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Quantifying Habitat and Resource Use Changes in the Segara Anakan Lagoon (Cilacap, Indonesia) over the Past 25 Years (1978-2004)

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Abstract: This study assesses the changes in habitat and resource use of the Segara Anakan lagoon (SAL) located in Cilacap, Indonesia in relation to coastal development over a period of 25 years. The SAL was chosen for this study due to its social importance and its ecological significance, as it is one of the few mangrove areas left in Java, and the lagoon area is rapidly decreasing. The SAL ecosystem was mapped from 1978 through 2004 using satellite images and a GIS package to determine coastal habitat area changes. The main changes in land cover and land use involved the conversion of a large part of the estuary to new land (2966.8 ha) and mangrove area (3497.2 ha), and the subsequent conversion of these areas, and of older sections of the mangrove forest, to rice agriculture, semi-intensive fishponds, new settlements and other land uses (11,315.6 ha). Over the whole period the largest portion of mangroves was converted into rice fields (8886 ha or 43.2% from the total mangrove area). The mangrove decrease amounted to 1.4% per year since the last decade. Land use resulted from increased urbanization, and the expansion of agriculture and aquaculture, which lead to problems of settlement encroachment on agricultural land, land reclamation from swamps, silt deposition in the lagoon, and a decrease in fishery catches. This research provides an account of the coastal habitat and resource use changes in Segara Anakan, and their implications for coastal resource management and provides the ground work for a forthcoming ecosystem-based assessment of the Segara Anakan natural resources via the application of a trophic modelling approach.

Key words: Coastal habitat, coastal resources, Segara Anakan, Indonesia, satellite images, GIS.

Introduction

Segara Anakan is a large lagoon at the southern coast of Java, comprised by the only large estuarine-mangrove forest left in Central Java. The lagoon is connected to the Indian Ocean by the Western outlet (Plawangan Barat) and a tidal channel towards Cilacap as an Eastern outlet (Figure 1). The lagoon receives high amounts of fresh water and discharges including suspended sediments from Citanduy River, Cikujang River, Cikonde River and Cibereum River (Ardli and Widyastuti, 2001).

Various species of mangrove, fish, shrimps, crabs, molluscs, birds and mammals are found either in the lagoon, on the mud flats or in the mangrove areas. The mangrove forest of Segara Anakan (21,750 ha in 1983) contains 26 primarily mangrove species, of which the most abundant and commercially important ones are *Rhizophora apiculata, R. mucronata* and *Bruguiera gymnorrhiza* (White et al., 1989). Primary production in the lagoon is reported to range between 0.639 and 1.343 $mgC.m^{-3}.s^{-1}$ (Tomascik et al., 1997). The net primary production of mangrove litter of Segara Anakan was estimated as 134.3 g $DW.m^{-2}.day^{-1}$ (Tomascik et al., 1997).

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White et al. (1989) reported more than 45 species of fishes of which 17 are demersal, 12 residential and 16 occasional visitors. More than 85% of these species are of high economic value as fisheries commodities. The lagoon is a feeding, spawning and nursery ground for many commercially important fishes and crustaceans. The commercially important crustaceans found in the area are *Scylla* spp., *Portunus pelagicus, Tellina* spp., *Penaeus merguensis, P. chinensis, P. monodon, Metapenaeus ensis, M. elegan* and *M. dopsoni* (Dudley, 2000).

In the year 2000, the lagoon's fisheries production was about 488 tons comprising 41% shrimp, 39% fish, 13% crabs and 7% others. The most dominant fishing gear used (46%) is the "apong" (tidal filter net) (Dudley, 2000).

Human populations are concentrated in the three villages "Kampung Laut" i.e. Ujungalang (4959 people), Ujunggagak (3861 people) and Penikel (4490 people) (Yulastoro, 2003). The most important human activities are fishing, agriculture and aquaculture. Coastal settlements are generally densely populated with widespread poverty, especially among fishing communities.

Since 1978, land use and land cover change increased in this coastal region, as a result from increased urbanization and immigration leading to several problems. These include settlement encroachment on agricultural land, land reclamation from swamps, silt deposition in the lagoon, and a decrease in fishery catches.

