# Chapter 1
# Defining a Landscape-Scale Monitoring Tier for the North American Carbon Program

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**Abstract** Better knowledge of carbon stocks and fluxes is needed to understand the current state of the carbon cycle and how it might evolve with changing land uses and climatic conditions. For Canada, the United States, and Mexico, the North American Carbon Program (NACP) has been devised to measure and understand the sources and sinks of $CO_2$, $CH_4$, and CO in North America and adjacent ocean regions. At one scale, there are presently several national networks, each containing many thousands of plots, that provide broad characterization of carbon stocks in different land types (especially forest). At a much finer scale and far fewer are intensive sites where detailed and frequent measurements of various carbon cycle stocks and processes are made. There exists a large discontinuity in spatial coverage, frequency of sampling, and scope of research between the intensive sites and the extensive inventory plots. We define here an intermediate (~1 km$^2$), landscape-scale sampling system to help bridge the gap between these different measurement intensities.

**Keywords** Carbon storage, landscape, NACP, plot design, sampling

## 1.1 Introduction

The North American Carbon Program (NACP) is an interdisciplinary plan for research on the carbon cycle (Wofsy and Harriss 2002). The objective of the NACP is to measure and understand the sources and sinks of $CO_2$, $CH_4$, and CO in North America and adjacent ocean regions. Of particular concern is developing knowledge sufficient to predict the future state of the carbon cycle and to learn how to effectively manage long-lived carbon sinks (CCSP 2007). The NACP is designed

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to generate new techniques and models that will provide long term, mechanistically detailed, spatially and temporally resolved carbon fluxes across North America.

The NACP is distinct from previous studies of the carbon cycle in two principal ways: (i) by nature of its integrative, continental-scale approach that builds on a range of different and complementary observations, and (ii) by using powerful biophysical models to extend information from one domain to another. The scientific strategy of the NACP is to link these different observational scales and methods with new measurements at intermediate scales. Also critical to the success of the NACP is the integration of observations and models using advanced data-model fusion techniques (Wofsy and Harriss 2002). The purpose of this manual is to describe the comprehensive set of measurements to be obtained from these intermediate-scale sites that will help achieve the aims of the NACP.

A principal element of the NACP is long-term atmospheric measurements of the major carbon gases: $CO_2$, $CH_4$, and CO. Three-dimensional concentration fields of these gases will be combined with their anthropogenic source distributions using transport models in inverse ("top down") analyses to infer regional carbon sources and sinks (Denning et al. 2005). These measurements will be carried out from a variety of platforms, including networks of tall towers, aircraft, and eventually, new satellite-borne sensors. Data obtained from sensors mounted on tall towers will be recorded continuously, while aircraft and satellite measurements will most likely be made on weekly or monthly intervals to enable the following of seasonal variations in C exchange. An important part of the atmospheric measurement program will be regional-scale field experiments to test out procedures and coordination among research teams.

A second important element of the NACP is land surface carbon (C) inventories, fluxes, and process studies. In this instance, the change in C stocks, or direct measurements of land-atmosphere gaseous C fluxes, will be scaled-up to the region ("bottom up") in a variety of modeling frameworks. These frameworks include remote sensing, biophysical, and statistical paradigms. New process-level studies are needed to identify critical mechanisms that regulate C exchange. Complementing land surface measurements and modeling will be similar efforts over the oceans adjacent to North America.

## 1.2 A Hierarchical Approach for Land Inventories and Processes Studies

The NACP proposes to combine enhanced carbon inventories, remote sensing, and models to provide a complete carbon accounting for the land sector and comprehensive analysis of the mechanisms driving the fluxes. New emphases on carbon accounting, on lands (peatlands, scrub land, suburban landscapes) and carbon pools (roots, shrubs) that lack comprehensive inventories, and on scaling with remote sensing and models, will greatly improve the carbon budget for North America and more localized regions.

