SPECTRAL UNMIXING ANALYSIS OF URBAN LAND COVER FRACTIONS FROM LANDSAT DATA

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ABSTRACT: Geographic information of urban land-cover types is important for urban planning. This study explored the use of Landsat ETM imagery for mapping urban land-cover types in Ho Chi Minh City (HCMC) in 2010. Spectral unmixing model estimates abundance fractions of surface targets at sub-pixel level was used for urban-land cover mapping. This model was trained using endmembers extracted from the original image using minimum noise fraction (MNF) method. The mapping results was assessed using ground-verification data. The comparison results between classification map and ground-truth data revealed the overall accuracy of 89.6% and Kappa coefficient of 0.86. The results achieved from this study could be useful to assist local authorities in urban planning.

1. INTRODUCTION

In recent decades, Ho Chi Minh City (HCMC) known as Saigon capital of the South Vietnam until 1976 has rapidly urbanized following the reformed economic policy in 1986, allowing the city to change from a centralized economy to an oriented-market economy. From 1986 to 2010, the population of this city has almost doubled from approximately 3.8 million 7.4 million. Despite making up only 8.5% of Vietnamese population (GSO, 2010), HCMC contributes more than 20% of the country's gross domestic product (GDP). The fast-growing urbanization in both of urban growth and concentration of people in urban areas while lacking a proper urban planning strategy has been creating severe impacts on the environment and the heath of the public (Van, 2008; Storch and Downes, 2011).

Urban mapping is thus essential to provide information on land-cover patterns from a spatial perspective. This is critical to the process of urban planning. Remotely-sensed data has been widely recognised as an important data source for this purpose. Research on urban land-cover mapping using satellite data has been attracted the increasing attention world wide (Buyantuyev et al., 2007; Hu and Weng, 2009; Knight and Voth, 2011; Lu et al., 2011; Powell et al., 2007; Tooke et al., 2009; Van de Voorde et al., 2009; Weng and Lu, 2008). Among methods used for urban land-cover mapping, the spectral unmixing has been widely applied for analysis of land-cover fractions (Powell et al., 2007; Pu et al., 2008; Small, 2001, 2005; Wu and Murray, 2003).

This study was another attempt to evaluate Landsat ETM imagery and spectral unmixing analysis for urban land-cover mapping in HCMC. The mapping results were assessed using ground-verification data.

2. STUDY AREA

The study area covers the centre of HCMC with an area of approximately 40 km^2, lying between 10°10'-10°38' N and 106°2'-106° 54'E. HCMC has been rapidly urbanized due to the launch of a reformed economic policy in 1987. The rapid urbanization with either planed for informal urban planning has created environmental degradation problems and societal impacts (Van, 2008).

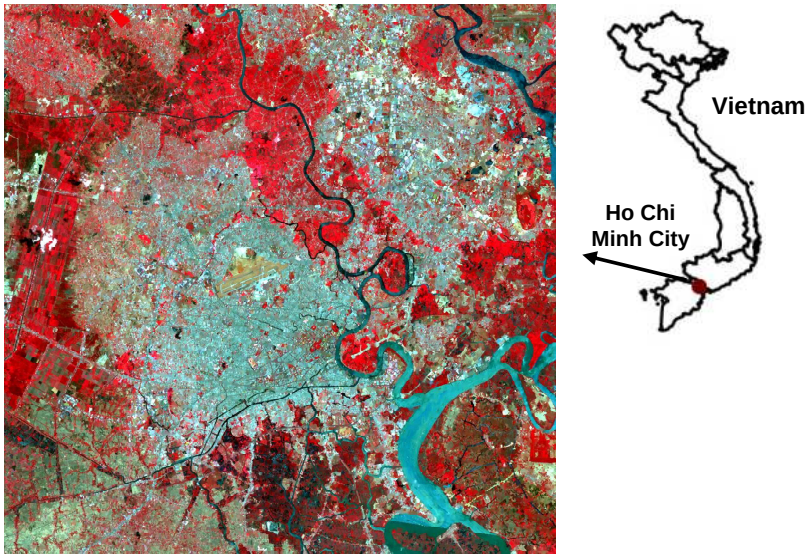

Fig. 2. Location of the study area. The Landsat ETM Plus in false colour for 2010 (RGB-432).

