MAPPING OF NATURAL ECOSYSTEMS IN SINGAPORE

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ABSTRACT

An image taken by the Landsat Thematic Mapper (Landsat TM) on 24 May 1989 was used to map the natural ecosystems present in the highly urbanized Republic of Singapore. The microBRIAN (a PC-based remote sensing software developed by CSIRO of Australia; acronym referring to **B**arrier **R**eef **I**mage **AN**alysis), an applications oriented image processing system was used to classify the various ecosystems. Only four of the seven bands taken by Landsat TM were used in the analysis. The ecosystems that were mapped in this study include the catchment area in the central region of the main island, and the reef flats in the southern islands of Singapore. The result of this study is a natural resource base map which can be used for resources management.

INTRODUCTION

Located at the southern tip of Peninsular Malaysia, the Republic of Singapore (bounded by latitudes $1^0$09'N and $1^0$29'N, and longitudes $103^0$38'E and $104^0$06'E) has a total area of 625.6km^2 in 1989 (MOCI, 1989). This area includes about 60 offshore islands, the majority of which are situated off the southern coast of the main island of Singapore. Since the end of the Pacific War in 1945, and particularly in the last 30 years, Singapore has undergone rapid environmental changes. These took the form of land clearance, water impoundment, canalising of water courses, foreshore reclamation, and levelling of hills (Chia & Rahman, 1991). In a situation where the tempo of change appears fast moving and the environmental alteration irreversible, it is vital that the natural ecosystems are carefully monitored. Remote sensing techniques provide a method of habitat monitoring. Landsat Multispectral Scanner (MSS) data had been used to investigate wetland communities by Dottavio and Dottavio (1984).

The purpose of this study is to map the natural ecosystems in modern Singapore using the technique of remote sensing to establish a resource base map for management reference purposes and habitat monitoring.

METHODOLOGY

Study Areas

The Central Catchment Area

The catchment area consists of four fresh water reservoirs surrounded by forest vegetation. This area is bounded by latitudes $1^0$20'N and $1^0$25'N, and longitudes $103^0$46'E and $103^0$50'E. The vegetation in the catchment area has been generally classified as secondary forest and thicket (Johnson, 1973). Corlett (1991) reported that the forest occupied an area of 2,059ha, within which small patches of primary rain forest could be found, particularly around MacRitchie Reservoir. The

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major part of the vegetation in the central water catchment area is tall secondary forest of between 40 to 70 years old (Corlett, 1991). Although the various types of vegetation species present in this area have been documented (Wee, 1964; Johnson, 1973; Corlett, 1991), a vegetation mapping of this area has not been thoroughly conducted.

The Southern Islands

The southern islands are the result of irregular seabed configuration with channels of over 20 m of water running through them (Chou & Chia, 1991). The seafloor is covered with unconsolidated sand and mud, some deposited at the end of the Pleistocene era after the sea level had risen (Chou & Chia, 1991). The islands are surrounded by reef flats of various extent and interspersed among these islands are numerous patch reefs. The reefs contribute to rather diverse habitats for living organisms. The coral richness and diversity of these islands have been studied (Chua & Chou, in press) but the overall mapping of this ecosystem is lacking.

Image Data

The image used in this study was taken by the Landsat Thematic Mapper (Landsat TM) on 24 May 1989. The 10% cloud cover in this image was restricted to the north-eastern islands of Singapore and hence was adequate for image analysis for most parts of the country.

Image Processing

A PC-based remote sensing software developed by CISRO of Australia; microBIAN, (acronym referring to **B**arrier **R**eef **I**mage **A**N**a**lysis) was used to classify the image. The two areas chosen for mapping were the central water catchment area and the reefs of the southern islands (Fig. 1). The northern mangroove area was found to be too small for accurate classification.

For the catchment area, the initial processing involved manually digitising the image data to separate the central catchment area from the rest of Singapore. The roads fringing the catchment area were used as a guide in the digitising process. To further isolate the catchment area from the reservoirs, the image was spectrally digitised. Before further processing, the image was linearly stretched to obtain the best contrast.

The southern islands were separated into five different groups; Ayer Chawan region, Hantu region, Semakau region, Sudong region and Sentosa region. The initial processing of the image data of the southern islands was to separate the land from the sea. From the sea image, the reefs were spectrally digitized to isolate them from the water. This was followed by enhancing the images to obtain the best contrast stretch.

