

**Land-Use and Land-Cover Change: Decadal-Scale Dynamics of Carbon Storage
Patterns as a Function of Land Ownership in the Southeastern Lower Coastal Plain
Region of the U.S.**

First Annual Progress Report

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Principal Investigators:

Michael W. Binford¹ (Department of Geography), Principal Investigator;
mbinford@geog.ufl.edu

Co-Investigators:

Grenville Barnes¹ (Department of Civil Engineering); gbarn@ce.ufl.edu
Henry L. Gholz^{1,2} (School of Forest Resources and Conservation); hgholz@nsf.gov
Scot E. Smith¹ (Department of Civil Engineering); ses@ce.ufl.edu

¹University of Florida, Gainesville, FL 32611

²National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230

Project URL: <http://www.surv.ufl.edu/nasa/>

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ABSTRACT

We are studying how carbon storage dynamics in forested ecosystems in the southeastern United States are influenced by climate variability and land ownership. The questions for this project are "How much carbon has been lost or gained from the SE Forests as a consequence of climate variation and ownership patterns?" and "How can we model future changes in carbon storage if we know how ownership will change?" Our focus is on non-public (private industrial, private non-industrial) lands in the region. Climate variability is defined by weather records from several stations within the study area. Four small (15 km x 15 km) sample areas have been selected for intensive study to determine the spatial and temporal patterns of changing land ownership and changing carbon storage over the 25-year period covered by data available from the Landsat program. Land ownership is being determined by compiling and mapping information from local-government records. Carbon storage is being measured with remote sensing methods calibrated by on-the-ground measurements in an ecosystem that has been under intense study for nearly 20 years. From the measurements and knowledge of climate variability and land-ownership, we are developing empirical models that describe the relationship between land ownership, land-cover and land-use change, carbon exchange, and change of carbon storage. We will propose that this study area be used as a long-term monitoring site for future measurements of carbon storage change.

Key Words: 1) Research Fields: Anthropogenic Effects, Carbon Cycle, Change Detection, Flux Towers, Historical Land Use, NPP GPP; 2) Geographic Area/Biome: Southeastern U.S. Coastal Plain, Florida, Temperate Forest; 3) Remote Sensing: Landsat; 4) Methods/Scales: Flux Towers, Land-cover Classification, Regional

INTRODUCTION

The key elements of the research are to describe land cover/land-use change over the past quarter century in our study area, to estimate how much carbon storage has been altered by the observed changes, and to relate the kinds of changes to land ownership and, in the future, management practices. These elements address the first two of the NASA ESE questions explicitly: a) what are the changes in land cover and/or land use (monitoring/mapping activities), b) what are the causes of LCLUC? The answers will be useful for addressing the third NASA ESE question: c) what are the consequences of LCLUC?

Unfortunately, a budget reduction at the beginning of the project required us to drop the component on management practices. If we have one major conclusion this early in the project, it is that management practices are the most important proximate driver of land-use and land-cover change and hence carbon storage in these ecosystems. Management practices are also a key variable in analyzing ownership patterns. We would suggest that the program allow us to reinstate our studies of land management practices.

Our focus is on non-public (private industrial, private non-industrial, and state) lands in the region, because these lands represent more than 85% of the region's area (NRC 1997), and because Federal lands in the region are managed with priorities that are not necessarily related to those of the region itself.

The substantive attention to social science in this project is about 50%, while the work load is about 35% social science, 35% flux tower and other carbon measurements, and 30% remote sensing mapping of forest cover and estimations of carbon cycle components. Our basic questions are how land ownership patterns change over time, and how those changes affect carbon storage as estimated by satellite remote sensing methods calibrated by on-the-ground measurements in a subset of our study areas. The thematic proportional coverage is 50% Carbon, 50% GOFD.

The overall project objectives, along with the status of associated tasks at the end of the first year, are as follows:

1. Determine changes in land-cover and land-use patterns in the lower Coastal Plain region from 1975 – 2000, using Landsat MSS and TM data.

The work objectives of this goal were:

- to work with the land-ownership team to delineate four study areas,
- to acquire, compile, normalize, and register Landsat data for the time period at four phenologically critical times of the year.
- to compile all available climatological data for the four study areas and for the 25-year period.
- To create a rational classification system for preliminary work identifying land-cover types that can be linked to known biomass and C measurements from previous work.

