NACP_INTENSIVE_WP_004

White Paper

North American Carbon Program

"Pilot Studies for Enhanced Forest Land Measurements"

Prepared by

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Forest Land Measurements of the North American Carbon Program

Land measurements will make a significant contribution towards answering the science questions that motivate the North American Carbon Program (NACP):

- What is the carbon balance of North America and adjacent ocean basins, and how is the balance changing over time? What are the sources and sinks, and the geographic patterns of carbon fluxes?
- What factors control the sources and sinks, and how do they change with time?
- Are there potential "surprises", where sources could increase or sinks disappear?
- How can we enhance and manage long-lived carbon sinks to sequester carbon?

Presently, significant uncertainties exist as shown by comparing estimates from land-based measurements with atmospheric approaches. Enhanced land measurements within the context of the NACP will have the following impacts as described in the strategic plan:

- Improve ongoing inventory and monitoring of national greenhouse gas emissions from land
- Develop well-quantified large-scale estimates of land-atmosphere C exchange
- Improve the ability to attribute observed changes to the full suite of mechanisms, including natural variability as well as direct and indirect human influences
- Provide the information on plant and soil components of ecosystem fluxes necessary to understand and interpret larger-scale regional and continental fluxes

The forest land measurement component of the North American Carbon Program involves development of a hierarchical, multi-tier monitoring approach that integrates the ongoing inventory and monitoring programs with intensive-site monitoring and process studies. *Extensive monitoring* consists of remote sensing of land cover and change detection, and field observations from large networks of inventory sample plots. *Intensive monitoring* is conducted at a small number of ecosystem process monitoring sites such as Long-Term Ecological Research (LTER) sites and the growing array of AmeriFlux sites that measure net ecosystem-atmosphere CO_2 and energy exchange.

A new monitoring tier at the landscape scale is proposed that will link extensive monitoring with the intensive monitoring and process studies using an intermediate set of biometric measurements. *Landscape monitoring* will include clusters of measurement sites that represent conditions over large landscapes. Important functions of landscape monitoring include assessment of how well the intensive sites represent the surrounding landscape, and enhancing availability of CO_2 flux estimates for forest land since existing towers have limited representation of mountainous terrain and disturbed areas.

To achieve the goal of linking intensive and extensive monitoring, landscape monitoring will incorporate data elements of both. Measurements at landscape monitoring sites will be intermediate to intensive and extensive monitoring in both spatial and temporal scales. Similar to intensive monitoring, important variables that define the ecosystem "state" such as vegetation type, foliage nitrogen concentration, and soil C:N ratio will be measured along with automated measurements of key "driving variables" such as light, temperature, and precipitation that control the rate of ecosystem carbon uptake and loss. These state and driving variables will allow models

of ecosystem C exchange that may be developed and tested at intensive sites to be refined and applied at a much larger and more representative range of locations in North America. This in turn will facilitate comparison with the spatially and temporally resolved estimates from the atmospheric portion (aircraft and tall towers) of the NACP.

Measurements at landscape monitoring sites will include key components of the carbon balance that will contribute to estimating land/atmosphere carbon flux at a variety of scales. Measurements that have previously only been taken at intensive sites will be extended to landscape monitoring sites as illustrated in table 1.

Table 1. Selected land measurement variables and scale of measurement.

Example Variable	Extensive Monitoring	Landscape Monitoring	Intensive Monitoring
Land cover	X	X	X
Leaf area	X	X	X
Disturbance	X	X	X
Live biomass	X	X	X
Litterfall		X	X
Soil CO_2 flux		X	X
Methane flux		X	X
Dissolved Organic C		X	X
Net Ecosystem Exchange of CO_2			X

Landscape monitoring sites will contribute to the NACP in several important ways. First, the wide number of sites and unbiased sampling designs should provide direct estimates of landscape-level C sequestration (and its uncertainty) via measured changes in terrestrial C pools. These estimates will provide the "ground truth" to atmospherically-derived measures that can extend beyond the areas covered by landscape monitoring. Secondly, the geographically-dispersed landscape sites combined with their acquisition of continuous meteorological data will provide ecosystem models with the required spatial and temporal resolution to accurately model the dynamics of North American C exchange. Five hundred landscape sampling sites within the US, for example, would provide data at a roughly 120 km scale.