**Table 1.1** Multi-tier concept with likely variables central to a land observation system

| Example data elements | Intensive sites (e.g., LTER, AmeriFlux, NEON) | Landscape-scale sample (new) | Extensive inventory (FIA and NFI) | Mapping and remote sensing |
|---|---|---|---|---|
| Land cover class | X | X | X | X |
| Leaf area index | X | X | X | X |
| Live biomass | X | X | X | X |
| Land cover change | | X | X | X |
| Wildfire disturbance | X | X | X | X |
| Climate variability | X | X | | |
| Soil $CO_2$ flux | X | X | | |
| Methane flux | X | X | | |
| Dissolved organic C | X | | | |
| Ecosystem $CO_2$ flux | X | | | |

A hierarchical approach to these land studies will support multi-scale interpretations, with intensive studies providing access to details and mechanisms that are extended using remote sensing, extensive inventories, and mechanistic models. This multi-scale approach to land data will join the atmospheric and ocean studies as components in a unified analysis framework. Constraints from the atmosphere and oceans will increase the sophistication and accuracy of the estimates based on land data.

Much of the infrastructure for an NACP sampling hierarchy is already in place. At one end of the hierarchy is complete spatial coverage of North America for a few remotely sensed properties of the land surface, and at the other extreme are detailed carbon cycle process studies taking place at a limited number of long-term research sites (Table 1.1). In general, precision of carbon stock estimates and sophistication of understanding of carbon cycle processes increases for a decreasing spatial domain. We discuss below the three hierarchical levels of information presently available that will be essential components of NACP success. In considering the characteristics of these levels and their carbon cycle information, the authors of the NACP and NACP implementation plan (Wofsy and Harriss 2002, Denning et al. 2005) realized that there is a gap in the hierarchy that will limit the ability of land-based data to contribute to NACP goals. This manual describes a new research echelon, an intermediate level at the landscape scale of the hierarchy, which will fill this gap and help ensure successful completion of the NACP.

## 1.3 Present Levels in a Land-Based Carbon Cycle Hierarchy

### *1.3.1 Extensive Coverage with Remote Sensing*

The NACP goal of providing spatially resolved, continental-scale information about carbon sources and sinks requires comprehensive information about the land surface that can only be provided by remote sensing. Needs include land classification by vegetation type, land-cover change detection, and estimates of land surface parameters that can be related to C uptake and loss.

Current US land inventory systems use a combination of high-altitude aerial photography and Landsat Thematic Mapper (TM) data to sample the largest scale and to detect change. TM data have been available since 1982 on a 16-day repeat cycle with a spatial resolution of 30 m, and since 1972 at a 72 m resolution.

Several sensors with coarse spatial resolution but higher (daily) temporal resolution have been used to drive terrestrial biogeochemistry models that estimate carbon stocks and fluxes, typically with limited information on land use history. The NOAA AVHRR (Advanced Very-High-Resolution Radiometer) sensors have provided fairly continuous global daily coverage at a nadir resolution of 1.1 km since 1979, but provide only limited spectral information. SeaWiFS provided a vegetation index of higher quality but for a shorter time period (Behrenfeld et al. 2001). The NASA MODIS sensor, launched on the Terra spacecraft in 1999, and Aqua in 2002, provide higher spectral resolution data (36 bands) at a moderate resolution (500–1,000 m, depending on wavelength). A variety of data products are available, including vegetation indices, land cover and cover change, surface reflectance, surface temperature, presence of fire, leaf area index (LAI), fraction of photosynthetically active radiation (FPAR) absorbed by the canopy, and terrestrial net primary productivity (NPP).

Additional sensors in the planning stage would provide new and useful information, including aspects of canopy chemistry and structure and soil moisture. Light detection and ranging (LIDAR) technology is particularly promising because satellite monitoring of vegetation structure has been beyond the scope of previous sensors, and these measurements are closely related to above-ground biomass, one of the most dynamic ecosystem carbon pools.

Several specific needs have been identified to provide data to the NACP on above-ground carbon stocks using remote sensing products and *in situ* data, including: (1) timely systematic and routine processing of satellite data from the North American continent into land cover and land cover change products, including both natural and human disturbances; (2) integration of satellite observations with *in situ* measurements of carbon stocks and existing inventories; (3) augmentation of satellite and *in situ* estimates of carbon stocks with airborne and surface measurements; and (4) development of appropriate estimation models for carbon stocks both above- and below-ground.

