URBAN LAND COVER AND SPATIAL VARIATION OBSERVATION USING SATELLITE IMAGE DATA – THE URBAN ENVIRONMENTAL MONITORING PROJECT

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INTRODUCTION

Land cover and land use changes associated with urbanization are important drivers of local geological, hydrological, ecological, and climatic change. Quantification and monitoring of these changes in 100 global urban centers are part of the mission of the ASTER instrument on board the NASA Terra satellite, and comprise the fundamental research objective of the Urban Environmental Monitoring (UEM) Program at Arizona State University (http://elwood.la.asu.edu/grsl/UEM/). The UEM program is using a variety of remotely sensed and GIS datasets (ASTER, Landsat, MODIS, astronaut photography, socioeconomic data, historical maps) to establish development trajectories within a pilot study for 17 urban centers located around the globe. The urban centers are selected on the basis of urban growth projections, geologic/geographic setting, and climatic patterns. Our goal is to determine classes or groupings of urban development trajectories defined by several variables (land use/land cover, landscape metrics, climatic patterns, and geologic hazard assessment).

One strategy to better understand urbanization has been to characterize and quantify land cover change, particularly rapid urban growth, through satellite remote sensing. Although historically aerial photography has been the basis for mapping land use/land cover in a region (Donnay et al. 2001). The advantage of using satellite imagery is that data can be collected and analyzed at time intervals more frequently, and with less cost and less subjective interpretation than with aerial photographs due to the higher information content of multispectral data. The UEM project is using a variety of remotely sensed and GIS datasets (ASTER, Landsat, MODIS, astronaut photography, socioeconomic data, historical maps) to establish development trajectories within a pilot study for 8 urban centers located around the globe.

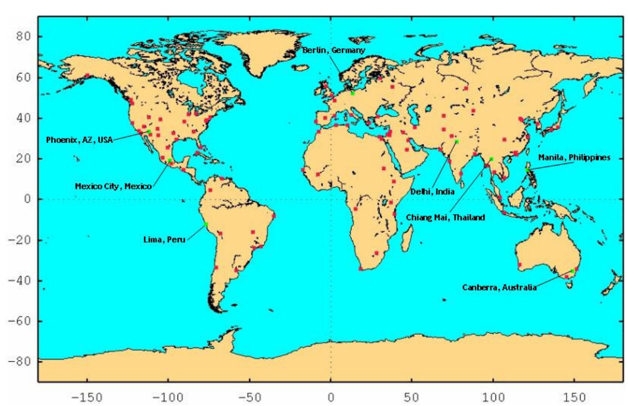

Figure 1. Location map of eight "intensive study" cities. Red squares indicate other UEM cities.

Within the UEM project we will continue to produce standardized land cover classifications for 100 urban centers located around the globe using ASTER data throughout the duration of the Terra mission. In addition, we will monitor the geological and ecological status of these cities using ASTER and MODIS.

Classification of urban development trajectories and spatial structure will be determined for a representative subset of 8 urban centers (see figure 1) using a coherent methodological approach to ensure comparability of the results. Ongoing research in this area includes development of detailed land cover classification models for the eight study cities developed for Phoenix, USA (Stefanov & Netzband, 2005, figure 2). In this paper, we present the results of classifying land use/land cover change for a small region of New Delhi, India using an expert system approach. This project is part of a larger study to analyze rapid urbanization through remote sensing in several cities throughout the world.

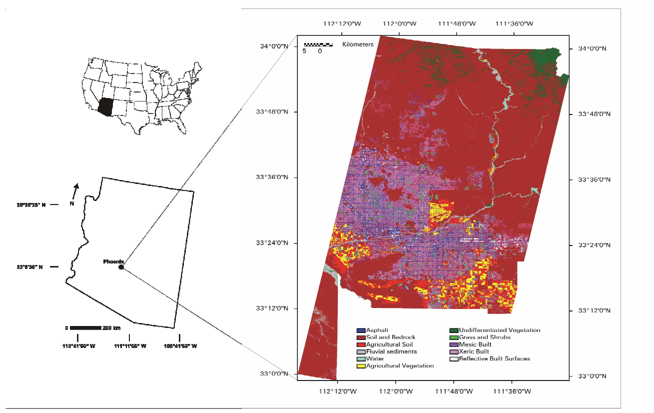

Figure 2. Land cover classification for the eastern Phoenix area.

