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Interpretation of Mangrove Ecosystem Dynamic in Bintuni Bay Nature Reserve Using Geographic Information System

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ABSTRACT

The aims of the research were to provide a base-line for interpreting and documenting future changes in vegetation cover. Base maps such as navigation map issued by Dishidros, the department of transportation year 1912 and 1917, and map of proposed Bintuni bay natural reserved issued by Biphut, Forestry Department year 2000, were compared to Landsat TMS images from 1989, 1999, and 2002 to evaluate changes in coastline: significant changes in land formation due to accretion and erosion were recorded. The database established for ecosystem dynamics, succession, and vegetation zonation at Bintuni Bay Nature Reserve is an important tool in future management of the conservation area.

Key words: mangrove ecosystem, GIS, Bintuny bay.

INTRODUCTION

Indonesia has some of the largest areas of mangrove forest remaining in the world, at some 4.152.000 hectares. According to a satellite image interpretation of 24 November 1999 issued by Forest Watch Indonesia (FWI/GFW, 2001), an area corresponding to 11% of the Indonesian mangroves is found in Bintuni Bay, and known as the biggest mangrove forest in SE Asia. Spalding *et al.* (1997) informed that about 40% of mangrove forest in Indonesia has been converted to agricultural uses such as fish ponds and charcoal industry in South Sulawesi, South Kalimantan, and northern part of Java.

New Guinea Island contains 5-7% of world biodiversity within a tremendous geographic variation (Petocz, 1983). It is stated that there are 14 terrestrial and five freshwater ecoregions in the island. Eight of them have been listed in the WWF Global 200 as amongst the most important natural habitats in the world (Olson *et al*., 2001). Bintuni Bay, West Papua Province of Indonesia, belongs to the New Guinea Mangroves (Ecoregion #129) but it is currently facing many threats (WWF, 2001). According to Ruitenbeek (1992), Bintuni Bay mangrove forest supports several industries that have a high economic value: fishery (US$ 35 million per year), woodchip (US$ 1.5 million per year) and traditional income (US$ 10 million per year). Over the last two years, the economic activities in the area still increase, and government and natural gas plan infrastructures have also been developed.

The eastern part of the Bintuni Bay mangrove forest has been proposed by the Government of Indonesia to be established as a nature conservation area. The proposed area covers 124.850 ha, as indicated in proposed map of Bintuni Bay Nature Reserve (Biphut, 2000). It is much smaller than the previous area proposed by WWF and AWB, 267.000 ha (Ruitenbeek, 1992) and 450.000 ha (Zuwendra *et al.,* 1991) respectively. The Bintuni Bay Nature Reserve had been officially established by Decree in 1982 by the Ministry of Agriculture (SK Mentan No. 820/Kpts/Um/11/1982). Until now, no detailed analysis has been done to justify that any changes to the border ensure that priority habitats are still protected.

For these reasons, this study was implemented to provide detailed information to serve as a base line for interpreting and documenting future changes in vegetation in Bintuni Bay mangrove forest.

MATERIALS AND METHODS

Map preparation

We collected available maps relevant to the area: Berau Gulf maps from 1912 and 1917 (Dishidros, 1991), which Bintuni Bay included. Proposed Bintuni Bay Nature Reserve Map (Biphut, 2000), Land Cover and Geology Map (FWI/GFW, 2001); and satellite images TMS 18 April 1989, 24 November 1999, 5 February 2002, and 28 August 2002. Type, time, scale, and accuracy of the maps was then evaluated (Kennedy and Kopp, 1999). The nature reserve border was digitized from the proposed Bintuni Bay Nature Reserve Map. Bias was found between the map and ground marking. The border was then regenerated after the map was corrected by comparing with the satellite image from 28 August 2002. To serve as a reference in the field, this satellite image was prepared as a color composite: band 4 (red), 5 (green) and 3 (blue). After the image contrast was adjusted using the histogram equalization method (Campbell, 1996), the map was then printed at a scale of

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1:75.000. This color composite was chosen because of the dramatic mangrove forest reflectance (Murai, 1999).