### 1.3.2 Extensive Sampling with Inventory Techniques

Across much of North America, large-scale land inventories are conducted by the USDA Forest Service (the Forest Inventory and Analysis, or FIA), Natural Resources Conservation Service (National Resources Inventory, or NRI), and the Canadian provincial/territorial governments and Federal government (National

Forest Inventory or NFI), employing multi-tier sampling strategies using remote sensing and ground measurements. These continuous inventories provide baseline information about land cover, management intensity, productivity, and disturbance that can be used to estimate carbon stock changes over 5–10 year periods. Very high sampling intensity (within continental US forestland, for example, there is an average of one sampling point every 24 $km^2$) allows detailed description of some of the causes of observed carbon stock changes, such as the effects of vegetation growth, mortality, and harvesting. Historical data are available to trace land use and management history.

Where available, land inventories provide a representative, statistically based sample of ecosystems and their range of conditions in response to past disturbances. Current land inventories are limited by incomplete data from certain regions and ecosystem types, lack of complete ecosystem C measurements, limited temporal resolution, and lack of easily available and usable historical data. In the US, the FIA program does an excellent job with its coverage of all forested lands, regardless of ownership, employing standardized sampling on a uniform grid. Data are not yet available from all plots, especially interior Alaska, and unfortunately there is no FIA equivalent for non-forest land, especially grazing land in the West. Major portions of Canada and Mexico have been at best sparsely sampled. Forest inventories have historically excluded urban and suburban areas, but these gaps are gradually being addressed.

In the US FIA program, additional carbon pools consisting of downed woody material, the forest floor, and 8 in. of mineral soil are sampled in a 1/16th subset of the FIA plots (the Phase 3 plots). Soil sampling consists of bulk density, carbon content, litter and duff depth, and depth to a restrictive layer below the mineral soil. Down woody debris sampling is transect-based and separates coarse and fine woody debris (see the FIA Phase 3 Field Guide, sections 11 and 14 for more information). Stumps, live and dead roots, and deeper mineral soils are presently not sampled.

In the US the NRI has data on land use and natural resource conditions and trends for non-Federal lands recorded in surveys at roughly 5-year intervals from 1982 (Nusser and Goebel 1997). Much of this information, including the STATSGO2 and SSURGO soil databases, is available through the USDA Geospatial Data Gateway (http://datagateway.nrcs.usda.gov/).

In the past, land inventories were designed to provide periodic estimates with a temporal resolution of 5–15 years, sufficient for some applications, but incompatible with the temporal resolution needed by the NACP. Newly implemented designs for forest inventories address temporal resolution using successive sample "panels" to approximate continuous sampling. Each panel is re-sampled with a period of 5–10 years. Supplemental data with higher time resolution can be merged with the inventory data to estimate the major causes of variations in C flux; productivity, mortality, harvest, and land use change. Sources of supplemental data include flux towers (productivity and trace gas dynamics), aerial and satellite disturbance surveys (land use change, damage and mortality), and timber and agricultural product surveys (harvest quantities).

### *1.3.3 Intensive Measurement Sites*

Intensive sites provide direct estimates of C flux and C stock changes across a range of temporal scales. In addition, research at these sites includes detailed studies of the mechanisms controlling carbon fluxes. Data from intensive sites will be critical for developing and testing models, for interpreting large-scale patterns, and for constraining models.

There are perhaps 50–100 sites carrying out intensive studies of the carbon cycle across North America. Many of these sites are part of the Fluxnet Canada, AmeriFlux or emerging NEON networks, and make continuous measurements of land-atmosphere $CO_2$ exchange from meteorological research towers. Summed over the course of a day, month, season, or year, data from these sites provide direct measures of ecosystem $CO_2$ source or sink strengths. Most intensive sites provide information specific to one ecosystem type. Because of the relatively small number of intensive sites, the existing range of conditions following past disturbances within most ecosystem types is not fully represented.