Landscape monitoring sites can become sites where special studies can be conducted to fill in data gaps for estimating ecosystem C flux, such as decay rates of downed dead wood. The new sites will have value for determining parameter values or validating the predictions of ecosystem process models. The new sites may also be useful as sites where the impacts of natural disturbances or management activities on ecosystem processes can be studied relative to a previously established baseline C budget, thus becoming important links with emerging climate change technology initiatives such as managing ecosystems to enhance carbon sequestration.

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Landscape Monitoring Workshop

A workshop was held in Portsmouth, New Hampshire, June 2003, to develop the sampling design and variable list for landscape-scale forest carbon monitoring. The 40 participants represented a cross section of government agencies, academia, and nonprofit research organizations, and included some of the leading experts in carbon measurements from the U.S., Canada, and Mexico.

Two outputs of the workshop are a detailed list of candidate variables and their measurement protocols, and a list of network design issues that must be considered in developing the overall strategy for selecting sample sites that represent landscape conditions. The list of variables is the starting point for development of a manual for field measurements, which will be authored by many of the workshop participants. The list of sampling design issues is the starting point for a journal article that will describe the hierarchical sampling system for the North American Carbon Program, also authored by workshop participants. These two products are under active development – drafts are expected before January 2004.

Some methods development will be required to adapt technology currently used at intensive sites or to develop new technology, so that it can be deployed efficiently over a much larger number of sites. Methods should be inexpensive and reliable. Protocols will need development and application testing for deployment over a variety of site conditions.

A design for selecting landscape monitoring sites, and a sample plot design that can be linked with extensive monitoring in the U.S., Canada, and Mexico has been proposed. The criteria for site selection include for the ability to produce unbiased large-scale estimates, representation of landscape characteristics, existing sites where basic measurements may already be taken or site history is known, potential to fill in significant gaps in observations from other sample tiers, and issues such as site security and landowner permission to collect and distribute information. The proposed design consists of a 1-km^2 area surrounding a flux tower or other significant feature of an intensive research site, over which a grid of sample plots is located (Figure 1). The basic sample plot is identical to that used in extensive forest inventories, with enhancements to add the new variables for extending the intensive measurements to the landscape. An important question to be answered through pilot testing is the degree to which the design and even the variable list can be modified to suit specific landscape characteristics and pre-existing data collection standards, yet still produce comparable and consistent estimates of carbon stocks and flux.

