ON THE VALUE OF HYPERSPECTRAL REMOTE SENSING IN MAPPING URBAN LAND COVER

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Introduction

Urban environments represent one of the most challenging areas for remote sensing analysis due to high spatial and spectral diversity of surface materials (Ben Dor et al., 2001, Roessner et al., 2001). Typical urban surface types include a wide range of roofs, roads, sidewalks and parking lots of variable age, quality and composition. Further complicating the urban landscape are bare soil, vegetation, and other landscaping elements, creating a spectral diversity that far exceeds natural environments. Given this general complexity, this study investigates the value of hyperspectral remote sensing data in accurate mapping of urban land cover. The investigations include the assessment of a comprehensive urban spectral library to describe issues of spectral characteristics and spectral separability of urban materials and land cover types. Mapping applications are presented from high-resolution AVIRIS data, simulated multispectral sensor configurations and LIDAR covering the Santa Barbara urban region. The analyses focus on different spatial and spectral sensor configurations and their affects on the mapping accuracy The next section will give a summary of the findings and conclusions. For more detailed information the reader is referred to the references at the end of the paper.

Summary of results

The investigations concerned with urban spectrometry provided a systematic and quantitative view of the spectral complexity and unique spectral characteristics of urban environments. Urban materials such as roofing materials, pavement types, soil and water surfaces, and vegetated areas, represent a large variety of surface compositions that are reflected in characteristic spectral properties. The analysis of spectral separability of urban materials and land cover types using the B-distance provided a detailed assessment of how specific urban land cover types separate based on their material properties. Some categories are not spectrally distinct over the spectral range between 350 nm and 2400 nm and have expected limitations in their accurate mapping from remote sensing datasets. Examples include: a) bare soil targets versus concrete roads, b) asphalt roads versus composite shingle, tar and gray tile roofs, c) gray tile roofs versus composite shingle and tar roofs, and d) asphalt roads versus parking lots. With the exception of concrete roads, these surface types mainly represent low reflectance targets with no significant broad absorption features. Road surfaces showed the largest variance in their spectral material separability and were especially confused with specific non-transportation cover types (Herold et al., 2004).

The evaluation of most suitable spectral bands again reflects the spectral diversity of urban environments. A set of fourteen optimal bands was derived for mapping the urban environment from the ground spectral library and the AVIRIS spectral library (Figure 1, Herold et al., 2003). The spectral location of the bands emphasizes the important features that characterize most urban targets, such as increasing reflectance towards longer wavelength, and the distinct small-scale spectral variation in the visible and short-wave infrared representing specific absorption features due to the material composition. A comparison of the bands most suitable for separating urban targets with the spectral configuration of common multispectral remote sensing systems showed that the unique urban spectral characteristics are not resolved in those sensors due to the location of the bands and their broadband character (Herold et al., 2003, Roberts and Herold, 2004).

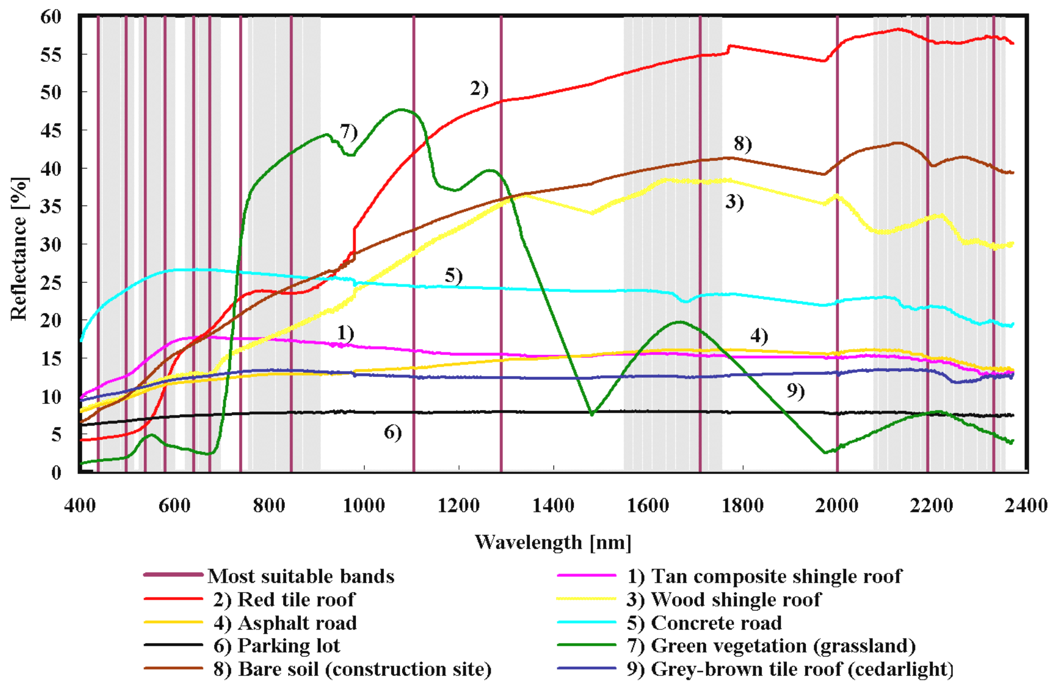

Figure 1: Most suitable spectral bands for urban mapping derived from the ASD spectral library and the AVIRIS data compared to spectral signatures of several urban land cover types and the spectral coverage of LANDSAT TM satellite sensor (gray in the background).