Study area selection details are in the next section. We selected four critical times for phenological variation, identified 43 available, cloud-free (in the study areas) Landsat scenes for Row 17, Path 39, and requested 30 scenes that were acquired with the first year's Landsat Data Buy budget. We received 28 images of the study area, and have not followed up on the missing two scenes. We acquired all available climatological data for the study areas for the 25-year period spanning the project. Gathering of final ground control points and georectification of the images is still in progress and will be completed by the end of April 2001.

2. Determine changes in land ownership/tenure across the same sample areas over the 25-year time period, and linking the ownership patterns with observed land-cover changes.

The primary goal of this component was to study how land ownership patterns have influenced changes in land use/land cover over the study time period of twenty-five years. Our initial objectives for the first year were:

- to work with the carbon and remote sensing team to delineate four study areas,
- to acquire and compile land ownership data for each study areas,
- to design and test a data model for the storage and retrieval of the ownership data,
- to establish a website for communicating project progress and findings.

Delineation of Study Areas:

Four study areas, each measuring 15 x 15 km were randomly selected. Each study area is located entirely in each particular county as the ownership data is maintained at the County Property Appraiser's Office. Study areas were selected and delineated in Alachua County, Clay County, Hamilton County and Union County. Each of these areas was selected to coincide with the Public Land Survey System (PLSS) that was used for the original division of land in Florida. These sites with the PLSS framework can be viewed at this [website](#), and are shown in Figure 1.

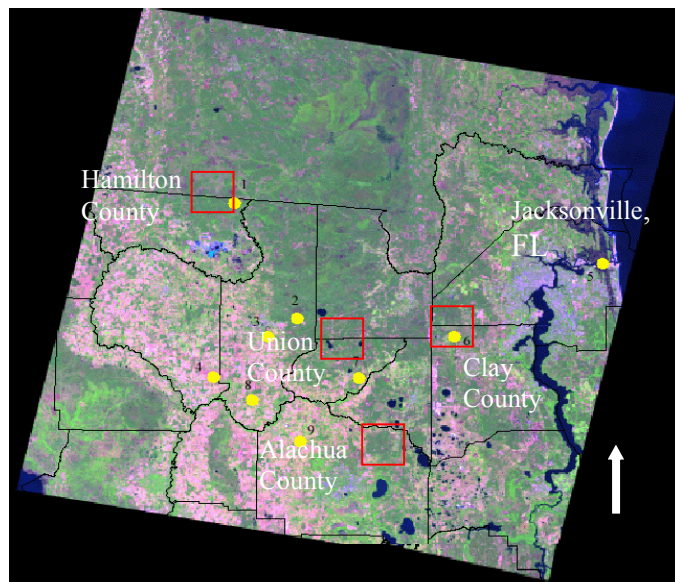


Figure 1. Composite (Bands 5,4, and 3 RGB) image of Landsat WRS 17-39 scene

showing random points (yellow dots), and final study areas (red boxes).

Acquisition, Compilation and Reformatting of Property Data:

The next step involved researching and acquiring the property ownership data at each of the four counties. For this purpose, field trips were made to the four county seats. In Alachua County, digital data were obtained for the years 1995 and 2000. In Clay County, digital data were obtained for the year 2000. The digital data included both the parcel geometry and the ownership attribute information in the format of an ArcView shapefile. Data were also obtained, in the form of paper maps, from the remaining two counties of Hamilton and Union. The parcel data for Union County have been digitized and are currently being edited. The attribute ownership information for these two counties still must be acquired and linked to the digitized parcel data. These data were reformatted for inclusion in the project database.

While we have been able to obtain current property information, it is proving very difficult to acquire historical or temporal data as the Property Appraiser's Offices are essentially only concerned with the current property status. The counties maintain and update one single ownership dataset and thus there is no historical record available for any of the previous years. Over the next 6 months we will pursue several strategies to try and obtain temporal data for selected time slices within the last 25 years (e.g. 1975, 1985, 1995, 2000). These will include tracing parcel changes through the tax parcel number system and identifying private or county entities that may have historical parcel records.