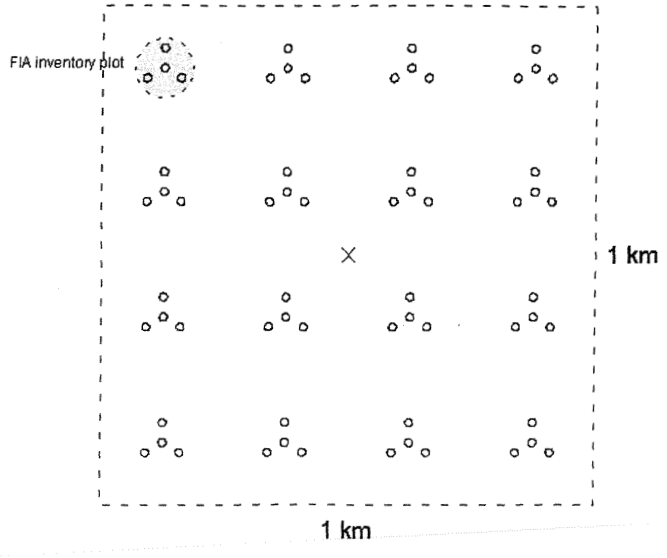
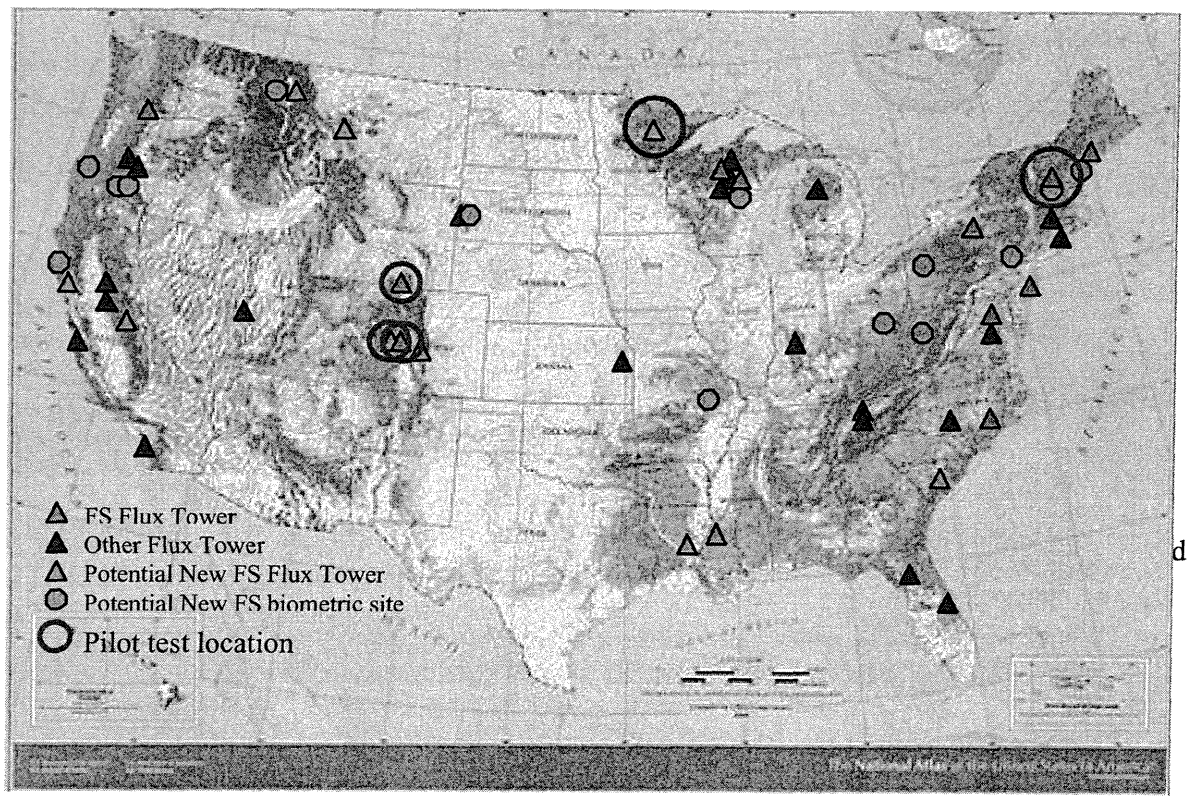


Figure 1. Proposed landscape sampling design for the U.S. using 16 FIA inventory plots. The exact number of sample plot locations will be determined by variability of the landscape and number of sampling strata. The cross represents a flux or meteorological tower.

The Pilot Studies

The workshop began the process of designing an efficient and effective sampling protocol for implementing landscape monitoring. The workshop products will guide three pilot studies to be implemented during 2004 and 2005. The pilot studies will test the application of the recommended design and variable list in a variety of landscapes, and based on the results of the tests, modify the design and variable list for future applications (Figure 2). Pilot studies will be sponsored by the Global Change Program of the USDA Forest Service. Currently, 3 pilot study proposals are in peer review. The three pilot studies are briefly described in the appendix.



