production forest, Indonesia introduces a system called The Indonesian Selective Cutting System (ISCS) and the system is being strongly enforced. The ISCS system provides the country with a better managed forest resources in sustainable ways.

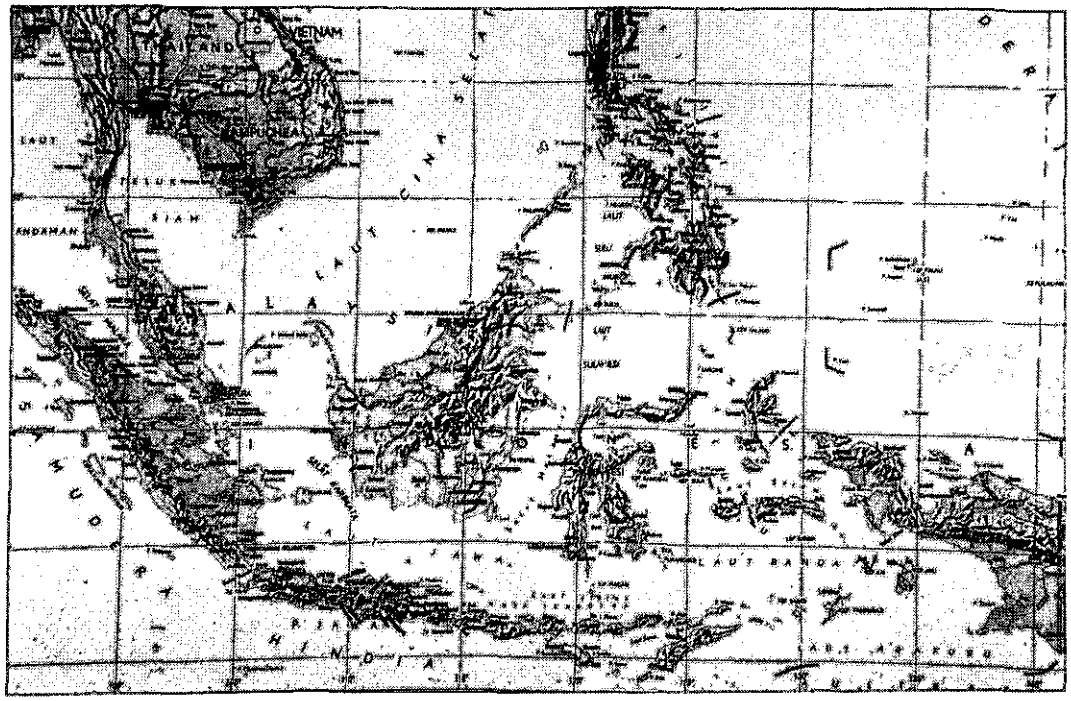

Figure 1: Country of Indonesia, 5100 Km across, 17508 islands, 186 million people, major islands: Sumatra, Java, Kalimantan, Maluku, Irian Jaya. (Atlas Dunia, 1992)

Table 1

FACTS ON INDONESIA

1992/1993

1.	Population	186 Millions,
2.	Gross Domestic Products	7 %,
3.	Income Per-capita	US $ 680,
4.	Rice Production in 1992	47,769,000 tons,
5.	Corn Production in 1992	7,987,000 tons,
6.	Vegetable production in 1992	5,222,000 tons,
7.	Fruits Production in 1992	6,660,000 tons
8.	Meat Production in 1992	1,232,000 tons,
9.	Fish Production in 1992	3,499,000 tons,
10.	Rubber Export in 1992	1,268,100 tons,
11.	Coffee Export in 1992	259,300 tons,
12.	Tea Export in 1992	121,300 tons,
13.	Spices Export in 1992	62,100 tons,

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(Source: Lampiran Pidato Presiden RI, 16 Agustus 1993)

Table 2

MINERAL, OIL AND GAS PRODUCTIONS IN INDONESIA

1992/1993

1.	Crude Oil	548.1	million barrels,
2.	Natural Gas	2,603.3	billion cubic feet,
3.	Coal	23,340.2	thousand tons,
4.	Tin	32.0	thousand tons,
5.	Nickel	2,378.4	thousand tons,
6.	Bauxite	868.0	thousand tons,
7.	Iron sands.....	316.2	thousand tons,
8.	Gold	40,318.0	kilograms,
9.	Silver	98,710.6	kilograms,
10.	Copper concentrate	838.7	thousand tons.

(Source: Lampiran Pidato Presiden, 16 Agustus 1993)

Table 3

ISLAND GROUP	TOTAL SCENE	AVAILABLE SCENE	
		NUMBER	PERCENT
Sumatera	38	35.5	93 %
Kalimantan	39	24.5	63 %
Sulawesi	27	20.0	74 %
Java, Bali, NTT, E.Timor, NTB	32	22.5	70 %
Maluku	11	5.0	45 %
Irian Jaya	33	11.5	35 %
Total	180	119.0	66 %

Coverage of LANDSAT MSS Scenes per-Island Group in Number of Scenes and In Percentage of Total Scenes (May 1991).