Sampling of the various components of the catchment area and the reefs was done using the programme module mTRAIN within the microBRIAN system. The training sites/samples defining reflectance values were obtained with the sample means having a standard deviation of not more than 3.0. These samples were then used in the nearest neighbour classifier to group the pixels into classes. The classification process was semi-supervised, allowing the computer to generate classes for pixels that do not fall within the samples taken. These mean classes generated were then clustered using Wards incremental sum of squares.

All pixels of the catchment area image were classified after the fourth run. An initial 155 classes were generated which were then clustered to finally give 11 meaningful classes. The five images of the reef areas were processed simultaneously. After the third classification run, 179 mean classes were obtained. These classes were then grouped into nine representative classes.

RESULTS

The Central Catchment Area

Figure 2 shows the final classified image map of the catchment area. Eleven classes were generated from the classification. From ground truthing, the various classes were confirmed to indicate different vegetation types and urban structures. The biggest class was the secondary forest occupying an area of 1,656.38ha (Fig. 2a). Parks and gardens, including the Singapore Zoological Gardens, plus the golf courses of the Singapore Island Country Club in the vicinity occupied an area of 540.56ha. The trees planted on the golf courses and in the parks were clearly demarcated from the regularly maintained turf by their different reflectance values. The landscaped trees and bushes in the golf courses and the recreation parks covered a total area of 342.56ha while the lawns and turfs occupied 138ha (Fig. 2b & 2c). On the other hand, the unkempt grassland with scattered scrub and bushes were distinct from the artificially managed vegetation. They were found to be surrounding the catchment area and were either cemetries or vacated villages. These areas of spontaneous secondary vegetation covered a total of 1,003.75ha and they represent a fast changing environment (Fig. 2d).

The north-eastern corner of the catchment area was undergoing constructional changes in 1989 where extensive widening of Mandai Road was going on. This was captured by the Landsat TM and represented here as a class of exposed soil and herbaceous weeds. This area, interestingly, was classified together with the exposed banks of the reservoirs, which were mostly mud banks with scattered weeds growing on them. The total area occupied by this class was 147.38ha (Fig. 2e).

The military rifle ranges and a Public Utility Board's covered service reservoir were grouped as one class. The other small classes derived from the classification included artifacts such as parts of the Bukit Timah Expressway and some military installations.

The Southern Islands

The subsetted images for the five regions in the southern islands were of the same size, however, the areas of the reef flats that were isolated for classification were of varying sizes. The Ayer Chawan region had an area of 333.06ha, Hantu area 221.13ha, and Sudong's 341.94ha for analysis. The Semakau area was more extensive (395.19ha) and Sentosa region had the smallest reef flats (136.88ha) to be analysed. The images produced from the combined classification of the five areas resulted in nine clustered classes. However, not every region was clustered into nine classes. Only the Sudong region had a final classified image consisting of nine classes. The Ayer Chawan, Hantu and Sentosa regions had eight final classes. Semakau region had the least, with a final 7 clustered classes.

The various components commonly found on a reef flat include coral rocks, live corals, sand patches, seagrasses and algae. The distribution of these components on the reef flat of the Semakau area in the enhanced image were similar to some of the known components like seagrass and sand patches. However, the classification showed more variation within the reef flat than was evident even from ground truthing.

An example of the final classified image is presented in Figure 3. The region shown includes P. (Pulau = island) Semakau, P. Sakeng and several patch reefs. The dominant class obtained from the classification of this area consisted of a mixture of coral rocks, live corals and scattered stands of seagrasses (Fig. 3a). This class occupied an area of 156.56ha of the total 396.19ha of patch reefs and fringing reefs classified. Denser patches of seagrass showed distinct reflectance values and were classified into a single class (Fig. 3b).

DISCUSSION

In this study, the same methodology was employed for the classification of the catchment area vegetation and the reef flats of the southern island. From the classified image, the forest in the catchment area covered a total of 1,656.38 ha. This was different from the figure reported by Corlett (1991) which was 2,059 ha. The present study is based on an image captured in May 1989, and it is not certain when and how Corlett conducted his survey. For the southern islands, processing the five images simultaneously gave different results from just classifiying one image. This could be due to several reasons such as more accurate and concentrated sampling of one particular area, or even the differences in habitats even though the five regions are all reef flats of both fringing and patch reefs.