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At present, funding to implement enhanced forest land measurements on a continuing basis is unavailable. One of the key goals of the pilot projects is determining the cost of installing and maintaining landscape monitoring sites. Also being considered is the extent and composition of the network. How many and which landscapes need to be included for a functional network over North America? Are there sufficient intensive monitoring sites in operation and correctly distributed to provide the infrastructure needed for efficient deployment of landscape monitoring? Preliminary estimates are that a network of 50 landscape types and 1000 sampling locations would cost from $5-10 million annually after initial equipment installation costs. Some of the funding may come from initiatives in future budgets of the Forest Service or other agencies, and it may be that funding from ongoing or new intensive sites will support landscape measurements at some sites. In fact it is often the case that existing intensive sites already include measurements that are comparable to those proposed for landscape monitoring, and so

the incremental funding need may be less than the estimated full amount. However, it is clear that for landscape monitoring to be successful, the program will need to be embraced by one or more federal agencies and also by our Canadian and Mexican NACP partners.

Timeline for NACP Landscape Monitoring Pilot Activities

Workshop #1	June 25, 2003
Workshop report	Sept 17, 2003
Pilot study proposals due	Oct 20, 2003
Proposal peer review complete	Dec 19, 2003
First draft of manual v 1.0 and journal article	Dec 31, 2003
Pilot project initiation and PI meeting	Jan 13, 2003
Initiate fieldwork	Apr 1, 2004
Publish manual v 1.0	Apr 15, 2004
Workshop #2	Jan 2005
Review and revise manual	Feb 2005

Appendix: Brief Description of the Landscape Monitoring Pilot Studies

Pilot study 1: "Understanding carbon pools and processes in peatland watersheds" – Forest Service and University of Minnesota. This study is located at the Marcell Experimental Forest in Northern Minnesota. In addition to testing the broad suite of measurement protocols, it features measurements of CO_2 and CH_4 gas fluxes as well as hydrologic transport of C in a northern peatland landscape. Hydrologic and atmospheric data has been collected for over 40 years. There has been a clear signal of climate warming over this time period of +1 degree C. There is no flux tower at this site. Measurements will be made in two distinct watersheds, one a forested bog and one a forested fen (Figure 3). These watersheds are typical of many watersheds in the western Great Lakes area.

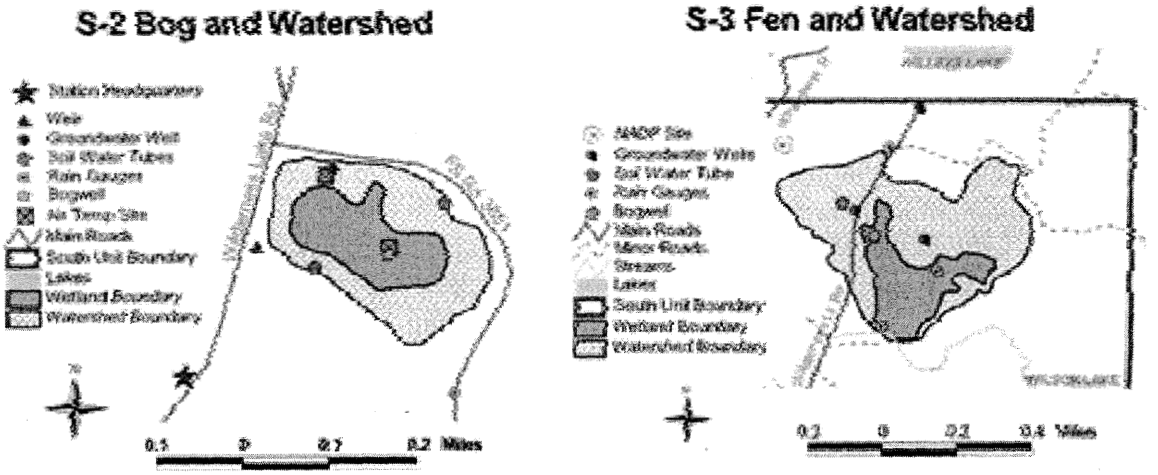

Figure 3. Watersheds of the proposed Northern Minnesota pilot study.

