EXPERT SYSTEM APPROACH FOR CLASSIFYING LAND COVER IN NEW DELHI INDIA USING ASTER IMAGERY

C. Cole [a], E. Wentz [a], P. Christensen [b]

[a] Department of Geography, Arizona State University, Tempe AZ 85287-0104
[b] Department of Geological Sciences, Arizona State University, Tempe AZ 85287-6305

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ABSTRACT:

In this study, we present the results of classifying land use/land cover change for a small region of New Delhi, India using an expert system approach. We employed Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) remotely sensed data from September 22, 2003. Our initial pilot area classified 8 different land cover categories with a 72% overall classification accuracy based on 25 random points.

I. INTRODUCTION

Urbanization is characterized by rural to urban land conversion. Urban planners and policy-makers desire scientifically based assessments on the short and long-term effects of these rural to urban land conversion activities. The effects of this process, however, are difficult to describe and even more difficult to adequately understand because of an extreme range of differences in the patterns and rates of urbanization, patterns of density, and the stages of urbanization in different environmental contexts. Open-ended questions remain such as when does the pattern of growth impact water supply or agricultural viability? At what point in the urbanization process does urbanization contribute to catastrophic urban vulnerability, such as infrastructure inadequacy, transportation gridlock, air pollution extremes, geologic hazards, and health risks?

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), more recently multispectral satellite imagery has been used to classify urban land use/land cover (Anderson et al. 1976; Haack et al. 1987; Martin et al. 1988; Cowen and Jensen 1998; Ridd and Liu 1998; Donnay et al. 2001; Stefanov et al. 2001; Zhu and Blumberg 2002; Stefanov et al. 2003a; Netzband and Stefanov 2003). 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. In this study, 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.

2. METHODS

2.1 Study Area

The study area covers approximately 192 square kilometers of New Delhi, India (Figure 1). The study area (28° 27'15" 28° 34' 44" North Latitude, 77° 10' 9" to 77° 18' 41" East Longitude) encompasses a small portion of the urban and non-urban area the city.

Figure 1. New Delhi, India

2.2 Data

This study employed 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) was harnessed to produce an initial minimum distance to means (MDM; Jensen, 1996) supervised 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.

2.3 Analysis

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 ancillary data. Producers and users accuracy assessment were performed quantitatively through the selection and confirmation of a twenty-five random control points.

3. RESULTS AND DISCUSSION

Figure 2 displays the results of our expert system classification of the small pilot area in New Delhi. Dominant land cover types are high and low density urban/residential (27.27 and 67.08 square kilometers, respectively) and undeveloped (40.48 square miles). Roughly 10% 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 or land use/cover changes between 1996 (the land use map) and 2003 (the satellite image). We need to investigate a solution to this problem.

The expert system resulted in a 72% overall classification accuracy based on 25 random points and a kappa coefficient of 0.6212. Table 1 summarizes the Producer's and User's Accuracy Assessment, based on 25 randomly selected points. The random selection of points did not select samples from all classes. In the best case, 4 out of the 8 classes were assessed, as reported in Table 1. The favored classes were undisturbed, vegetated, high and low density urban classes, which tend to be the ones that dominate the landscape (Figure 1). Producer and User accuracy was over 50% for all classes sampled. These classes tend to dominate the landscape and have the most homogeneous spectral signature. The disturbed classes (commercial, industrial, concrete) tend to be more heterogeneous and are traditionally more difficult to classify correctly in satellite data (Stefanov et al. 2001).

Class	Producer's	User's
Water	0	0
Undisturbed	88.89	88.89
Vegetated	50.00	100.00
High Density Residential/Urban	55.56	100.00
Low Density Residential/Urban	80.00	57.14
Disturbed/Commercial/Industrial	0	0
Disturbed/Asphalt/Concrete	0	0
Disturbed/Compacted Soil	0	0

