Chapter 2
Study Site Characterization

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Abstract This chapter is an overview of the main site characterization requirements at landscape-scale sampling locations. The overview is organized according to multiple "Site Attribute" headings that require descriptions throughout a given study site area, leading ultimately to a sufficient overall site characterization. Guidance is provided to describe the major site attributes similarly across landscape-scale locations so that inter-site comparisons can be facilitated.

Keywords Site, characterization, climate, forest age, land use, soil

2.1 Introduction

Site characterization is required for: (1) interpreting observations and understanding processes, (2) comparing observations among study sites or with other data sets, and (3) establishing a basis for extrapolating (or scaling) from the study site to other similar sites or areas. It is desirable to characterize study sites in ways that are compatible with common standardized definitions and protocols, such as those used in national data bases. USDA's Forest Inventory and Analysis (FIA) and National Resources Inventory (NRI) are examples of long-term inventory programs that set national standards (Nusser and Goebel 1997, Bechtold and Patterson 2005). Likewise, DOE's AmeriFlux network and the National Science Foundation's (NSF) Long-Term Ecological Research (LTER) network are example of intensive

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C.M. Hoover (ed.) *Field Measurements for Forest Carbon Monitoring*,

monitoring programs with data requirements and standards (Law et al. 2005). While it may be impossible to completely reconcile standards and requirements among different ecosystem studies programs, an effort should be made to be as consistent as possible, even if this means classifying the same variable in more than one way.

Although there may be no universal definition of the term "site characterization" specifically for carbon cycle studies, this activity is assumed to include surveys of all critical biotic and abiotic factors of the local environment, as well as the history and impacts of human activities in the study location(s) of interest. Selected geographic and political site descriptors, such as county or congressional district, may also be useful. A "site" may be composed of more than one distinct element of a landscape, i.e., may be a mosaic of patches with distinct characteristics. Characterizing a landscape may therefore require multiple sets of site variables, each associated with a map of the site showing the distinct patches. Alternatively, some site variables may be shown as a continuum of values on a map or image of the landscape.

This chapter is organized according to multiple "Site Attribute" headings that require standardized descriptions throughout the study area, leading ultimately to a sufficient overall site characterization. Under each Site Attribute section that follows, there are lists of both the 'Basic' attribute features that should be described in a standardized manner for every landscape-scale study site, and 'Advanced' attribute features that may be collected at any study site if resources permit. Published reference and/or internet sources are included for each attribute, which provide standard data bases and methodologies for consistent site characterization results across landscape-scale locations.

2.2 General Attributes

2.2.1 Geographic and Ownership Description

Important general information about research sites includes location and ownership. Common geographic descriptors such as state and county are very useful. The study site or landscape area should be described with precise geographic coordinates (lat/long or UTM) to facilitate overlay with maps or other geographic data. The ownership of the land should be recorded using a specific agency name if the land is public, and a generic name (e.g., nonindustrial private) for private land. If the land has protected status, such as an Experimental Forest or Research Natural Area, this should be noted.

2.2.2 Present Land Use/Land Cover

Land use/land cover is a basic site classification that allows comparison or extrapolation of results to similar, broadly defined areas. Current land use/cover should be

recorded or mapped for each area using a national inventory protocol such as FIA or NRI, or a standard land cover classification such as NLCD 2001 (specify which classification schemes are used).
Recommended major land use/land cover categories and sub-categories include:
Water
Developed – residential
Developed - industrial
Forest
Cropland
Grass/field
Wetland

Advanced land-use features that indicate management intensity may include:
Agricultural management:
No-till
Fertilizer use
Irrigation
Herbicides

Forest management:
Clearcut
Partial cutting
Thinning
Site preparation
Regeneration
Fuels management
Fertilization

Hydrologic management:
Dams
Reservoirs
Canals

Suggested web sites:

FIA	http://fia.fs.fed.us/
NRI	http://www.nrcs.usda.gov/technical/NRI/
USGS Eros Data Center	http://edc.usgs.gov/products/landcover.html

2.3 Land Cover Change

Land cover changes represent one of the most significant drivers of changes in carbon stocks and fluxes. For example, a study by Casperson et al. (2001) based on analysis of forest inventory data suggested that land-use history (broadly defined to include harvesting for products and land-use change) accounted for more than 90%

of recent carbon accumulation in forests. All major historical land use changes and disturbances should be discussed in terms of their geographical distribution, frequency and intensity, the size of the area occupied by each, and the impact on land cover. The dates of the changes or disturbances should be recorded. Basic land cover change features should be characterized for all study sites, with precise dating of events if possible.