Data from intensive sites help estimate parameter values or test physiological models of C exchange and are critical to relating fluxes and remote-sensing data. Companion physiological and ecological measurements enable the partitioning of carbon fluxes into plant and soil components and can reveal mechanisms responsible for variation in these fluxes. At several sites, biomass-based estimates of C storage have validated C budgets from direct flux data (e.g., Barford et al. 2001, Curtis et al. 2002).

## 1.4 A New, Intermediate Level of Study is Needed: Process and Stock Monitoring at Landscape-Scale Sites

There is a large discontinuity in spatial coverage, frequency of sampling, and scope of research between the intensive sites and the extensive inventory plots. There are probably 1,000-fold more inventory plots than intensive sites in North America. For most of the US, Canada, and parts of Mexico, inventory plots provide excellent coverage of the full range of ecosystem states and with abundant replication. However, inventory plots are typically visited only once in 5–10 years, whereas intensive sites provide some data at intervals of 30 min, allowing a better understanding of the mechanisms underlying the temporal aspects of carbon exchange. Inventory sites provide information about the major C stocks (stems, soil, coarse woody debris) but typically do not assess other important C pools including foliage and roots.

To provide better representation of the range of ecosystem conditions with detailed, high-resolution measurements of ecosystem C, and to facilitate linking intensive sites with remote sensing, a new set of sites intermediate in intensity of measurement and number is needed. It is not practical to work intensively in all ecosystem types and across the full range of land use histories in North America. Yet, process data from across this range is crucial for robust analysis. A new network of medium-intensity sites at the landscape-scale is needed to achieve the goals of the NACP.

The purpose of this manual is to describe the comprehensive set of measurements to be obtained from these sites that will help achieve the aims of the NACP. The measurements made at these sites must meet several requirements. First, they should provide valid statistical estimates of major C stocks and their spatial distribution, and be able to detect change in these stocks over a short time period (one to a few years). Secondly, they should be representative of a large enough area so that surface characteristics can be directly detected by the full range of Earth observing satellites and used in modeling studies. Thirdly, they should provide the terrestrial information necessary to parameterize and run vegetation-dynamics and biogeochemically-based models of ecosystem function such as TEM, Biome-BGC, CENTURY, CASA, and IBIS.

Measurements at these sites will address major components and processes in the carbon balance, including annual net primary productivity (NPP), leaf area index, leaf nutrients, soil respiration, litterfall, dynamics of coarse woody debris, and $CH_4$ flux. Depending on technology development, it may soon be practical to measure C balance with eddy flux at many of these sites. It will be important to obtain accurate records of land use, including past history as well as current management practice. Environmental conditions, including soil moisture and solar radiation (see Chapter 3), should be measured at each site to facilitate assessment with ecosystem models.

The new sites will serve as vital links between the approximately 100 intensive sites and the much larger number of inventory sites. Because these landscape-scale sites will measure directly components of C balance, they will be a key resource for testing models developed at the intensive sites. Direct measures of components of the carbon balance will also be critical for setting appropriate conversion factors for the quantities that need to be estimated in inventories.

Coverage of North American ecosystems by intensive sites that make up the LTER and AmeriFlux networks is incomplete (Hargrove et al. 2003) and will remain sparse even with the additional intensive sites of the National Ecological Observatory Network (NEON). In addition, the eddy covariance methodology used at many intensive sites is poorly suited to steep topography, so intensive carbon cycle information is often not available, increasing the value of the landscape-scale sites in these situations. Similarly, these landscape-scale sites will have extra value in regions and vegetation types lacking inventory plots.

## 1.5 Overview of a Landscape-Scale Site

The first goal of the new sampling system is to provide statistical estimates of major C stocks and fluxes across an area of land. The new system must therefore be compatible with existing inventory systems to provide ready comparison and extrapolation across the landscape. This requirement suggests the use of FIA-compatible plots within the United States and NFI-compatible plots within Canada.

The second goal of the new system is to be able to tie information on C stocks and fluxes to remotely sensed variables over the same landscape. The spatial resolution (pixel size) of some important land resource satellites is large (up to 1 × 1 km), suggesting that a relatively large land area is necessary for a medium-intensity site. A third goal for these sites is to provide measurements of carbon storage or loss that can be compared with and are independent of other measurements based on different methodologies such as eddy flux towers. This suggests that some intermediate intensity sites may wish to incorporate eddy flux measurements or other "continuous" measurements such as soil $CO_2$ flux. Over a forest, the flux source ("footprint") region of eddy covariance measurements may extend hundreds of meters, again suggesting a relatively large scale.