Design and Testing of Data Model:

Conventional GIS are not designed to handle spatio-temporal data in an efficient manner that facilitates the kind of space-time analysis inherent to our study. We have therefore designed a spatio-temporal data model (Figure 2 below shows the fundamental structure of this model) to handle the ownership data in both the spatial and temporal domains. The data model focuses on "objects," but has been implemented using a conventional relational database. Through the design and implementation of such a model, we are able to query and track ownership changes and identify trends through the study time period. The database has been developed and tested with data from the Alachua County study site over the 1995 – 2000 time period. A paper outlining the development of this model was presented at the Annual Congress of Surveying and Mapping (ACSM) National Conference held in Las Vegas in March of this year.

Integration of Property, Land Use/Cover and Carbon Information:

The analysis and modeling envisioned in this project requires the integration of several diverse sets of information. Figure 2 represents a conceptual diagram of the proposed strategy for integrating the land ownership, land use/land cover and carbon information for this analysis and modeling.

Establish Project Website:

A [website](#) has been built describing the project goals and research objectives. This [website](#) has been updated and maintained on a regular basis and the maintenance of the website will continue throughout the duration of the project.

In summary, the following goals have been achieved for this component of the study:

- Selected and delineated four study areas
- Acquired all available digital property data sets
- Reformatted digital property data
- Acquired and digitized parcel geometry from paper maps in Union County
- Designed and tested data model
- Designed and developed project [website](#)
- Defined strategy for integrating ownership, land use and carbon data

Critical Issues:

A land/forest management component was included in the original proposal, but later dropped due to budgetary constraints. This is a critical element of our analysis since it links property ownership and land use. In addition to knowing the class of property ownership (private, commercial, etc.), we need to understand how the behavior of these different property owners has changed over the past 25 years. In several instances, land/forest is owned by one class of owner, but operated by another class. By re-incorporating the land/forest management component we will be able to illuminate these complex property relationships.

