2001-2002 Progress Report
to the NASA Land Use Land Cover Change Program

The Spatial and Temporal Dimensions of Contemporary U.S. Land Cover and Land Use Change and Implications for Carbon Dynamics

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Abstract

We are studying the spatial and temporal dimensions of contemporary U.S. land use and land cover change and their consequences on local, regional, and national carbon dynamics. Our research objectives are to (1) determine how the rates and causes of conterminous U.S. land use and land cover change vary (a) locally and regionally, (b) temporally, and (c) sectorally (e.g., type of land cover conversion), and (2) assess how changes in conterminous U.S. land cover and land use affect local, regional, and national carbon fluxes. To address the first objective, a low cost sampling strategy based on ecoregions was developed and is being used to localize estimates of the rates of land use and land cover change. We have selected a probability sample of 20 km by 20 km blocks for each of 84 conterminous U.S. ecoregions and have begun analyzing land cover change based on five dates of Landsat MSS, TM, and ETM data (nominally 1973, 1980, 1986, 1992, and 2000). Our goal is to identify +/- 1% change in cover within each ecoregion, at an 85% confidence level. First year results show that the nature of land cover change varies considerably from place to place. While the driving forces of change also vary from place to place, we are finding that similar driving forces may have different implications in different ecoregions.

To meet our second objective, we are using the CENTURY ecosystem model to simulate carbon consequences at three scales (for each of the 20 by 20 km sampled blocks, for each of the 84 corresponding ecoregions, and for a national summary). Because of concerns about the complex model parameterization requirements, we are also investigating the potential for using simpler booking models for carbon accounting associated with land cover change. Following an analysis of the two modeling approaches, we will undertake carbon assessments for the ecoregions with completed land cover change databases. We expect that the results will provide a clearer understanding of the variability of land use and land cover change across the U.S. and the corresponding consequences of that change on carbon stocks and fluxes.

Keywords

Research Fields	Land Cover Change, carbon dynamics
Geographic Area/Biome:	United States
Remote Sensing:	Landsat
Methods/Scales:	Change Detection

Scientific Scope of Research

Part 1. Earth Science Enterprise Scientific Questions

Our research addresses several of the interdisciplinary science questions posed by the Land Use Land Cover Change Program of the NASA ESE, including:

a) What are the changes in land use/land cover? To address this question, we use a stratified sampling approach to estimate changing land cover within ecoregions using five dates of Landsat images spanning 1973 to 2000.

b) What are the causes of LCLUC? Associated with our measurement of the rates of change, we are using field observation, socio-economic data analysis, and literature reviews to identify the major driving forces of change for each ecoregion.

c) What are the consequences of LCLUC? We assess carbon dynamics within each ecoregion using the CENTURY model, our estimates of land use change derived from satellite images, and other carbon-relevant parameter files.

Part 2. Proportion of Social Science

We estimate that the driving forces element of our research, which has a strong social science basis, comprises approximately 25 percent of our work.

Part 3. Theme Proportions

Carbon (50%); water (0%); nutrients (0%); GOFC (0%); change detection (50%); other (0%)

Goals

Our life-of-project goal is to complete a national assessment of the rates and causes of land cover change since 1972 and analyze the corresponding consequences of that change on local, regional, and national carbon budget. Project objectives and timelines are:

Completed Objectives (2000-2001)	**Start**	**Finish**
Tested and refined sampling strategy and change detection methods for five pilot regions	October 2000	November 2000
Developed framework for documenting regional driving forces of land cover change	January 2000	December 2000
Initiated the mapping of Eastern U.S. ecoregions	January 2001	December 2001

Investigation alternative approaches for carbon accounting	December 2000	February 2002
Assembled databases of CENTURY parameters for pilot areas (e.g., atmospheric N deposition, historical fertilization data, biomass and net primary productivity measurements, and crop rotation change)	June 2000	March 2002
Complete the documentation of Eastern U.S. rates and driving forces of land cover change analysis	January 2001	December 2002
Upcoming Objectives (2002-2003)		
Complete the analysis of carbon dynamics for Eastern U.S. Ecoregions	March 2002	December 2002
Initiate the analysis of the rates and driving forces of change in selected central and western U.S. ecoregions	January 2003	December 2003
Remaining Objectives		
Complete analysis of land cover change in remaining ecoregions	January 2003	December 2003
Complete analysis of carbon dynamics in remaining ecoregions	January 2003	September 2004

Accomplishments

We had three major accomplishments during the past year.