To meet these separate goals, the standard landscape-scale site will consist of inventory plots arrayed across a minimum 1 × 1 km land area (Fig. 1.1). The gridded area should be centered on a meteorological tower or other special research installation. Use of a sampling grid is a relatively efficient and unbiased way to select sampling locations (Haining 1993). Between 16 and 36 inventory plots may be adequate

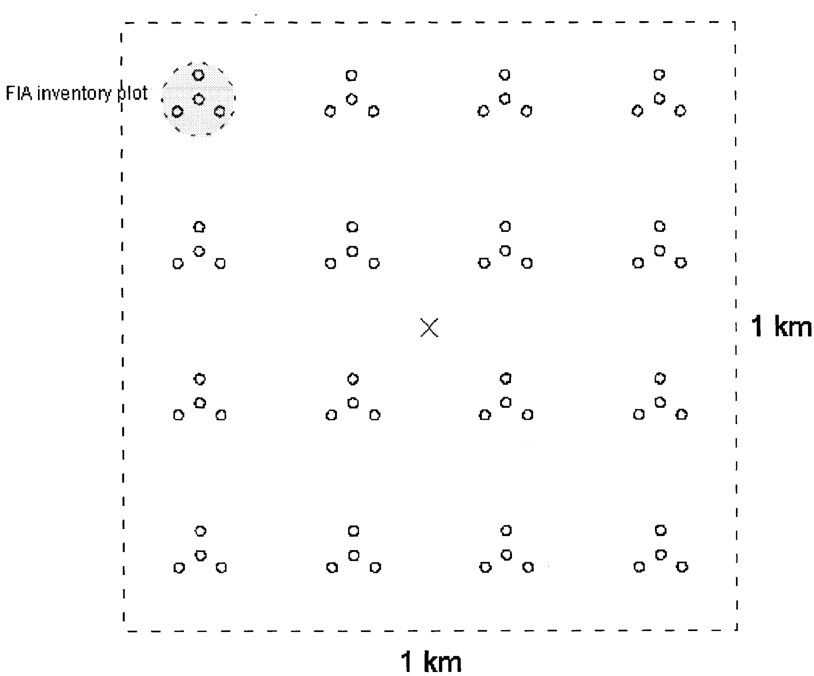


**Fig. 1.1** Proposed landscape-scale sampling design for the U.S. using 16 FIA inventory plots. Researchers may need to install additional plots to ensure that measurement precision is within desired limits. The FIA design is shown in more detail in Fig. 1.3. The cross represents a meteorological or flux tower