Segara Anakan is subjected to a multiple resource use conflict, overexploitation of coastal resources and environmental degradation. The coastal communities traditionally exploit mangroves. Key management issues are the decreasing size of the lagoon due to heavy riverine sediment input from upland activities, water quality problems, particularly pesticides runoff from upland agriculture and poor economic conditions of the coastal inhabitants (Dudley, 2000; Yulastoro, 2003; BPKSA, 2003).

In 1997 the Segara Anakan mangrove forest area was about 13,577 ha (Tomascik et al., 1997), and has been severely degraded and reduced by a rate of 192.96 ha per year since then (Ardli and Widyastuti, 2001). In 1980 the lagoon extended over an area of 3636 ha but constantly decreased to only 600 ha in 2002 (White et al., 1989; BPKSA, 2003). The lagoon is rapidly filling up with sediments because of high rates of upland soil erosion. Fishery yields have also been affected due to the environmental changes and the loss of lagoon area (Dudley, 2000).

The importance of integrated coastal conservation and management plan for the SAL was established in 1992 by the Indonesian government and the ASEAN-USAID CRMP (Cicin-Sain and Knecht, 1998). Coastal habitat maps are regarded to be fundamental for the purpose of coastal management planning (Stevens and Connolly, 2004; Mumby et al., 1999; Cicin-Sain and Knecht, 1998). For this reason periodic mapping of coastal habitat, land resources were performed to observe trends and changes (Cicin-Sain and Knecht, 1998).

Due to the spatial nature of habitats and associated temporal changes, the assimilation of data using traditional analytical methods is often difficult. Mapping using remote sensing and Geographic Information Systems (GIS) has proven to be effective to address problems inherent in the analysis of spatial data. GIS can be used to effectively collect, archive, display, analyze, and model spatial and temporal data (Stanbury and Starr, 1999). It may also be used to combine scientific and cultural data to assess and manage marine and coastal habitats (Cicin-Sain and Knecht, 1998). GIS is an "organized collection of computer hardware, software, geographic data, and designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information" (ESRI, 1990).

Satellite data are now available that can be used to map and monitor changes from continental to local scales and over temporal scales (Treitz, 2004). Landsat thematic mapper (TM) and (Le Systeme Pour l'Observation de la Terre) SPOT images are adequate for mapping marine and intertidal habitats (Donoghue and Mironnet, 2002; Mumby et al., 1999), as well as mapping land and mangrove cover changes (Vasconcelos et al., 2002; Weiers et al., 2004; Ardli and Widyastuti, 2001; Long and Skewes, 1996). Many environmental and ecological properties can be measured using remote sensing (Mumby et al., 2004). Accurate maps of their distribution and abundance are essential for monitoring changes over time, for assessing habitat condition, and for investigating their links with other ecological system components that rely directly or indirectly on them (Long and Skewes, 1996). To monitor changes efficiently over large areas, accurate, objective and inexpensive mapping techniques are required. Image processing of high-resolution Landsat TM and SPOT satellite data has many of these advantages over traditional photo-interpretation mapping (Long and Skewes, 1996; Mas, 2004; Mumby et al., 1999).

The objectives of the present work were (1) to map and analyse dominant habitats of the Segara Anakan ecosystem (lagoon/estuarine, mangrove, mud flat, open water area, river, aquaculture and agriculture) and to monitor and assess their temporal (1980's – present time) and spatial changes by the analysis of the satellite data and by the use of field data for ground truthing, and (2) to assess the socio-economic consequences of habitat use changes.

Methods

Study Area

The SAL ecosystem is located in the south-western part of Central Java (108°46'–109°03'E; 7°34'–7°47'S), west of Cilacap city (Figure 1). The lagoon is protected from the open ocean by a barrier island, called Nusakambangan.

The climate at Segara Anakan is tropical and humid, with a southeast monsoon dry season and a northwest monsoon rainy season. Rainfall during the rainy season exceeds 300 mm/month and decreases to 100 mm/month or less in the dry season (Tomascik et al., 1997). Tides are diurnal with amplitudes of 0.2–2.6 m (average 1.48 m) within the lagoon (White et al., 1989).