However, the overall classification was found to be accurate from observations during ground truthing. As compared to traditional methods of mapping over large areas, more accurate results than this might not have been achieved unless very intensive and costly field sampling methods are used. There are still some limitations that should be highlighted. Variations amongst the reef flats of the different regions of the southern islands may be attributed to differences in reflectance due to depth. The seas of Singapore are turbid which restricts the use of this technique beyond the reef edge. TM imagery has thus failed to overcome the problem of poor penetration in turbid waters, as has been reported by authors using other satellite data (Claasen *et al* 1984).

This study shows that microBRIAN, originally designed for analysis of images from the Great Barrier Reef, is also useful for analysing images of highly urbanised Singapore. With this tool, natural resoucre data base maps of Singapore can be created using remotely sensed images captured from space.

The data obtained from this 1989 image as base maps may be used for future references. Currently, some obvious ground changes have already taken place. Areas of changes are mainly on the spontaneous secondarily vegetated area left by vacated villagers. The Mandai Road expansion work has been completed and the exposed ground is now covered by landscape vegetation. As for the southern islands, dumping of earth spoils has been ongoing (Quek, 1989) and plans have been announced for more reclamation works along the main coastline of Singapore and around the islands. Thus the importance of a base map and the feasibility of using satellite imagery for monitoring the environmental changes cannot be underemphasised.

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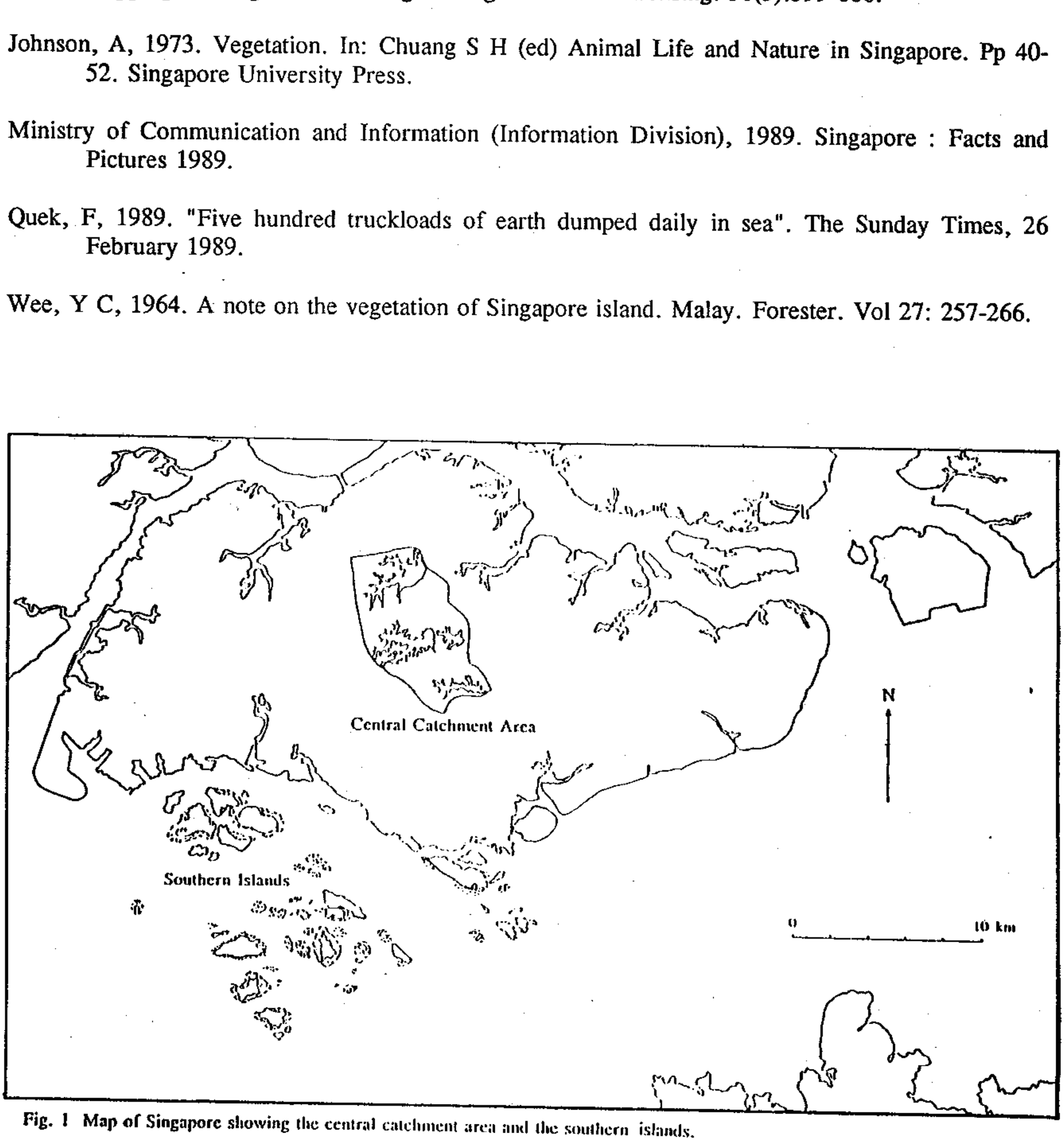