Transect survey, ground observation truthing and satellite image classification

Locations to be sampled were deliberately selected to sample a range of conditions, topography, areas, and reflectance values for the forest. Position of plots, direction and distance were indicated in digital maps of satellite images using field data collected by GPS (Garmin 12 XL and Trimble GeoExplorer 3). Four transects were made in different places: Pitoboni, Sumbari Utara, Atuwaipa, and Taberai. Detailed measurement was done in continuous plot sampling with transect length of between 80 to 140 meters. Besides the transect surveys, ground observation truthing was conducted to identify vegetation dominance over larger areas. Inspection was undertaken in four different places from a rubber boat. Unsupervised classification was used to reduce complicated information from satellite images and the limited data on mangrove species distribution (Schultz and Engman, 2000). Grouping of reflection level combinations depend on number of classes determined in the field.

Changing of landcover

The Landsat TM 5 satellite images covering the same area from years 1989, 1999, 2002 were used to monitor landcover changing. Geographical reference of the maps was corrected using a polynomial geometric transformation level 2 (Burrough and McDonnel, 1998). The three Landsat images were then compared one to another to see the changes in landcover.

RESULTS AND DISCUSSION

Satellite image analysis

From all the available maps, not one satisfied the desired levels of geographical accuracy. The best map was the digital map produced from the Forest Watch Indonesia (FWI/GFW, 2001) satellite analysis, but this still contained some errors in landcover classification (for example lowland forest is classified as 'unproductive dryland' or 'montane forest').

To overcome the lack of a good quality base map, we used the satellite image Path 105, Row 62, dated 24 November 1999 from the Forest Watch Indonesia archives, and the same set for 28 August 2002 purchased from LAPAN. The geographic reference for the two images was corrected based on data from GPS readings in the field, for instance at Manokwari airport, streets in Manokwari town, Babo airport, and several sites inside Bintuni Bay and its network of river channels. As this image was already at level L1G (geometric and radiometric correction), it was sufficient to correct the X or Y axis. There proved to be a difference of 170 meters between the geographic image and field reality.

The Nature Reserve boundaries as obtained from the corrected Biphut map (Figure 1) were then overlaid on the corrected image, as shown in Figure 2. The results of classifications are shown in Figure 2, where several types of mangrove forest can be differentiated, but not yet identified, due to limited data from the field. Even though, the detail transect survey was conducted, the data could not be use as a primary variable in satellite imaginary classification due to the limited areas covered, content of moisture vapor in the atmosphere and complexity of forest structure and composition (NRCAN, 1998). As a result, correlation between color gradation and the mangrove species can not be explained yet. Moreover, it is clear that several areas of lowland forest are also included in the proposed Nature Reserve. This is important to future management as it will involve issues of logging operations which were observed during the field survey.

Mangrove ecosystem dynamic

Figure 3 and Table 1 shows the change that occurs in a selected area over the time period 1989-1999-2002. It is very clear that the forest condition is extremely dynamic, where there is active erosion of the shoreline in one site, and accretion of the shore line at another. As an example, the area of Karaka (Crab) Island was 15.19 ha in 1989, and only 6.81 ha in 2002. Over the same period, a nearby, as yet unnamed, island increased in size from 119.15 ha to 746.34 ha. The question arises whether this new island is in fact part of the Nature Reserve or not?

Table 1. Change of landcover area at unnamed island and Karaka island.

Year	1989	1999	2002
Unnamed island			
Vegetation area	119.15 ha	711.42 ha	746.31 ha
Increasing area	-	592.27 ha	34.92 ha
Rate of increasing area	-	59.23 ha/yr	11.64 ha/yr
Karaka Island			
Vegetation area	15.19 ha	9.08 ha	6.81 ha
Increasing Area	-	6.19 ha	2.26 ha
Rate of increasing area	-	0.619 ha/yr	0.753 ha/yr

Sandy (1984) explained that sedimentation will occurred if capability of water to transport materials is reduced as a result of decreasing of water current velocity. Abrasion will takes place on the contrary. These Phenomena were indicated in the field by mangrove species dominant, *Avicennia* sp. and *Sonneratia* sp. in sedimentation area because of their succession capability, and existing *Rhizophora* sp. and *Bruguiera* sp. in abrasion area.