The majority of the fourteen most suitable spectral AVIRIS bands are located outside or near the edge of the spectral coverage of common broadband multispectral satellite systems such as IKONOS and LANDSAT TM. Expected spectral limitations of these systems were confirmed by the AVIRIS classification results. The difference between overall classification accuracy of urban classes was nearly 30% between IKONOS and AVIRIS, and ~13% between LANDSAT and AVIRIS, with distinct differences for individual classes. However, the AVIRIS land cover classification of twenty-six different urban land cover classes illustrated general limitations in mapping the urban environment even using hyperspectral optical remote sensing data. This again reflects the very similar spectral characteristics of certain land cover types indicated in the spectral separability analyses. Due to high spectral within-class variability resulting from roof geometry, condition, and age, their separability and classification accuracy was low, reaching only 66.6% for the twenty-two urban categories (Herold et al., 2003, Roberts and Herold, 2004). Nevertheless, for specific important land cover types such as wood shingle roofs, this investigation produced a very detailed level of classification with high accuracy. It should be noted that this image classification applied a simple pixel-based Maximum Likelihood classification algorithm on a purely spectral basis

The use of three-dimensional information provided by LIDAR data can significantly improve the mapping of urban land cover. In particular for classification of buildings/roofs and roads, LIDAR seems to be very important since both classes have distinct three-dimensional characteristics (Figure 2). In fact, the combination of IKONOS and LIDAR data produced more accurate results than using only spectral data from AVIRIS. AVIRIS, on the other hand, performed better for other classes like vegetation and bare soil. The combination of AVIRIS and LIDAR provided the best land cover classification performance with over 90 % overall accuracy for 6 classes.

The land cover classification results showed a strong dependence on the spatial resolution. The map accuracy significantly decreased between 4 and 16 m spatial resolution. At coarser resolutions the spectral signals from individual urban land cover features (mainly buildings, roads, and green vegetation) increasingly merge into mixed pixels. The individual classification accuracies for the categories steadily decreased, i.e. green vegetation gets increasingly overmapped due its distinct spectral characteristic, whereas built areas tends to be underestimated (Herold and Roberts, 2004).

