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LANDUSE CHANGES OF A RECREATIONAL ISLAND AS OBSERVED BY SATELLITE IMAGERY

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ABSTRACT

Landuse pattern on Sentosa Island has changed significantly over the years due to rapid development of recreational facilities. In this study, landuse changes were analysed using three temporally-spaced satellite images: 1986 (SPOT), 1989 (Landsat Thematic Mapper) and 1991 (SPOT). The microBRIAN (a PC-based remote sensing software developed by CSIRO of Australia), an applications oriented image processing system, was used to analyse the three images. The resulting classified image maps were compared for temporal changes in landuse. The western and southern parts of the island were found to have changed significantly while the eastern half of the island remained relatively unaltered. Since the island was designated for recreation in 1972, much development has taken place. However, at least 38% (1.47ha) of the island remains covered by natural vegetation.

INTRODUCTION

The seabed configuration of the waters of Singapore is highly irregular, being strewn with numerous islands and shoals. Most of the coastal waters are not more than 30m deep. Channels of over 20m of water run through the groups of islands on the southern coast (Chou and Chia, 1991). Sentosa Island is one of the largest of this group of southern islands. Originally covered by secondary forest, it has undergone rapid changes since 1972 when it was first designated as a recreational island. Extensive development has been carried out to make the island attractive to both investors and visitors. During the various phases of development, natural vegetation was cleared, several beaches reclaimed, many artificial gardens created and buildings constructed all over the island. The fort and bunkers built by the British during the Second World War have also been converted into tourist attractions.

From the socio-economic view point, Sentosa Island can be considered a success, having achieved the status of a recreational resort island. However, to the conservationist, Sentosa Island may be perceived as being over exploitated, resulting in considerable destruction of its natural habitats. It cannot be denied that the island's attractions contribute positively to national income, but much has been at the expense of its natural resources. In order to make assessments of proper landuse, records of successive development are needed. One approach is the application of remote sensing technology. In an earlier study, the use of microBRIAN and satellite imagery for landuse mapping on Sentosa Island was assessed (Loo, et al., 1991a). This paper reports the continuation of the assessment using microBRIAN to analyse three images taken in three different years.

MATERIALS AND METHODS

Image Data

The images used in this study were taken by SPOT MSS on 18 June 1986 and 4 March 1991, and Landsat Thematic Mapper (Landsat TM) on 24 May 1989. The SPOT imagery had three channels of data, while the Landsat TM imagery had seven channels, of which only four (channels 1, 2, 3 and 5) were used for the study.

Image Processing

A PC-based remote sensing software developed by CSIRO of Australia; "microBRIAN", (acronym referring to Barrier Reef Image ANalysis), was used to classify the images. The initial processing involved separating the land from the sea for the three images. The images were then manually digitised to isolate Sentosa island from the other land masses. Linear stretching was done on the images to obtain the best contrast.

Sampling of the various components of Sentosa Island 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. 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.

The three images of Sentosa island were processed separately to give better resolution. All pixels of the 1986 image were classified after the fourth classification run. An initial 69 classes were generated for the 1986 image. The 1989 image was classified after the third run resulting in 74 initial classes. The 1991 image gave an initial 47 classes after the third classification run. For each of the images, the initial classes were clustered to give eight to ten representative classes.

RESULTS

The classified image map of Sentosa Island in 1986 showed that most of the island was covered by vegetation. This vegetation type being natural secondary forest, occupied 42.9% (1.55ha) of the island's classified area (3.61ha) (Fig. 1). However, development had been ongoing to convert the island into a recreational island. Along the north coast, the vegetation was cleared for the construction of the new ferry terminal (coloured orange in Fig. 1). The extensive artificial landscaped area, were the golf courses. The two swimming lagoons in the south were fully enclosed and separated from the open sea.

Two significant differences were observed in the image map of 1989 (Fig. 2) when compared with that of 1986. A programme of lagoon and beach improvements undertaken by Sentosa Development Corporation (Wong, 1991) resulted in the addition of reclaimed beaches to create new bays along the coast and the contruction of revetments to protect the reclaimed beaches. This work was especially obvious at the western tip of the island, at Siloso Beach. The other notable landuse change observed in the 1989 image was the construction work in the central part of the island. The most prominent is the hotel project situated just behind the swimming lagoons, which began in 1988 (coloured purple in Fig. 2). Other land clearing and construction works were concentrated in areas south of the new ferry terminal. The construction of the Underwater World was also noted near Fort Siloso. The total land area estimated from satellite imagery for Sentosa in 1989 was 3.73ha, of which 38.7% (1.45ha) was covered by secondary forest.

The 1991 image map showed the changes that took place at the swimming lagoons (Fig. 3). The stone revetments of the swimming lagoons located in the south of Sentosa island were being removed. As seen from the image map, this was ongoing during the satellite pass. The area near Siloso Beach, at the western tip of Sentosa, also underwent changes. Much of the secondary forest found in 1986 was cleared for the construction of a five-star hotel. The construction of the other hotel near the swimming lagoons as noted in the 1989 image map was still not completed by March 1991. Other scattered land clearing and construction works were concentrated in the western half of the island. The satellite imagery used in 1991 showed that Sentosa island had increased in area to 3.85ha due to beach reclamation. However, the secondary forest cover had not changed significantly, with 1.47ha left in 1991.

DISCUSSION

The potential of the microBRIAN system in classifying vegetation in Singapore had already been demonstrated in an earlier study involving the central catchment area (Loo, *et al.*, 1991b). As compared to traditional methods of mapping of large areas, more accurate results than what remote sensing technology can achieve, may not be possible without extensive time-consuming and costly field sampling methods. The use of the same computer programme for analysis also eliminates bias in sampling and surveyor errors. This study shows that the changes in landuse patterns on Sentosa Island from 1986 to 1991 is identifiable from satellite imagery.

It must be noted that there are limitations in the use of remote sensing technology. One example is the differing atmospheric conditions during a satellite pass. Air pollutants, for example, may interfere with the true spectral reflectance of land features. This results in differing spectral reflectance obtained from various satellite imagery, even though the features may be the same. However, there are computer software now available which allows for atmospheric correction. Thus temporally different image data may be calibrated before they are analysed. In this study, calibration of the three images used was not done as Sentosa is a small island and ground truthing can be easily conducted to verify the classification.

Due also to differences in wavelenths of the sensors on board the satellite and spatial resolution between SPOT and Landsat TM imagery, the areas estimated from the 1989 and 1991 image map of Sentosa island seem to suggest that the secondary forest has increased from 1.45 to 1.47ha. Hence this methodology may not give good enough details if they are of prime concern since accurate and refined mapping may not be attainable for small areas. Although not extensive, this study illustrates the feasibility of applying remote sensing technology to the monitoring of landuse changes over time.

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