MAPPING COASTAL ECOSYSTEMS OF AN OFFSHORE LANDFILL ISLAND USING WORLDVIEW-2 HIGH RESOLUTION SATELLITE IMAGERY

Ping Chen [a,*], Soo Chin Liew [a], Rachel Lim [b], Leong Keong Kwoh [a]

[a] Centre for Remote Imaging, Sensing and Processing, National University of Singapore, 10 Lower Kent Ridge Road, Singapore 119076 - (crschenp, crslsc, crsklk)@nus.edu.sg
[b] National Biodiversity Centre, National Parks Board, 1 Cluny Road, Singapore 259569 - lim_li-feng@nparks.gov.sg

Abstract – The Worldview-2 satellite imagery with 2-m spatial resolution and 8 spectral bands is used to map the coastal ecosystems for our study site, an offshore island of Singapore. The eastern side of the study area is used as a landfill, while the western part of the island is left natural with rich biodiversity where large stretches of seagrass meadow, mangroves and coral reefs are distributed in the intertidal zone. An image acquired during low tide was first corrected for Rayleigh scattering and gaseous absorption in the atmosphere. Unsupervised classification and contextual editing were used to create the final coastal ecosystem map which contains information on both substrate types and the habitats cover. Field surveys were also conducted. The produced map will be used for coastal assessment and management and as well as for comparative study.

Keywords: Remote Sensing, coastal, ecosystem, mapping, habitat, WorldView-2

INTRODUCTION

Remote sensing techniques provide a useful tool for effective monitoring and sustainable management of our natural environment. Mangroves, seagrasses and coral reefs are the three major tropical coastal ecosystems of the world. They are highly productive and provide many important biological functions and economic services (Nagelkerken, 2009). Since the tropical coastal ecosystems are of high spatial complexity and temporal variability, remote sensing imagery has been found to be very useful in providing timely and up-to-date information on these areas. But the submerged and highly heterogeneous environments in the intertidal zone also impose challenges for remote sensing coastal ecosystem mapping. To have detailed and accurate ecosystem maps will aid for better understanding of the complex ecosystem, which are of importance to coastal assessment and management.

Many researchers (e.g. Andréfouët et al. 2003, Mumby et al. 2002) have used Landsat, SPOT, IKONOS or QUICKBIRD satellite data for coastal ecosystem studies. They also examined and compared different satellite data for inventory and mapping and indicated that generally the high resolution IKONOS and QUICKBIRD data can improve the accuracy of habitat mapping compared to Landsat and SPOT data.

WorldView-2 satellite, lunched in October 2009, provides a high resolution 0.5m panchromatic and 2m 8-band multispectral imagery. The eight spectral bands include the four traditional visible to near infrared (VNIR) bands, which are Blue (450-510 nm), Green (510-580 nm), Red (630-690 nm) and NIR1 (770-895 nm) and an additional four spectral bands, which are Coastal Blue (400-450 nm), Yellow (585-625 nm), Red Edge (705-745 nm) and another NIR2 (860-1040 nm) bands. The 8 bands are designed to improve the segmentation and classification of land and aquatic features beyond any other space-based remote sensing platform (DigitalGlobe, 2009). Due to its unique in the high spatial and spectral resolution, we used the 8-band spectral imagery to derive the coastal ecosystem map in our study. As WorldView-2 is a new lunched satellite, publication of using this new data for coastal ecosystem mapping has not been found, to the authors' knowledge. But the classifications for the littoral zone applications were compared between the simulated WorldView-2 and QuickBird imagery which were created from a hyperspectral data. Their results show that the overall accuracy was 89% and 94% for the simulated 4-band QuickBird and 8-band WorldView-2 imagery (Puetz, 2009).

STUDY SITE

Our study site is located at eight kilometres south of the main island of Singapore, which covers an area of 603.4 hectares. The eastern side of the study area was assigned for landfill use. The Semakau Landfill, commissioned in 1999, was created by enclosing the eastern half of Pulau Semakau, Pulau Sakeng and a part of the sea between the two islands with a 7-km perimeter rock bund which is lined with impermeable membrane and marine clay to protect the surrounding marine ecosystem. The western part of Pulau Semakau was unaffected by the landfill construction and is left natural with rich biodiversity where the seagrasses, mangroves and corals are found in the intertidal zone. These coastal ecosystems support a large variety of flora and fauna.