(Kadri, 1994)

The ISCS is very important to follow, considering that the forest of Indonesia is needed to be converse, because the forest of Indonesia has:

a). 10% of the world plants species,
b). 12% of world mammal species,
c). 16% of the worlds reptile and amphibian species, and
d). 17% of the world bird species.

It has also been recognized that 430 of about 1500 bird species and nearly 200 of the 500 mammal species can only be found in Indonesia, no where else. Some species, such as the nearly 400 species of dipterocarp trees in Sumatra and Kalimantan, and the 7000 species of fish in the marine and coastal zones, already make major contributions to the country's economy. This biodiversity species must be conserved, preserved and developed in sustainable way. Its extinction must be prolonged. No other country has responsibility for more diverse and unique species than does Indonesia. It is a great challenge, but one that can be met. Conservation and sustainable development is a moral and economic obligation for all.

In order to speed up the development planning, since 1985, two large programs has been launched in Indonesia. The two programs are:

1. Land Resource Evaluation and Planning (LREP) with main objective of strengthen in the land resource data and natural resources information system in various agencies and, at the same time, strengthening 18 planning agencies in 18 provincial government offices to conduct resource evaluation and planning. In this program, digital topographic database was created, while soil data and land use data of the 18 provinces were also developed. The program will be completed in 1996.
2. The second program is in the resource evaluation and planning in the marine and coastal areas. Under the program called Marine Resources Evaluation and Planning (MREP), natural resource data from coastal and marine areas of 10 provinces in Indonesia, and three large straits within the archipelago area being inventoried, compiled and later will be used for planning in the 10 provincial planning offices.

The above mentioned activities are also being intended to support the investment program in the provinces and to better planned the development efforts in a sustainable way. In implementing this program, various survey and mapping technologies are being utilized, including: aerial photo technology, airborne laser technology, airborne radar technology, remote sensing satellite technology, global positioning system technology, and geographic information system (GIS). In the field of satellite remote sensing technology, various data coming from many satellites, including LANDSAT, SPOT, ERS-1 and NOAA are being utilized.

3. Remote Sensing Technology for Forest Resource Study in Indonesia

Part of the Indonesia's land resource evaluation and planning is assessing the forest resource potentials. Indonesia possesses one of the richest tropical forest, having 89% of the known forest types and covering about 10% of the world's tropical forest resources. It is imperative that appropriate and continuous management be applied to safeguard the sustainable utilization of these resources. To achieve this, adequate and reliable data and information is required to support policy making, definition of strategies and the setting up of development program guidelines and its implementation.

Remote sensing technology has been applied extensively for forest inventory and management. Landsat MSS data acquired from 1986 to 1991 were being utilized for forest mapping, while the Landsat TM data and SPOT data were being utilized for the second stage. The Indonesian archipelago required 180 scenes of 180 X 180 km Landsat imagery. The Landsat MSS coverage over the island group within the 1986-1991 range, 66% of the data are acquired, totalling 119 scenes out of 180 scenes (Table 3).