Fig. 1 Map of Singapore showing the central catchment area and the southern islands.

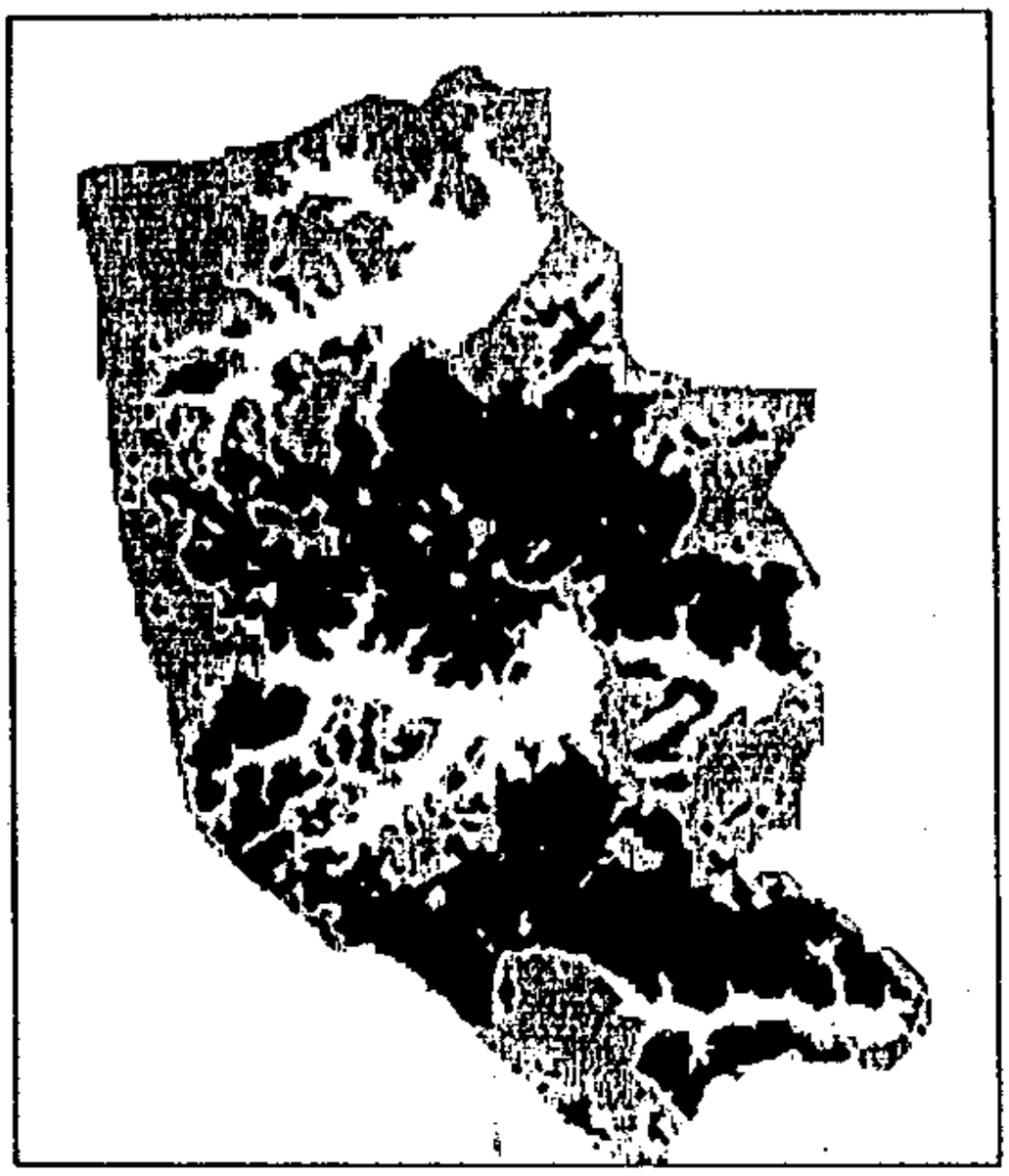

Fig. 2a Classified image of catchment area showing secondary forest (dark areas)

