MAPPING COASTAL HABITATS OF SINGAPORE USING HIGH RESOLUTION SATELLITE IMAGERY

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ABSTRACT: Remote sensing technologies provide a useful tool for coastal resources inventory. In this study, the high resolution satellite imagery (WorldView-2 and GeoEye-1) acquired in 2010 and 2011 were used to map coastal habitats for the main island, all the offshore islands and patch reefs of Singapore where rich biodiversity with seagrasses, mangroves and coral reefs are distributed in the intertidal zone. Images acquired at low tide were first corrected for Rayleigh scattering and gaseous absorption in the atmosphere. Hierarchical unsupervised classification and contextual editing were used to produce the final coastal habitat map. Field surveys were also conducted in some studied area. For the intertidal zone, the classification scheme included sandy beach, mangroves, seagrass, sandflat or mudflat with seagrass/algae, rocky shore with algae, sand/rubble, coral rubble with seagrass/algae/coral, reef slope, lagoon, sand flat, mud flat and shallow water. Both substrate types and the habitats cover were mapped. For the terrestrial areas in the islands, the classification scheme included built-up land, open land and other vegetation (secondary forest, scrub and grassland, etc). The map shows the distribution and zonation of the coastal habitats in Singapore and it will be used for coastal resources assessment and management as well as for future comparative study.

1. INTRODUCTION

Remote sensing imagery provides an effective way to observe, monitor and map coastal environments (Andréfouët, S., Kramer, P., et al, 2003; Mumby, P. J., Edwards, A. J., 2002). WorldView-2 is the first commercial satellite to provide the eight spectral bands in the visible to near-infrared range and the 2m spatial resolution imagery. This high resolution imagery presents new opportunities for detailed habitat mapping (DigitalGlobe, 2009).

Mangrove forests, seagrass meadows and coral reefs are three of the most important coastal habitats of the world. Mangroves not only provide valuable ecosystems services such as coastal erosion protection, water filtration and the areas for fish and shrimp breeding, they also harvested as building materials and are used as medicine. Seagrass beds provide feeding and nursery grounds for many organisms, such as dugongs and juvenile fish. They also anchor sediments, protect shorelines from erosion, remove nutrients and help control coastal water quality. However, these habitats are also the most vulnerable ecosystems worldwide and experienced a dramatic decline. They can be affected or degraded by oil pollution and water sedimentation due to shipping activities and coastal reclamation.

To protect and preserve the coastal habitats, it is necessary to monitor the status of habitats regularly. In order to achieve that, a map with detailed classification of the habitats plays an important role in the understanding, monitoring and aid in the decision making process for an effective management of the coastal habitats.

The objective of this study is to generate a large scale habitats map of Singapore using high resolution satellite imagery.

2. STUDY AREA

At present, there are more than 60 offshore islands and patch reefs in Singapore. Two of the largest offshore islands, Pulau Tekong and Pulau Ubin, are located to the northeast of the main island. Most of the offshore islands and patch reefs are still situated southwest of main island of Singapore, despite being reclaimed or merged over the years for coastal development.

There are a variety of coastal habitats in Singapore, which include mangroves, seagrasses, algae and coral reefs, etc. The rocky, sandy and muddy seashore types are also distributed along the coastline of Singapore islands.

3. DATA AND METHODS

In this project, Worldview-2 satellite imagery acquired in 2010 and 2011 were used for the coastal habitats mapping which include the area of the main island, all the offshore islands and patch reefs of Singapore. GeoEye-1 satellite imagery acquired in 2010, with four spectral bands and 2m spatial resolution, were also used in the habitat mapping when the cloud free WorldView-2 imagery could not be obtained for some study area.

The images were first converted to the top of atmosphere (TOA) spectral radiance using the band calibration coefficients provided by the image metadata files and then corrected for Rayleigh scattering and gaseous absorption in the atmosphere. As all the data that we used were received at low tide and the water depth in studied area varied between 0-1m, water column correction were not processed.

After the atmospheric correction, a hierarchical unsupervised classification was utilised on the image to derive dominant statistically different spectral clusters based on their spectral reflectance values. These clusters were then aggregated and assigned to the thematic categories based on our visual interpretation and the spectral signature. Each image was classified through the hierarchical unsupervised classification, filtering and contextual editing. Then the classified images were mosaicked to produce the final coastal habitats map.

Our classification scheme was divided into two parts according to the geographic location. For the terrestrial areas in the islands, our scheme included the following land use/land cover categories: builtup land, rock bund, water, open land and other vegetation (secondary forest, scrubland, grassland, etc); For the intertidal zone, the scheme included sandy beach, mangroves, shallow water, sand flat, mud flat, rocky shore with algae, sand flat or mud flat with seagrass/algae, seagrass meadows, rubble/sand, coral rubble with seagrass/algae/coral and reef slope zone. The classification scheme was designed to categorise habitats by both substrate type and the habitats cover. The final map consisted of 18 thematic categories.