The study area includes the Segara Anakan lagoon, the rivers Citanduy, Cibereum and Cikonde in the northern part of lagoon, Motean in the eastern and Klaces in the southern part of the lagoon. The topography, the elevation/contour, the soil types, and the distance from the line of maximum tide inundation determine the spatial distribution of the coastal habitats. To discriminate between the different coastal habitats information on their spatial domain is required. Since coastal habitats require to be influenced by tidal waters (Walsh, 1974 in Long and Skewes, 1996), the coastal habitat area was defined by using spatial feature influenced by the tides such as mangroves, lagoon waters and rivers of Segara Anakan from Landsat image of the baseline year 1978.

Data Material

Satellite images acquired in this study are listed in Table 1. Landsat TM and SPOT *multispectral* (XS) images were used to determine coastal habitat changes in this study. The analysis was based on the available data, cost-effectiveness, and the available spectral and spatial resolution (Mumby et al., 1999; Weiers et al., 2004).

Landsat MSS and TM images were registered and resampled to a Universal Transverse Mercator (UTM) coordinate system for zone SUTM 49 on the WGS 1984 projected output image composed of 30 m × 30 m pixels with an RMS error of less than 1.0 pixel. SPOT images were also registered and resampled to a UTM (SUTM 49) projected output image composed of 20 m × 20 m pixels with an RMS error of less than 1.0 pixel that was obtained from the Biotrop Training and Information Centre (BTIC).

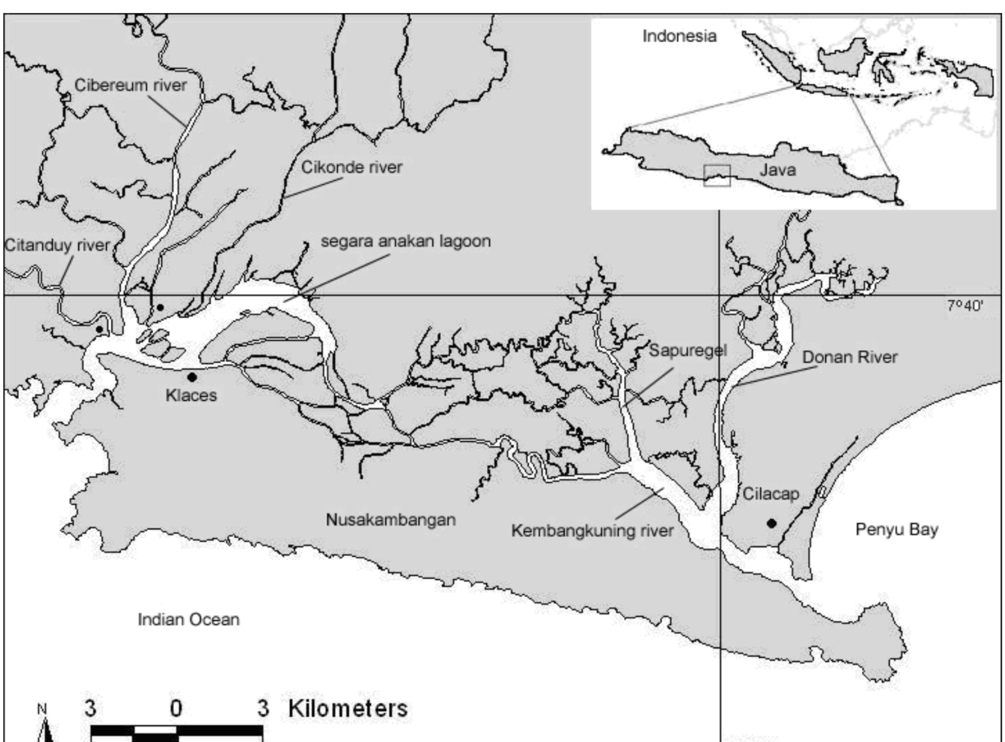

Figure 1: Segara Anakan lagoon, Cilacap District, Central Java.