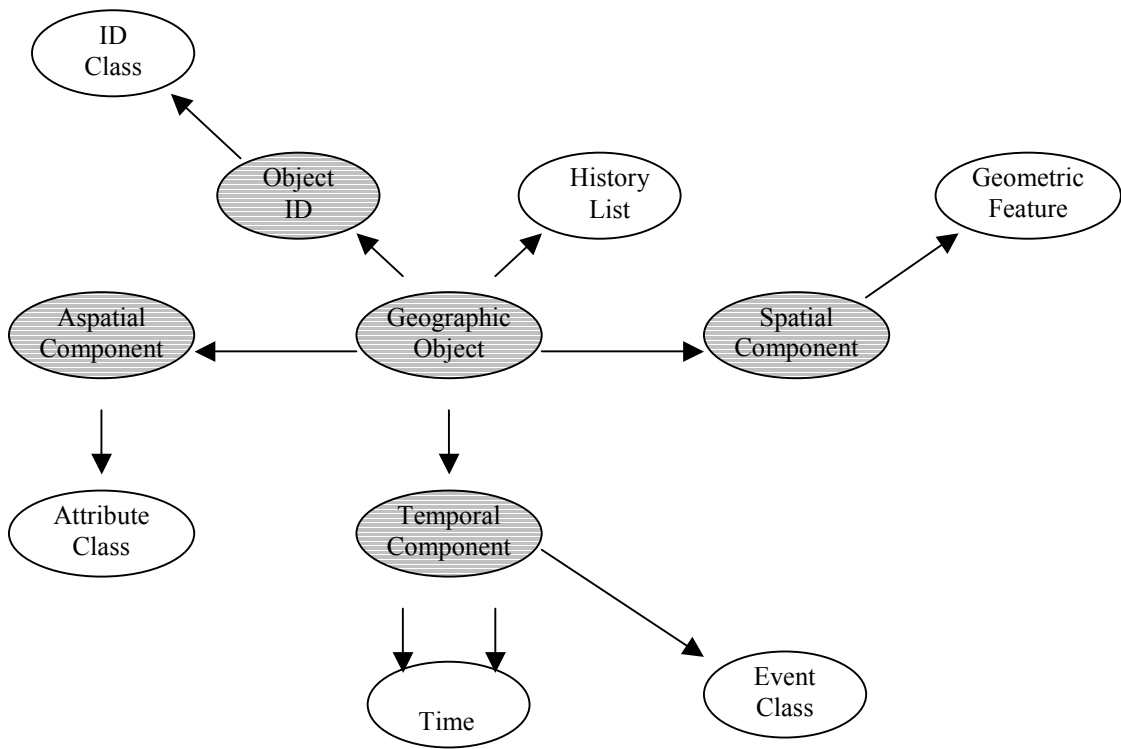


Figure 2. Structure for Defining Spatial Objects in a Temporal Data Mode

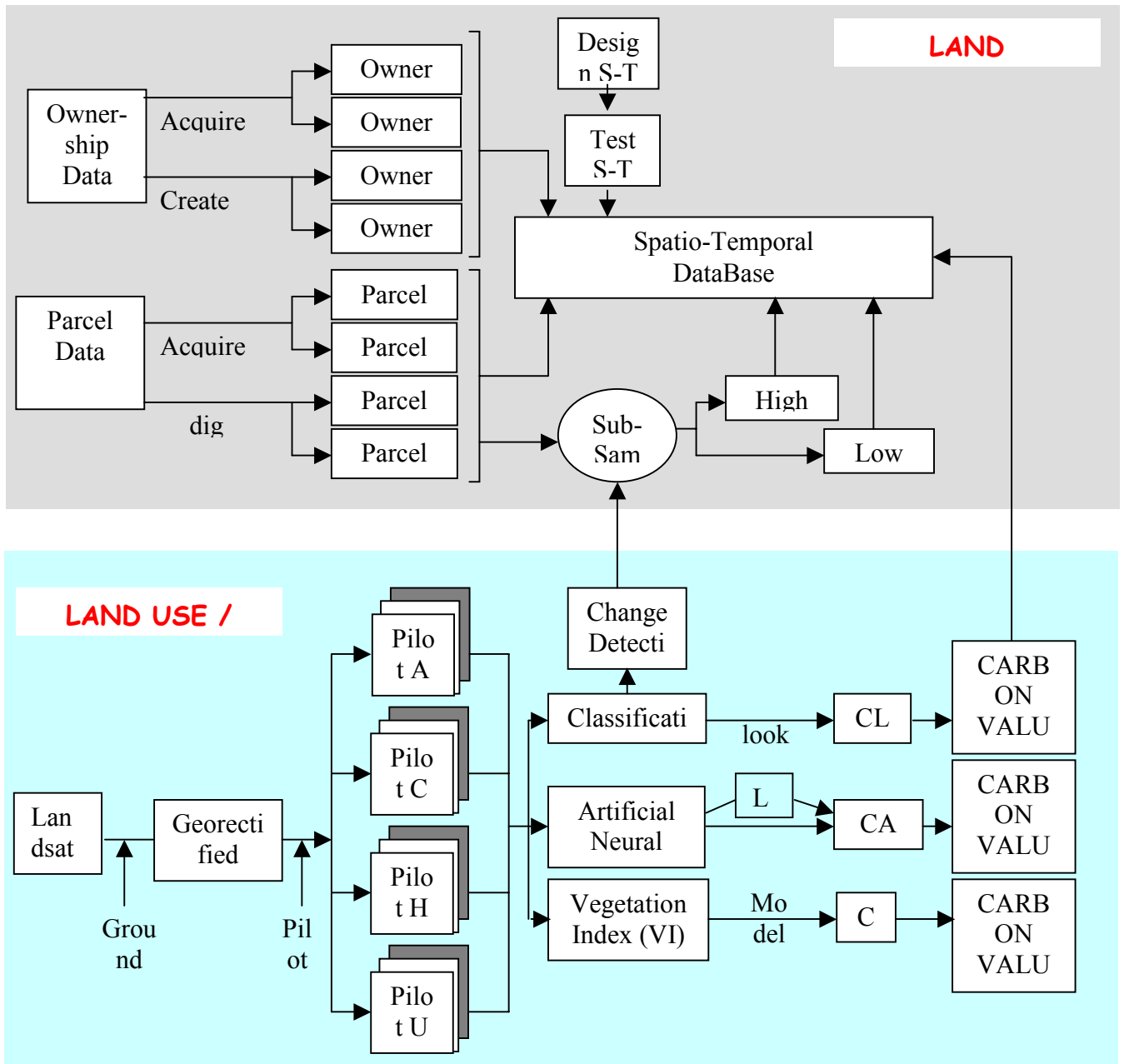


Figure 3. Conceptual diagram of the proposed strategy for integrating the land ownership, land use/land cover and carbon information for this analysis and modeling.

