INVESTIGATION OF IMAGING SPECTROSCOPY FOR DISCRIMINATING URBAN LAND COVERS AND SURFACE MATERIALS

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1. INTRODUCTION

Urban growth has been recognized by many globe change agendas as not only a regional phenomenon but also a continental, global scale phenomenon (Hepner et al., 1998). Many urban areas face environmental degradation, such as loss of open space, natural vegetation, agricultural lands, wetlands, and natural habitat at an increasing rate. The development of urban information systems, which contain baseline information and the urban growth models, is crucial for predicting regional patterns of urbanization. The implementation of the urban systems requires a variety of digital data sources, such as land covers and surface materials, as well as a temporal database.

Although urban analysis is one of the most common applications of remote sensing, the information derived from remotely sensed data is often insufficient for operational use. One of the main problems is that the spectral and spatial resolutions of sensors are too coarse to identify the desired information for urban analysis (Hepner et al., 1998). The urban landscape is extremely heterogeneous with a variety of land cover types and surface materials mixing together within a small area. If many materials are located within one sensor pixel, each material will contribute its unique spectral characteristic to the mixed pixel and make the pixel spectrally impure. In addition, many urban materials, such as soils and impervious surfaces, yield similar spectral signatures. Therefore, broadband data, such as Landsat, and pixel-based analysis, such as maximum likelihood classification, are inadequate for discriminating urban land covers and surface materials (Forster, 1985; Ridd, 1995).

Hyperspectral data such as AVIRIS which covers spectral range from 400 to 2500 nm and has 224 continuous channels with 10-nm bandwidth is capable of discriminating most of the terrestrial materials including urban surface materials (Goetz, 1992; Clark, 1999). Imaging spectroscopy has been successfully applied to geological, aquatic, ecological and atmospheric research (Curran, 1994). Surprisingly, it has been used sparsely for the study of urban areas (Ridd et al., 1992; Hepner et al., 1998). The objective of this study is to investigate the feasibility of using the field spectra as the reference to identify the urban land covers and surface materials in the low-altitude AVIRIS scene.

2. DATA COLLECTION

The urban area of Park City, Utah has a representative mixture of land covers and surface materials for western U.S. cities and other urban areas of the earth undergoing rapid urban growth. Although Park City area is not highly urbanized, it contains the diversity of land covers, surface materials, and vegetation associations. Park City also provides the typical example where urbanization spreads from lowlands to adjacent uplands. Therefore, the methodologies, spectral signatures and techniques investigated in this study should then be transferable to many western U.S. cities and other urban areas around the world with similar environments.

The low-altitude AVIRIS data with spatial resolution 2.9 m was obtained on 19 October 1999. There was no ground calibration site located in the low-altitude AVIRIS flight line and no field spectra were obtained during the low-altitude overflight. High-altitude AVIRIS data of Park City area was obtained from the Park City flight on 5 August 1998. The high-altitude AVIRIS data with spatial resolution 20 m was first corrected and then used to simulate the ground truth for calibrating the low-altitude AVIRIS data. A radiative transfer model (ATREM) provided by the University of Colorado was applied to the radiance data to remove the solar spectral response, atmospheric absorptions and atmospheric scattering. The path radiance scattering overcorrected by the ATREM was

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further corrected by the offset parameter provided by the USGS. Other artifacts of the spectra, which are small-scale spikes irresoluble by the ATREM, were also corrected by the multiplier parameter provided by the USGS derived from the ground calibration site (Rockwell, 2000). The spectrum of the bright rooftop of a supermarket in the high-altitude scene was selected and then edited to remove the residual atmospheric absorptions. Relatively, the ATREM calibration and path radiance correction were first applied to the low-altitude AVIRIS data. Then the same pixels, which cover approximately 6 by 6 pixels in the low-altitude scene over the supermarket roof, were sampled and averaged to provide the spectrum. This low-altitude spectrum was divided into the edited high-altitude spectrum to obtain the multiplier used to calibrate the low-altitude data.

Although existing spectral libraries provide many urban surface materials, their diversity is not enough for this study. The ability of the reference spectra to separate plant species as well as manmade materials might vary from one region to another and decrease as the geographic area covered increases. Thus, a regional spectral library of Park City was constructed to better match the AVIRIS data for the spectral analysis. During the summer and autumn of 2000, 80 urban surface materials including 20 roofing materials, 12 paving materials, 23 vegetation and other 25 materials, were measured in 9 field collection sites around the study area using an ASD field spectroradiometer.

3. ANALYSIS AND RESULTS

The selection of the optimal spectral analysis strategy to discriminate the urban surface materials is tied to spectral reflectance characteristics of the targets. Therefore, the spectral signatures of the urban field spectra were examined before determining the analysis strategy. In the broadband data, water and asphalt usually are confused due to low reflectance. However, the field spectra show that water has apparent fluctuation in the visible region due to the underwater materials, which are water plants in this case. Asphalt also has a broad weak absorption near 2.3 µm due to the hydrocarbons. Sand, concrete, and gravel are usually indistinguishable in the broadband data due to bright reflectance. In the field spectra, they could be discriminated by the magnitude in the visible region or by the weak absorption at 2.2 µm caused by the montmorillonite, which is narrower and stronger in the sand and gravel spectra than in the concrete spectrum. In addition, the spectral curve of concrete from red to near infrared region (0.6 –1.3 µm) is a concave, which is different from the convex of sand and gravel in the same spectral region. However, the strong absorption features of their individual chemical compositions might be flattened and broadened. Also, if dirt covered the targets during the measurement, weak absorption features at 0.95, 1.15, and/or 2.2 µm can be found.

Lacking of consistent, strong, and well-defined absorption features, most urban surface materials are not differentiable by matching the absorption bands. The full spectral mapping methods such as Spectral Angle Mapper (Yuhas et al., 1992; Kruse et al., 1993), which compare the spectra using full wavelength range, might be feasible for mapping urban materials with continuum shapes and/or very broad absorptions. Imaging processing was undertaken using ENVI 3.2 software. Low-altitude AVIRIS data with fewer materials mixed in one pixel were analyzed by the pixel-based method, spectral angle mapper (SAM). Field spectra of the most common land cover types and surface materials in Park City were chosen as the reference to compare the spectral similarity with the image spectra. The results of the SAM analysis show that many urban surface materials were discriminated including lawn grass, dry grass, conifer, deciduous, turbid water, clear water, concrete, asphalt, paint, and membrane, etc.

4. SUMMARY

This preliminary study demonstrated that the imaging spectroscopy approach with low-altitude AVIRIS data and field spectra makes it possible to discriminate the urban land covers and surface materials. The low-altitude AVIRIS data with 2.9 m spatial resolution successfully differentiates many surface materials in the urban scene.

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