Table 1. Producer's and User's Accuracy Assessment

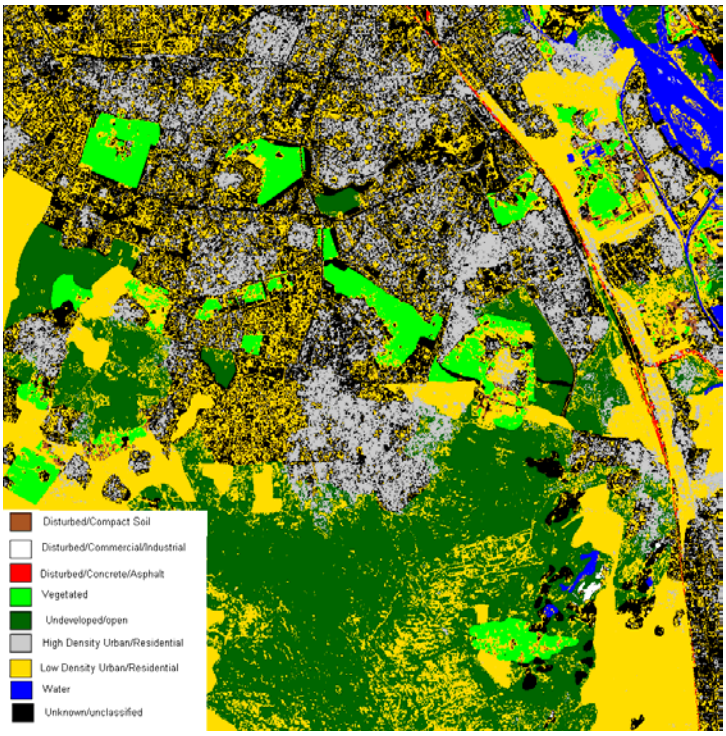

Figure 2. Classified land cover data in New Delhi

4. CONCLUSIONS

This effort represents our first effort at duplicating the expert system approach developed by Stefanov et al. (2001) for Phoenix to a different study area. 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.

5. REFERENCES

Anderson, J.R., E. Hardy, J. Roach, and R. Witmer (1976). A land use and land cover classification system for use with remote sensor data. United States Geological Survey Professional Paper 964.

Botkin, D.B., Estes, J.E., and MacDonald, R.B., 1984. Studying the Earth's vegetation from space. BioScience, 34, pp. 508-514.

Cowen, D.J. and J.R. Jensen (1998). Extraction and modeling of urban attributes using remote sensing technology. In:

People and Pixels: Linking Remote Sensing and Social Science, National Academy Press, Washington, D.C., pp. 164-188.

Donnay, J.-P., M.J. Barnsley, and P.A. Longley (2001). Remote sensing and urban analysis. In: *Remote Sensing and Urban Analysis*, Taylor and Francis, London, UK, pp. 3-18.

Haack, B., N. Bryant, and S. Adams (1987). An assessment of Landsat MSS and TM data for urban and near-urban land-cover digital classification. *Remote Sensing of Environment, 21, 201-213.*

Jensen, J.R., 1996. Introductory Image Processing: A Remote Sensing Perspective (2nd ed.). Upper Saddle River: Prentice-Hall.

Martin, L.R.G., P.J. Howarth, and G. Holder (1988). Multispectral classification of land use at the rural-urban fringe using SPOT data. *Canadian Journal of Remote Sensing, 14 (2), 72-79.*

Netzband, M. and W.L. Stefanov (2003). Assessment of urban spatial variation using ASTER data. Proceedings of the 4th International Symposium on Remote Sensing of Urban Environments, Regensburg, Germany.

Ridd, M.K. and J. Liu (1998). A comparison of four algorithms for change detection in an urban environment. *Remote Sensing of Environment, 63, 95-100.*

Stefanov, W. L., Ramsey, M.S., and Christensen, P.R., 2001. Monitoring urban land cover change: An expert system approach to land cover classification of semiarid to arid urban centers. Remote Sensing of Environment, 77, pp. 173-185.

Stefanov, W.L., Ramsey, M.S., and Christensen, P.R., 2003. Identification of fugitive dust generation, transport, and deposition areas using remote sensing. Environmental and Engineering Geoscience, 9, pp. 151-165.

Zhu, G. and D.G. Blumberg (2002). Classification using ASTER data and SVM algorithms: The case study of Beer Sheva, Israel. *Remote Sensing of Environment, 80, 233-240.*

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7. FURTHER INFORMATION

If you have questions about this research, please contact E. Wentz (wentz@asu.edu).