ORNL/TM-1999/216

BigFoot

Characterizing Land Cover, LAI, and NPP at the Landscape Scale for EOS/MODIS Validation

Field Manual Version 2.1

ORNL/TM-1999/216

Environmental Sciences Division

BIGFOOT FIELD MANUAL

VERSION 2.1

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Environmental Sciences Division
Publication No. 4937

Date Published: September 1999

Prepared for the
National Aeronautics and Space Administration
Budget Activity Number 46 WF 04 40 2

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
Managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
For the
U.S. DEPARTMENT OF ENERGY
Under contract DE-AC05-96OR22464

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PREFACE

The Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics is operated as part of the National Aeronautics and Space Administration's (NASA's) Earth Science Enterprise. The ORNL DAAC (http://www-eosdis.ornl.gov/) maintains data related to biogeochemical dynamics. As part of its role, the DAAC supports the NASA Earth Observing System (EOS) Validation Program by archiving and distributing field-measurement and remote-sensing data associated with validation. The goal of the EOS Validation Program is to make a comprehensive assessment of all EOS science data products.

The BigFoot Project is funded by the Earth Science Enterprise to collect and organize data to be used in the EOS Validation Program. The data collected by the BigFoot Project are unique in being ground-based observations coincident with satellite overpasses. In addition to collecting data, the BigFoot project will develop and test new algorithms for scaling point measurements to the same spatial scales as the EOS satellite products. This *BigFoot Field Manual* will be used to achieve completeness and consistency of data collected at four initial BigFoot sites and at future sites that may collect similar validation data. Therefore, validation datasets submitted to the ORNL DAAC that have been compiled in a manner consistent with the field manual will be especially valuable in the validation program.

ACKNOWLEDGMENTS

This project is funded by NASA's Terrestrial Ecology Program, directed by Dr. Diane Wickland.

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ABBREVIATIONS

AGRO	agricultural cropland
ASPN	aspen
BLSP	black spruce
BOREAS	Boreal Ecosystem-Atmosphere Study
BORIS	BOREAS Information System
CORN	corn
DAAC	Distributed Active Archive Center
DBH	diameter at breast height (4.5 ft above ground)
EHWD	eastern hardwood
EOS	Earth Observing System
ET	evapotranspiration
FALO	fallow
f_{APAR}	fraction absorbed photosynthetic active radiation
GALF	gallery forest
GEWEX	Global Energy and Water Cycle Experiment
GPP	gross primary production
GPS	Global Positioning System
HARV	Harvard Forest
HEML	eastern hemlock
IGBP	International Geosphere-Biosphere Programme
JKPN	jack pine
KONZ	Konza Prairie
LAI	leaf area index
LANDSAT	land satellite
LTER	Long-Term Ecological Research
MDNR	Manitoba Department of Natural Resources
MODIS	moderate resolution imaging spectrometer
MODLand	MODIS Land Discipline Group or MODIS Land Science Team
MP	mesh plot
MSKG	muskeg
MTCLM	Mountain Climate Simulator
NAD	North American Datum
NASA	National Aeronautics and Space Administration
NDVI	normalized difference vegetation index
NEE	net ecosystem exchange
NOAA	National Oceanic and Atmospheric Administration
NOBS	northern old black spruce
NPP	net primary production
NPP_A	aboveground NPP
NPP_B	belowground NPP
NSA	Northern Study Area
OLDF	oldfield meadow
ORNL	Oak Ridge National Laboratory

PAR	photosynthetically active radiation
RDPN	red pine
SGPR	shortgrass prairie
SHRB	shrub community
SOYB	soybean
SVI	spectral vegetation index
TGPR	tallgrass prairie
TM	Thematic Mapper
USDA	U.S. Department of Agriculture
UTM	Universal Transverse Mercator
VEMAP	Vegetation/Ecosystem Modeling and Analysis Project
WHC	water-holding capacity
WTLD	wetland

Section 1

Project Overview

Objectives

- Develop an understanding of the environmental and ecological controls on leaf area index (LAI), total net primary production (NPP), and carbon allocation within and among biomes
- Examine relationships between NPP and net ecosystem exchange (NEE) and how to translate between them using ecological models
- Develop algorithms to scale vegetation cover, LAI, fraction absorbed photosynthetic active radiation (f_{APAR}) and NPP from point measurements to larger regions (several square kilometers)
- Quantify errors and uncertainties that exist when scaling vegetation characteristics from small plots to large areas

Methods

- At a given site, measure land cover, LAI, f_{APAR}, and NPP (aboveground and belowground components) for a 5 x 5 km area
- Extrapolate field measurements to high-resolution grids (cover, LAI, f_{APAR}, and NPP) using Landsat imagery and statistical and ecological models
- Characterize errors in these grids using independent field observations
- Compare field-verified high-resolution grids to Moderate Resolution Imaging Spectrometer (MODIS) product grids
- Isolate effects of land-cover generalization, image grain size, and ecological modeling parameters on MODIS NPP estimates
- In the field, examine spatial autocorrelation of cover, LAI /f_{APAR}, and NPP, and use this information to guide scaling algorithms

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Background and Summary

The objective of BigFoot is provide ground validation of MODLand (MODIS Land Discipline Group) land cover, leaf area index (LAI), f_{APAR}, and net primary production (NPP) products. The name BigFoot was selected to describe the multiple scales, or footprints, of ground validation that the project will undertake (Figure 1.1). The current BigFoot study plan covers measurement, mapping, and modeling activities at four sites, each equipped with a meteorological flux tower that makes continuous measurements of energy, water, and carbon fluxes for a roughly 1-km^2 footprint. Ground validation measurements will be conducted both within the 1-km^2 eddy flux tower footprint and in an outlying area covering 25 km^2.