Pilot Study 2: "Scaling field and flux measurements using a tiered remote sensing approach" – Forest Service and University of New Hampshire. This study will take place at the Bartlett Experimental Forest in central New Hampshire (Figure 4). In addition to testing the broad suite of measurement protocols, this study will investigate methods for scaling from intensive sites to landscapes using tiered multi- and hyper-spectral remote sensing, the PnET ecosystem process model, and extensive networks of field plot data. The site has been actively monitored for 70 years, and includes a variety of forest management treatments that represent typical activities of the region. The investigators are installing a new flux tower at the site to begin measurements at the same time this study begins.

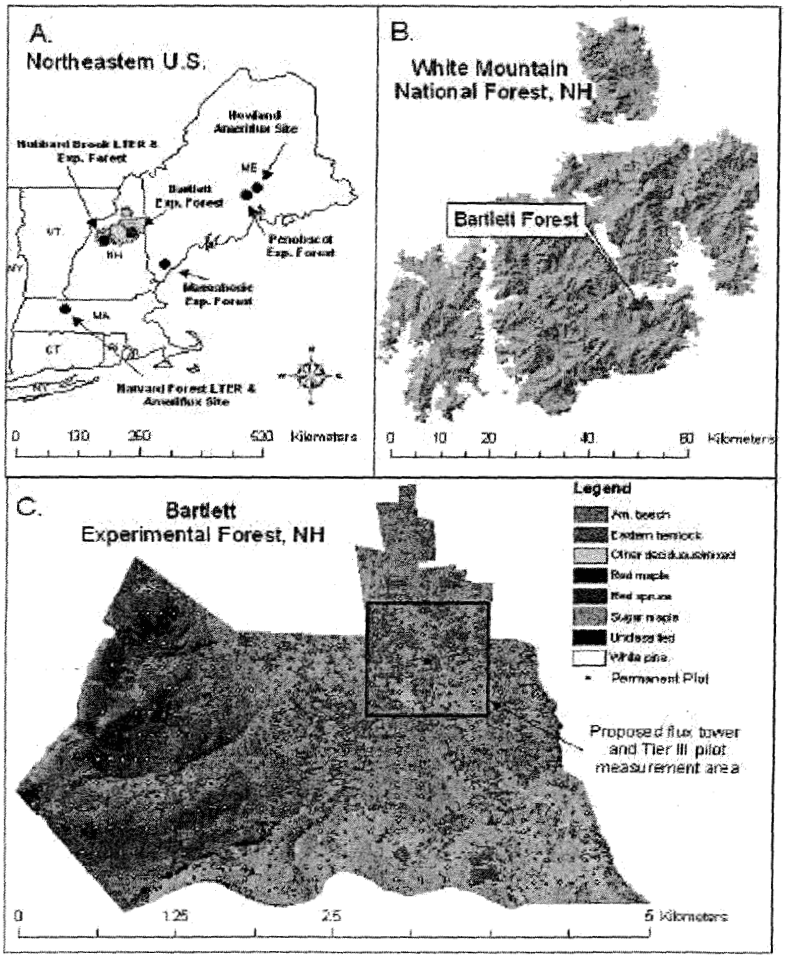

Figure 4. Location of a.) regional forest ecosystem monitoring sites in the northeastern U.S.; b.) the Bartlett Experimental Forest (BEF) within the White Mountain National Forest; and c.) long-term and eddy covariance monitoring sites at the BEF in relation to forest species distribution and topographic relief.

Pilot Study 3: "Regional estimate of carbon pools, fluxes, and storage in the subalpine Rocky Mountains" (Forest Service and University of Colorado). This study involves three alpine/subalpine Experimental Forests in the Rocky Mountains, two of which are AmeriFlux sites (Niwot Ridge and GLEES) and another site without a tower (Fraser). The area is characterized by high landscape variability in elevation, slope, and aspect (Figure 5). This will provide a rigorous test of the broad suite of measurement protocols and sampling design in a variety of conditions. In addition, the investigators will determine how well fluxes at intensive sites represent landscape conditions.

