Progress Report for NASA LCLUC Program

# Land Use, Carbon, and Water in the Southeastern Uplands

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## Background

Land cover and land use (LULC) change is an important determinant of changes in water cycles and carbon storage. While land cover and land use have been much studied, there remains considerable uncertainty when quantifying the extent, causes, and consequences of past, current and future land cover and land use change. Three main sources of uncertainty are:

1) A lack of past land use data, and the difficulty of producing detailed, current, accurate maps of land use change over large area areas and in a timely fashion,
2) Few direct measurements of water cycling for many important land use types in many regions, hindering our ability to estimate the net effect of land use change on water quality, quantity, and C budgets.
3) Uncertainty about the site-specific history and future of LULC change. We currently don't possess a quantitative, site-specific record of LULC longer then 30 years old for most of the World, and are unsure about the best methods to predict future LULC.

LCLU has primary control over freshwater quality in much of the world, including the southern Appalachian Mountains of North America. Farming, logging, and construction all may cause substantial sediment input into water bodies, one of the primary causes of degraded water quality in North America, and alters light and temperature in the stream environment. Sediment alters channel morphology, water flow, and substrate. Fertilizers, pesticides, and other chemicals find their way into waterways via overland and subsurface flow. By altering inputs, upland land use decisions substantially determine the structure and function of aquatic ecosystems. Because sediments and near-stream morphology are affected in the long term (decades to centuries) by upland erosion and sediment deposition, water quality and the stream hydrograph (the timing of quantity) are dependent on both present and past landcover.

LULC also has primary control over C pools in the southern Appalachians. The main competing landuses – forestry, agriculture, and urban/industrial uses, have substantially different C pools on a per-area basis. Further, these land uses are not distributed evenly across the landscape, and the relative impacts on C storage is highly dependent on location. Regional estimates of LULC change, based on county-wide averages, appear inadequate because impact is concentrated in productive near-stream areas. We also lack the ability to predict the trajectory and location of future land use. Previous work has shown current LULC, the transportation network, and terrain position are the strongest predictors of future LULC. However our knowledge of past and current land use and transportation networks are poor. Our ignorance of present and past LULC hinders our ability to predict future land use.

We proposed that estimates of water quality and quantity in the southern Appalachians may be improved primarily through three activities: 1) the improvement of terrain representation, with an important threshold at a resolution near 5 meters, 2) the inclusion of accurate, timely landcover data, developed through rapid classification techniques, and 3) the development of forest-based, surface erosion and hydrology models. Further, we hypothesize that these timely and accurate LULC information will substantially improve our estimates of carbon pools in the southern Appalachians, through the specific combination of land use change and terrain-specific differences in C accumulation and storage. Finally, we hypothesized that improved resolution and a finer temporal time-scale in both past and present LULC data will substantially improve the accuracy of developed LULC change prediction methods.

## Research Questions

NASA ESE scientific questions that are addressed:

- What are the causes and what are the consequences of LULC?
- Where are land use and land cover changing, and what is their extent over long time scales?
- What are the projected changes of LCLUC and their potential impacts?

Themes covered in this project: Water, 40%, Mapping/monitoring landcover change, particularly forests (40%), Carbon (10%), drivers of landuse change, including social/economic variables (10%).

## Research Goals

The primary goals of the proposed research are to:

1) Map accurate past and present LULC for study watersheds in the southern Appalachians, develop methods for rapid, accurate, large-area classification of forest/non-forest land use in southeastern U.S. upland ecosystems, and apply these methods to quantify land use change in representative watersheds in the Southeast,
2) Quantify the impacts of past and present land use on water quantity and quality in southeastern uplands, and
3) Analyze factors driving human land use choice by developing quantitative models of these choices that incorporate socio-economic data; then use these models to estimate past and future land use changes and their impacts on C and water cycles.