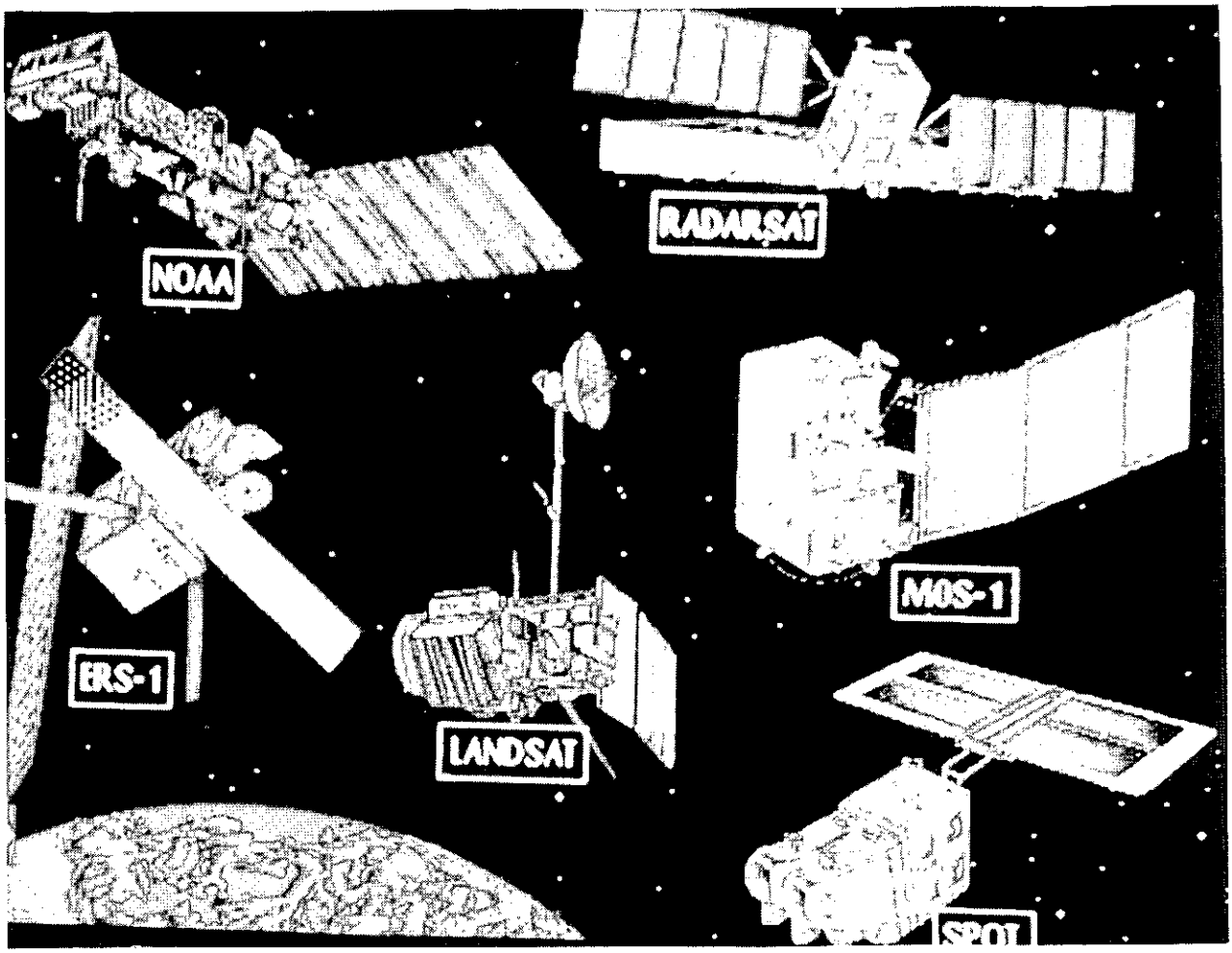

Figure 2: Remote Sensing Satellites currently in operations. Satellites with optical sensors: NOAA, LANDSAT, MOS-1, SPOT. Satellites with radar sensors: ERS-1, RADARSAT.

(Geoscope, 1993)

From the interpretation of Landsat MSS images (acquisitions between 1986 to 1991) for the first stage of NFI forest land use estimations, it is indicated that more than 120 million hectares (or 63 %) of Indonesia land area is forest cover (Nuryanto, 1994) (Figure 2). The compositions according to forest land use types (percentage also to Indonesia land area) are as follows:

- lowland forest 82.9 million hectares (43 %),
- swamp forest 17.7 million hectares (9.3 %),
- submontane forest 10 hectares (5.2 %),
- mangrove forest 3.7 million hectares (2 %),
- mountain forest 3.3 million hectares (1.7 %),

The forest cover distribution according to major island groups are as follows:

- Sumatra : 23.628.590 hectares (49.66 % of the island),
- Kalimantan : 38.943.650 hectares (72.22 % of the island),
- Sulawesi : 11.378.710 hectares (60.80 % of the island),
- Maluku : 6.411.290 hectares (82.47 % of the island),
- Irian Jaya : 34.966.480 hectares (84.71 % of the island),
- Nusa Tenggara : 2.216.130 hectares (27.72 % of the island),
- Java and Bali : 3.034.630 hectares (22.04 % of the island),

As shown in the above mentioned data, it is evident that Irian Jaya possess the most forest cover, i.e. 84.71 % of its land area, followed closely by Maluku, i.e. 82.47 , whereas Java and Bali have the least, i.e. only 22.04 %.

The Government of Indonesia, based on the Forest Land Use Planning by Consensus (Tata Guna Hutan Kesepakatan / TGHK) 1984, stated that the total forest of Indonesia is 143 million hectares, comprising of:

- 30 million hectares of protection forest (HL),
- 19 million hectares of nature conservation and recreation forest (HSA),
- 31 million hectares of Limited Production Forest (HPT),
- 33 million hectares of production forest (HP),
- 30 million hectares of conversion forest (HPK and HNB),
- and about 50 million hectares other land use (APL),

NOAA-AVHRR (Advanced Very High Resolution Radiometer) are also being used for continuous forest monitoring, even though the resolution is approximately 1.1 km. (Figure 3).