3. Determine changes in the regional C storage over the time period, by estimating the changes in C stored in tree, understory and litter biomass over time resulting from land use changes in the sample areas, based on a synthesis of existing data and ongoing studies on carbon storage in regionally representative ecosystems.

This objective is being met by three different methods. 1) We will produce look-up tables (LUT) based on biomass and carbon measurements made in local systems since 1979, and from the

literature for the different land cover types in our study area. Preliminary classifications have shown that there are 10 easily separated classes, including Riparian/Urban Deciduous Forest, Cleared Grassy Areas, Young, Growing Pine Plantations, Clearcuts > 1 year old, Urban and Clear Grassy Areas, Urban and Recent Clearcuts, Mature Pine Forests, Young Pine Plantation/Mixed Forest, Cypress Swamps, and Open Water. The literature compilation of data is in the early stages of development and results look promising. 2) Calibrate indices derived from satellite data with on-the-ground measurements of biomass, carbon content, and carbon exchange processes. These indices await registration and normalization of all satellite data and we did not plan to accomplish this step during year 1. 3) Conduct ongoing measurements of biomass, carbon content, and carbon exchange processes.

Eddy covariance measurements of net CO₂ exchanges above the canopy of a naturally-regenerated, uneven-aged, mixed pine forest were begun in January 2001 at the new flux tower site on the University of Florida's Austin Cary Memorial Forest (ACMF). The 40m tower was obtained at no cost to the project, with an instrument shed and power provided by the University. Data have been logged on a half-hourly basis almost continuously since. Energy balance closure on this site is within 10% at low levels of net radiation, decreasing to within 20% at high net radiation.

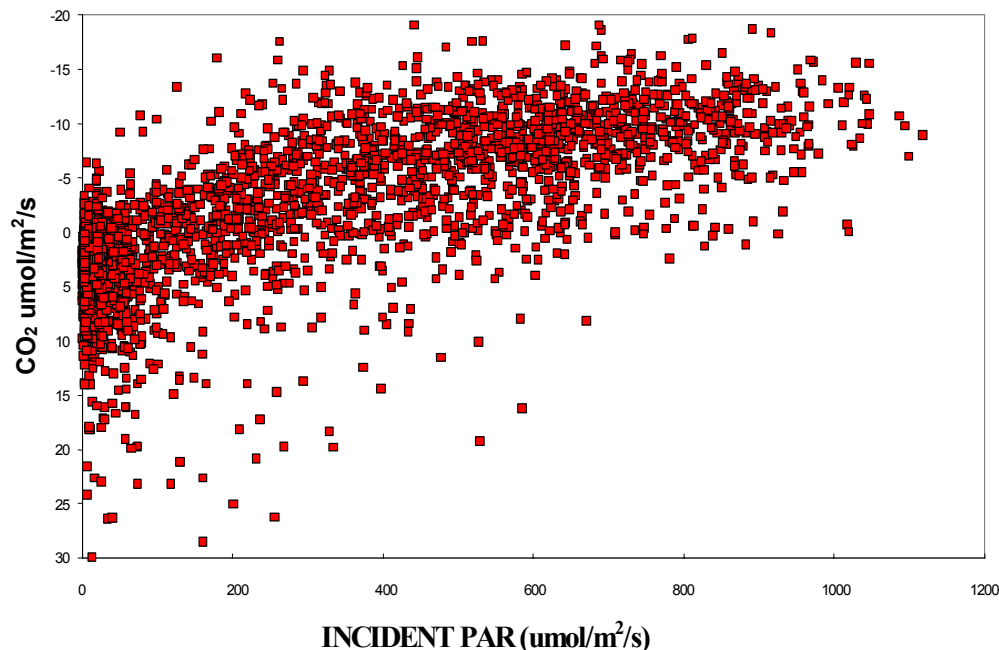


Figure 4. Day-time net CO₂ exchanges from Jan.-March, 2001 at the ACMF pine site.