3. DATA

Landsat ETM Plus imagery acquired from U.S. Geological Surveys (USGS) for 2010 was used in this study. Landsat ETM data has three visible bands (blue, green and red), one near infrared (NIR) band, two shortwave infrared (SWIR) bands, and one panchromatic (PAN) band with a resolution of 15 m. The 2000 HCMC land-use map (scale: 1/25,000) collected from the Sub-National Institute of Agricultural Planning and Projection (Sub-NIAPP) was also used for field investigation, endmember selection, and preparation of the ground-truth data for classification accuracy assessment.

4. METHODS

The spectral unmixing method used endmembers to estimate percentage of each land-cover type in a pixel from Landsat ETM data. In this study, we used the minimum noise fraction (MNF) method to capture the spectral variability of spectral bands into the first few components. A scatter plot of these components can form a triangle. Pixels at the corners of this triangle can be used as pure endmembers. Based on the analysis of feature space of the first three MNF components, we found that four spectral endmembers were sufficient to cover almost variability of study area. They were high albedo surface, low albedo surface, vegetation, and soil (Fig. 2). Thus, we formed a four-endmember unmixing model for classification. Since the model has an unconstrained linear umixing problem (i.e. abundance sum-to-one and abundance nonnegativity), this problem can be solved by using the constrained least squares method (Heinz and Chein, 2001).

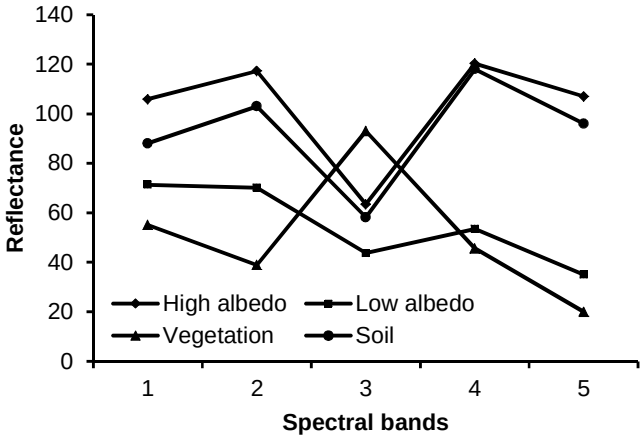

Fig. 2. Endmembers trained in spectral unmixing model for urban land-cover mapping.

In this study, deriving a fraction map that has the same spatial resolution with Landsat data (30×30 m) for classification accuracy assessment by digitizing pure urban areas from high-resolution imagery was a real challenge, we validated the classification results by making a pixel-by-pixel comparison between the classification map and ground-truth data prepared after the field investigation. The classification results (fraction maps) were first hardened into four desired classes. A comparison between the classified map and ground-truth data was performed using confusion matrix.

5. RESULTS AND DISCUSSION

The classification results obtained from a four-endmember unmixing model was presented in Fig. 3. The fraction maps had values from 0 to 1. Bright areas indicated higher fractions and dark areas indicated lower fractions. The black colour indicated a pixel where the endmember was absent. For assessment of classification results, these fraction maps were hardened into four desired land-cover classes (i.e. high albedo, low albedo, vegetation, and soil) (Fig. 4). In general, high-albedo class was spatially concentrated in the centre of the city, while low-albedo class mostly distributed in the south portion of the study area. Vegetation class was more common in the north-western part and soil class was scattered over the region.

Comparison between the classification map and ground-truth data revealed good agreement between the two datasets. The overall accuracy was 89.6% and Kappa coefficient was 0.86. The lowest per class for measure of producer accuracy was observed for soil class (83.7%) in compared to high-albedo class (94.9%), low-albedo class (92.5%), and vegetation class (86.7%), due to spectral confusion between this class and high-albedo class during classification, especially in areas undergoing construction.