Natural disturbances:
Wildfire
Drought
Flood
Weather damage (ice, wind)
Pest outbreaks

Human disturbances:
Fire
Deforestation and/or afforestation
Timber harvest
Stand treatments (see "forest management" above)
Grazing
Agricultural treatments (see "agricultural management" above)
Introduced species

Advanced land cover change features that may be characterized include tree ring chronologies, carbon dating, and isotope characterization.

Suggested web sites:

http://landcover.usgs.gov/landcovertrends.asp

2.4 Present Vegetation Composition

Vegetation composition is associated with variability in ecosystem carbon stocks (Sun et al. 2004). Characterization of vegetation composition according to a common plant functional type is required for using site data in models, and for extrapolating results from individual sites or landscapes to larger or similar geographic areas. Major species and/or species groups are required for vegetation characterization, such that the site composition can be readily related to one of the classification systems listed below. Major plant species should be recorded in terms of geographical distribution and the size of the area occupied by each. In this section we present a few of the more common vegetation classification systems. Sometimes it is necessary to have the site classified according to more than one system, or to at least be aware of how to crosswalk from one system to another.

Forest Inventory and Analysis (FIA) – the FIA program uses a forest type classification that is relevant to land management. The system is based on a set of rules that determine forest type from the dominance or co-dominance of different tree species. There is a two-level hierarchy comprised of forest type groups and forest types. Details are available in the FIA field manual (see web site below).

Food and Agriculture Organization (FAO) – the United Nations FAO has developed a classification system that is commonly used for the world's forests, and is the basis for reporting global forest statistics in periodic Forest Resource Assessments. The FAO classification system is primarily designed to determine how "natural" forests are by determining whether trees are planted or natural, and if natural, whether the forest is "primary" (or mostly undisturbed) or "secondary" (recovering from disturbance).

National Land Cover Data (NLCD) – National land cover data is derived from Landsat satellite imagery and is classified by vegetation types that are more detailed than the basic land cover classes. Since this is a common product for mapping vegetation, it may be necessary to classify sites according to this scheme.

International Geosphere/Biosphere Program (IGBP) – MODIS and other satellite data products use the IGBP vegetation classification system, which includes 11 vegetation classes.

Advanced vegetation cover features that may be characterized include detailed descriptions of species including understory vegetation, which may also be used to construct biodiversity indices.

Suggested web sites:

FIA http://fia.fs.fed.us/
FAO http://www.fao.org/forestry/index.jsp
NLCD http://landcover.usgs.gov/index.asp
IGBP http://edcdaac.usgs.gov/main.asp

2.5 Forest Stand Age

In forest ecosystems, stand age is one of the most important variables affecting all of the carbon pools (Pregitzer and Euskirchen 2004). Stand age may not be the same as time since disturbance if the trees are of multiple ages. Time since disturbance is described in the previous section titled "land cover change". We intend *stand age* to represent the weighted mean age of live trees in the overstory. Stand age is intended to represent time since tree establishment (not time since tree reached breast height). In mixed-age stands, it may be useful to record both mean stand age and maximum tree age (age of oldest tree sampled).

Individual tree age is best measured from increment cores, although in some cases land management records may contain information about the dates of past disturbance events that may have initiated a new stand of trees. Since stand age is intended represent the mean age of live trees in the overstory, it may be estimated from as few as two to three dominant trees from the overstory of the stand (FIA 2005). These trees should be selected to represent the distribution of tree sizes and species within the overstory, and may be selected using existing information on stem diameter distribution. Investigators should use either visual inspection, or preferably, stem diameter distribution data to assign each sampled tree a weight indicating the fraction of the overstory it represents. (The sum of weights should be 100%.)

Core each representative tree at breast height (1.37 m or 4.5 ft) with an increment borer. Extract core from borer, and inspect to be sure that the core reached the tree pith. Count rings between the pith and the outside edge of the core (inside bark). Correct this age to account for years required to reach breast height, with default values of 5 years for eastern species, 5 years for western hardwoods, and 10 years for western softwoods (FIA 2003). Multiply age of sampled trees by their respective weights, and total for stand age.