- We accelerated our analysis of the rates and causes of ecoregion land cover change and doubled the number of ecoregions analyzed. We have completed measuring change and determining corresponding driving forces for two-thirds of the eastern United States ecoregions (Mid-Atlantic Coastal Plain, Atlantic Coast Pine Barrens, Southeastern Plains, Piedmont, Northern Piedmont, North Central Appalachia, Blue Ridge, Ridge and Valley, and Central Appalachia) and two western ecoregions (Madrean Archipelago and Montana Valleys and Foothill Prairies). The analysis includes the interpretation of all five dates of Landsat imagery (1973, 1980, 1986, 1992, and 2000).

- We have also completed the first ecosystem carbon assessment – Southeastern Plains. To reach this point, we consulted with several carbon modelers and developed an improved parameterization strategy.

- We improved our sampling design and are now consistently able to produce estimates of land use and land cover change that are within our prescribed margin of error (+/- one percent). This was accomplished by changing from 20 km by 20 km to 10 km by 10 km sample blocks.

In addition, the following papers were accepted or submitted for publication:

Loveland, T.R., T.L. Sohl, S.V. Stehman, A.L. Gallant, K.L. Sayler, and D.E. Napton, 2002. A strategy for estimating the rates of recent United States land cover changes. Photogrammetric Engineering and Remote Sensing (in press).

Griffith, J., S. Stehman, T. Sohl, and T. Loveland, 2002. Detecting trends in landscape pattern metrics over a 20-year period using a sampling-based monitoring program. International Journal of Remote Sensing (in press).

Liu, S., T.R. Loveland and R. Clement, 2002. Contemporary carbon dynamics in terrestrial ecosystems in the Southeastern Plains of the United States. Journal of Geophysical Research (submitted).

Discussion of Gaps

Previously, we grappled with issues associated with our carbon modeling strategy. The carbon modeling strategy has been challenged in LCLUC peer reviews with concerns raised about the complexity and appropriateness of the CENTURY model. We have consulted with several carbon modeling experts, including Richard Houghton of the Woods Hole Research Center and Tagir Gilmanov of South Dakota State University, and have concluded that our modeling approach is generally sound. Areas where additional research is needed include (a) establishing baseline conditions for model initialization, and (b) dealing with the fate of carbon. We are addressing these issues in the context of each ecoregion carbon assessment.

Modifications to Original Approach

Our estimates of change are based on the use of probability sampling using ecoregion-specific random selection of 20 km by 20 km sampling blocks to estimate +/- one percent of the actual change in each ecoregion with a confidence level of 0.85. Results from the previous year showed that we could not consistently meet the sampling objectives. This was especially true with ecoregions experiencing very high rates of change. To remedy this issue, we tested several strategies (i.e., changing sample block sizes, use of stratification, etc.). We concluded that reducing our sample block size from 20 km to 10 km will allow us to consistently meet our goal of identifying +/- one percent of the actual change.

Progress and Significant Results

<u>Part 1. New Findings</u>

Results from the completed ecoregions provide compelling evidence that the characteristics of land cover change vary considerably from one region to the next. In essence, there is no single story of change in the conterminous, but instead change varies

in time and space (figure 1). Generalizations that can be made are: (1) the highest rates of change are associated with southern and plains ecoregions where short-rotation cyclic forest harvesting and replanting is taking place; (2) the northern ecoregions that include the eastern seaboard megalopolis cities are still experiencing significant urbanization; (3) the period with most significant change was from 1992 to 2000; and (4) when considering the eastern ecoregions as a whole, forest conversions (planting and harvesting cycles) represent the major land cover change (figure 2).