Future activities

Examine if there is a link between zonation and forest type to the dynamics over the whole Bintuni Bay: is erosion linked to specific forest types? Is it possible to identify areas of accretion from tree diversity at a site? In the near future, the Bintuni Bay area is going to experience very rapid development-in industries, infrastructure, and in population growth (UNIPA and BAPPEDA Manokwari, 2001). Perhaps the only way to monitor this growth and its impacts on the natural habitat over such a large scale is by remote sensing. With this in mind, it is important to maintain the GIS unit at Universitas Negeri Papua to provide ongoing, independent, monitoring of the areas (BKSDA PAPUA II, 2005).

CONCLUSION

The limited areas covered content of moisture vapor in the atmosphere and complexity of forest structure and composition caused no correlation between color gradation and the mangrove species. Land formation due to accretion and erosion changed significantly from 1989 to 2002. A

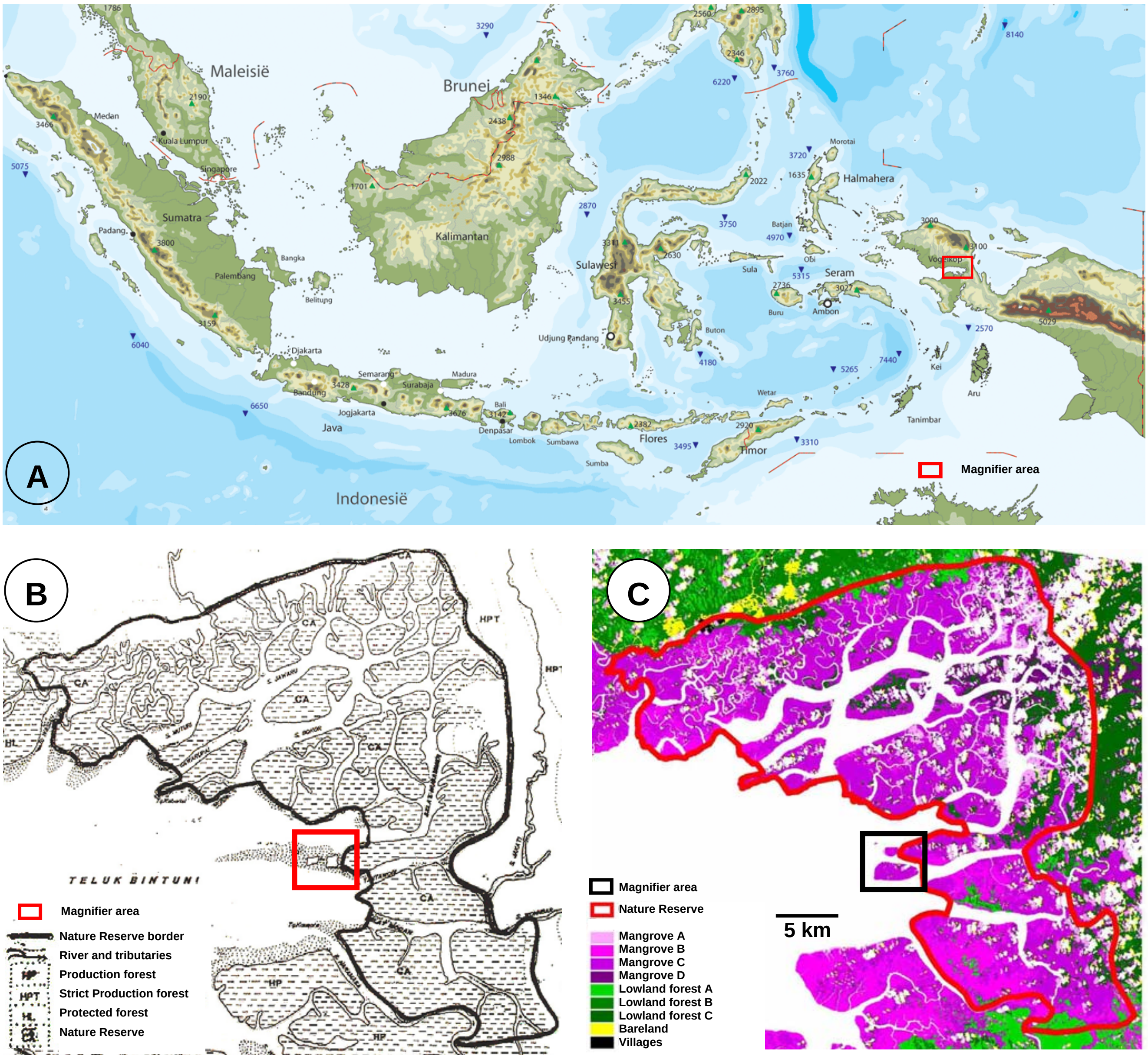

Figure 1. Map of Bintuni Bay Nature Reserve and the area of this study. A. BBNT in Indonesian archipelago. B. Proposed BBNT by Biphut (2000). C. Classified Landsat Image for Landcover at BBNT based on Landsat ETM (28 August 2002).

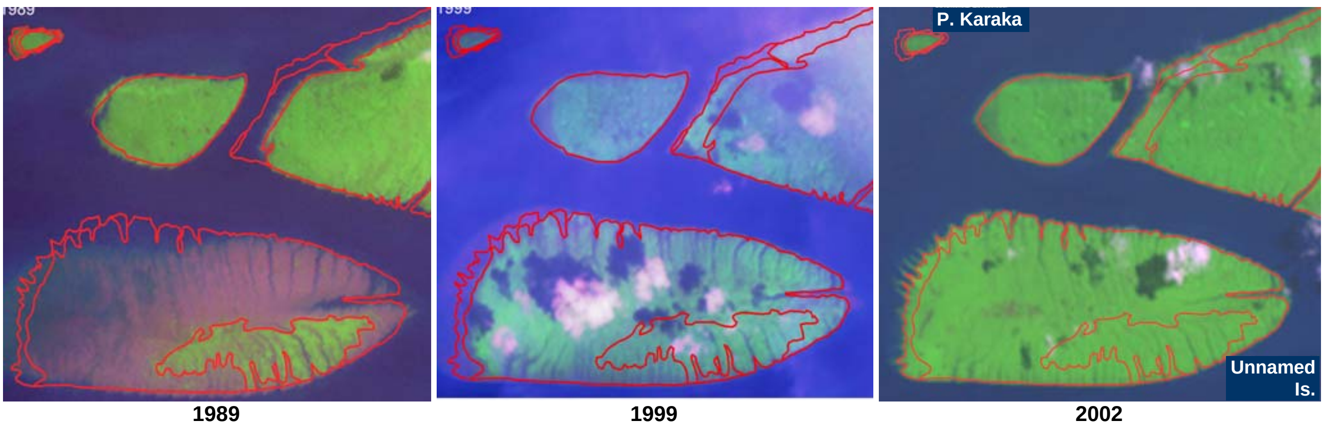

Figure 2. Mangrove ecosystem dinamic in Bintuni Bay Nature Reserve. Source: A. Landsat Image TM, 18 April 1989; B. Landsat Image ETM, 24 November 1999; C. Landsat Image ETM, 28 August 2002.

decline of Karaka Island area doubled by just fewer than 7 ha in 2002 as it was in 1989. In contrast, a 119.15 ha of unnamed island soared by 746.34 ha in the same period of time. Issues of logging operations that were observed during the field survey are located within the proposed nature reserve boundary. This ecosystem dynamics, succession, and vegetation zonation at Bintuni Bay Nature Reserve play an important role in management of the conservation area.

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