Forest analysis on large scale are being conducted using the 1:20.000 scale aerial photographs, and the objects that may be observed are:

1. Forest detail stratification using crown closure, crown diameter and stand height,
2. Forest land use in detail
3. Forest relevant information as, for example, the forest land reserve for other purposes, road construction plans, exploitation plans, watershed management plans..

Under the Minister of Forestry decree, 1992, it has been decided that forest inventory activities must be conducted using 1:20.000 scale aerial photographs, while for forest monitoring and management activities may be conducted using satellite imagery.

4. Remote Sensing and GIS for Marine Resources Evaluation and Planning in Indonesia

The Indonesian archipelago with more than 17000 islands stretching more than 5100 kilometers from West to East occupies 81000 long kilometer coastlines. Efforts are currently underway to sustainably exploits the coastal area's natural resources and initial works being organized to conduct marine and coastal resource inventory and evaluation.

Figure 3-a: LANDSAT TM Imagery, Waropen Area, Irian Jaya Province, Indonesia. The Band Combinations are Band 6, Band 4 and Principal Component Band 2 & 3.

(Remote Sensing BPPT, 1994)

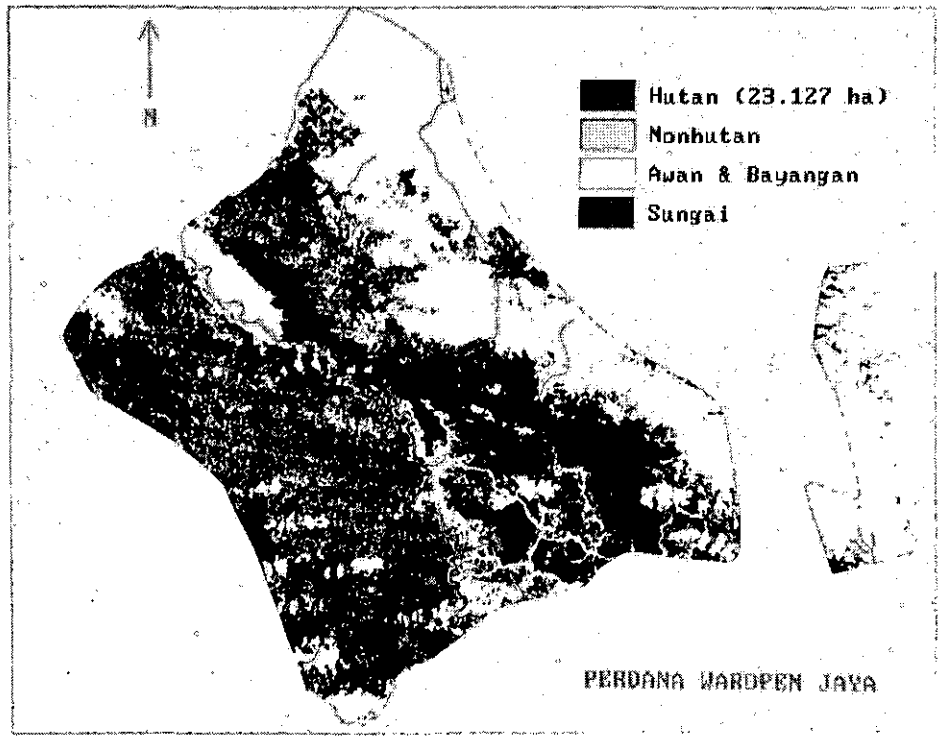

Figure 3-b: Classified Map of Waropen Area, Irian Jaya province, Indonesia as derived from LANDSAT TM Data. The forest area (23,127 hectares) and the non-forest area may be delineated.

