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Mapping the distribution of mangrove species in the Core Zone of Mai Po Marshes Nature Reserve, Hong Kong, using hyperspectral data and high-resolution data

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ABSTRACT

Mangrove species compositions and distributions are essential for conservation and restoration efforts. In this study, hyperspectral data of EO-1 HYPERION sensor and high spatial resolution data of SPOT-5 sensor were used in Mai Po mangrove species mapping. Objected-oriented method was used in mangrove species classification processing. Firstly, mangrove objects were obtained via segmenting high spatial resolution data of SPOT-5. Then the objects were classified into different mangrove species based on the spectral differences of HYPERION image. The classification result showed that in the top canopy, *Kandelia obovata* and *Avicennia marina* dominated Mai Po Marshes Natural Reserve, with area of 196.8 ha and 110.8 ha, respectively, *Acanthus ilicifolius* and *Aegiceras corniculatum* were mixed together and living at the edge of channels with an area of 11.7 ha. Additionally, mangrove species shows clearly zonations and associations in the Mai Po Core Zone. The overall accuracy of our mangrove map was 88% and the Kappa confidence was 0.83, which indicated great potential of using hyperspectral and high-resolution data for distinguishing and mapping mangrove species.

1. Introduction

Mangrove forests are ecologically and socioeconomically significant, because of their important ecological role in shoreline stabilization, reduction of coastal erosion, sediment and nutrient retention, storm protection, flood and flow control, and water quality control (Bahuguna et al., 2008). However, during the past century, these forests declined at an alarming rate, perhaps even more rapidly than inland tropical forests (Wilkie and Fortune, 2003). Therefore, there is an emerging demand for conservation and restoration efforts. To be effective and timely, these conservation efforts must be able to access up-to-date and historical information not only on the mangrove forests extent, but also on forest species composition and distributions (Wang and Sousa, 2009; Kuenzer et al., 2011).

Traditionally, species discrimination for floristic mapping needs intensive field work, which is costly, time consuming, and sometimes inapplicable due to the poor accessibility of mangrove areas (Kent and Coker, 1992). Remote sensing has emerged as an optimal tool for mapping and monitoring of mangroves (Blasco et al., 2001), primarily because the technology allows information to be gathered from the environment which is practically difficult to explore (Kumar et al., 2013; Vaiphasa et al., 2006). In the previous studies, multispectral sensor on satellite platforms, like synthetic aperture radar (SAR), Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper (TM), Indian Remote Sensing satellites (IRS), and SPOT XS are mostly used for mangrove mapping because of their cost-effective advantages (Vaiphasa et al., 2005; Wang and Sousa, 2009; Kumar et al., 2013). But the coarse spatial and poor spectral resolution of these sensors compromises their usefulness for discriminating mangrove at the species level (Wang et al., 2004a,b).

In contrast, hyperspectral data contain information that relates to important biochemical properties of plants has a significant role to play in this direction (McDonald, 2003; Wang and Sousa, 2009). Among several hyperspectral sensors, the only satellite-based hyperspectral sensor, HYPERION on the EO-1 plat form has been used in mangrove species distinction. Based on the HYPERION images, Demuro and Chisholm (2003) have discriminated two

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classes of mangrove communities in Australia, and Kumar et al. (2013) distinguished five mangrove floristic composition classes of Bhitarkanika National Park, Odisha, India, which are considered to be difficult for any multispectral sensor (Green et al., 2000). However, mangrove species to be classified by HYPERION images usually correspond to be at regional scale, because of the coarse spatial resolution of 30 m.

The availability of high-resolution satellite imagery has opened up new opportunities for mapping mangrove communities at local scale (Yang et al., 2009). Wang et al. (2004a,b) used IKONOS and QuickBird satellite imagery in conjunction with different image processing techniques to distinguish three mangrove species on the Caribbean coast of Panama. Everitt et al. (2008) indicated that QuickBird imagery can be used successfully in distinguishing and mapping black mangrove along the south Texas Gulf Coast. Although these high spatial resolution images had promising results in separating mangrove species, the poor spectral resolution have limited the number of species that could be distinguished. Recently, the airborne AISA+ image with both high spatial and spectral resolution have been used in mangrove communities mapping (Jensen et al., 2007; Yang et al., 2009). But these data have limitations with regard to data availability. Because they are airborne generated and requires the coordination of a flight campaign, and trained personnel (Kuenzer et al., 2011). In this case, HYPERION image used along with high spatial resolution data may provide the opportunity to improve the accuracy of mangrove mapping at species level.

The objectives of this study are: (1) to determine the potential of using hyperspectral and high-resolution data for distinguishing and mapping mangrove species in the Core Zone of Mai Po Marshes Nature Reserve (MPMNR), Hong Kong; (2) to analysis the distribution and composition of Mai Po mangrove species.

2. Materials and methods

2.1. Study area

The Mai Po Marshes Nature Reserve (22°28′–22°32′ N and 113°59′–114°04′ E, Fig. 1) is situated in the northwestern New Territories of Hong Kong, bordering the mudflats and mangrove forests of Inner Deep Bay (Dept. Geog. & Resource Mang., 2008). The area is influenced by the Pearl River generally and, specifically, by the Sham Chun River and Deep Bay. Climate here is largely governed by the continent of mainland China. Summers are hot and humid with winds from the south and southeast. In the winter, continental air streams from the north and northeast bring cool and dry weather.

