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Object-based urban detailed land cover classification with high spatial resolution IKONOS imagery

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Improvement in remote sensing techniques in spatial/spectral resolution strengthens their applicability for urban environmental study. Unfortunately, high spatial resolution imagery also increases internal variability in land cover units and can cause a 'salt-and-pepper' effect, resulting in decreased accuracy using pixel-based classification results. Region-based classification techniques, using an image object (IO) rather than a pixel as a classification unit, appear to hold promise as a method for overcoming this problem. Using IKONOS high spatial resolution imagery, we examined whether the IO technique could significantly improve classification accuracy compared to the pixel-based method when applied to urban land cover mapping in Tampa Bay, FL, USA. We further compared the performance of an artificial neural network (ANN) and a minimum distance classifier (MDC) in urban detailed land cover classification and evaluated whether the classification accuracy was affected by the number of extracted IO features. Our analysis methods included IKONOS image data calibration, data fusion with the pansharpening (PS) process, Hue–Intensity–Saturation (HIS) transferred indices and textural feature extraction, and feature selection using a stepwise discriminant analysis (SDA). The classification results were evaluated with visually interpreted data from high-resolution (0.3 m) digital aerial photographs. Our results indicate a statistically significant difference in classification accuracy between pixel- and object-based techniques; ANN outperforms MDC as an object-based classifier; and the use of more features (27 vs. 9 features) increases the IO classification accuracy, although the increase is statistically significant for the MDC but not for the ANN.

1. Introduction

Timely and accurate information on the status and trends of urban land cover and biophysical parameters is crucial when developing strategies for sustainable development and improving urban residential environmental and living quality (Yang *et al.* 2003, Song 2005). Developing techniques that enhance our ability to monitor and map urban land cover are therefore important for city planning and management.

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Remote sensing of temperature variations around major power plants as point sources of heat

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Variations in land surface temperature (LST) around major point sources of heat were studied using the Tampa Bay region as a case study. LST in the Tampa Bay region, FL, USA, was retrieved from Landsat Thematic Mapper (TM) 6 and Enhanced Thematic Mapper Plus (ETM+) 6 high-gain thermal bands. The TM6 image data were obtained on 29 January (winter season) and 3 April 2007 (spring season). The ETM+6 data were obtained on 11 April 2007 (spring season). Spatial profiles of LST around four major fossil-fuelled power plants (FFPPs) were considered in this study. Temperatures were found to be highest at power plants and to decay to an average background temperature within 1.2–2.0 km from the FFPPs. The average background temperatures obtained in January and April were 17°C and 29°C, respectively. Results indicate that LST in close proximity to the FFPPs could be up to 10°C hotter than the surrounding areas. These findings suggest that FFPPs are significant heat sources and populations living within 1–2 km from an FFPP might be at significantly higher risk of heat-related illnesses and mortality.

1. Introduction

Land surface temperature (LST) is amongst the key parameters controlling the physical, chemical and biological processes of the Earth (Dousset and Gourmelon 2003, Duffy *et al.* 2007, Jensen 2007, Anderson and Kustas 2008). Replacement of vegetated areas with non-evaporating and impervious materials like asphalt and concrete as a result of urbanization causes changes in thermal physical properties in urban areas (Pu *et al.* 2006). These modifications generally cause thermal climate in urban areas to be warmer than surrounding non-urban areas, especially at night (Voogt and Oke 2003). This phenomenon is called urban heat island (UHI) (Oke 1982, Kim 1992). UHI occurs as a result of population increase and replacement of vegetation with non-vegetative features such as buildings, road and railway networks, automobiles (vehicles) and industrial facilities.

UHIs may increase temperatures in urban areas located in temperate regions during winter, thereby reducing energy needs for heating homes and facilitating the melting of snow on roads. However, adverse effects of UHIs include increase in (1) air pollution, (2) greenhouse gas emissions, (3) energy consumption for air conditioning and (4) heat-related illnesses and mortality. These adverse effects are more severe in summertime (EPA 2007).

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Segmented canonical discriminant analysis of *in situ* hyperspectral data for identifying 13 urban tree species

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A total of 458 *in situ* hyperspectral data were collected from 13 urban tree species in the City of Tampa, FL, USA using a spectrometer. The 13 species include 11 broadleaf and two conifer species. Three different techniques, segmented canonical discriminant analysis (CDA), segmented principal component analysis (PCA) and segmented stepwise discriminate analysis (SDA), were applied and compared for dimension reduction and feature extraction. With each of the three techniques, 10 features were extracted or selected from four spectral regions, visible (VIS: 1412–1797 nm), near-infrared (NIR: 707–1352 nm), mid-infrared 1 (MIR1: 1412–1797 nm) and mid-infrared 2 (MIR2: 1942–2400 nm), and used to discriminate the 13 urban tree species with a linear discriminate analysis (LDA) method. The cross-validation results, based on training samples that were used in the feature reduction step, and the results calculated from the test samples were used for evaluating the ability of the *in situ* hyperspectral data and performance of the segmented CDA, PCA and SDA to identify the 13 tree species. The experimental results indicate that a satisfactory discrimination of the 13 tree species was achieved using the segmented CDA technique (average accuracy (AA) = 96%, overall accuracy (OAA) = 96% and kappa = 0.958 from the cross-validation results; AA = 90%, OAA = 90% and kappa = 0.896 from the test samples) compared to the segmented PCA and SDA techniques, respectively (AA = 76% and 86%, OAA = 78% and 87%, and kappa = 0.763 and 0.857 from the cross-validation results; AA = 79% and 88%, OAA = 80% and 89%, and kappa = 0.782 and 0.879 from the test samples). In this study, the segmented CDA transformation is effective for dimension reduction and feature extraction for species discrimination with a relatively limited number of training samples. It outperformed the segmented PCA and SDA methods and produced the highest accuracies. The NIR and MIR1 regions have greater power for identifying the 13 species compared to the VIS and MIR2 spectral regions. The results indicate that CDA or segmented CDA could be applied broadly in mapping forest cover types, species identification and/or other land use/land cover classification practices with hyperspectral remote sensing data.