Work for this period has been focused on goals 1 and 2, with substantial activity in these areas, and the initiation of analyses for goal 3. We have defined a set of study watersheds and the larger study region in which to conduct our research. We have established sampling protocols for water quality and quantity, initiated water quality sampling, and obtained relevant historical land use information and contemporary data for these studies. We have collected and registered satellite data from a number of sources, and begun developing models and data with which to pursue our analyes.

Goal 1.

We have collected past landcover data from the primary archive sources for our study region. These include data from historical maps (the Love Survey, circa 1840, the USGS Ashe/Ayers inventory, 1904), historical aerial photographs (1950, 1970, 1984), MSS (1970, 1980, 1990), Landsat (1980's, 1990's, 2000), and SPOT (2003). Much of these data have been interpreted/classified to landcover classes in a common coordinate system, a process which is ongoing. We have compiled detailed delineation of LULC and land use transitions (Figure 1).

We have also used these data sets, particularly the Landsat TM and ETM+ data for continued development of rapid classification methods. These methods, based on a hierarchical classification scheme, entail a database of seed points for each class and a type-definition including the relative spectral variation, type phonologies, and characteristic response for specific spectral indices and ratios. We have further developed a regional database of "typic" sites. Automated change detection within these sites has proven to be quite complicated. Classification accuracies appears to be significantly affected by small shifts in seed pixel landuse, thus highly

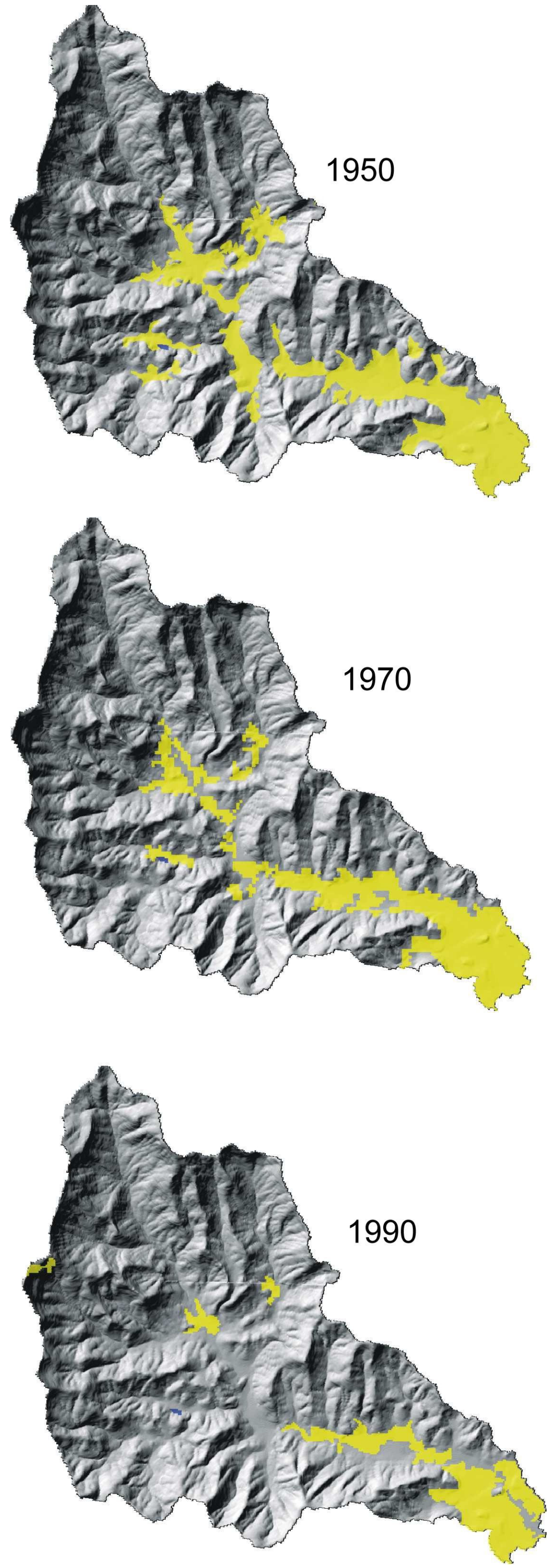


Figure 1: Landcover transition in one of the study watersheds used in this study. Agriculture (yellow) recedes down valley.

accurate, automated identification of land use category shifts in the type trainers appears to be key. We have expanded the set of training pixels, and are testing various automated winnowing strategies. These data are now being integrated into a rapid classifier for the southern Appalachian region.