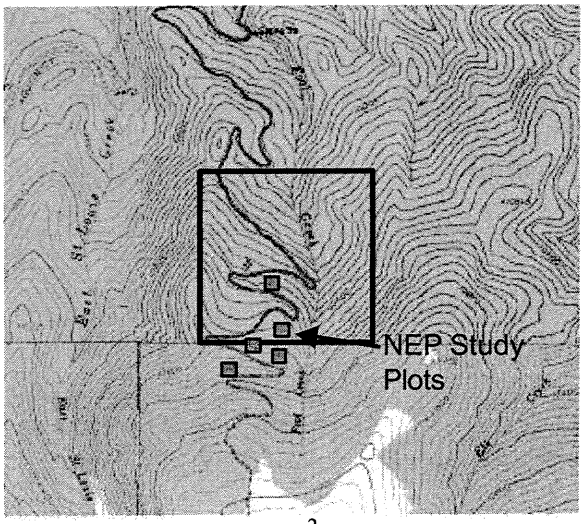

Figure 5a. Proposed km^2 Tier 3 sampling area in Fool Creek Watershed, Fraser Experimental Forest

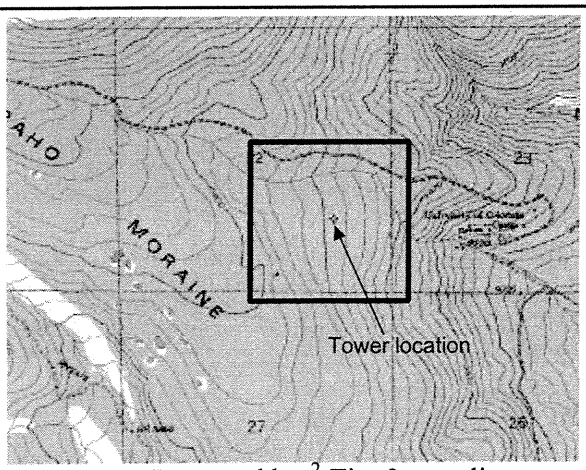

Figure 5b. Proposed km^2 Tier 3 sampling area surrounding the Niwot Ameriflux eddy covariance tower in Niwot Ridge LTER.

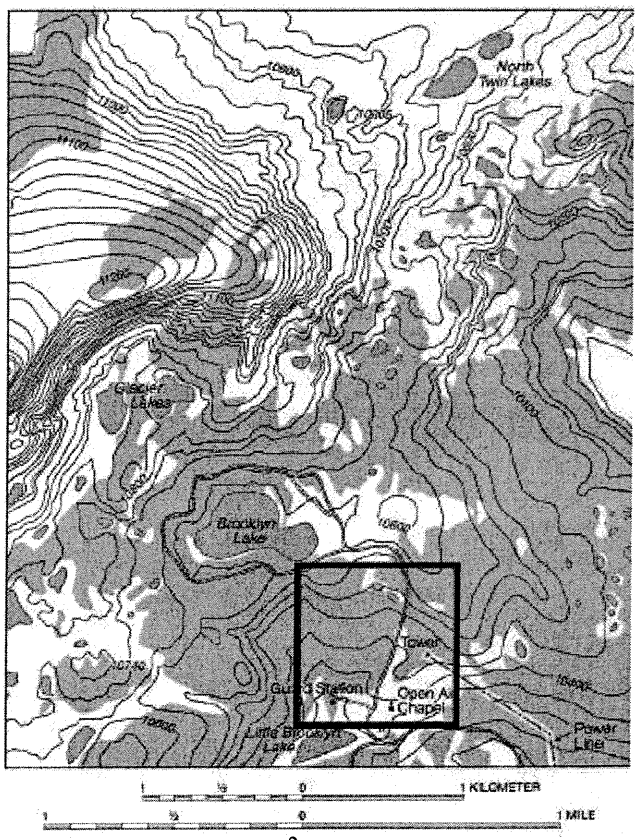

Figure 5c. Proposed km^2 Tier 3 sampling area surrounding the GLEES Ameriflux eddy covariance tower.