Table 1: List of satellite images used in this study

Sensor	*Platform*	*Spectral coverage (μm)*	*Number of channel*	*Spatial resolution (m)*	*Path/Row (scene)*	*Acquisition date*
MSS	Landsat 5	0.50–12.6	4 (G,R, 2 x NIR)	79 (MS) 240 (TIR)	129/065	25-04-1978
HRV 2	SPOT 1	0.50–0.89	3	10 (PAN) 20 (MS)	289-365/0	10-10-1987
TM	Landsat 5	0.45–2.35	7 (B, G, R, NIR, 2 x MIR, thermal IR)	30 (MS) 120 (TIR)	121/065	05-07-1991
HRV 2	SPOT 3	0.50–0.89	3	10 (PAN) 20 (MS)	289-365/0	11-07-1995
HRV 2	SPOT 1	0.50–0.89	3	10 (PAN) 20 (MS)	289-365/0	19-03-1998
TM	Landsat 5	0.45–2.35	7 (B, G, R, NIR, 2 x MIR, thermal IR)	30 (MS) 120 (TIR)	121/065	22-06-2001
TM	Landsat 5	0.45–2.35	7 (B, G, R, NIR, 2 x MIR, thermal IR)	30 (MS) 120 (TIR)	121/065	19-01-2003
HRG 1	SPOT 5	0.50–0.89	3	5 (PAN) 10 (MS)	289-365/0	07-06-2004
HRV 1	SPOT 2	0.50–0.89	3	10 (PAN) 20 (MS)	289-365/0	30-12-2004

Resampling was done by the nearest neighbour method, which sets the radiometric value of the output pixel equal to the nearest input pixel in the original geometry, in order to preserve the original values of the image. A digital elevation model along with soil, land use/cover, stream and road network digital maps (scale of 1:50,000), was obtained from the Segara Anakan Management Agency (BPKSA).

Mapping Approach

Image Processing

In the pre-processing phase, the images were cut to include only the areas of interest. They were then rectified by using ground control points (with the geometric corrected image as a base) with a linear polynomial transformation and nearest neighbour resampling with a root mean square error of less than one pixel.

Classification (Supervised Image Classification)

Supervised classification with a maximum likelihood algorithm (available in ERMapper 5.5) was used in this study, because this classification algorithm produces consistently good results for most habitat types (Donoghue and Mironnet, 2002). The training polygons were digitized on-screen based on terrain knowledge acquired during fieldwork and was distributed throughout the study areas. The pixels in the polygons that were selected as representative of each class were plotted in spectral space and a visual check was made that all classes could be separated in at least one combination of bands, for ellipses containing 95% of the class pixels.

To increase the size of the sample to be used in classification accuracy assessment, the layer with the field-checked sites was overlaid on the corrected satellite images, and homogeneous polygons with similar spectral reflectance, when viewed in several band combinations, were drawn around those sites. The layer of polygons created using this process was later used for checking the accuracy of the classified map.

Accuracy Assessment

Accuracy assessment for the coastal habitat maps from the Segara Anakan ecosystem was based on 37-ground truthing points recorded during field survey (May 2004-February 2005). Using ecological information in a Geographic Information System (GIS), one can formulate and apply location and topological (the relation between area-based objects) rules to the classified satellite data to improve the mapping accuracy (Long and Skewes, 1996). A standard error matrix was determined to assess the classification accuracy, using data from the output map as the row, and the reference data (ground truth points) as the column in the matrix (Congalton, 1999 in Alonso-Perez et al., 2003).

Post-classification Analysis and Change Detection

After accuracy assessment, the classified images were exported to the GIS facilities to generate the coastal habitat map. Analysis and quantification of coastal habitat differences between the different dates was included in the GIS database. Once both maps had exactly the same number of feature pixels they were subject to a cross-tabular comparison. This indicates the differences in extent of each class and the transitions that had taken place between the two dates. The characterization of land cover change is done using aggregated measurements of area by cover type at both dates and quantifying transitions. The change analysis is limited to these measurements due to the different generalization levels and minimum size of mapped units for the data sources available for the study (1978–2004).