Our results show that based on the ecoregions we have analyzed, there is an overall decrease in forest cover. This is occurring at a time in which industrial forestry activities are increasing. However, the balance between planting and harvesting is slightly tilted toward a reduction in forested area. In the Mid-Atlantic Coastal Plain, Southeastern Plains, Piedmont, and southern end of the Ridge and Valley ecoregion, we have observed planting to harvesting cycles of approximately 20 years. In our analysis of carbon dynamics in the Southeastern Plains ecoregion, we estimate that the ecoregion is a strong sink with approximately 0.045 to 0.078 giga tons C/year (+/- two standard errors) sequestered annually (figure 3). The implications of short-cycle rotations on forest sustainability considering the loss of soil nutrients and organic matter deserves further study.

Part 2. New Potential

Nothing to report

Part 3. New Products

As ecoregions are completed, we will make all data, including Landsat images, land cover interpretations, and carbon assessments, available via the project web site.

Conclusions

- We have resolved all major methodological issues related to land cover change estimation and carbon modeling.

- We are making significant progress in documenting the 1973-2000 ecoregion rates and causes of change, and am in the process of undertaking the carbon assessments for the completed manuscripts.

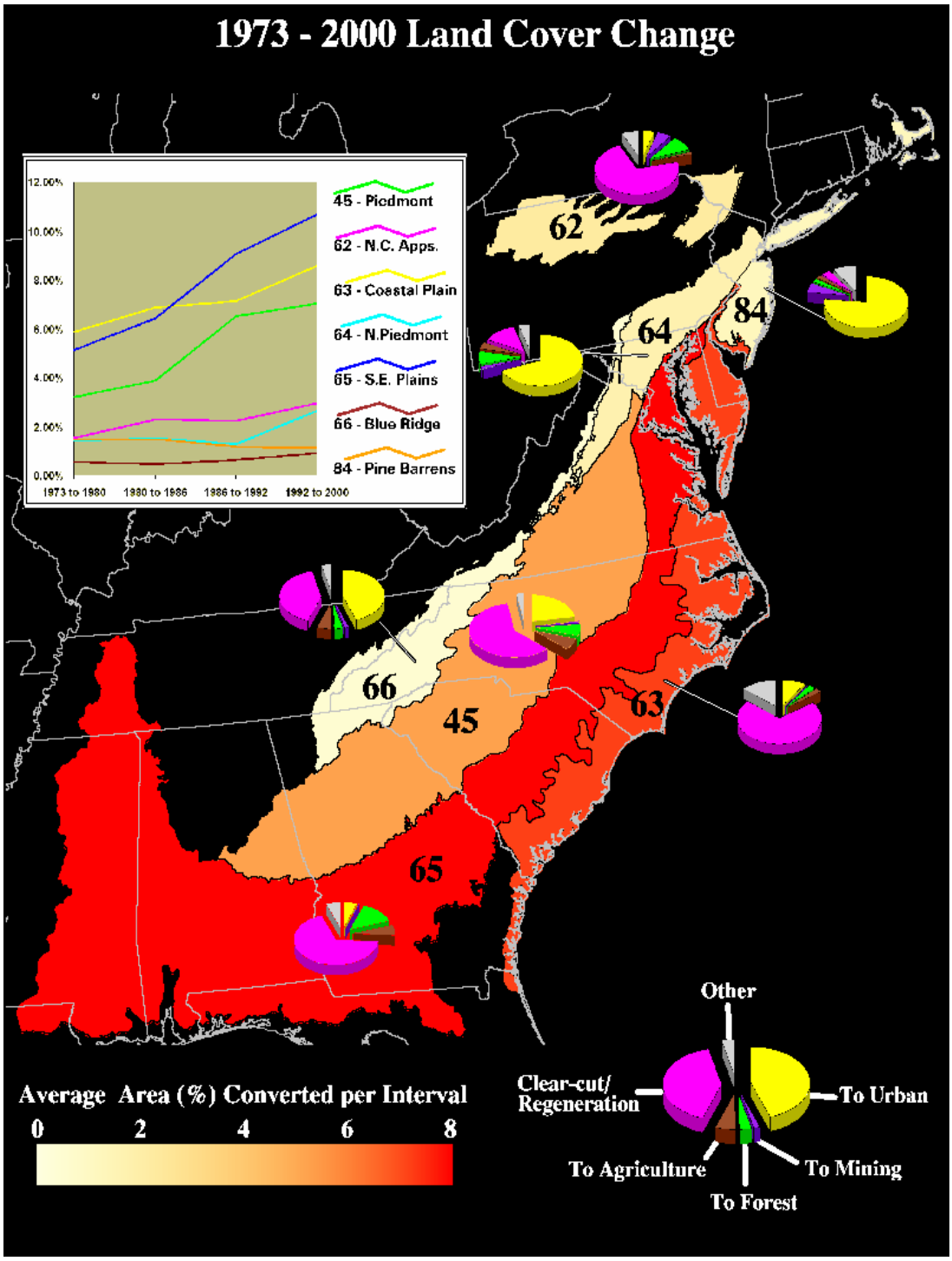

Figure 1. Rates of change and common transitions for selected eastern United States ecoregions.