Goal 2
Questions:

a. What are the quantitative impacts of LULC on water quality in the southern Appalachians? Specifically, how are turbidity, total suspended solids, nitrogen, and cations differ among LULC, and how does LULC change affect these variables?
b. How are stream hydrographs of small watersheds changed with LULC?
c. Are process-based models such as WEPP an improvement over lumped-parameter approaches, like those embodied in the MULSE and its derivatives?
d. How does terrain resolution (DEM grain) affect predictive accuracy?

We have identified study watersheds based on size, current LULC (from contemporary imagery), past LULC (from previously-described historical images and maps), and expected future LULC. Automated flow proportional and time samplers have been deployed that provide information on selected water quality parameters (Figure 2). Cross section surveys and stage level samplers have been installed to provide flow rates. We have installed samplers on a minimally impaired forest site (Dryman Fork), a previously harvested (circa 1920) forest site (Addie Branch), a site experiencing low residential development pressure (Reed Mill Site), and the pasture site (Sutton Branch). We have installed a fifth sampler on a fully developed site (Crawford Branch). In addition, the Addie Branch and Reed Mill sites have already been in operation for almost

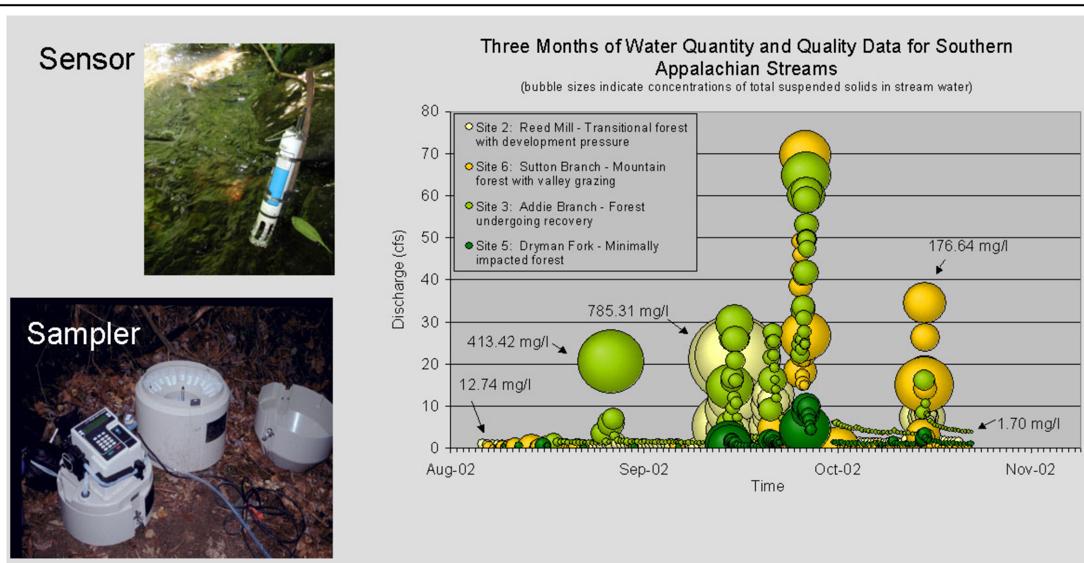


Figure 2: Water samplers and measurements at study watersheds. Peak flows are higher and sediment loads during stormflow substantially increase with increasing non-forest landuse.

two full years, providing us with additional data for model calibration and validation. We have already begun analyses of these data to identify hydrodynamic trends in sediment yield with land use condition.