Results

Since 1978, the Segara Anakan region has changed enormously. From 1978 to 2004, the main changes in land cover and land use involved the conversion of large part of the estuary which is lagoon and river into new land (2966.8 ha) and mangroves (3497.2 ha), and the subsequent conversion of these areas and older sections of the mangrove forest to rice agriculture, semi-intensive fishponds, new settlements and other land uses (11,315.6 ha) (see Tables 2 and 3). A large part (43.2 %) of the total mangrove area changed into rice fields, and minor parts into other land use area such as aquaculture (2.7 %), dry land agriculture (5.8 %), rural settlement (0.9 %), industry (0.4 %) and other landcover types (2.1 %).

In the first 17 years period (1978–1995), new land areas rapidly increased in the western part of the SAL. The older part of this new land was then converted into new mangrove forest. These changes were mainly caused by the high sedimentation rate of the SAL system, estimated at 1–3 million ton/year (Purba, 1991). In the western region (Karanganyar, Klaces and Motean) mangrove change was more pronounced due to stronger logging and sedimentation compared to the eastern area. During this period, these changes favoured the

Table 2: Segara Anakan coastal habitat changes (in ha)

Habitat	*1978*	*1987*	*1991*	*1995*	*1998*	*2001*	*2003*	*2004*
Mangrove	17090.1	15827.6	12592.3	10974.6	10938.3	9881.6	9597.0	9271.6
Lagoon	3491.0	2224.8	1187.4	1173.1	1173.2	1004.1	991.6	931.8
River	2731.2	2203.8	2281.4	2286.4	2286	2270.9	2336.6	2323.6
Mud flat	462.5	655.4	859.8	381.6	317.6	144.6	29.6	27.4
Rural settlement	61.7	247.8	260.8	258.8	263.8	292.0	309.0	312.1
Rice field	0	1725.7	5783.5	7786.9	7778.3	8875.2	9203.8	9442.6
Dry land agriculture	0	717.5	596.5	593.7	625.0	632.0	696.4	755.3
Aquaculture	0	136.0	175.5	282.1	355.0	603.9	540.3	568.3
Industry area	0	97.9	99.3	99.3	99.3	132.2	132.2	203.8
	23836.5	23836.5	23836.5	23836.5	23836.5	23836.5	23836.5	23836.5

Table 3: Temporal trajectory of mangrove conversion in Segara Anakan

Land-cover	*1978-1987 (ha)*	*Annual change 1978-1987 (ha)*	*1987-1995 (ha)*	*Annual change1987-1995 (ha)*	*1995-2004 (ha)*	*Annual change 1995-2004 (ha)*	*Total (1978-2004) (ha)*
Mangrove (unchange)	14086.5	-	10058.6	-	8431.5	-	-
New mangrove areas	1741.1	193.5	916.0	114.5	840.1	84.0	3497.2
Mangrove, converted	3003.6	333.7	5769.0	721.1	2543.0	254.3	11315.6
Rice fields	1708.1	*189.8*	5232.7	*654.1*	1945.2	*194.5*	*8886.0*
Dry land agriculture	*678.8*	75.4	*307.8*	38.5	*202.8*	20.3	1189.4
Aquaculture	*127.8*	14.2	*150.5*	18.8	*271.0*	27.1	549.3
Rural settlement	*156.1*	17.3	*23.7*	3.0	*4.4*	0.4	184.2
Industry	*46.7*	5.2	*0.1*	0.0	*27.4*	2.7	74.2
Others	*286.1*	31.8	*54.2*	6.8	*92.2*	9.2	432.5
Mangrove (incl. unchange, converted and new)	-	-	-	-	-	-	20587.3

Remarks:

- Mangrove (unchange) refers to the area that remained covered by mangroves over the reference time
- New mangrove areas refers to mainly former lagoon area of mud flats that due to siltation got habitable for mangroves
- Mangrove converted represents former mangrove areas, which were converted into different land use types.

development of rural settlements (258.8 ha), the implementation of rice fields (7786.9 ha) and of industrial areas (99.3 ha) (see Table 2).