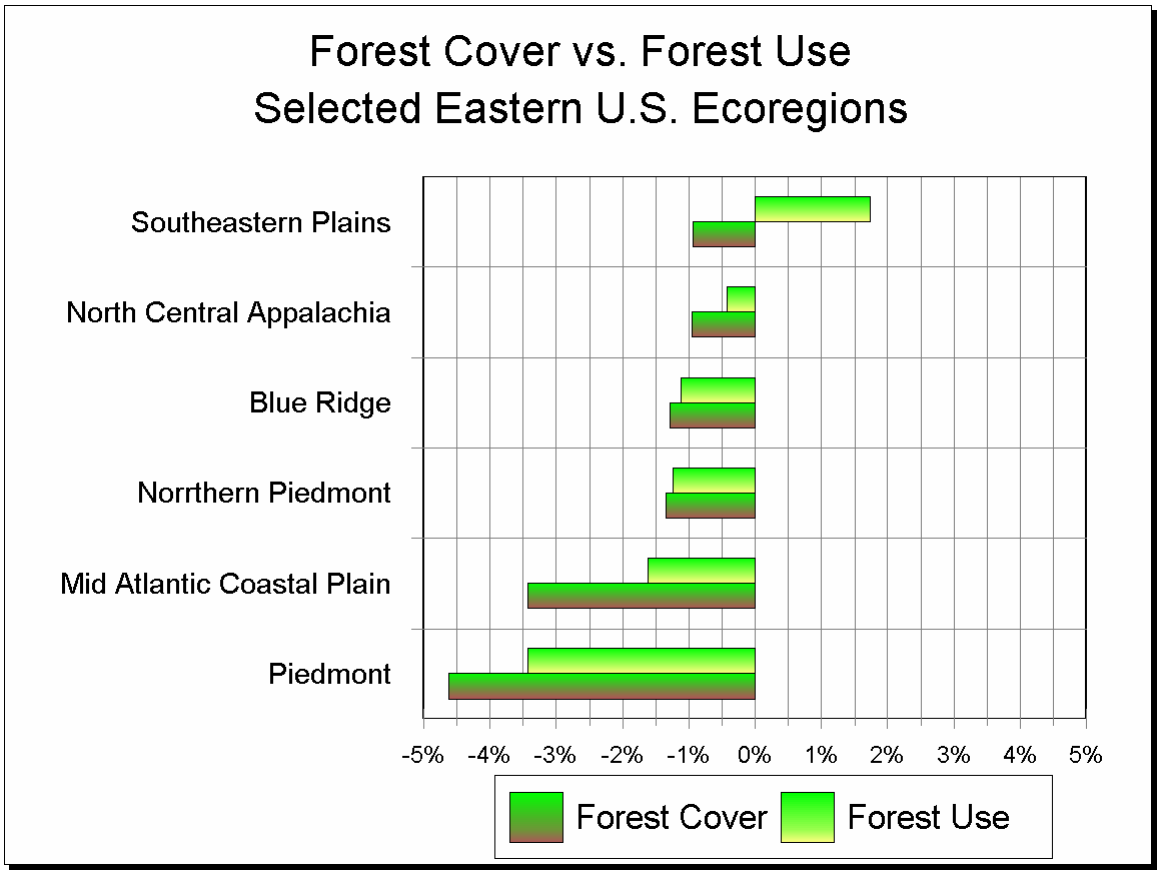

Figure 2. All eastern United States ecoregions we have studied show a decrease in forest cover. If we consider forest land use (forest cover and forest clearcuts are both forest land use), the Southeastern Plains can be singled out as having an expanded forest base.