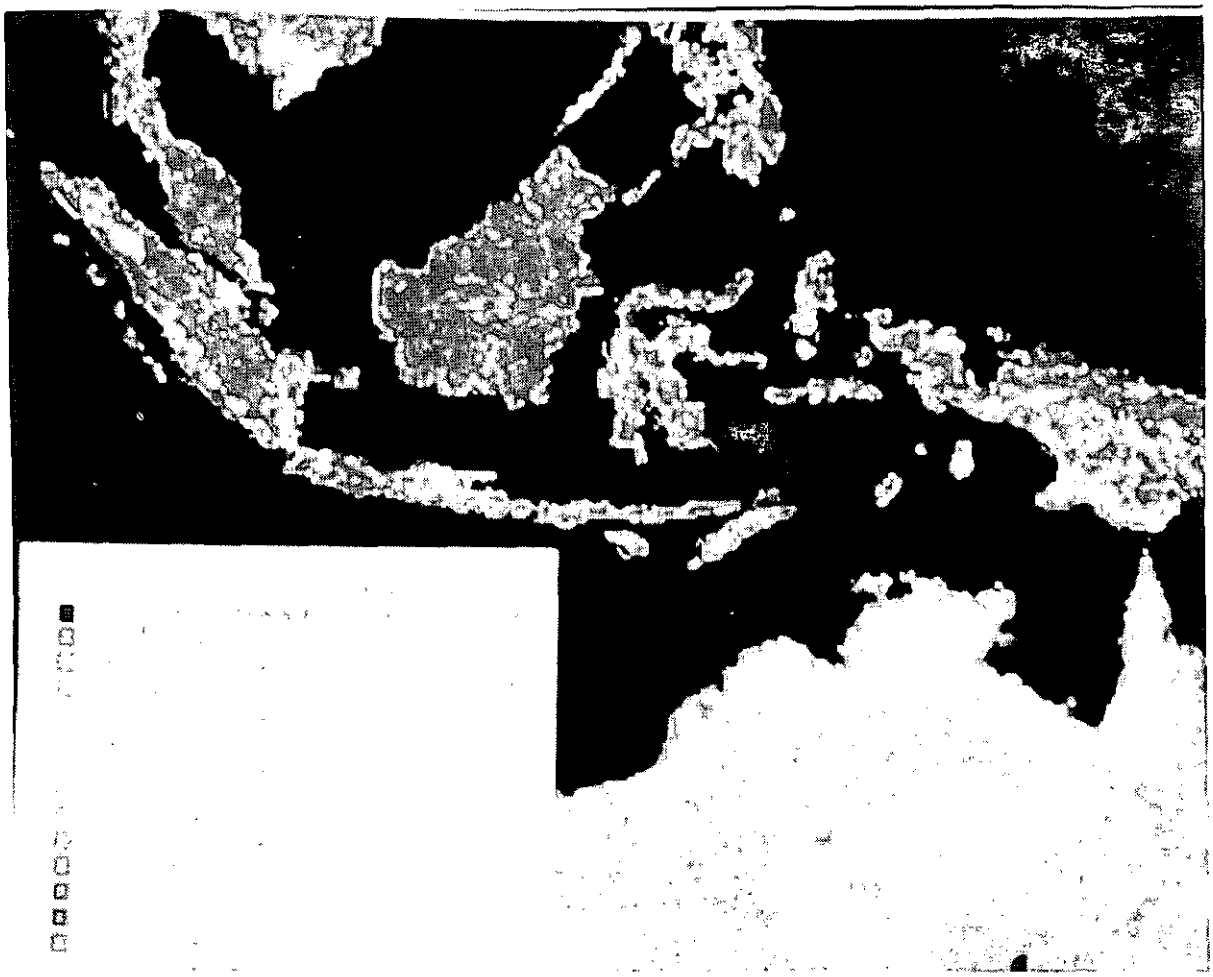

Figure 3-c: NOAA-AVHRR Global Area Coverage Imagery over the Indonesian region, showing the forest conditions over the country. NOAA data are being utilized for continuous monitoring.

(Geoscope, 1993)