SPOT5 imagery acquired in 2010 was also used as reference for differentiating mangroves from other vegetations as its shortwave infrared (SWIR) band is good for mangroves detection.

Field surveys were conducted in some studied area, Pulau Semakau, Cyrene reefs and Pulau Ubin, in 2010 and 2011. For the inter-tidal zone, ground observation and GPS-guided field reference photographs and video images were recorded during low tide conditions in our fieldwork.

The pan-sharpened 0.5m multispectral imagery and the data from field surveys were used for evaluating the classification results.

4. RESULTS AND DISCUSSION

The spatial distribution and zonation of each habitat in Singapore can be observed from the satellite image derived coastal habitats map. For example, mangroves and mudflats are the main habitats along mainland Singapore's northern coastline. The large mudflats are located at off Sungei Buloh Wetland Reserve, Sungei Mandai and Pasir Ris Park. While sandy beaches are mainly distributed along the mainland southern coastline and the coral reefs are mainly among the southern offshore islands.

Examples of the habitats map and the map legend are shown in Figure 1.
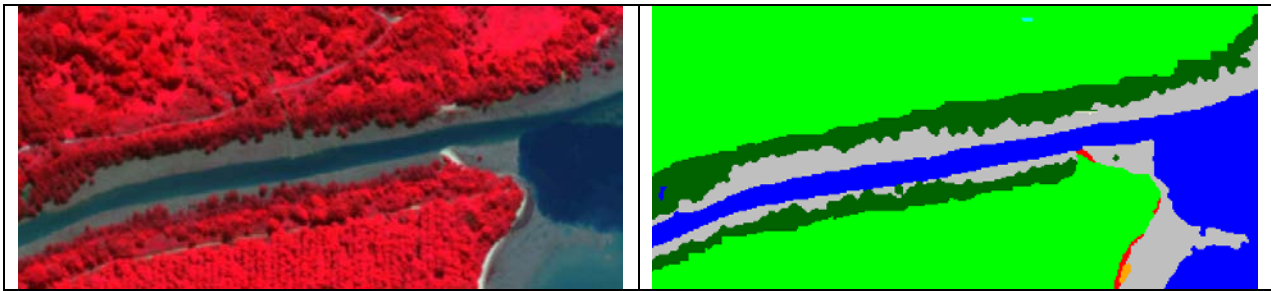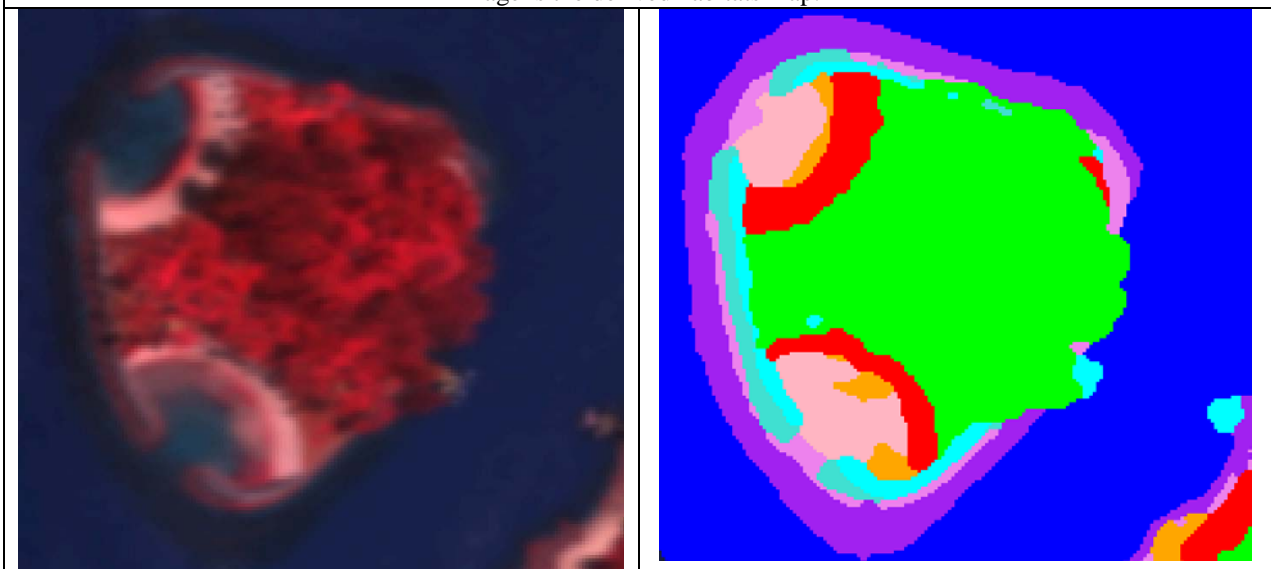
Figure 1a. The image shown on the left is the WorldView-2 satellite image displayed in Band (7, 5, 3) and the image on the right is the derived habitats map.
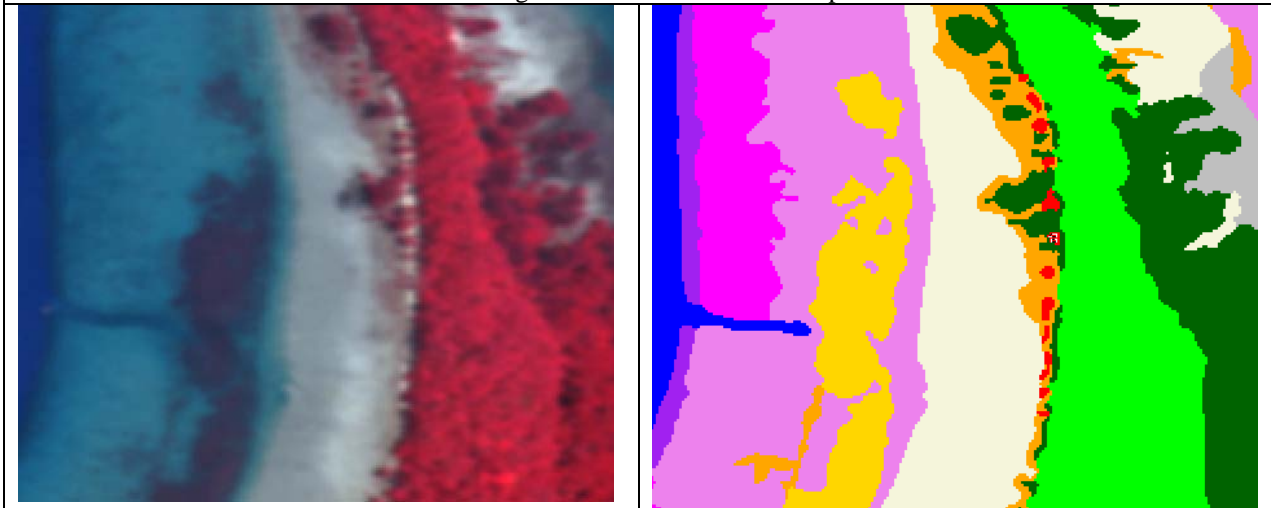
Figure 1b. The image shown on the left is the GeoEye-1 satellite image displayed in Band (NIR, R, G); The right image is the derived habitats map.