CASE STUDY DELHI, INDIA

The study area covers approximately 18839 square kilometers of Delhi, the capital of India. Delhi is one of the prime mega cities of the world. Situated on 28 30' North latitude and 77 00' East longitudes, it lies at an altitude of between 700 and 1,000 feet (213 and 305 meters). It is situated on the bank of one of the most polluted river of the world; River Yamuna (a tributary of the Ganges River). There is a large-scale transformation of land in Delhi over a period of time since independence but the scale and its magnitude was never so fast as that of the last decade of the previous century. This is mainly the result of migration, industrialization and globalization. Many Multinational Companies (MNCs) are coming to Indian metros like Delhi, Bangalore and Hyderabad and eating up the valuable fertile agricultural lands.

Landcover Classification

We utilized Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) remotely sensed data to classify urban land cover from September 22, 2003. ASTER 15 meter resolution visible to near infrared imagery (VNIR bands 1-3) to produce land cover classification. Ancillary data used were land use derived from a Survey of India Delhi and its Environments Map from 1996. The data were digitized into vector-based GIS files and converted into WGS 84 (datum) UTM (Zone 43N) coordinate system. The paper map was classified using 14 classes, as follows: Urban High Density, Urban Low Density, Water, Cultivated Area, Park, Orchard, Undeveloped, Mines, Historical Lands, Fluvial Rock, Golf Courses, Airport, Commercial/Industrial, and Disturbed Concrete and Asphalt. The vector data were converted into raster files with a 15 meter resolution. Other ancillary data were Normalized Difference Vegetation Index (NDVI) calculated from the ASTER image. The schema and approach largely followed classification efforts previously performed by Stefanov et al. (2001) for the Phoenix urban area using Landsat Thematic Mapper (TM) imagery. We modified it slightly for suitability to the New Delhi study. We developed an expert classification system to recode the initial minimum distance to means results (Stefanov et al., 2001, 2003). This Boolean decision rule based system includes the initial MDM land cover classification (VNIR bands) and New Delhi land use and NDVI ancillary data.

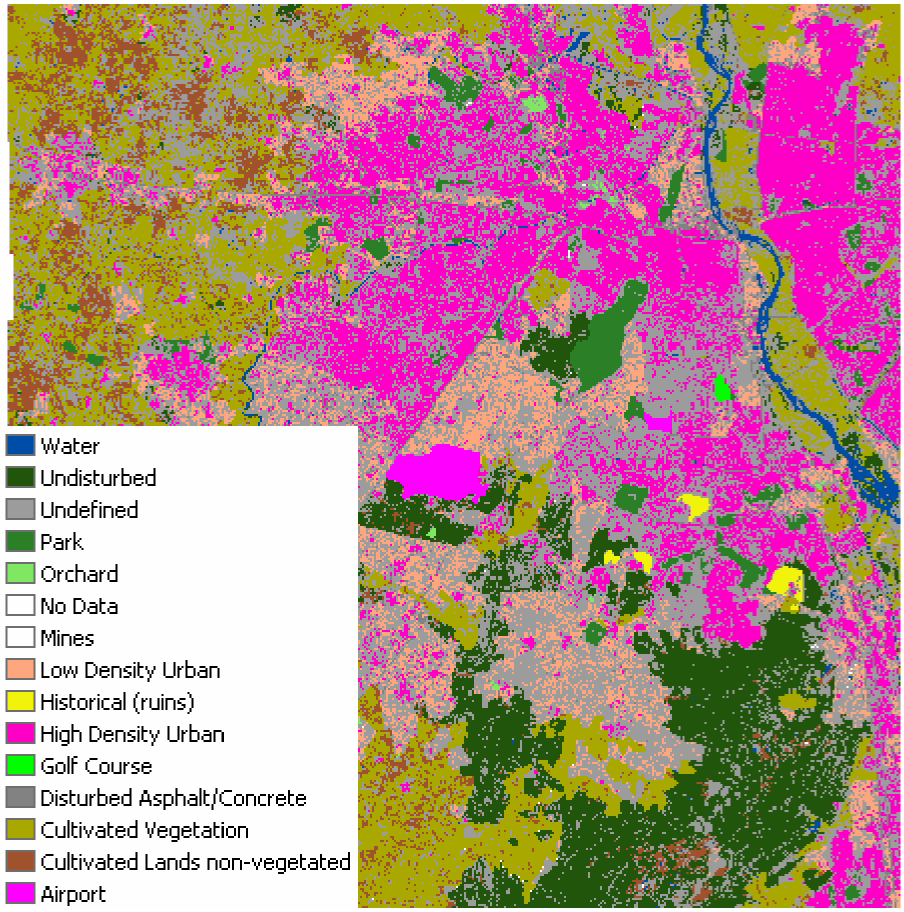

Figure 3: Classified land cover data in Delhi, India

Figure 3 displays the results of our expert system classification of the study area. Dominant land cover types are cultivated vegetation (23%), high density urban (16%), cultivated land without vegetation (10%), and undeveloped (9%). Roughly 30% of the pixels remain unclassified. We believe this is due to the problems of geographic registration between the land use map and the satellite image, land use/cover changes between 1996 (the land use map) and 2003 (the satellite image), and cross-spectral similarities between urban high-density and other prevalent classes within the imagery. We also note that the Yamuna River watercourse has changed since land use map was generated. We tried to defer to the actual ASTER data for classification in this regard, but there may be gaps and/or discrepancies that result from this. We need to investigate solutions to these problems.