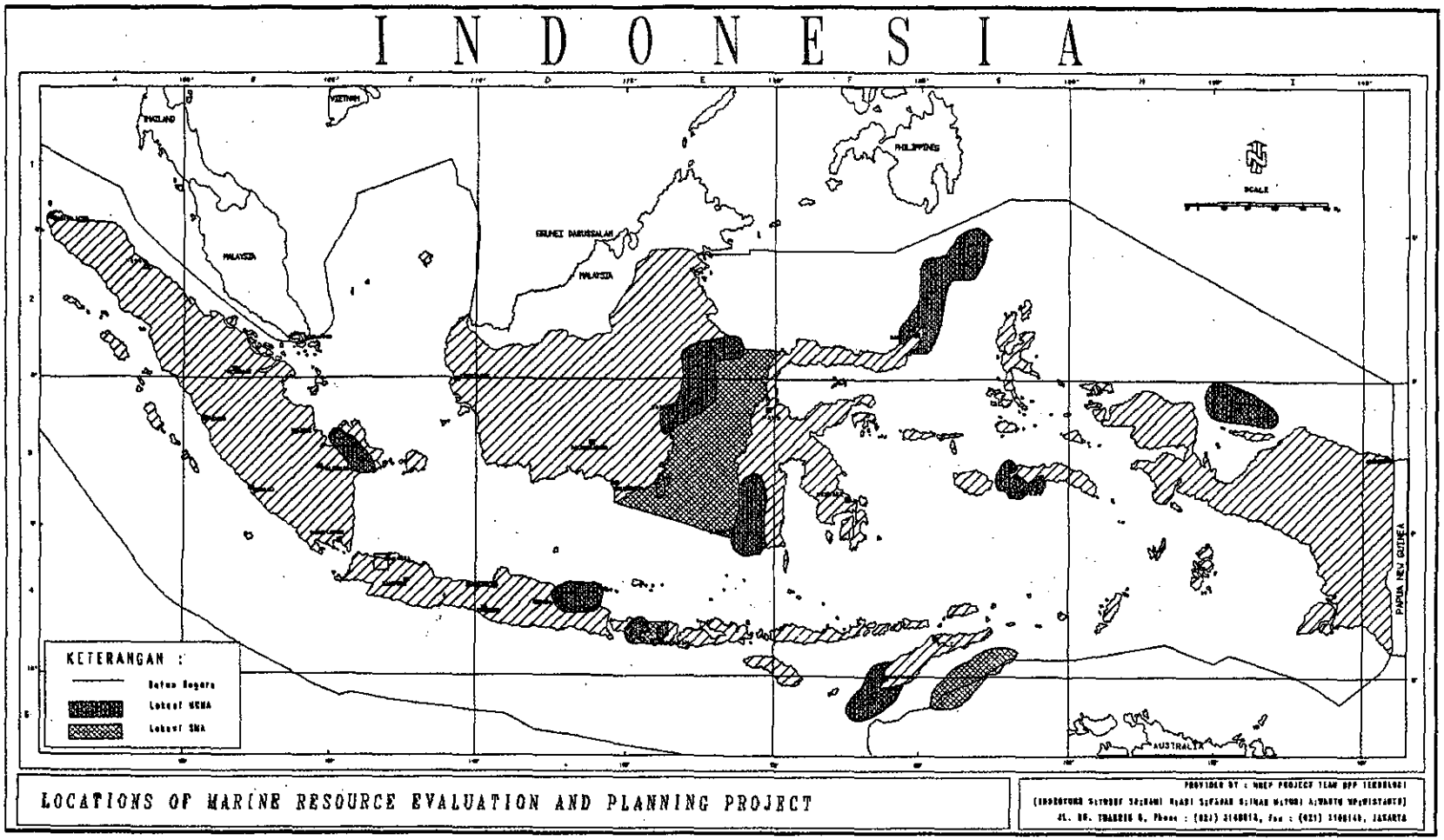

Figure 4: Locations of the Marine Resource Evaluation and Planning (MREP) Project, covering 10 provinces and three straits. (MREP Project BPPT, 1994)

