Development of a Method for Remote Sensing of Land-Cover Change 1980-2000 in the USFS North Central Region Using Heterogeneous USGS LUDA and NOAA AVHRR 1 km Data

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Abstract - A 1980 national land-cover classification (USGS LUDA aggregated t o 1km) was combined with 2000 satellite imagery (AVHRR NDVI time series) to derive land-cover change information for forest, urban, and agriculture categories in southeast Michigan, part of the USFS North Central Region. To derive useful land-cover change data using a heterogeneous dataset, we a) interpreted a s ample o f N APP p hotographs from 20 00 following 1980 LUDA protocols and used this interpreted land-cover for calibrating a 2000 AVHRR ISODATA classification, and b) used NRI land-cover statistical data to develop relationships between 1980 NRI and 1980 LUDA proportions for the three classes to develop expected proportions in each class for 2000 AVHRR. We further constrained this by using the NRI predicted proportions with an allocation procedure in IDRISI. Results showed that these approaches we adopted in order to produce comparable classifications improved on AVHIRR ISODATA classifications alone.

I. INTRODUCTION

With appropriate methodologies, national land-cover classifications combined with current satellite imagery are an increasingly useful source of regional land-cover change information. Our goal w as to develop an image processing method to derive 20-year land-cover change data for the seven-state North Central Region in support of the USFS Hot Spots of Landscape Change Program. The methodological objective was to use a NAPP photo-derived national land-cover classification from 1980 (USGS LUDA) combined with AVHRR satellite imagery from 2000 and identify~' areas within which substantial changes have occurred between agriculture, forest, and urban classes. While deriving land-cover change data using heterogeneous datasets is useful, accurate data comparability poses a methodological challenge. We report development of a method to make these datasets comparable over the North Central Region, and provide an example for one ecological sub-region in northeastern Illinois.

II. STUDY REGION

The results in this paper are from a subset of a larger region comprised of the states of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri and Wisconsin. As can be in Figure 1, this region is dominated by agriculture -including the majority of the U.S. corn and soybean belt. In the north and west the region borders on the wheat belt of the Great Plains. Forested areas occur on glacial landscapes that are a matrix of forest, wetlands, and lakes in the north and in areas of topographical relief (e.g. Ozarks and Shawnee Hills) in the south. Urban centers developed near water and rail transportation routes. Major trends within the region w ere hypothesized to be 1) the conversion of agriculture near urban centers to urban land-use, and 2) the conversion of agriculture in marginally productive areas to forest. To test these hypotheses and assess trends spatially over the entire region, we used a remote sensing approach.

III. DATA

Because the study focused on transitions between broad cover types over a large region, a coarse resolution sensor was appropriate for the analysis. A change analysis using AVHRR from 1980 and 2000 was initially proposed. Although it is preferable to generate change information from same-source data, we decided on an alternative for the following reasons: 1) a search of AVHRR data holdings at the USGS showed that they had insufficient data to produce

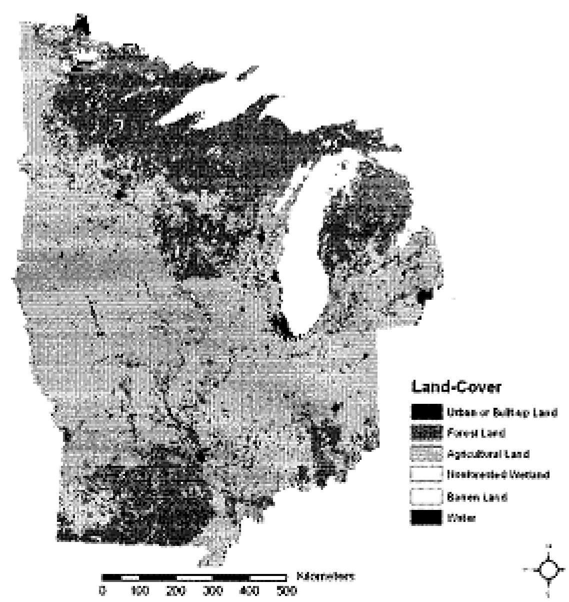

Fig. I. Land-Cover/Use in the North Central Region in 1980 (USGS LUDA aggregated to 1km).

1-km resolution composites necessary for classification prior to 1989; 2) a second data set, the AVHRR Pathfinder, extends from July 1981 through 2000, but at a spatial resolution of 8-km which was too coarse for the grain of land-cover change in the region; and 3) the USGS LUDA (Land Use and Land Cover) dataset from approximately 1980 might be combined with an AVHRR 2000 1-km classification to provide land-cover change information at resolutions at 1-km.