2.6 Topography

Topographic information about landscapes is useful in carbon cycle studies. Soil characteristics including carbon content are strongly influenced by topographic position (Kulmatiski et al. 2004). Topography influences the movement of carbon across the landscape in soil and water. The ability to interpret the "footprint" of CO_2 flux estimates from eddy covariance measurements is strongly affected by topography (Baldocchi et al. 2000). Many ecosystem process models use elevation as a basic data layer. Topography of a region is provided by USGS topographical maps available at a variety of scales (1:5,000–1:25,000 and more). Topography may also be determined from digital elevation maps.

Basic topographic features should be characterized, including:

Ground control points (latitude/longitude/elevation) at or near the center of all measurement plot locations

List of different land forms, including plateaus, mountains, hills, and valleys

Slope classes

Advanced topographic features that may be characterized include:

Land forms of differing surface water drainage potential

Locations of streams, rivers, lakes, reservoirs

Drainage basin delineation

Relief intensity (maximum difference in elevation per sq. km, expressed in meters)

Remote imagery of the region, e.g., aerial photographs, Shuttle Radar Topographic Mission (STRM) images

Ground control points (latitude/longitude/elevation) for remote image geographic registration

Suggested web sites:

http://gos2.geodata.gov/wps/portal/gos
http://edcdaac.usgs.gov/gtopo30/gtopo30.html

2.7 Soils and Geology

In forest ecosystems, carbon in soils often represents the largest percentage of all ecosystem carbon, exceeding 75% of the total in some forest types, and averaging about 50% for U.S. forests (Heath et al. 2003). Ecosystem process models usually require information about soil characteristics. For example, a key parameter in the PnET model is soil water holding capacity (Pan et al. 2004). Thus, a good characterization of soils is an essential classification of landscape-scale carbon monitoring. Soil characterization includes a summary analysis of soil types present in the survey map products of the USDA soil taxonomy classification system. All major soils and/or categories should be discussed in terms of their geographical distribution and the size of the area occupied by each soil type, according to the USDA State Soil Geographic Database (STATSGO).

Basic soil features should be characterized for all study sites, including:
USDA soil type
Texture and soil size separates
Organic matter content
Bulk density and compaction

Advanced soil features that may be characterized include:
Texture profile distribution of soil size separates
Chemical properties, e.g., pH, CEC, base saturation
Permeability and drainage
Contamination and pollution (if relevant)

Suggested web sites

http://soils.usda.gov/
http://www.essc.psu.edu/soil_info/index.cgi?soil_data&conus

Information about parent materials and bedrock composition available in soil survey reports can be considered adequate for the purposes of site characterization. Basic geologic features should be characterized, including:
Parent material composition
Depth of soil to bedrock

2.8 Climate and Air Quality

Climate and air pollution are important drivers of processes that affect productivity and ecosystem carbon, and are almost always key input variables for a wide range of carbon models (Schaefer et al. 2002, Nemani et al. 2003, Potter et al. 2003). Climate and air quality characterization should consist of annual, seasonal, or monthly ranges and averages. Finer-scale weather characterization is covered in the chapter on micrometeorology (next chapter).

Basic climate and air quality variables should include:
Surface air temperature
Precipitation - frequency and distribution
Solar radiation flux
Relative humidity
Nitrogen deposition
Tropospheric ozone exposure

Advanced climate and air quality features that may be characterized include:
Wind direction and speed
Potential evapotranspiration
Data summaries of historical air quality in the region, in terms of ambient concentrations of hydrocarbons, carbon monoxide, nitrogen oxides, sulfur oxides, photochemical oxidants, and particulates

Suggested web sites:

http://www.ncdc.noaa.gov/oa/climate/climateresources.html

We remark in closing that the main goal for site characterization at landscape-scale sampling locations is to describe the major site attributes similarly across locations so that inter-site comparisons can be facilitated. Although investigators are also encouraged to classify site attributes in as many ways as possible as a means to more readily extrapolate across non-landscape-scale sites with varying classification systems, that is a secondary priority to well-standardized descriptions across sites in the landscape-scale network.

It is recommended that standardized worksheets (with units, wherever appropriate) be developed by investigators to include the basic and advanced attributes listed in this chapter. The worksheet templates will aid site teams in organizing their descriptions rapidly and consistently. A section for listing references should be included for each landscape-scale site description worksheet as well, which will be particularly valuable if these citations are not readily available as published papers in the literature.

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