Within another approach emphasizing more binary the distinction between the urban fabric and the 'green surrounding' represented by vegetated areas (parks or agriculture) five major land use/land cover class have been extracted. Supervised classification has been applied using maximum likelihood classification for the same ASTER data of September 2003 by selecting two sites, one in the central Delhi and other in the east Delhi (Trans Yamuna). These sites were selected with a view to compare the land use pattern between old (central) and new (fringe) parts of the city. Accuracy assessment was done for classification scheme and it showed 96.41% overall and 91.02% kappa accuracy for the central Delhi area and 95.15% overall and 89.04% kappa accuracy for the Trans Yamuna area classification. The classification result shows that the central part of Delhi is sparsely built with approximately 40% of built up area In this area open green and forest/plantation/orchard occupying an area of 39% and 17% respectively fig 1. When compared with other classified image of Trans Yamuna it is seen that the built up area is high 55% of the total area In this area open green and forest/plantation/orchard is very less 26% and 12% respectively fig 2. Density of built up land is high is the fringe areas as compared to the core because of less land value and also construction is unplanned i.e. not on approved plan and also many of these constructions are illegal.

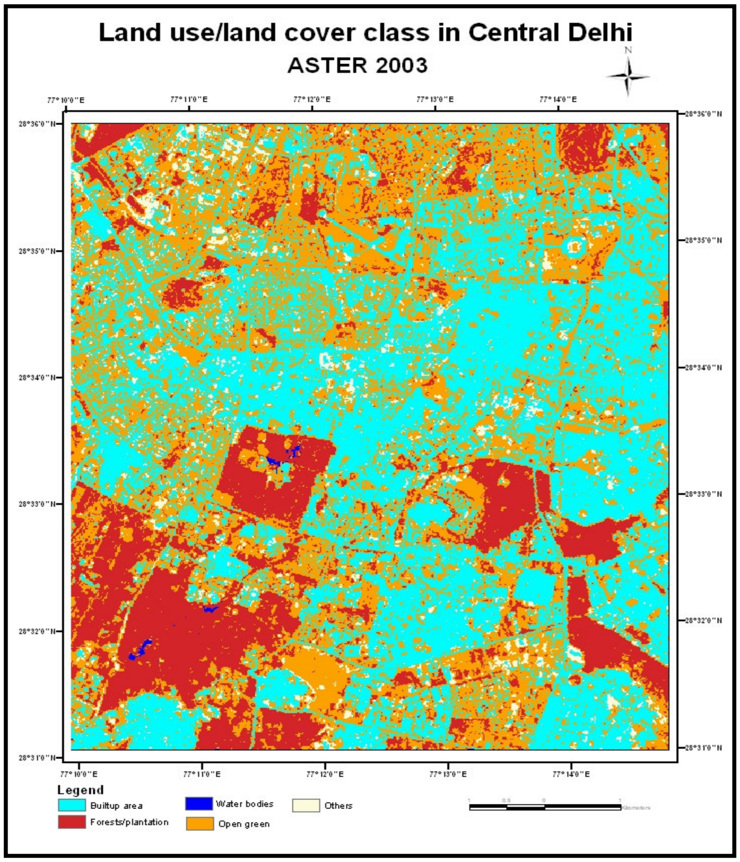

Figure 4: Classified land cover in Central Delhi, India

CONCLUSIONS

This classification results represent our first effort at duplicating the expert system approach developed by Stefanov et al. (2001) for Phoenix to a different study area accompanied by an analysis by local collaborators. There are several notable differences between the approaches. We elected to utilize the higher-resolution ASTER data instead of the Landsat TM data they used. This decision was based on the objectives of the larger project in which this study supports. Furthermore, ancillary data (in particular data associated with water rights) were not available for New Delhi. The land use data (another ancillary data set) we created may only make a marginal contribution to the classification due to several factors. We had difficulty registering the vector data to the satellite data. Secondly, the map was created in 1996 and the satellite data were collected in 2003. Land cover changes no doubt took place during this time. Finally, land use interpretation from the map may or may not be accurate. We do not have access to aerial photographs to verify our classification. We plan to continue to investigate the best approach for classifying land cover in New Delhi. We will integrate normalized difference vegetation index and texture analysis into the next model.

References

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