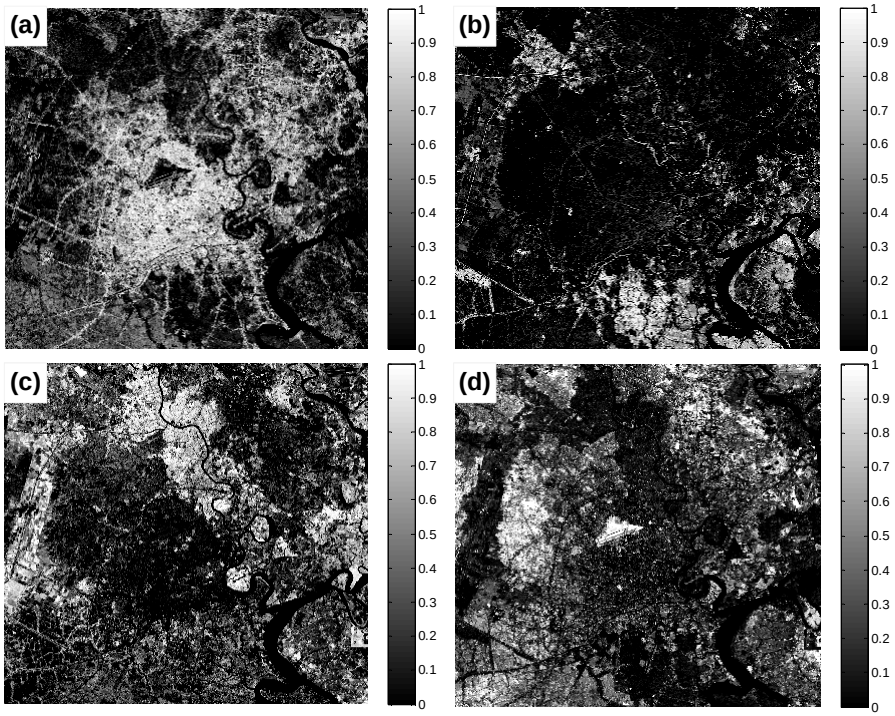

Fig. 3. Fraction images generated from the four-endmember LMM for 2010.

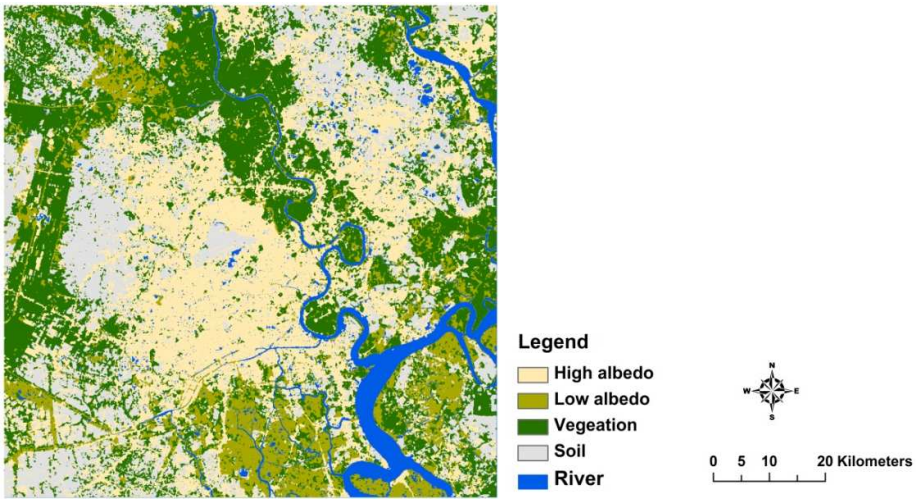

Fig. 4. The 2010 urban land-cover map obtained by hardening fraction maps.

6. CONCLUSIONS

The application of a four-endmember unmixing model to the Landsat data confirmed its validity for mapping urban land-cover types for 2010 in HCMC. The overall classification accuracy and Kappa coefficient achieved by comparison between the classification and ground-truth data were 89.6% and 0.86, respectively. The results obtained from this study appeared promising for investigation of urban growth in HCMC. The results could be critical for policymakers in face of urban planning.

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