Fig. 2b Classified image of catchment area showing landscaped trees and bushes (dark areas)

Fig. 2c Classified image of catchment area showing turfs and lawns (dark areas)

Fig. 2d Classified image of catchment area showing grassland with scattered scrub and bushes (dark areas)

Fig. 2e Classified image of catchment area showing exposed banks of reservoirs and construction (dark areas)

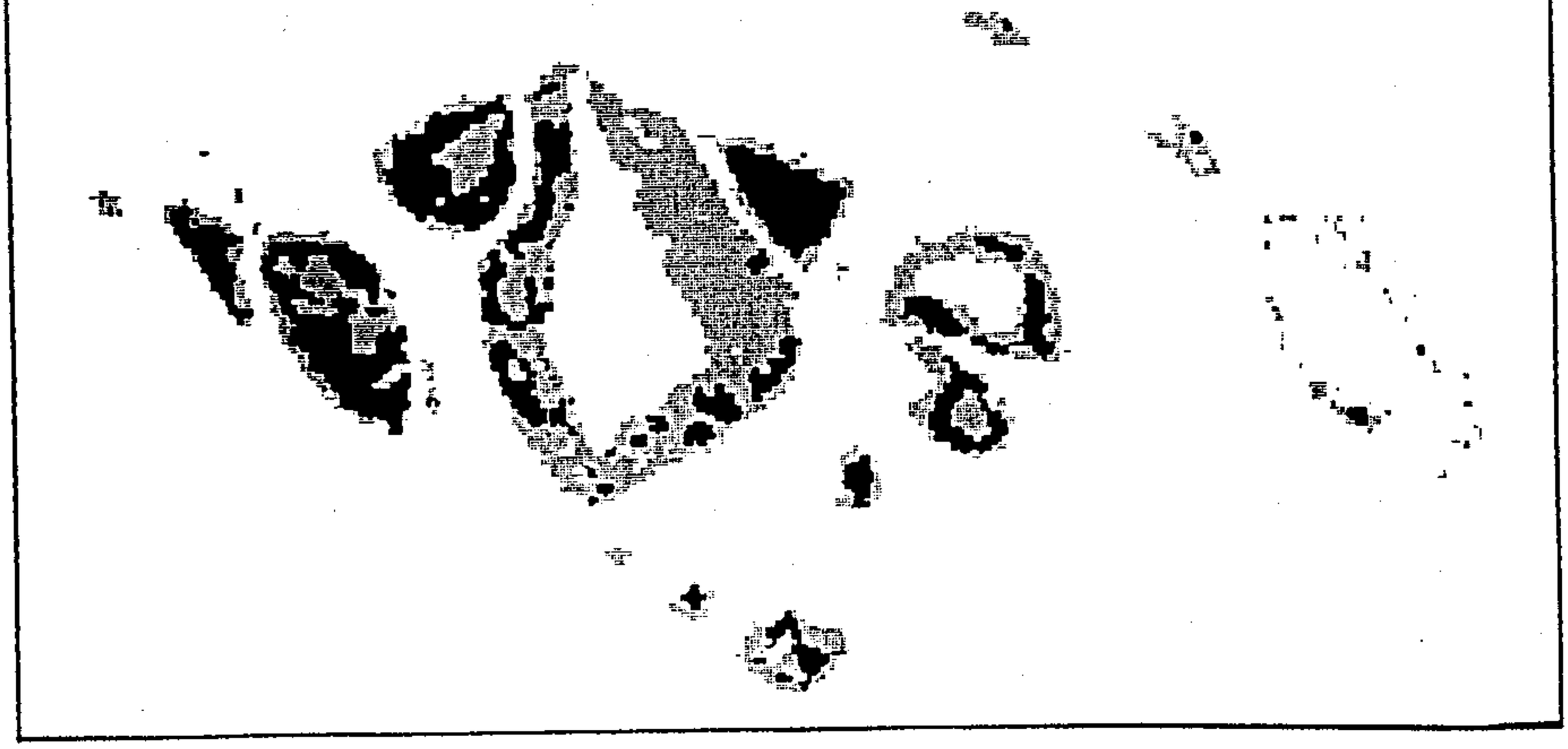

Fig. 3a Classified image of Semakau region showing reef flat cover consisting of a mixture of coral rocks, live corals and scattered seagrass stands (dark areas)