MATERIAL AND METHODS

The WorldView-2 satellite image acquired on March 24, 2010, was used in our study for land use/land cover and habitat mapping. Our main purpose for the mapping is to investigate and monitor the coastal ecosystems of our studied area.

The image was first corrected for Rayleigh scattering and gaseous absorption in the atmosphere. As the data was received at low tide, the water depth in studied area varied between 0-0.8m, water column correction was not processed.

After the atmospheric correction, an unsupervised classification

---

* Corresponding author.

(the ISODATA algorithm) 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. The final coastal ecosystem map was created through the unsupervised classification, filtering and contextual editing.

Our classification scheme was divided into two parts according to the geographic location. For the terrestrial area, our scheme included the following land use/land cover categories: secondary forest, builtup land, rock bund, water, open land, grassland and trees on filled-up Landfill Cell; For the intertidal zone, the scheme included sandy beach, natural and replanted mangrove forest, water, sand flat, mud flat, rock/sand with algae, seagrass, rubble/sand, coral rubble with algae/seagrass/coral and reef slope zone. The classification scheme was designed to categorise habitats by both substrate type and the habitat cover. For this paper, we further grouped those land use/land cover classes on the Landfill use area into one single category and renamed as Landfill Use. The final map consisted of 16 themes.

Field surveys were carried out on the inter-tidal zone during low tide conditions in June 2010. Ground observation and GPS-guided field reference photographs and video images were recorded during our fieldwork.

The 0.5m Pan-sharpened WorldView-2 multispectial imagery and the data recorded during the field surveys were also used to analyse the classification results in our study.

RESULTS AND DISCUSSION

The created coastal ecosystem map and the map legend were shown in Figure 1. This ecosystem map shows the spatial distribution and zonation of each thematic category in the study site. We also calculated the area of each thematic class from the created map.

In the western intertidal zone of Pulau Semakau, the extensive dense seagrass meadows shown in orange colour on the map cover an area of about 12.8 ha. This category comprises mostly of *Enhalus acoroides* (tape seagrass) and intermittently of some other species such as *Thalassia hemprichii* (sickle seagrass) and *Cymodocea serrulata* (serrated ribbon seagrass), which stretches about 1.7 kilometres in length and is distributed between mangrove habitat and coral reefs. There is another species of seagrass, *Holiphila ovalis* (spoon seagrass) which was found in the sandy areas. During the field surveys we found that the size of this species of seagrass is small and it was patchy in distribution as compared to the other seagrass species. Therefore, it could not be recognised from the satellite image due to its very low density of the coverage. Seagrass meadows are a valuable resource. They are sediment stabilizers as their rhizomes and roots bind sediments together, thus reducing soil erosion. The natural mangroves and replanted mangroves on the map displayed in dark green and green colours cover the area of about 26.2 ha and 13.1 ha, which also shelter a wide variety of plants and animals. The other two classes coloured in magenta and dark purple on the map cover the area of about 36.4 ha and 5.4 ha which consisted of many coral colonies. For some classes, multi-temporal classification method may further improve the classification results (Wolter et al., 2005). This needs our further research to verify when multi-date data is obtained. The right side area shown in wheat colour in Figure 1

is the part of Landfill Use area.

