2000-2001 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:

To develop the capability to perform repeated global inventories of land-use and land-cover from space. Specifically, we are testing a strategy for using a spatial framework,

sampling, and moderate resolution satellite data for quantifying land cover change at relatively local levels. Because of the efficiencies of sampling, and the scalable characteristics of the ecoregions spatial framework, out strategy – if proven to provide relevant information on change, can be expanded to the continent, hemisphere, or globe.

Further the understanding of the consequences of land-use and land-cover changes on environmental goods and services, the carbon and water cycles and the management of natural resources. Our research focuses directly on the implications of land cover changes on carbon dynamics.

To improve understanding of human interaction with the environment, and thus provide a scientific foundation for sustainability, vulnerability and resilience of land systems and their use. An element of our work is to determine the driving forces of change operating at the regional level. As a result, we are developing a framework for linking the rates and causes and change. This research should provide a foundation for future research on predicting the vulnerability of external forces on localities and regions.

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
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 2001
Initiated investigation of the use of bookkeeping models for carbon accounting	December 2000	May 2001
Upcoming Objectives (2001-2002)		
Complete the documentation of Eastern U.S. rates and driving forces of land cover change analysis	January 2001	December 2001
Initiate the analysis of the rates and driving forces of change in the Southwest and West U.S. ecoregions	January 2001	December 2002
Finalize carbon modeling strategy and test procedures in pilot areas	May 2001	December 2001

Initiate an assessment of the implications of Eastern U.S. land cover change on carbon dynamics	January 2002	December 2002
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

Discussion of Gaps

The primary gap in our investigation during the past year has involved the progress made in developing the initial ecoregions carbon assessments. Progress has been slower than expected due to the complexity of the CENTURY model's parameterization requirements. As a result, we initiated two parallel activities:

- We continued research on sources of CENTURY parameters and model enhancements with a specific focus on Eastern U.S. sites.

- We initiated an investigation of alternative modeling strategies that would be less data demanding but would still permit an understanding of the implications of local to regional land cover change on carbon dynamics.

Approaches to Problems

In addition to the carbon modeling issues previously described, our early testing of the sampling framework and change detection methods required solving several problems. The most important problems were:

- Sampling issues: Ecoregions with very high rates of change have change estimates with wider variances than expected. In order to reduce the variance of the estimates of land cover in those ecoregions where the estimates of change exceed our +/- 1 percent rule, we are using sub-regional stratification techniques developed by Professor Steve Stehman (SUNY-ESF).

- Change detection issues: Early tests of automated change vector analysis techniques led to significant use of on-screen interpretation techniques so that we can accurately identify the specific land cover types for each date.

- Landsat 7 cloud coverage: Because of persistent cloud coverage over several eastern sample sites, we do not have the 2000 satellite data needed to complete the final dates of interpretation for approximately 10 percent of the eastern ecoregions sample sites. The problem is most significant over Appalachian sites. Our solution to the problem is to wait for 2001 coverage to be obtained.

Progress and Significant Results

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

Results from the pilot 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.

For example, the overall area changed for the five ecoregions during the 1973 to 1992 period is as follows:

- North Central Appalachia: 4.1%
- Northern Piedmont: 3.0%
- Southeastern Plains: 13.4%
- Madrean Archipelago: 1.7%
- Montana Valleys and Foothill Prairies: 5.3%

The rates of change in some ecoregions have been steady, and in others, there have been pulses of more rapid change. The following table shows the periodic rates of change and margins of error for those rates:

Ecoregion	North Central Appalachia	Northern Piedmont	South-eastern Plains	Madrean Archipelago	Montana Valley/ Foothills
1973-1980	**1.4%** +/- 0.8%	**1.3%** +/- 0.6%	**4.7%** +/- 1.1%	**0.5%** +/- 0.3%	**1.5%** +/- 0.7%
1980-1986	**2.3%** +/- 1.4%	**1.3%** +/- 0.4%	**6.2%** +/- 1.8%	**0.7%** +/- 0.6%	**1.8%** +/- 0.9%
1986-1992	**1.8%** +/- 0.8%	**1.0%** +/- 0.4%	**8.2%** +/- 2.2%	**0.6%** +/- 0.4%	**2.8%** +/- 2.1%

The specific land transformations occurring are generally uniform within ecoregions but different between regions, as noted in the following table:

Ecoregion	1973 to 1980		1980 to 1986		1986 to 1992	
	Area (km^2)	Conversion	Area (km^2)	Conversion	Area (km^2)	Conversion
North Central Appalachia	192	Forest to Disturbed	257	Disturbed to Forest	223	Forest to Disturbed
Northern Piedmont	177	Agriculture to Urban	174	Agriculture to Urban	111	Agriculture to Urban
Southeastern Plains	6278	Forest to Disturbed	7484	Forest to Disturbed	10,490	Forest to Disturbed
Madrean Archipelago	66	Agriculture to Shrub	207	Agriculture to Shrub	86	Agriculture to Shrub
Montana Valley/ Foothills	487	Grass to Agriculture	617	Grass to Agriculture	1198	Agriculture to Grass

Part 2. New Potential

Carbon Model Enhancement: Many studies show that rooting properties of plants have significant impacts on carbon exchange between soil and the atmosphere. Few models have the capability of simulating the change of rooting characteristics on soil carbon dynamics along with land cover and land use change. A new multi-soil-layer model

based on CENTURY was developed and will be tested to assess the influences of land cover change on deep soil carbon dynamics (for example, converting crop lands to forests increases carbon sequestration in deep soil layers because of the difference in rooting depth).

Data-Model linkage. To effectively deploy ecosystem model to the 20x20 km sampling blocks and to incorporate the land cover and land use dynamics into the modeling process, it is necessary to develop a dynamic linkage between the model and the various databases (including land cover and land use, climate and soils). The data-model linkage is underway.

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

- During the first year, we finalized the methodology for estimating land cover change and make substantial progress in applying the methods to Eastern U.S. ecoregions.

- The complexity of carbon modeling, especially parameterization issues, have caused us to explore other options, while still pursuing the use of the CENTURY model for assessing carbon dynamics.

- Several manuscripts are in preparation and will be submitted to journals within a month:

    A Strategy for Estimating the Rates and Causes of Recent United States Land Cover Changes – for submission to Environmental Management

    An Analysis of Geographic Framework for Monitoring Land Cover Change: Options, Recommendations, and Outstanding Issues – for submission to Professional Geographer