For our T2 land-cover data we used AVHRR 1-km data. The Eros Data Center (EDC) processes the AVHRR (1-km resolution) daily observations to produce bi-weekly maximum Normalized Difference Vegetation Index (NDVI) composites of the conterminous United States. We acquired these composites from EDC for the months of May through October 2000 . For our T land-cover dataset we used the digital USGS LUDA . This dataset is available through the US Geological Survey and is a digital representation of national land use and land-cover. Interpretation of land surface features for LUDA was carried out using NASA or NHAP high-altitude aerial photos at scales of 1:58,000 or smaller. Dates of the photos ranged from 1976 to 1981. The minimum mapping unit was 10 acres for urban and water features and 40 acres for all others. The LUDA Level I categories are 1) urban and built-up, 2) agricultural land, 3) forest land, 4) water, 5) wetland, and 6) barren land . Natural Resource Inventory (NRI) statistical data were acquired for the closest dates to T1 and T2: 1982 and 1997. NRI classes and data were recoded to match the LUDA classes. LUDA, AVHRR, and NRI data were analyzed for change by land-cover class by Major Land Resource Area
(MLRA) .

IV. METHODS

Several methods have been developed to extract land-cover change information from remotely sensed data. These include: 1) multi-date composite image change detection, 2) image algebra change detection (band differencing and ratioing), 3) post-classification comparison change detection, 4) multi-date change detection using ancillary data source as date one, 5) spectral change vector analysis, and 6) manual on-screen change digitization of change . Given the project goals and the best available datasets, we adopted the fourth method for this project.

We implemented three new approaches to merging heterogeneous spatial datasets for change analysis: 1) we developed a 2000 satellite image ISODATA classification in a way that approximated the 1980 photo-interpreted classifications as closely as possible; 2) we used a third independent data set collected consistently across the two dates to constrain and improve the comparability of the classifications, and 3) we combined these in an allocation procedure. We implemented the first approach by interpreting a sample of NAPP photographs from 2000 following 1980 LUDA protocols (Figure 2). The interpreted land-cover maps were used for calibrating the 2000 AVHRR classification to LUDA and validating their comparison. We implemented the second approach by using NRI land-cover statistical data to construct relationships between 1980 NRI and LUDA proportions for the three c lasses. W e then us ed t hese with 2000 NRI data to develop expected proportions in each class for 2000 AVI{RR classification. Because the AVHRR NDVI captures phenologic differences across a large region; we used t he N RI ecological classification (MLRAs) to stratify' the region for all procedures. There are 36 MLRAs total, and we regrouped these into 18 MLRA groups based on similar phenology interpreted from the AVHRR imagery.

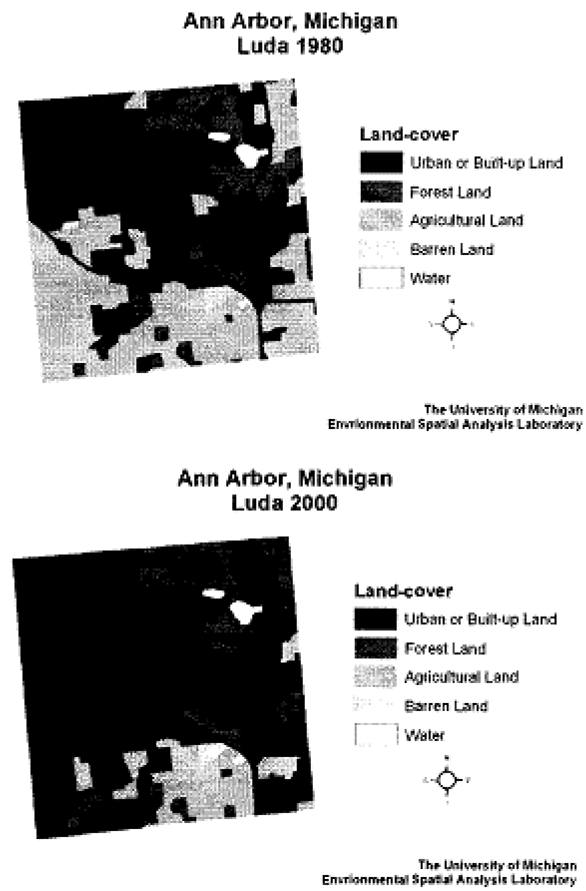

Figure 2. Land-use change from NAPP photo interpretation for a photo near Ann Arbor, Michigan, where a) shows land-use in 1980 (LUDA),
and b) shows land-use in 2000 ("simulated LUDA").

