Developing Land Cover Scenarios in Metropolitan and Non-Metropolitan Michigan, USA: A Stochastic Simulation Approach

Annual report for the period September 1, 2002 to August 31, 2003

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July 7, 2010

Abstract

We proposed to develop a stochastic LCLUC modeling approach and apply it to both metropolitan and non-metropolitan counties in Michigan. During the past year we have spent most of our effort compiling land-cover and land-use data bases. We have completed classification of six Landsat composites covering Southeastern Michigan, dated between 1984 and 1999. We have developed a statistical model to relate socioeconomic projections at the county level to the proportions of land cover types within the counties. During the coming year we will integrate these projections with our spatial simulation methods and develop a software tool for applying these methods to our data.

Keywords

Research Field Keywords: Land Use Modeling, Urbanization, Change Detection

Geographic Area Keywords: North America, Temperate Forest

Remote Sensing Keywords: Landsat, Aerial Photography

Methods/Scales Keywords: GIS, Stochastic Processes

NASA ESE Scientific Questions

The work we are doing attempts to address each of the following NASA ESE research questions:
a) What are the changes in land cover and/or land use (monitoring/mapping activities)? Our work addresses this question by developing rigorous descriptions of the spatial locations and patterns of change over three-year intervals between 1984 and 1999 and compares the patterns of change between metropolitan and non-metropolitan areas in the State of Michigan, USA.
b) What are the causes of LCLUC? The descriptions provide a means to evaluate where changes are more likely and develop specific hypotheses about the drivers of those changes. Our analysis of spatial and temporal variations in the models seeks to understand the roles of different driving variables on the spatial patterns of land cover change and landscape fragmentation.
c) What are the consequences of LCLUC? Our aim is to produce reasonable land cover scenarios. The reason for developing scenarios is to produce baseline land cover projections that can be used in models to evaluate the potential ecological impacts of those changes.

Proportion of Themes

Social Science: We estimate this to be about 50%. We draw on social science research, have a resource economist on the team, and engage social science principles in the interpretations.
Carbon: 25%, one of the consequences of change we seek to evaluate is on carbon storage
GOFC: 25%, our methods may be useful to the GOFC objectives and implementation.

Project Goals

1. *(Essentially completed this period) Develop a spatial database to represent land use change and land cover change in metro and non-metro areas of Michigan between 1984 and 2000*
   - The objective of generating a land cover change database in Southeastern Michigan is complete. The Northern Michigan database will be less extensive (probably 1 county) than originally planned and will be created later, given our budget reduction.
   - 30 Landsat TM scenes have been acquired, georeferenced, cloud-masked, haze-corrected, radiometrically calibrated, classified, and accuracy assessed. Independently assessed accuracies, based on air photo interpretation, range from 70 to 80 percent.
2. *(Essentially completed this period) Estimate the future shares for sample metro and non-metro counties in each of three major land use types--agriculture, forest, and development*
   - About 80% complete. David Wear has estimated statistical models that predict shares on the basis of demographic and economic projections and is producing estimates.
3. *Apply generalized additive models (GAM) to predict land cover change probabilities based on initial pattern of land cover and socioeconomic/biophysical predictor variables.*
   - We have demonstrated the method (Brown et al. 2002) and will be working in the coming year to automate the process of model estimation.
4. *Develop land cover simulations conditioned on the countywide estimates of future land cover amounts, estimated land cover transition probabilities, and spatial patterns of change.*
   - This goal will integrate the outcomes of 2 and 3 above in the form of a graphical user interface that we are planning to build in the coming year. It will integrate estimation of generalized additive models with stochastic simulation to generate land cover projections.
   - Application of the methodology to the Michigan study area is planned for 2004.
5. *Evaluate predictive ability of simulation approach and adequacy of uncertainty estimates.*
   - Amy Burnicki (PhD student) was awarded a NASA ESS Fellowship to examine the error patterns of land cover change and to evaluate how these propagate in change modeling.

Progress of the Study

Co-PI Pierre Goovaerts resigned the University of Michigan in October 2002 and is now working with BioMedware, Inc., a local spatial analysis software development company. His PhD student who had been working on the project is no longer working with Pierre or on the project. The implication of this change is that our progress in implementing the algorithms has been slowed somewhat. We have been putting our effort into producing the multi-temporal land-cover data and algorithm implementation will be the focus of the next phase of the project. We have implemented a contract with Dr. Goovaerts so that algorithm development can continue.

The land-cover classifications, to six classes for six different dates, will be complete by the end of the reporting period (August 2003) for Southeastern Michigan (a 10 county area). We will scale back our analysis and comparison with Northern Michigan, likely focusing on one county only, instead of four. The statistical model for estimating the land cover proportions in the counties on the basis of demographic and economic projections as been developed, by David Wear at the USDA Forest Service. The subcontract has been executed and the next step here for Wear to make estimations of future (2020) land cover proportions within the target counties. He will also provide error variances for these proportions, which can be used in the propagation of uncertainty through the simulation process.

In addition to the objectives and timeline outlined on the previous page, we will pursue several topics that are important to implementation of the simulation methodology during the next project phase. First, we will work on developing a graphical interface for the simulation approach in VisualBasic or VisualC++. Second, we have identified error propagation as an important topic for further investigation. Amy Burnicki, PhD student working under the direction of the PI, has acquired funding under NASA's Earth System Science Fellowship program to develop methods for accuracy assessment of an image time series. She will evaluate the patterns of spatial, temporal, and thematic dependence of error in both land cover classifications and change detection. Her results should have broader impact on the LCLUC community, as researchers seek to grapple with accuracy issues in multi-temporal image data.

Our most significant results to date are:

- New Findings – We have used data compiled from the Censuses of Population and Agriculture to report on dominant patterns of land use change within the US at the county level. A paper, in review at *Ecological Applications*, reports on the striking increase (500%) in the area exurban development across the US. We have also demonstrated the degree to which forest regrowth in the Upper Midwest is occurring on all land use types in a new paper to appear in *Landscape Ecology*.
- New Potential – We have outlined the various approaches to land use and land cover modeling in a new chapter for inclusion in the book on Land Change Science. This book highlights the differences between the approach this project is taking to land cover projection and a more mechanistically more realistic approach involving agent-based modeling. Because Brown is also leading a project to develop agent-based models of land use and cover change, we expect to be able to make some useful comparisons of approaches to land use change modeling on the basis of these two projects.
- New Products - We will have new data and software, but these are not yet complete.

Conclusion

We are making reasonable progress towards the objectives of our project. The approach and methods of the project are basically intact, though some minor modifications have been made and noted in this and the previous report. We anticipate producing projections of land cover patterns that reproduce spatial patterns of change better than can be produced by other state-of-the-art methods. In addition to the projects and empirical analysis comparing patterns of change in Michigan, we expect the methods and software produced will be useful to the broader community. The project is having a significant educational impact. We have engaged a PhD student (Amy C. Burnicki, Natural Resources and Environment) who is working exclusively on this project, has been learning much about the remote sensing and land cover change science, and has now received a fellowship to continue her work on error propagation in land cover change analysis and modeling. She will complete a dissertation on work related to the project. Further we have employed about 4 undergraduate students to work on the project as independent research learning opportunities.

Publications

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