The Mai Po Marshes Nature Reserve (MPMNR) has been managing by the World Wide Fund for Nature Hong Kong (WWFHK) since 1983, and added to Wetland of International Importance under the Ramsar Convention in September 1995. The mangrove stands in Inner Deep Bay represent one of the most prominent features of the MPMNR. It is the largest remaining mangrove area in Hong Kong and one of the few extensive mangrove areas in Southern China, bearing high environmental and ecological values (Tam and Wong, 2000; UNEP-WCMC, 2006). The reserve was divided into five different management zones by Agriculture, Fisheries and Conservation Department (AFCD) Hong Kong based on the habitat types, ecological values and existing land uses, i.e. the Core Zone, the Biodiversity Management Zone, the Wise Use Zone, the Public Access Zone, and the Private Land Zone. This study only focuses on the Core Zone (Fig. 1), which is mainly dominated by large amount of mangrove forests. In this area, a total of six species of mangroves has been recorded, namely: *Acanthus ilicifolius*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Excoecari aagallocha* and *Kandelia obovata* (AFCD, 2011).

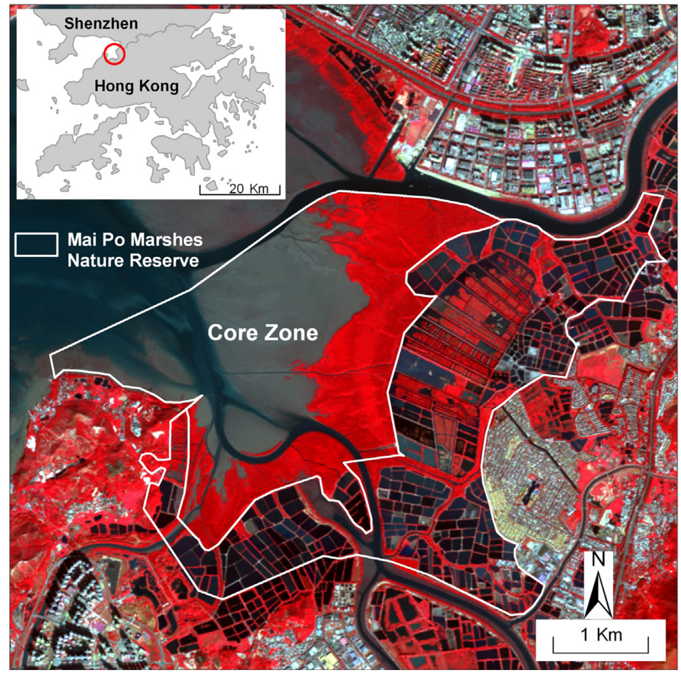

Fig. 1. Location of the study area and field samples.

2.2. Image preprocessing

Hyperspectral image data acquired by the on-board HYPERION sensor of the National Aeronautics and Space Administration (NASA) Earth Observing-1 (EO-1) satellite were used. This image was acquired on 21th, November, 2008 (10:51 local time) covered the whole area of Mai Po reserve. The spectral bands of the image ranged from 357 to 2576 nm with a spectral interval of 10 nm (242 bands in total) and a spatial resolution of 30 m. A number of the bands were intentionally not illuminated and others (mainly in the overlap region between the two spectrometers) correspond to areas of low sensitivity of the spectrometer materials (Datt et al., 2003). Therefore, in this study, only 147 out of the total 242 bands were used, a complete description of bands selection can be found in Pengra et al. (2007). Then the minimum noise fraction (MNF) was used to minimize the influence of systematic sensor noise during image analysis, the FLAASH model was used in atmospheric correction. The theories and processes of MNF and FLAASH are listed in Tan et al. (2005).

Two SPOT-5 images (pixel sizes 10 m and 2.5 m, respectively, geometrically and radiometrically preprocessed at Level 2B in WGS 84), taken on 21th, November, 2008 (10:52 local time), were used in this study. The first image (10 m) contains four bands (0.50–0.59 μm, 0.61–0.68 μm, 0.79–0.89 μm, and 1.58–1.75 μm). The second image (2.5 m, PAN, 0.51–0.73 μm) was obtained by combining two panchromatic images of 5 m resolution acquired simultaneously. Then the SPOT-5 Super mode multi-spectral image (2.5 m) was resulted from the fusion of these two images used Gram Schmidt (GS) fusion (Laben et al., 2000).

All pre-processing and analysis of the EO-1 HYPERION imagery and SPOT-5 images was done using the image processing system ENVI (Environment for Visualizing Images, Research Systems, Inc.).

2.3. Field surveys and endmember collection

The field works were conducted in the Core Zone of MPMNR in July 2013. Intertidal mangrove forests were surveyed along a floating walkway which was constructed by WWFHK for observing birds (Duke and Khan, 1999). The size of each sample plot was 5 m × 5 m