The largest patch of the new mangrove area (43.2%) was converted into the rice fields that are mostly located in the northern, northwestern and northeastern parts of the lagoon, where parts of it belong to the Ujung Alang and Penikel villages. This is a low lying area with a great abundance of fresh water inflow, and therefore suitable for rice culture. Only a very small part (0.4%) of the mangrove area of the year 1978 was converted into industrial area (about 74.2 ha). There are also important additions of the new mangroves (3497.2 ha) derived from former mud flats and the open lagoon (from 193.5 to 84 ha per year) (Table 3).

Since 1978, the size of the mangrove forest has been fluctuating as a result of both deforestation and mangrove encroachment. From 1978 to 1987 approximately 3003.6 hectares of forest were cut down, while 1741.1 hectares of new mangrove forest were established on new grounds in the *estuary* during this period.

While mangroves covered about 17,090 ha in 1978 and rice fields were not existent at that time, both mangroves and rice fields covered about the same area in 2004 (ca 9000 ha) (see Figure 2). More than 50% of the mangrove areas in 2004 were disturbed especially in the western part of Segara Anakan (BPKSA, 2003). The increase of other land uses such as aquaculture, industry, rural settlement, dry land agriculture and others did not significantly change the extent of the converted mangroves area, because of new mangroves that were building up. From 1995 to 2004 only 597.8 ha of mangroves were converted into land use (exclude rice fields) (see Tables 3 and 4.), while at the same time about 840.1 ha of new mangroves were created.

The general decline of the rate of mangrove conversion from the period 1987–1995 to 1995–2004 (from –3.4% to only –1.4% per year) (see Table 5), may be (at least in part) due to the projects CRMP and SACDP conducted in Segara Anakan, as mentioned above.

Table 6 shows that all aquatic resources greatly decreased over the study period and that this decrease was paralleled by economic losses, except for the shrimps, which yielded higher benefits in the year 2000 despite their substantial catch reductions due to a three-fold increase of the unit prize. On the other hand, rice production, which was non-existent in 1978, contributed almost 30% to the total resource value of the year 2000 and helped to increase the overall resource value from 15,363.2 to 19,916.8 (29.6%).

Discussion

Sedimentation has been one of the main management concerns in the river basin, particularly regarding the impacts on the low land activities, including the Segara Anakan. It has been attributed to deforestation and poor agricultural management practices in the upland areas of the Citanduy river basin, as well as to the volcanic eruption of Mount Galunggung in 1982, which is located in the river basin. The transformation of land use activities has been accelerated by the immigration of farmers, who have almost doubled the population since the year 1978 (Table 7).

New economic opportunities arose from the rice fields development, generating many income activities from farm labour, harvesting, gardening and dryland cropping, and fishponds were created. While rice has been the dominant agricultural activity over the past decade in Segara Anakan, the cultivation of other agriculture products, generally cash crops, occurs on a much smaller scale. These crops include soybean, palm sugar production, fruits and vegetables, and are often sold to supplement the household income. Rice fields are managed through various labour arrangements, notably, farmers working the land themselves, hiring labour, and/or receiving help from family members.

Mangrove conversion has led to several problems besides reducing fishery yields. It has led to a reduction of biodiversity, loss of habitats and nursery areas, increase in coastal erosion, loss in productivity, soil acidification, pollution, and alteration of water drainage patterns. While producing economic benefits, *aquaculture* development has also been associated with environmental gradation of the SAL, since it is also based on the conversion of mangroves and causes pollution of the surrounding waters. Decreasing lagoon size and with it decreasing fishing ground, are considered the cause for the declining fish production in the SAL as well as offshore Cilacap (Table 6). The loss of biodiversity in mangrove-converted areas of the SAL has been reported since 1980s (Sastranegara et al., 2003). Intertidal crab diversity was higher and more constant in the undisturbed area with high mangrove coverage (90%) compared to areas of crab hunting, logging and prawn ponds with mangrove coverage of 89%, 33% and 0% respectively. Alongi et al. (2005) reported human induced disturbance that creates a sharp zonation of dry, hypersaline soil overlying less saline, wetter soil, suppressing surface microbial and root growth.