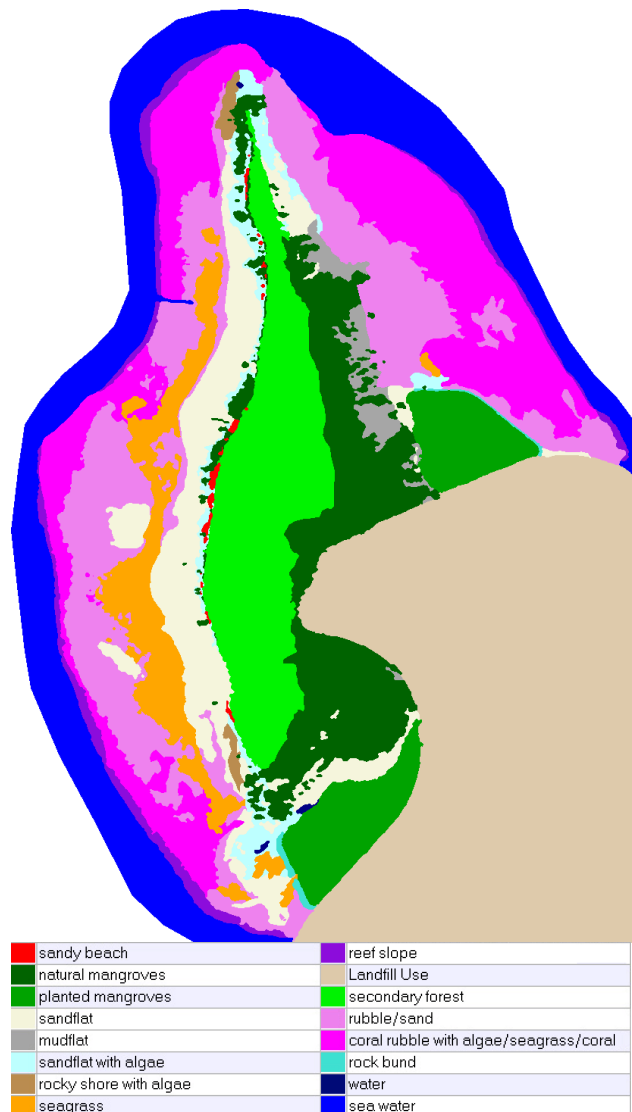| sandy beach | reef slope |
natural mangroves	Landfill Use
planted mangroves	secondary forest
sandflat	rubble/sand
mudflat	coral rubble with algae/seagrass/coral
sandflat with algae	rock bund
rocky shore with algae	water
seagrass	sea water

Figure 1: Coastal ecosystem map of Pulau Semakau.

Our results demonstrated that high resolution WorldView-2 satellite imagery for coastal ecosystem mapping provides an effective way for rapid identification of substrate types and the habitat cover in shallow water of coastal intertidal zone. The distribution and extent of each thematic category as well as the patterns of diversity can also be clearly recognised from the map. Therefore, high resolution imagery makes it possible to produce more accurate and detailed coastal ecosystem map.

SUMMARY AND CONCLUSIONS

This paper presented an approach for tropical coastal ecosystem mapping using WorldView-2 satellite imagery. The produced coastal ecosystem map provides the most up to date high spatial resolution information for Pulau Semakau which can be used for inventory and monitoring activities. This is also the first time in Singapore where a high-resolution map derived from satellite imagery is close to the field survey. The map will be invaluable for coastal ecosystems assessment and management and as well as for future comparative study.

REFERENCES

References from Journals

Andréfouët, S., Kramer, P., et al, 2003, "Multi-site evaluation of IKONOS data for classification of tropical coral reef environments". Remote Sensing of Environment, 88, pp. 128–143.

Mumby, P. J., Edwards, A. J., 2002, "Mapping marine environments with IKONOS imagery: Enhanced spatial resolution can deliver greater thematic accuracy". Remote Sensing of Environment, 82, pp. 248–257.

Puetz, A. M., Lee, K., Olsen R. C., 2009, "WorldView-2 data simulation and analysis results". Proc. of SPIE Vol. 7334, 73340U; doi:10.1117/12.818187.

Wolter, P. T., Johnston, C. A., Niemi, G. J., 2005, "Mapping submergent aquatic vegetation in the US Great Lakes using Quickbird satellite data". International Journal of Remote Sensing, 26 (23), pp. 5255-5274.

References from Book

Nagelkerken, I., 2009, "Ecological Connectivity among Tropical Coastal Ecosystems". Springer.

References from Websites

DigitalGlobe, 2009, "8-Band Multispectral Imagery". http://www.digitalglobe.com/index.php/48/Products?product_id =27