Day-time data (Figure 4) indicate a mean maximum of about -11 $\mu\text{mol}/\text{m}^2/\text{s}$ above an incident PAR level of 400 $\mu\text{mol}/\text{m}^2/\text{s}$, with maximum half-hourly values reaching -15 $\mu\text{mol}/\text{m}^2/\text{s}$ and a “light compensation point” at about 200 $\mu\text{mol}/\text{m}^2/\text{s}$ PAR. The data in Figure 1 represent periods with well-mixed canopy conditions (defined here as with $u^* > 0.2$ m/s), but have not been otherwise filtered. These results are very similar to those obtained over the nearby AmeriFlux even-aged pine plantation canopies (Clark et al. 1999 and in preparation) and suggest that carbon gain is likely to be substantial even in this more “natural” pine forest (night-time CO₂ release data are currently being analyzed, but also do not appear to be markedly different from the

plantations). This is not too surprising, given the relatively low age of the trees in this stand (mean age ca. 50 years compared to <25 years for plantations, with maximum tree ages for these species >200 years) and the much lower stocking density at the ACMF site. However, it also may result from somewhat lower than expected day-time carbon gain in the plantations under the drought conditions of this year, since the plantations have higher levels of foliar biomass and LAI (Figure 5) (and hence, higher evapotranspiration).

We also have been using backup equipment from the AmeriFlux project to display a belowground eddy covariance system at this site on-and-off throughout 2001 in an attempt to simultaneously measure tree canopy and understory/soil CO₂ and energy fluxes. This work proceeds, but data acquisition has been hindered by frequent still air conditions near the understory layer.

A complete meteorological station, consistent with AmeriFlux guidelines for such stations, is fully operable at the top of the tower. Both flux and meteorological data from this site will be contributed to the AmeriFlux CDIAC database at ORNL, once it has been fully corrected and proofed.

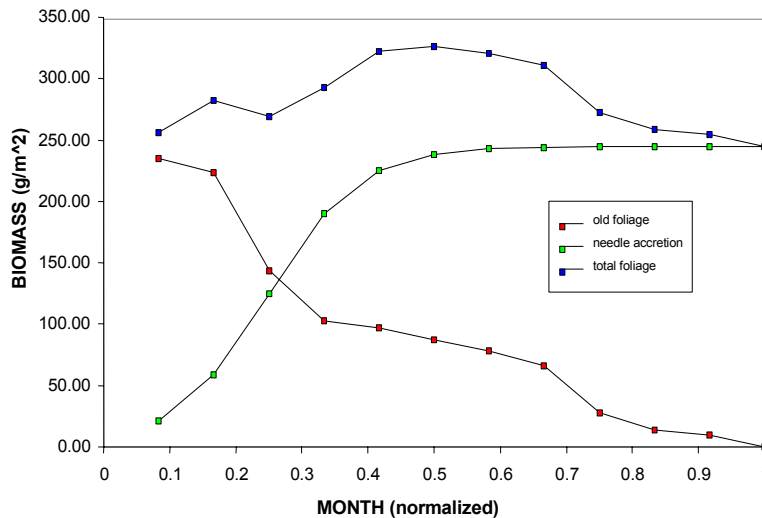


Figure 5. Seasonal changes in foliar biomass of the canopy at the ACMF pine forest flux site. For comparison, the nearby AmeriFlux mid-rotation, pine plantation stand had maximum foliar biomass of 505 and 569 g/m² in 1998 and 1999, respectively (unpubl. data).

SCHEDULE

Schedule of Activities May 2000 - April 2001

Activity	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
<i>I. Land-Use Change</i>												
acquire imagery	■	■	■	■	■	■						
pre-processing				■	■	■						
Data Analysis						■	■	■	■	■	■	
Fieldwork							■		■			■
<i>II. Land Ownership</i>												
site selection	■											
research digital records		■	■	■	■	■						
research public records				■	■	■	■	■	■	■	■	■
Data Organization												
Integrate with LULC												
Integrate with Carbon data												
Follow-up Fieldwork												
<i>III. Carbon Dynamics</i>												
tower flux measurements	■	■	■	■	■	■	■	■	■	■	■	■
litterfall collections	■	■	■	■	■	■	■	■	■	■	■	■
tree growth measurements						■						
prescribed fire experiment									■	■	■	■
biomass data synthesis	■	■	■	■	■	■	■	■				

Figure 6. Time line for first year's tasks. All tasks are proceeding as shown, with minor modifications described in the text.