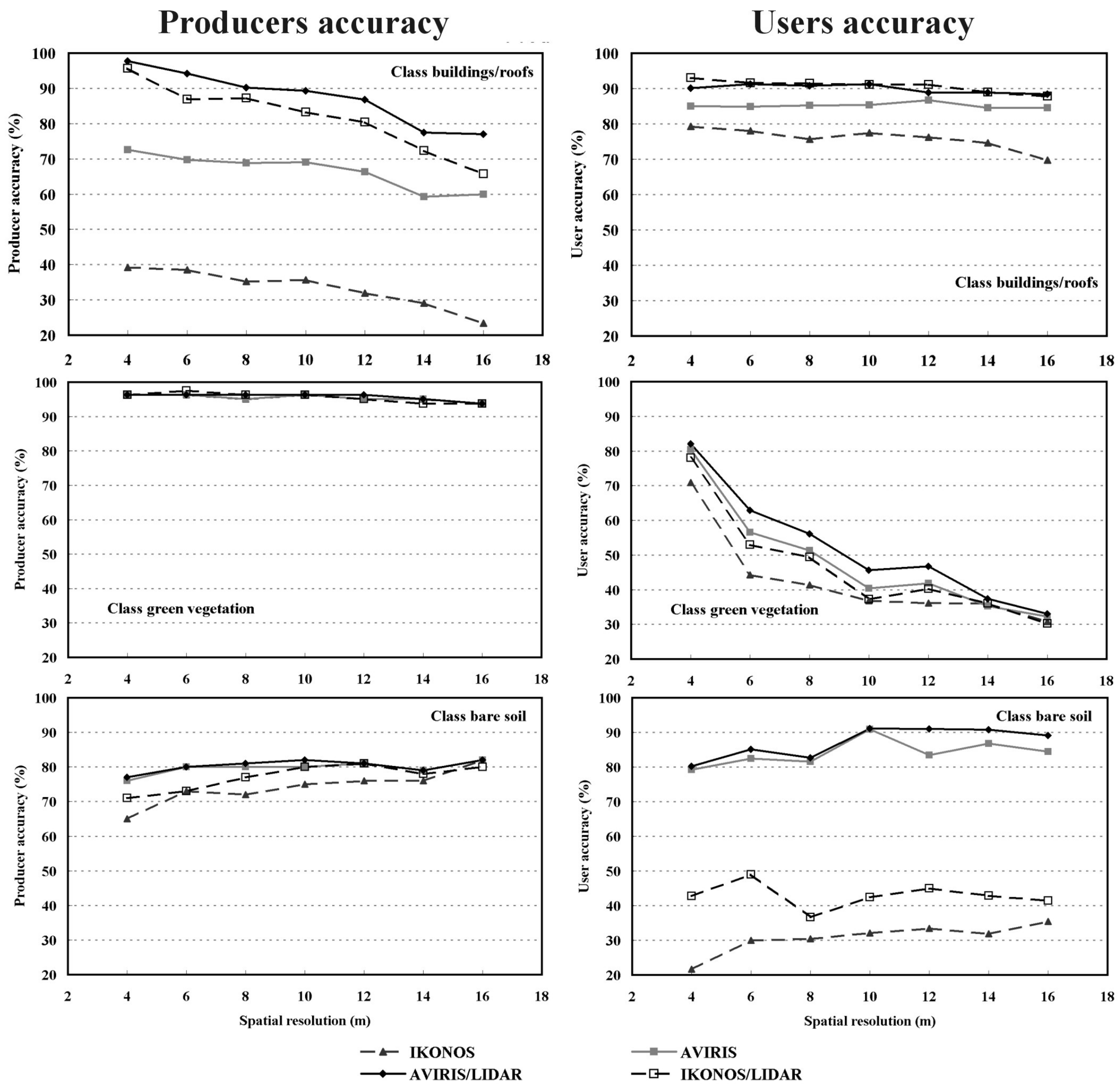

Figure 2: Producer and user accuracies in four land cover classes for different sensor configurations (IKONOS, LIDAR, AVIRIS) and degraded spatial resolutions.

In terms of spatial-spectral tradeoffs, the variations in map accuracy with spatial resolution (4–16 m) were smaller than those for changing spectral information (IKONOS, AVIRIS, LIDAR, Figure 3). This suggests that it would be proper to pick a low spatial resolution AVIRIS dataset over a high-spatial resolution IKONOS dataset, at least from a pixel-based spectral mapping perspective. Moreover, the decrease in overall accuracy from 4 to 16 m for the AVIRIS data was only a difference of seven percent. For the combination of IKONOS/LIDAR this change was nearly 20 %. At 16 m spatial resolution the classification performance of IKONOS/LIDAR drops below the AVIRIS accuracy. Hence, AVIRIS data analyses are less sensitive to changes in spatial resolutions. Although the trends certainly vary for individual land cover classes, IKONOS and LIDAR classification data strongly depend on the accurate representation of individual urban land cover features and should only be used at fine spatial resolutions. If only coarse spatial resolution data are available hyperspectral datasets should be preferred for urban land cover mapping (Herold, 2004).

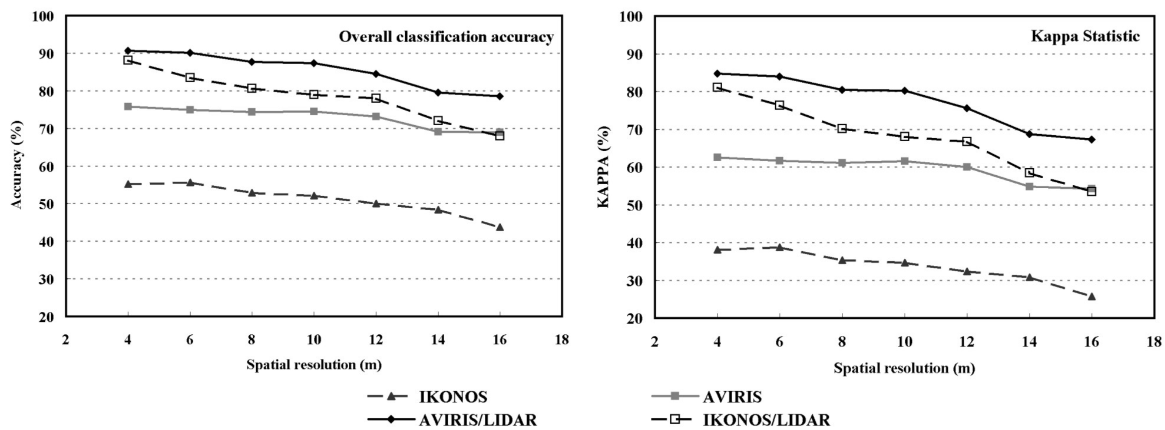

Figure 3: Overall accuracies and KAPPA coefficient for different sensor configurations and varying spatial resolution.

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