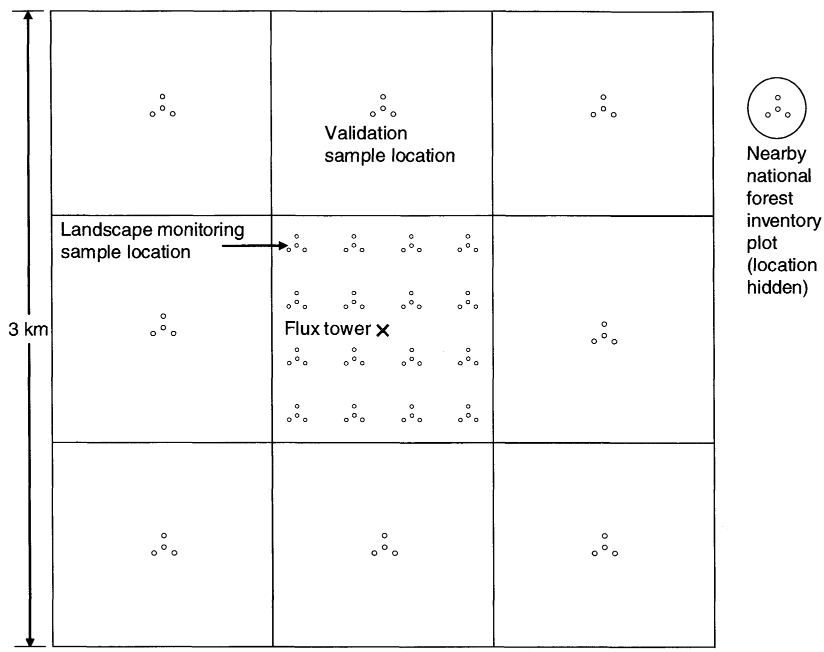


**Fig. 1.2** Landscape-scale sampling area expanded to 3 × 3 km to include additional landscape features. The individual 1 × 1 km squares may be arranged in different configurations depending on the features of the landscape that are targeted for sampling. In this example, the additional 1 × 1 km squares are areas where LIDAR imagery will be acquired, and only a very small number of additional field sampling locations established to validate estimates

depending upon anticipated variability of the land area and desired precision. The 1 × 1 km land area may be expanded by adding adjacent 1 × 1 km sampling areas if estimates for a larger variety of landscape conditions are required (Fig. 1.2).

Other measures such as soil characteristics, soil respiration, litterfall, canopy N%, etc. should be carried out at or immediately adjacent to each inventory plot (note that in the FIA system, four of the grouped circular subplots constitute a "plot"). If it is not feasible to sample at each inventory plot (because of high cost, such as for $^{14}C$ analysis), groups of plots may be combined and one sample taken for each group. The goal should be to sample extensively across the 1 × 1 km grid rather than intensively at one or several inventory plots. This design should provide an unbiased estimate of carbon stocks and fluxes across the 1 km "pixel" but this may represent only one or a few actual satellite pixels (probably less due to registration issues). To improve the connection with satellite data, multiple 1 × 1 km sites may be needed.

## *1.5.1 Inventory Plots*

The United States FIA and Canadian NFI forest inventory plots differ in design, and, in turn, both differ from a system proposed for the Mexican states of Jalisco and Colima (Wulder et al. 2001, USDA 2007). In the US, all FIA units have implemented a common sampling design consisting of four clustered, 24 ft radius subplots (total sampled area of 672 $m^2$ or 0.166 acre) for trees at least 5 in. in diameter and four 6.8-ft radius microplots (total area of 54 $m^2$ or 0.0133 acre) for smaller trees (Fig. 1.3). Subplot 1 is the center of the cluster with the other three subplots located 120 ft away at azimuths of 360°, 120°, and 240°, respectively.

In contrast, the NFI plots are larger and laid out concentrically (Anonymous 1999). The "large tree plot" has a fixed-radius of 11.28 m (37.01 ft) and area of 400 $m^2$ (1/10 acre), and the "small tree plot" has a fixed-radius of 3.99 m (13.09 ft) with an area of 50 $m^2$ (0.0124 acre).

The Mexican system (Anonymous 2002) consists of a 30 x 30 m square primary sampling unit (PSU) containing five clustered subplots, each of 5 m radius (total sample area of 392.7 $m^2$ or 0.097 acre). The PSU is divided into a grid of nine 10 × 10 squares with subplots centered in the corner and middle grid cells of the PSU. Trees larger than 12.5 cm DBH are measured on each subplot and saplings (2.5 cm ≤ DBH ≤ 12.5 cm) are measured on 3 m radius plots centered on the subplots (total area of 141.4 $m^2$ or 0.035 acre). Each of these sampling designs serves as a satisfactory solution for assessing tree and shrub carbon stocks on a plot of land. To maintain compatibility with existing inventory systems, we recommend that inventory plots match the design of the standard inventory plot in their country. We discuss