Figure 1c. The image shown on the left is the WorldView-2 satellite image displayed in Band (7, 5, 3) and the image on the right is the derived habitats map.

Builtup	Coral rubble with seagrass/algae/coral	Openland
Rock bund	Mangrove	Reef slope
Sandflat	Seagrass medow	Water
Mudflat	Sandflat or mudflat with seagrass/algae	Rocky shore with algae
Lagoon	Other vegetation	Small patch reef
Sandy beach	Sand/rubble	Shallow water

Figure 1. Examples of Singapore Habitats Map and the Map Legend.

For the habitats map in Figure 1a, the dark green color shows the narrow fringe mangroves, the mudflat shown in grey colour and the red colour shows the narrow sandy beaches.

The dense seagrass meadows colored light orange in Figure 1b is mainly the tape seagrass (*Enhalus acoroides*). Another class in the map shown dark orange color is sandflat or mudflat with seagrass/algae. In some sites, seagrass was seen growing interspersed with algae, thus making it difficult to be differentiated from the satellite image. This is especially so for areas where seagrasses, such as *E. acoroides* and smooth ribbon seagrass (*Cymodocea rotundata*) and green algae, such as sea lettuce seaweed (Ulva sp.) and sea grapes (Caulerpa sp.) are found together within an area. However, the multi-temporal images may improve the differentiation between the two classes (Wolter et al., 2005). But this needs our further study to verify when multi-date images are available.

To protect our coastal environment and minimise impacts from coastal developments, some local habitats were created artificially. This includes reclaimed beaches, man-made lagoons, rock bunds and concretised canals. For example the man-made lagoons and the sandy beach shown on Figure 1c and the sandy shores along the East Coast Park have been created through reclamation.

5. SUMMARY AND CONCLUSIONS

The satellites, WorldView-2 and GeoEye-1, cover larger areas with 2m high spatial resolution, which are especially suitable for local mapping applications. The more detailed spatial information make it possible to identify and delineate the extent and distribution of narrowly fringed mangroves, small patches of seagrass/algae and the seashore types in Singapore.

The habitats map produced can help to monitor the current coastal habitats of Singapore and the information provided can be used for the assessment and management of coastal resources as well as the conservation of biodiversity. This is Singapore's first national large scale high resolution coastal habitat map derived from satellite imagery, which will be used as database for the future comparative study.

6. ACKNOWLEDGEMENT

7. REFERENCES

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