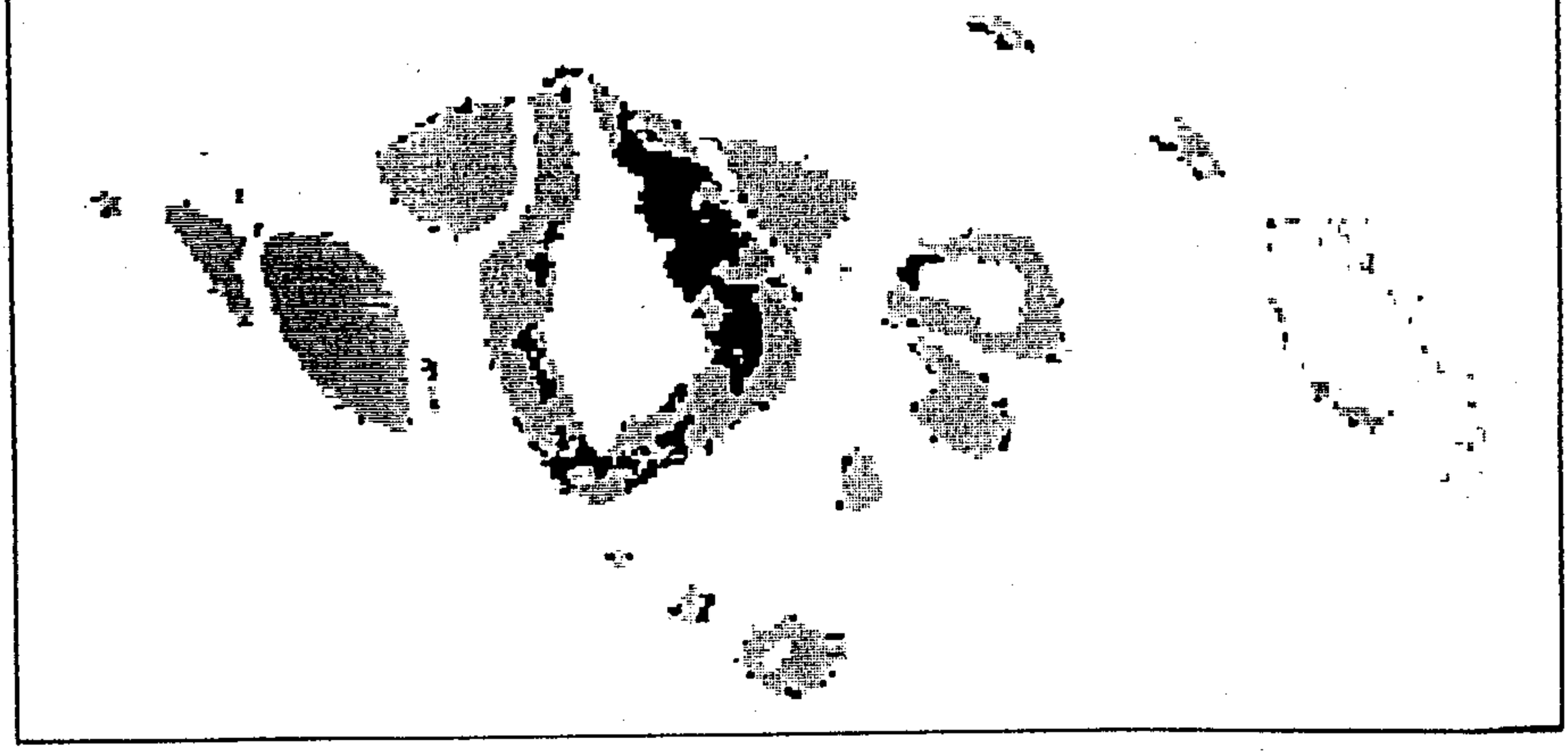

Fig. 3b Classified image of Semakau region showing reef flat cover consisting of denser patches of seagrass (dark areas)