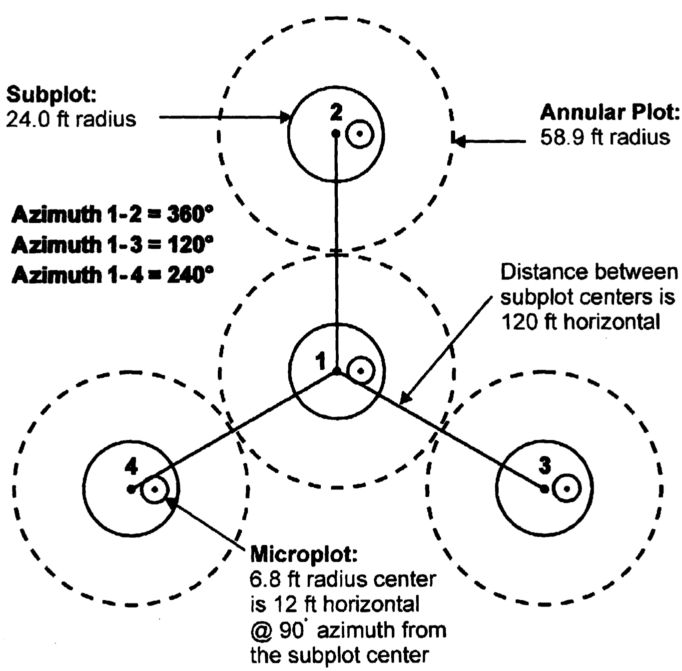


**Fig. 1.3** USDA Forest Service Forest Inventory and Analysis plot. The "annular" (58.9 ft radius) plots are not used in the landscape-scale sampling design

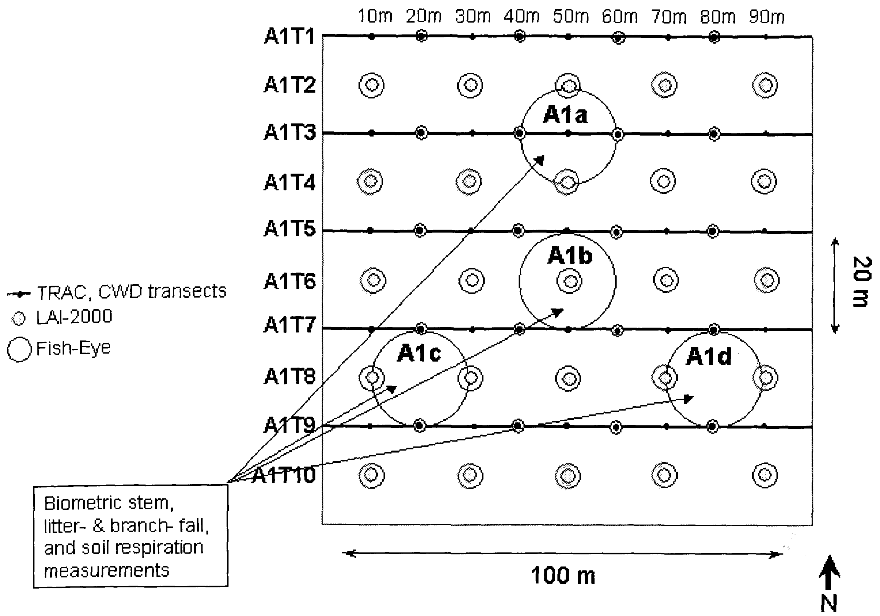


Fig. 1.4 Detail of additional measurement locations around a cluster of FIA-type subplots. These measurements would be repeated around each cluster of subplots

exceptions to this rule later in the manual. One possible exception relates to the assessment of coarse woody debris (CWD). The US, Canadian, and proposed Mexican systems use "Y"-shaped, "cross", and straight line-intersect transects, respectively, for measuring CWD. Recent work suggests that "Y"-shaped or "cross" designs lead to estimation errors (Gregoire and Valentine 2003) and that a single transect with length equivalent to the sum of the segments in the current systems would be better. In this manual, however, we recommend an improved method for sampling CWD, perpendicular distance sampling (Chapter 6).

For some measurements the sampling intensity may need to be increased, necessitating an overlay on the plot design. An example of this (Fig. 1.4) shows one FIA cluster of plots overlain with additional sampling locations for leaf area index, litter fall, soil respiration and other factors. Additional information is included in the chapters describing specific measurements.