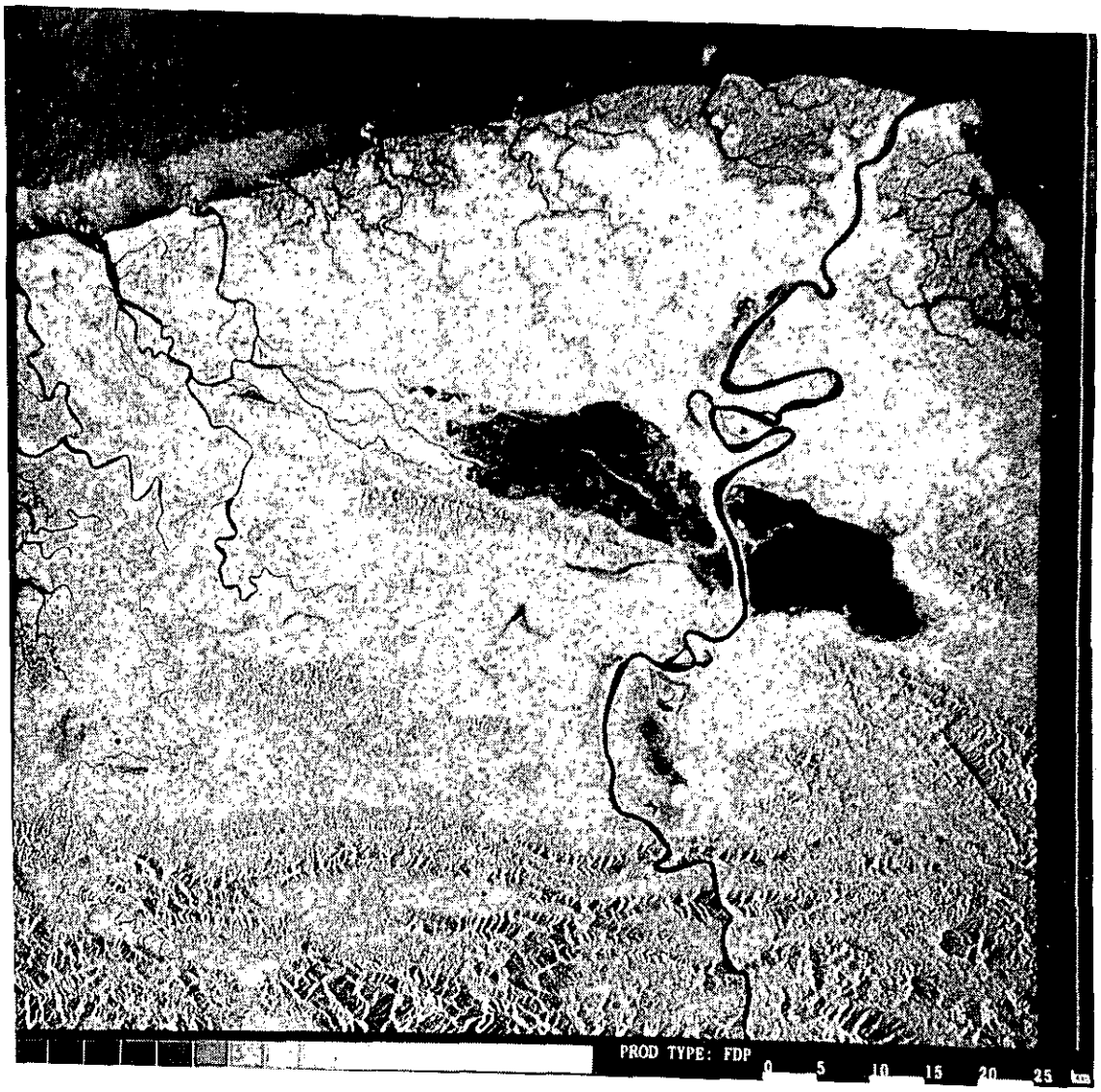

Figure 5 : ERS-1 radar imagery over the Mamberamo River, Irian Jaya Province, Indonesia. Radar imagery is capable of penetrating cloud and very sufficient to be applied in dense vegetated areas. This imagery is being utilized for coastal plain planning activity.

(Source: ACRES-Australia, 1994)

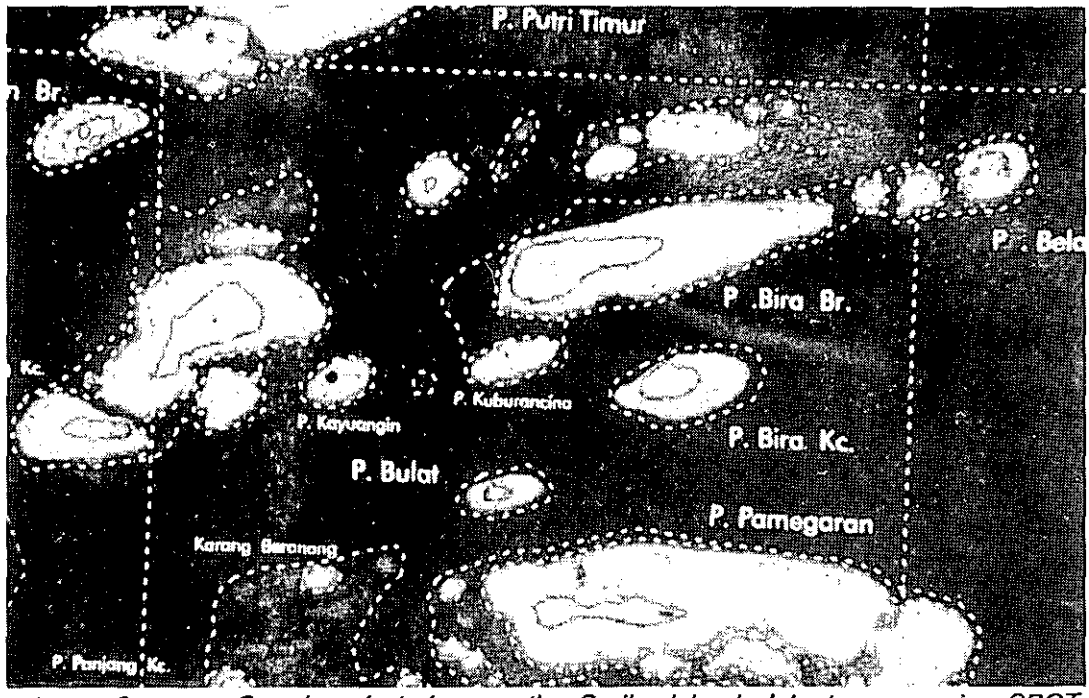

Figure 6-a: Corral reef study over the Seribu island, Jakarta area using SPOT satellite imagery. (SPOT Image, 1992)