Overall, it appears that the current changes have produced an overall economic benefit to the greatly

Table 4: Matrix of the coastal habitat changes mapping of 1978 and 2004 (in ha)

Year			*2004*								
	Habitat		*Rural settlement*	*River*	*Rice field*	*Mangrove*	*Lagoon*	*Mud flat*	*Dry land agriculture*	*Industry area*	*Aqua-culture*
1978		Area	312.1	2323.6	9442.6	9271.6	931.8	27.4	755.3	203.8	568.3
	Mangrove	17090.1	198.6	189.7	8483.1	6795.4	44.6	-	726.8	120.0	531.9
	Lagoon	3491.0	15.4	182.4	787.8	1570.8	887.1	27.4	-	-	20.1
	River	2731.2	29.3	1934.7	171.7	548.9	-	-	21.7	9.6	15.3
	Mud flat	462.5	7.1	16.8	-	356.5	-	-	6.8	74.2	1.1
	Rural settlement	61.7	61.7	-	-	-	-	-	-	-	-

Table 5: Habitat changes in percent

Habitat	*1978-1987*	*1987-1991*	*1991-1995*	*1995-1998*	*1998-2001*	*2001-2004*
Mangrove	-7.4	-20.4	-12.8	-0.3	-9.7	-6.2
Lagoon	-36.3	-46.6	-1.2	0.0	-14.4	-7.2
River	-19.3	3.5	0.2	0.0	-0.7	2.3
Mud flat	41.7	31.2	-55.6	-16.8	-54.5	-81.1
Rural settlement	301.6	5.2	-0.8	1.9	10.7	6.9
Rice field	1725.7	235.1	34.6	-0.1	14.1	6.4
Dry land agriculture	717.5	-16.9	-0.5	5.3	1.1	19.5
Aquaculture	136.0	29.0	60.7	25.8	70.1	-5.9
Industry area	97.9	1.4	0.0	0.0	33.1	54.2

Table 6: The SAL resources changes during 1978–2000s

Resources	*Amount (ton)*		*Unit value/kg ($)*		*Total value (000 $)*	
	1978	*2000s*	*1978*	*2000s*	*1978*	*2000s*
SA						
- Fish	516.3	190.3	0.55	0.45	284.0 (1.8%)	85.6 (0.4%)
- Crabs	250.0	150.0	1.50	1.15	375.0 (2.4%)	172.5 (0.9%)
- Shrimp	404.0	200.0	1.11	3.41	448.4 (2.9%)	682.0 (3.2%)
- Rice	0	48062.0	0	0.12	0	5767.4 (28.9%)
- Other crop	0	4615.3	0	0.10	0	461.5 (2.3%)
Offshore						
- Fish	15 412.9	13 153.0	0.55	0.45	8477.1(55.2%)	5918.8 (30.0%)
- Shrimp	5 206.0	2 000.0	1.11	3.41	5778.7(37.6%)	6829.0 (34.3%)
Total	21789.2	68370.6			15363.2	19916.85

Table 7: The human population in the SAL: 1978 and 2001

Location (village)	*1978*	*2001*	*% per year*
Ujungalang	3507	4959	1.80
Ujunggagak	3069	3861	1.12
Penikel	1589	4490	7.94
Total	8165	13310	2.74

Source : Yulastoro, 2003.

increased human population, but the lagoon ecosystem, its aquatic resources and its biodiversity have significantly been affected. The question to be asked is, if the SAL is going to further develop into an agricultural area, which would mean that the lagoon and its aquatic resources would finally disappear, or if it is desirable (and ecologically feasible) to maintain the SAL system as such, even at a much smaller as original size. Since Java is already almost depleted from swamp and lagoon

