Land Use and Water in the Southeastern Uplands of North America

Introduction

Land cover and land use change is an important determinant of global and regional water cycles. 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, that hinders our ability to estimate the net effect of land use change on global and regional water cycles, and

3) Poorly developed tools for predicting future land use change, particularly those that integrate social, economic, and biophysical variables.

We propose research that addresses these three sources of uncertainty in the southeastern uplands of North America, and thereby substantially reducing uncertainty in our knowledge of land use and water cycles in the region.

Research Objectives

The primary goals of the research are to:

1) Further 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 cover and land use change in representative watersheds in the Southeast,

2) Quantify the impacts of past and present land cover and land use on water quantity and quality in southeastern uplands, and

3) Analyze factors driving human land cover and land use choice and develop quantitative socio-economic models of these choices; then use these models to estimate past and future land use changes and their impacts on C and water cycles.

Project Team

The research team consists of a collaborative group from three institutions:

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Additional team members will include a Post-Doctoral associate at both the Coweeta Hydrologic Lab and USFS Southern Station, and graduate and undergraduate students at the University of Minnesota.

Facilities

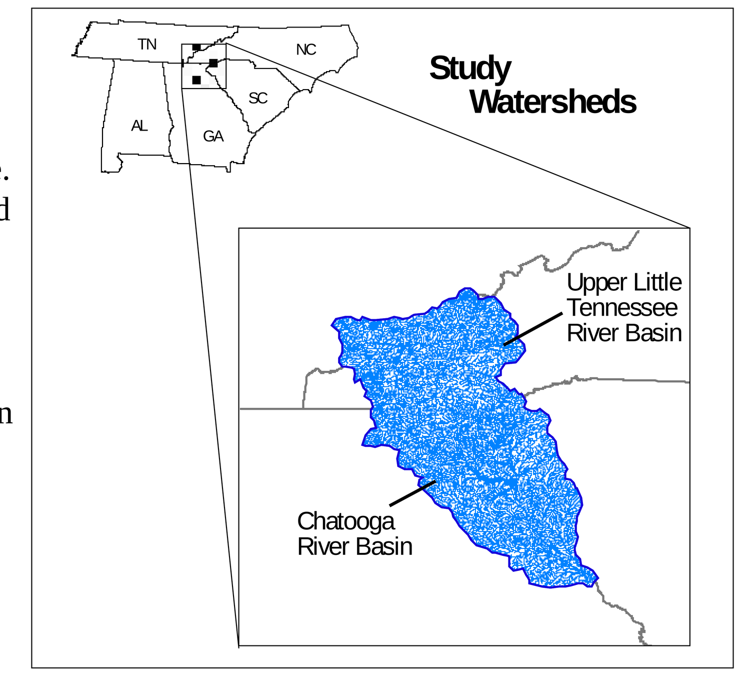
Programming, image processing, and data analysis largely take place in the Remote Sensing and Geospatial Analysis Lab at the University of Minnesota (http://rsl.gis.umn.edu), using resources of the Earth Resources Spatial Analysis Center (ERSAC, http://www.ersac.umn.edu). ERSAC houses a complete suite of commercial and customized research software and hardware for remote sensing and image processing analysis.

Water quality and quantity research will be centered on the Coweeta Hydrologic Lab (http://coweeta.ecology.uga.edu) . The Coweeta Lab is within a half-day drive of all potential sampling locations and serves as the logistical center for all field data collection and sampling. Lab space and equipment, storage, chemical and physical analytical facilities, transportation, housing and computing and data analysis support are all available at the lab.

Study Area

Research will be focused on two large watersheds in parts of Georgia, North Carolina, South Carolina, and Tennessee. These watersheds represent a range of current and past land uses and span from the Smoky Mountains to portions of Metropolitan Atlanta, one of the world's fastest-growing urban areas.

The two study watersheds encompass over 180,000 acres in parts of 14 counties. The watersheds contain a broad range of land cover types, population densities, and disturbance histories, ranging from forest invasion of recently abandoned farmlands to established urban/suburban developments.



The study region contains the Coweeta Hydrologic lab, a leading center for watershed research since the 1930s. Coweeta is also the center for other large scale research projects, beginning with the International Biosphere-Geosphere Program of the 1960s, and continuing through the Coweeta NSF-LTER research today.