1. Introduction

Urban forests play an important role in improving landscape aesthetics, in providing wildlife with habitat, in reducing water and air pollution and moderating the urban

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Mapping urban forest tree species using IKONOS imagery: preliminary results

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Abstract A stepwise masking system with high-resolution IKONOS imagery was developed to identify and map urban forest tree species/groups in the City of Tampa, Florida, USA. The eight species/groups consist of sand live oak (*Quercus geminata*), laurel oak (*Quercus laurifolia*), live oak (*Quercus virginiana*), magnolia (*Magnolia grandiflora*), pine (species group), palm (species group), camphor (*Cinnamomum camphora*), and red maple (*Acer rubrum*). The system was implemented with soil-adjusted vegetation index (SAVI) threshold, textural information after running a low-pass filter, and brightness threshold of NIR band to separate tree canopies from non-vegetated areas from other vegetation types (e.g., grass/lawn) and to separate the tree canopies into sunlit and shadow areas. A maximum likelihood classifier was used to identify and map forest type and species. After IKONOS imagery was preprocessed, a total of nine spectral features were generated, including four spectral bands, three hue–intensity–saturation indices, one SAVI, and one texture image. The identified and mapped results were examined with independent ground survey data. The experimental results indicate that when classifying all the eight tree species/groups with the high-resolution IKONOS image data, the identifying accuracy was very low and could not satisfy a practical application level, and when merging the eight species/groups into four major species/groups, the average accuracy is still low (average accuracy = 73%, overall accuracy = 86%, and $\kappa = 0.76$ with sunlit test samples). Such a low accuracy of identifying and mapping the urban tree species/groups is attributable to low spatial resolution IKONOS image data relative to tree crown size, to complex and variable background spectrum impact on crown spectra, and to shadow/shaded impact. The preliminary results imply that to improve the tree species identification accuracy and achieve a practical application level in urban area, multi-temporal (multi-seasonal) or hyperspectral data image data should be considered for use in the future.

Keywords Urban forest · IKONOS · Stepwise masking system · Maximum likelihood classifier · Tree species identification

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Estimation of subpixel land surface temperature using an endmember index based technique: A case examination on ASTER and MODIS temperature products over a heterogeneous area

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ABSTRACT

Land surface temperature (LST) is a key parameter in numerous environmental studies. Surface heterogeneity induces uncertainty in estimating subpixel temperature. To take an advantage of simultaneous, multi-resolution observations at coincident nadirs by the Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER) and the MODerate-resolution Imaging Spectroradiometer (MODIS), LST products from the two sensors were examined for a portion of suburb area in Beijing, China. We selected Soil-Adjusted Vegetation Index (SAVI), Normalized Multi-band Drought Index (NMDI), Normalized Difference Built-up Index (NDBI) and Normalized Difference Water Index (NDWI) as representative remote sensing indices for four land cover types (vegetation, bare soil, impervious and water area), respectively. By using support vector machines, the overall classification accuracy of the four land cover types with inputs of the four remote sensing indices, extracted from ASTER visible near infrared (VNIR) bands and shortwave infrared (SWIR) bands, reached 97.66%, and Kappa coefficient was 0.9632. In order to lower the subpixel temperature estimation error caused by re-sampling of remote sensing data, a disaggregation method for subpixel temperature using the remote sensing endmember index based technique (DisEMI) was established in this study. Firstly, the area ratios and statistical information of endmember remote sensing indices were calculated from ASTER VNIR/SWIR data at 990 m and 90 m resolutions, respectively. Secondly, the relationship between the 990 m resolution MODIS LST and the corresponding input parameters (area ratios and endmember indices at the 990 m resolution) was trained by a genetic algorithm and self-organizing feature map artificial neural network (GA-SOFM-ANN). Finally, the trained models were employed to estimate the 90 m resolution subpixel temperature with inputs of area ratios and endmember indices at the 90 m resolution. ASTER LST product was used for verifying the estimated subpixel temperature, and the verified results indicate that the estimated temperature distribution was basically consistent with that of ASTER LST product. A better agreement was found between temperatures derived by our proposed method (DisEMI) and the ASTER 90 m data ($R^2 = 0.709$ and RMSE = 2.702 K).

1. Introduction

When referring to land observation from space, the land surface temperature (LST) is a physical parameter very important to a wide variety of scientific studies (Sobrino et al., 1991; Wan & Li, 1997; Qin et al., 2001). Satellite observations of LST have been widely applied in environmental monitoring, such as detecting conditions prone occurring wildfire (e.g., Pu et al., 2007), assessing ecosystem health and drought severity (e.g., Kustas & Anderson, 2009), monitoring volcanic eruptive activity (e.g., Lombardo & Buongiorno, 2006), and exploring urban heat island effects (e.g., Weng et al., 2004; Stathopoulou & Cartalisa, 2009). A common use of thermal infrared (TIR) data is to derive surface energy budgets (Kustas et al., 2003; Liang, 2004) from high-resolution thermal data, providing assessments of evapotranspiration (ET) down to scales of individual agricultural fields (Loheide & Gorelick, 2005). This type of thermal information is necessary for a reasonable allocation of water resources in northwest China as well as in other arid and semiarid regions around the world. However, due to a relatively lower thermal radiation that is emitted by land surfaces, most satellite sensors are not capable of providing as much finer-scale information in thermal bands as in visible and short infrared ones. Therefore, these satellite-based thermal observations generally

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