Estimating Urban Impervious Surfaces by Linear Spectral Mixture Analysis: A Case of Urban Area of Shanghai (2002-2008)[1]

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1. INTRODUCTION

In recent years, impervious surface has emerged not only as an indicator of the degree of urbanization but also a major indicator of environmental quality. As one of the most important industry cities, Shanghai is rapidly increasing in population and area. The impervious surface expansion occurs through the encroachment into the adjacent and suburb land. Extracting information of impervious surface from satellite images allows one to monitor urban changes over time and integrate the environment management and urban planning activities [1], [2]. Estimating impervious surfaces from medium spatial resolution satellite images has therefore attracted more interests recently in remote sensing community.

2. METHOD

For extracting the impervious surface distribution, the vegetation-impervious surface-soil (V-I-S) model proposed by Ridd can be implemented by using the technique of linear spectral mixture analysis (LSMA) [3]. Four endmembers, high-albedo, low-albedo, vegetation and soil can be selected to model complicated urban land cover. The concrete procedures of extracting the impervious surface distribution by means of the LSMA can be described as follows.

1) Spectral Normalization and Noise Removal: A brightness normalization method was applied to highlight the shape information while minimizing the effects of absolute reflectance values [4]. Brightness variability within each component was reduced or eliminated, thus allowing a single endmember representing each component. Then a minimum noise fraction (MNF) transformation was applied to the Normalized data for the purpose of ordering the components in terms of signal-to-noise ratios [5]. Most information was contained in the first few components, and the others were regarded as noises.

2) Endmember Selection and Spectral Unmixing: The first three MNF components were used to select endmembers by using pixel purity index (PPI) algorithm [6]. The PPI algorithm works as a simple technique designed to search for a set of vertices of a convey hull in a K-dimensional hyperspectral image cube. The algorithm is initialized by a large set of randomly generated K-dimensional vectors called "skewers". A skewer is defined as a random unit vector to "skew" the data, i.e., to find extreme pixels in the direction of each skewer. The PPI only generates a list of candidates from which final endmembers must be manually selected [7]. To find the best quality fraction images, a fully constrained least squares (FCLS) was applied to unmix the six normalized Landsat images [8].

3) Impervious Surface Estimation and development: Impervious surface fraction is obtained by adding high-albedo fraction to low-albedo fraction with water masked [9]. The impervious surface may be mixed with other land cover types, such as moist trees, grass, and dry soils [10]. Because of different thermal responses between impervious surface and other cover types, the land surface temperature (LST) derived from thermal infrared data was assisted to improve impervious surface estimation.

3. EXPERIMENTAL RESULTS

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The 1st -5th and 7th bands of the Landsat 7 ETM+ images (Nov. 27, 2002) and Landsat 7 TM images (April 25, 2008) of the same area were employed for extracting impervious surface cover of Shanghai. Initially, the pixel digital number (DN) was changed to standard reflectance. A brightness normalization method was applied to reduce brightness variation. Then a MNF transformation was applied to reduce the image data dimensionality to three. A list of pixels of high purity was generated through PPI processing. A manual selection procedure is then performed by successively projecting the data toward lower dimensional spaces. One pixel falling at the corners of the data cloud was selected for each endmember by repeatedly mutual comparison. As the four endmembers were extracted, we apply FCLS algorithm to unmix the normalized six reflective bands and estimate the impervious surface by adding the high and low albedo fractions. Further, we use the LST to remove the confused fractions from the impervious surface.

4. CONCLUSION

In this research, impervious surface distribution in 2002 and 2008 is estimated through the LSMA method using Landsat TM/EM+ images. The estimation accuracy for impervious surface was assessed by using 100 samples with a ground area of 150 m by 150 m selected randomly from the colored satellite image. The overall root mean square error (RMSE) of the result using the method propounded ahead was 4.13%, which was a promising accuracy. Experimental results indicate that, the mean impervious surface fractions of Shanghai urban area is 63.91% in 2002 and 71.25% in 2008, ascending obviously. They show that Shanghai has a high density of construction and a low density of vegetation and water, thus there exists a crisis in environment. And the impervious surface distribution appears to be sprawling from the urban areas to the suburb areas.

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