Data

A rich set of supporting data are available, including a near thirty-year satellite data record, historical aerial photographs at approximately decadal intervals back to 1950, historical maps of past early land cover and land use, physical and biotic inventories, and comprehensive demographic data. Much of these data have been assembled for a portion of the study area, including land cover and land use in the 1840s, 1950s, 1970s, and 1990s.

We will measure current and past land cover and land use from 1950 to 2000, based on aerial photographic and satellite imagery. Researchers and students at the University of Minnesota are currently processing historic aerial photographs and developing land cover and land use data. Satellite imagery will be classified using methods defined as part of this project. Two field campaigns are planned for collecting data to register images and ground truth for both training and accuracy assessment.

Water quantity and water quality data are continually collected at the Coweeta Hydrologic Lab and in surrounding watersheds. Additional field sample locations will be established by this group to aid in further development, calibration and validation of water quality and quantity modeling.

Overall, we aim to provide a broad, diverse, and highly accurate set of data for analyzing causes and consequences of land use change and the impact on water quality and quantity in the region.

References

Bolstad P., and T. Lillesand. 1992. Rule-based classification models: Flexible integration of satellite imagery and thematic spatial data. *Photogrammetric Engineering and Remote Sensing*. 57:67-74.

Southern Appalachian Man and the Biosphere Cooperative. 1996. Southern Appalachian Assessment Summary Report. Report 1 of 5.

Partners

Objective 1: Rapid Land Use Classification

While substantial progress has been made in developing satellite-based land cover and land use mapping tools, rapid, spatially-detailed, and categorically-detailed identification of land use change on continental to global scales is still beyond our capabilities. A key present task is to reduce human input as much as possible in the classification process, while maintaining or improving classification accuracy and categorical detail. With this research we aim to further develop algorithms that address this need.

Most land use classification methods rely primarily on the spectral components of the imagery, however accuracy is often improved when adding ancillary spatial data, multi-date imagery, or shape, texture, or other spatial components of the imagery. Similarly, robust discrimination metrics, such as Tasseled-Cap transformations, and ancillary data may be used to automate classification, effectively minimizing analyst intervention and speeding up classification. We plan to expand semi-automated hybrid classification methods that use a combination of spectral, spatial, multi-temporal, and ancillary data (Bolstad and Lillesand, 1992).

Multispectral and pan-sharpened Landsat ETM data will be the primary spectral data sources, although we will also develop these rapid classification methods using mid-resolution MODIS data for comparisons. For a smaller subset area, we plan to also compare other land use classifications, such as aerial photography and high resolution pan-sharpened IKONOS data.

Objective 2: Land Use, Water Quantity and Water Quality

Water Quantity:
Land use impacts on surface water quantity are important in southeastern uplands (Southern Appalachian Assessment Summary Report 1996). A substantial body of research in the region (principally conducted by the Coweeta Hydrologic Laboratory) has documented the relationships between disturbance and water quantity. Thus, our research provides a unique opportunity to link historical, current, and future patterns of land use with water quantity.

Our approach will use a number of model types applied at a range of scales, combined with direct measurements to estimate the cumulative effects of multiple land uses on surface water quantity. We will measure water quantity using staged samplers, and combine these data with gauged flow measurements to provide validation data for the models. Water quantity modeling will be performed on the time series of mapped land uses collected with this project (1950-2000).

Water Quality:
Previous research efforts conducted in southeastern uplands indicate land use changes have significant impacts on water quality. Our objectives are to: 1) determine the effects of land use change on soil transport and sediment delivery to water resources, and 2) determine the effects of land use change on water quality and the potential impacts on aquatic ecology, drinking water supplies, reservoir life expectancy, and capital investments.

The impacts of land use change on soil erosion, transport and sediment yield will be determined through the development and application of a GIS based, finite element soil erosion model. This model will employ land use, land use change, soils, elevation, climactic and hydrographic data to produce estimates of changes in sediment yield following various LULC scenarios.

Objective 3: Social and Economic Causes of Land Use Change

The final objective of this project is to improve understanding of the factors that influence land use choices in southeastern uplands. To do this, we plan to extend spatially-explicit socioeconomic models on the causes of land use change. These models are driven by market conditions, infrastructure, land use, and physical and biological constraints and characteristics to estimate land use probabilities.

We aim to: 1) use historical observations on land uses and driving variables to test theories of land use choices and the influence of changing markets, institutions and environmental conditions on these choices, 2) model the mechanisms of land use choice, and use these models to estimate past land use across the landscape, and 3) use these same models to forecast potential land use changes in the future.