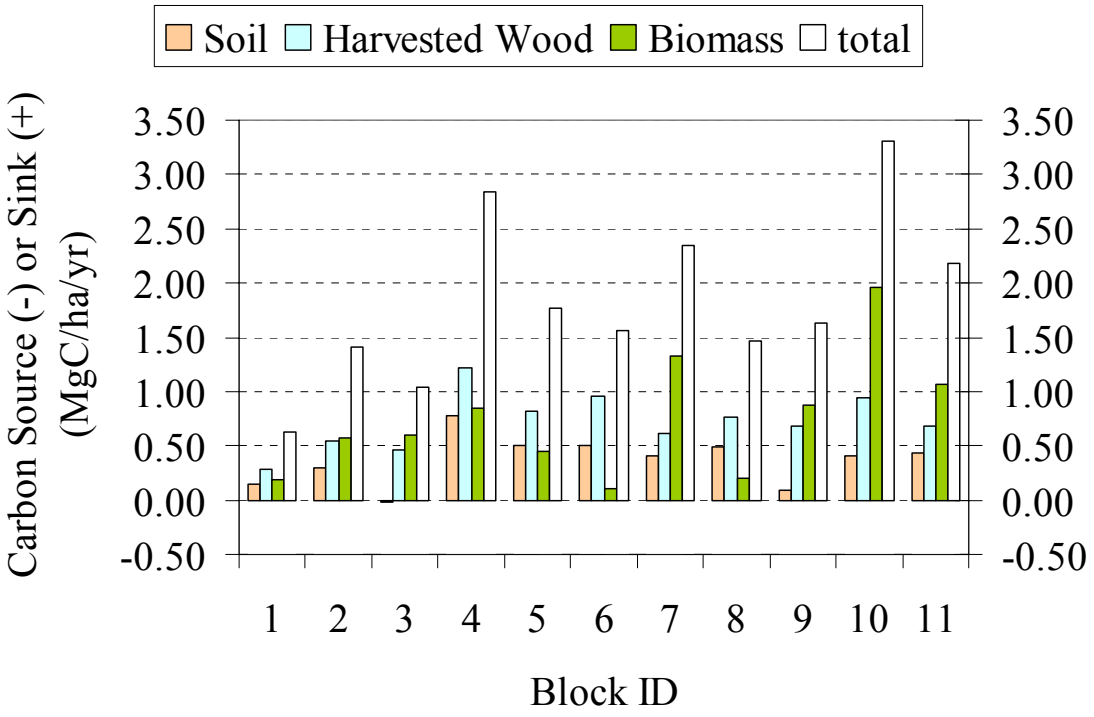

Figure 3. Carbon sources and sinks for sample blocks in Southeastern Plains ecoregion. Overall, the ecoregion is a strong sink, with 0.045 to 0.078 giga tons C/yr (+/- two standard errors) sequestered.