### *1.5.2 Precision of Estimates*

Since the inventory plots provide a statistical sample of the carbon pools across the landscape-scale site, it is important to declare up front what would constitute an acceptable level of error in the estimates. Setting this acceptable error level too high may result in poor correlation with remotely sensed variables or have insufficient statistical power to reject a false null hypothesis. A reasonable, acceptable margin of error for studies of carbon pool size is plus or minus 10%. For estimating a mean with 95% confidence, the sample size $n$ needed is:

$$n = \frac{16}{(d / \sigma)^2}$$

where $d$ is the acceptable range of the error and $\sigma$ is the standard deviation. As an example, Hollinger (unpublished) found that the standard deviation of biomass estimates made from FIA-sized subplots in a relatively homogeneous spruce-hemlock forest was 33% of the mean. To obtain a precision of ±10% of the mean with 95% confidence, 44 subplots (11 FIA plots) would be necessary. Over a more variable landscape, more plots would be necessary to meet this target or it would be necessary to accept a reduced precision. Designs with 16 FIA plots will reach the desired precision when $\sigma < 40\%$ and with 36 FIA plots when $\sigma < 60\%$ of the mean. The variance ($\sigma^2$) will depend upon the pool or flux being sampled, but should be estimated for all important parameters so that the necessary sample size can be calculated. Carbon in soils, for example, can be highly variable, necessitating additional sampling.

## 1.6 Implementation Issues

The new landscape-scale monitoring tier should be comprehensive in its coverage of North American ecosystems, and represent a variety of disturbances and stages of ecosystem recovery following disturbance. Each landscape-monitoring site should ideally be representative of landscape conditions over a larger area. Because some of the envisioned measurements require multiple site visits per year (as frequently as weekly for periods of high litterfall or for soil respiration measurements), it is efficient to use clusters of sampling locations as described here to minimize travel time between sampling locations, and to take advantage of existing infrastructure such as that found at established intensive sites.

The current network of intensive carbon monitoring sites should be considered a candidate list for enhancement with landscape-scale monitoring. Some of these sites already include landscape-scale carbon monitoring (for example, Ehman et al. 2002, Law et al. 2003). However, the current network of intensive monitoring sites does not fully represent all ecosystems and contains significant gaps in highly disturbed areas and steep terrain. Additional candidate sites to expand the landscape-scale network that already have some established infrastructure include experimental farms and forests maintained by government agencies, universities, and the private sector, and reserved areas that do not have restrictions on research activities. The analysis by Hargrove et al. (2003) is a good start at identifying areas that are under-represented, but this analysis should be expanded to reflect the needs of landscape-scale monitoring to include better representation of disturbed and managed areas.

Since data from landscape-scale sites are intended for use in a variety of applications under the NACP, standardized methodologies and outputs are required. However, in many cases the new measurements will be overlaid on existing intensive sites and the spatial distribution of landscape characteristics for sampling are highly variable, so some flexibility in application of the design principles described in this document is required. As mentioned earlier, the exact number of sampling locations required within a $1 \times 1$ km land area depends on homogeneity within the area. If multiple $1 \times 1$ km sampling areas are required, the spatial arrangement of the sampling areas may be adapted to the landscape. It is highly recommended that the individual sampling areas be no smaller than $1 \times 1$ km to allow co-registration with information from satellite sensors. Sampling protocols within the $1 \times 1$ km land areas may be adapted to take advantage of existing sample plots, or to stratify the landscape to increase the probability of randomly locating samples in important conditions that represent small proportions of the landscape. Finally, the exact suite of measurement may vary between landscape monitoring sites depending upon local conditions. When considering variations from the recommended design, however, the ability to provide standardized outputs that are compatible with those from other sites must be maintained. Thus, any local variation should be **in addition to** the standard design.

Other factors should also be considered in developing a sampling design and measurement protocol for a landscape-scale monitoring site under the NACP. Adherence to the NACP policies for data management (Cook and Thorton 2005) is required. Sampling locations should be accurately geo-referenced, and the coordinates made available to users without restrictions. This may require obtaining landowner permission to release the coordinates or other site data. Security of the site from unwanted manipulation, and of the installed equipment, should be a major consideration in site selection since a potentially long period of measurement and monitoring will be important to the NACP. And finally, safety must be the top priority for all measurement and monitoring activities.

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