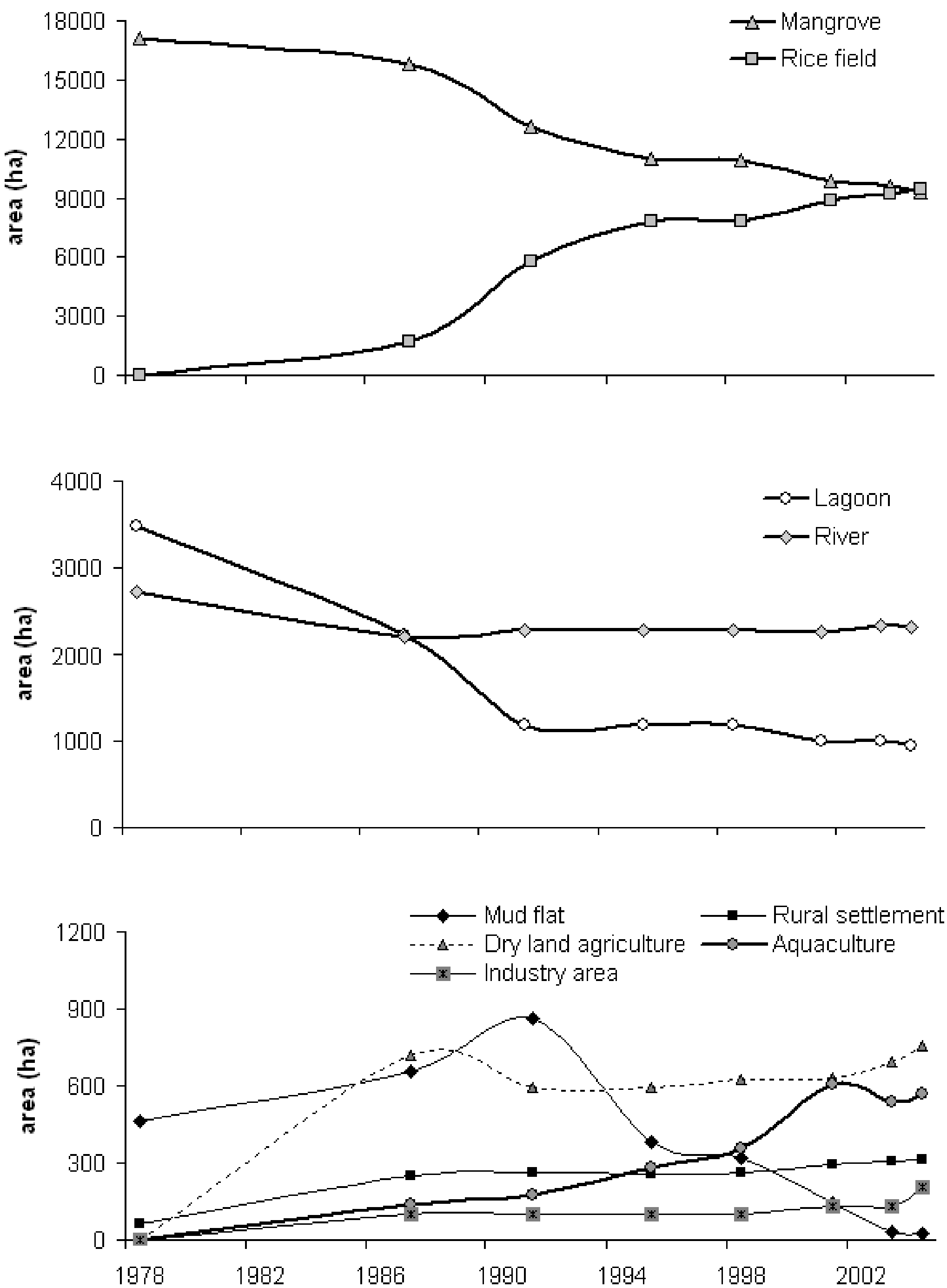

Figure 2: Extent of change from 1978 to 2004 by land use types.

areas, a loss of the SAL would mean a great loss of a unique ecosystem, and of the diversity of habitats and species, which will be unrecoverable.

Economists may argue that the total conversion of the lagoon into agriculture land may be beneficial to the region in the long run, but it should be emphasized, that despite the great changes already done to the SAL, the contribution of the aquatic resources to the overall resource value of the region still amounts to about 70% (of a total of nearly 20 million US $) and it is difficult to imagine how a loss of about 14 million US $ could be compensated.

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