TABLE I
NRI LAND-COVER STATISTICS FOR 1980 AND 2000

Land-use Percentage, Ann Arbor, Michigan

Year	1980	2000	Change
Urban	52.26	76.18	23.92
Agriculture	35.81	10.82	-24.98
Forest	10.10	11.33	1.23
Non-Forest Wetland	0.00	0.00	0.00
Barren	0.91	0.75	-0.16
Water	0.92	0.92	0.00

These approaches were integrated by a classification procedure that combined ISODATA clustering methods with a multi-objective land allocation procedure (MOLA) ~8]. The 2000 AVHRR NDVI composite data were used with the PCI ISOCLUS procedure to produce initial clusters. ISOCLUS signatures were compared to the signatures obtained over the NAPP-derived land-cover, and iterated. The initially classified images were then imported into IDRISI to be used in the IDRISI MOLA decision support module. Rank images, one for each land-cover class/cluster, were constructed that ranked each ISOCLUS pixel in relation to its Mahalanobis distance from the land-cover cluster center. The predicted proportions of each land-cover/cluster from the NRI and LUDA statistical analyses were also used to direct the procedure. The expected number of pixels for each land-use forced the procedure to continue allocating the highest ranked available pixels to a land-use until the expected value is reached.

V. RESULTS

The procedure produced a final raster image with each pixel classified into a land-use class/cluster and each land-use class/cluster having the expected number of pixels determined from the NRI-LUDA relationship. Clusters were then aggregated to the desired output Level I land-cover categories. We used a sample of NAPP interpreted photos for validation. Results showed that the approaches we adopted in order to produce comparable classifications improved on AVHRR classifications alone. In this paper we are reporting our method, plus results of the 2000 classification from the MLRA that is comprised of suburbanizing Chicago and outlying agricultural areas. Results are shown in Figure 3.

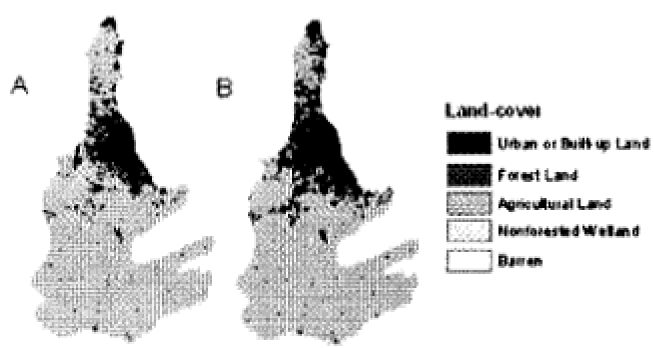

Fig. 3. Land-Cover in 1980 and 2000 in MLRA 110 covering a portion of northeast Illinois including Chicago

Additional results include a set of interpreted high-altitude photographs (n=78) for the North Central Region, including the northeast Illinois region. These form a second dataset of results comparing 1980 LUDA with 2000 "simulated LUDA". These pairs are also illustrative of the effect of spatial scale and class heterogeneity on land-cover class separability.

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REFERENCES

[1] U.S. Geological Survey. 2000 Conterminous AVHRR. CD-ROM, 2001.

[2] U.S. Geological Survey. Land use and land cover digital data from 1:250,000- and 1:100,000-scale maps--data users guide 4. Reston, Virginia: U.S. Geological Survey, 33pp., 1990.

[3] J.R. Anderson, E.E. Hardy, J.T. Roach, and R.E. Witmer, A Land Use and Land Cover Class qication System for Use with Remote Sensor Data. U.S. Geological Survey, Professional Paper 964, Reston, VA, 1976.

[4] S .M. Nu sser and J .J. Go ebel, "The National R esources Inventory: a long-term multi-resource monitoring programme," Environmental and Ecological Statistics, 4:181 -204, 1997.

[5] J.R. Jensen, Introductoiy Digital Image Processing: A Remote Sensing Perspective. 2nd Edition. Englewood Cliffs, NJ: Prentice Hall, 1996.

[6] J.T. Tou and R.C. Gonzalez. Pattern Recognition Principles. Addison-Wesley Publishing Co, 1974.

[7] J.R. Eastman, P.A.K. Kyem, J. Toledano, and W. Jin, "GIS and Decision Making," in Explorations in GIS Technology, Vol. 4. Geneva: UNITAR European Office, 1993.

[8] D. Hanink, and Allocation Models Geographical Systems,R. Cromley. "Coupling Land Use with Raster GIS," Journal of vol. 1, pp. 137-153, 1999.