A process-based model (WEPP) and a lumped-parameter model, WCS, based on the MSLE, were parameterized, modified, and run for a set of study watersheds. Predicted sediment yield, from contemporary LULC data and DEM data, were compared to measured sediment yield (Figure 3). Results indicate a strong dependence of grid size on predictive ability. The results of a model run are shown. Predictions appear sensitive to DEM resolution, the spatial resolution of landcover, and relatively insensitive to soil properties.

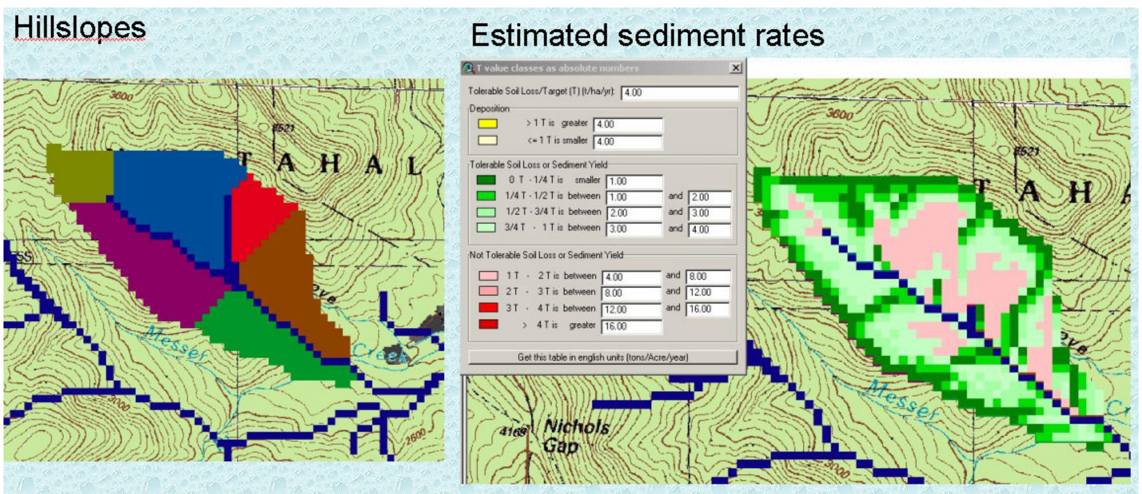


Figure 3: Hillslope facets and predicted sedimentation rates for a study watershed when using the WEPP model. WEPP was developed for agricultural watersheds, and requires substantial modification for application in mixed forest/agricultural landscapes. Current modeled rates appear high, based on measurements, compared to measured sediment yields.

## Publications

Riedel, Mark S. and James M. Vose. 2002. The dynamic nature of sediment and organic constituents in TSS. In Proc. National Monitoring Conference 2002. United States Advisory Committee on Water Information - National Water Quality Monitoring Council. May 21 – 23, Madison, WI.

## Presentations

Riedel, Mark S. and James M. Vose. 2002. Forest road erosion, sediment transport and model validation in the Southern Appalachians. In Proc. Second Interagency Hydrologic Modeling Conference, United States Advisory Committee on Water Information – Subcommittee on Hydrology, Las Vegas, NV, July 28th – August 1st, 2002.

Riedel, Mark S., P.V. Bolstad, and James M. Vose. 2003. Landuse and sediment in Southern Appalachian Streams. Accepted poster, Chapman Conference on Ecosystem Interaction with Landuse Change, Santa Fe, New Mexico, June 14-18.

P.V. Bolstad and T. Gragson, 2003. Estimating the ecological footprint of human land use in the southern Blue Ridge from pre-Euroamerican times to the present. Accepted poster, Chapman Conference on Ecosystem Interaction with Landuse Change, Santa Fe, New Mexico, June 14-18.