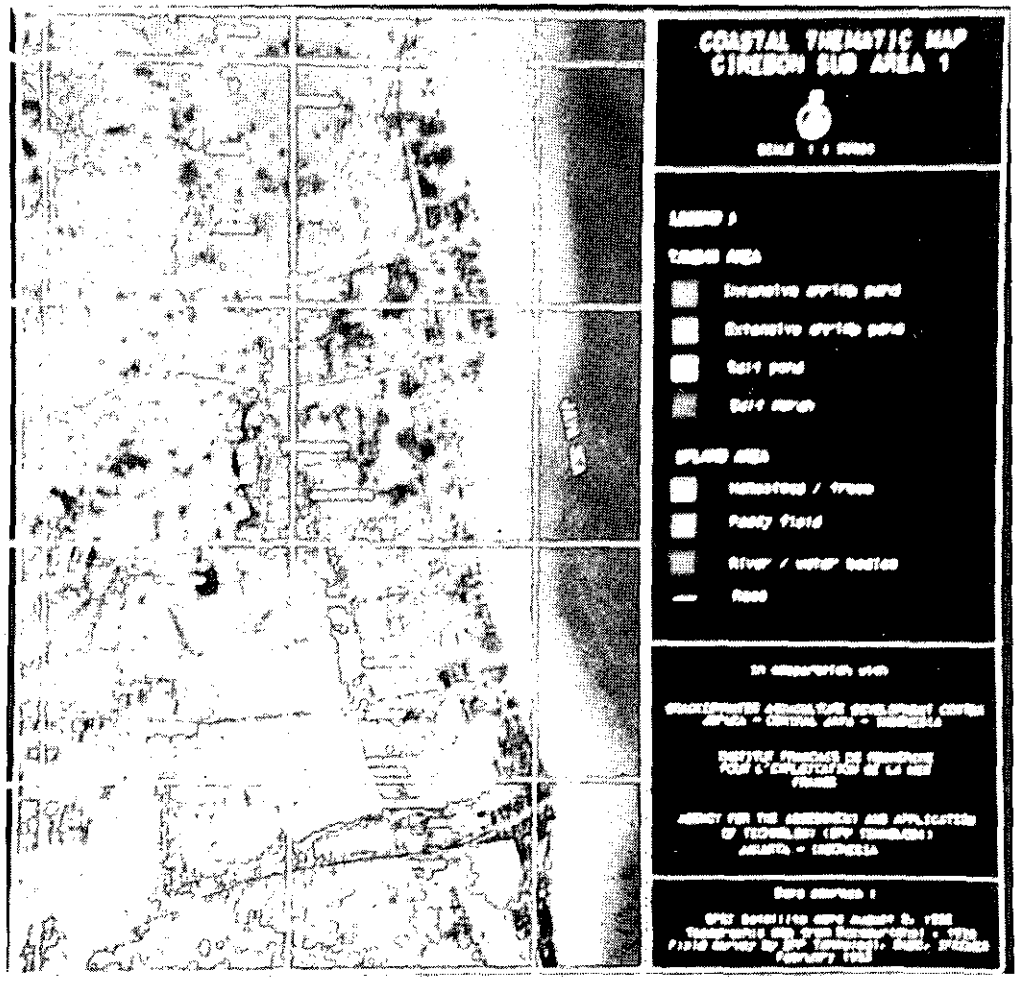

Figure 6-b: Coastal Thematic Map over the Cirebon, West Java Area, developed from SPOT imagery and applied for aquaculture.

(Agus Wibowo, 1994)

Since 1993, a major program dedicated toward marine resource evaluation and planning (MREP) have been launched. The area covering 10 marine and coastal management areas of 44,200 square kilometer land areas and 82,100 square kilometer marine areas are being assessed both on its physical and on its socio-economic conditions. Meanwhile, additional three important straits, the strait of Lombok, the strait of Makassar and the Timor Gap are also included in the evaluation and planning (Figure 4) Activities included in the MREP program are:

1. The development of Coastal Environmental Map in the MREP area,
2. The development of GIS database
3. The development of GIS analytical procedures for marine and coastal evaluation and planning.

Remote sensing satellite technology are being applied in this activity. The utilization of Landsat TM and SPOT data are included. Shallow water mapping being conducted using three-dimensional image processing algorithm dedicated for satellite data. In the meantime, the capability of airborne laser for shallow water mapping, such as the Laser Airborne Depth Sounder, is also being assessed to support the MREP program. Including in the technological assessment are the satellite and airborne radar imaging technology, including the JERS-1 satellite data, ERS-1 satellite data and the airborne STAR-1 and STAR-2 data (Figure 5).

Some results on the applications of remote sensing satellite data for marine resource evaluation and planning are exemplified in Figure 6.

5. Conclusion and Remarks

Natural resource development in Indonesia always putting the sustainable approach as one of the conditions. This is exemplified in the forest utilization and management program, in the land resource planning and in the marine-coastal resource planning .

In order to meet the conditions, the utilization of remote sensing technology as a tool which is capable of providing continuous natural resources data are obvious considering the size of the country and the wide area of land and ocean that should be covered.

The remote sensing data acquired are being ingested into a geographic information system database for analytical studies and decision making tool related to natural resources management and monitoring.

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