The core BigFoot products will be 25-km^2 surfaces at 25-m spatial resolution for land cover, LAI, f_{APAR}, and NPP. Land cover and LAI will be based on land satellite (LANDSAT) ETM+ (i.e., passive-sensor) imagery, and NPP will be based on spatially distributed, process-based biogeochemistry models. The models will be initialized with the land cover and LAI surfaces and driven by time-series meteorological data. Validation of BigFoot land cover and LAI surfaces will be based on ground sampling of land cover and LAI, which is not used in development of the original surfaces. Validation of BigFoot carbon and water flux estimates will be made over the flux tower footprints at a daily time step, based on flux tower measurements, and for the 5 x 5 km study area (henceforth referred to as the MODLand footprint) based on a sample of new aboveground NPP (NPP_A) measurements. Belowground NPP (NPP_B) will be measured mostly in the immediate vicinity of the flux towers.

For comparisons to MODLand NPP products, the BigFoot 25-m^2 grid at each site will be overlain with the 1-km^2 MODLand grid that is spatially consistent with the MODIS imagery. NPP models will be run for calendar years 1999 and 2000 for the Northern Old Black Spruce (NOBS) boreal forest and agricultural cropland (AGRO) study area and compared with MODLand NPP products produced at 8-day and annual time steps (Figure 1.2). Similar analyses will be conducted for

Figure 1.1. Conceptual model illustrating the use of field measurements and remote sensing to characterize the vegetation cover, f_{APAR}, LAI, and NPP for the BigFoot sites.

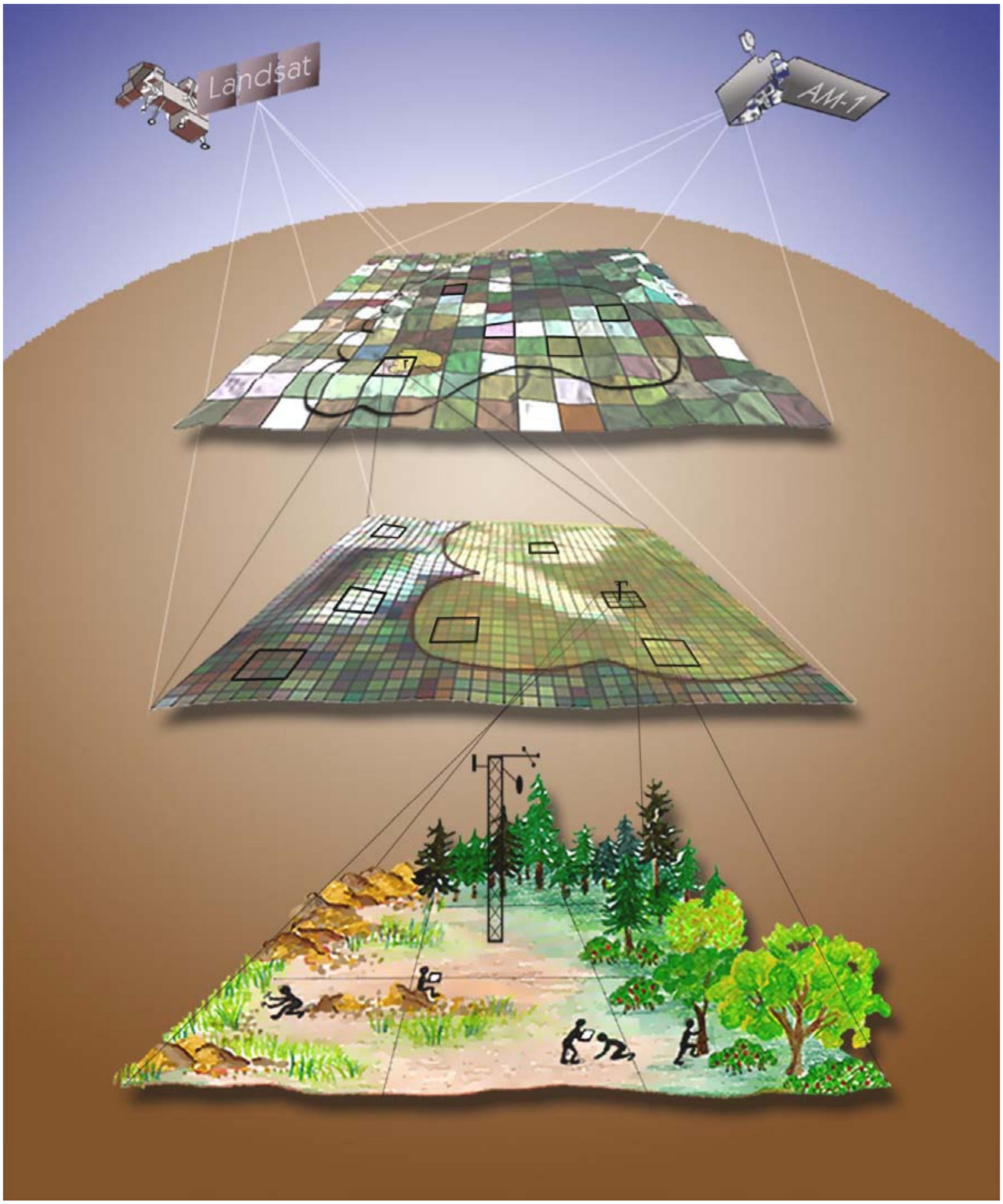
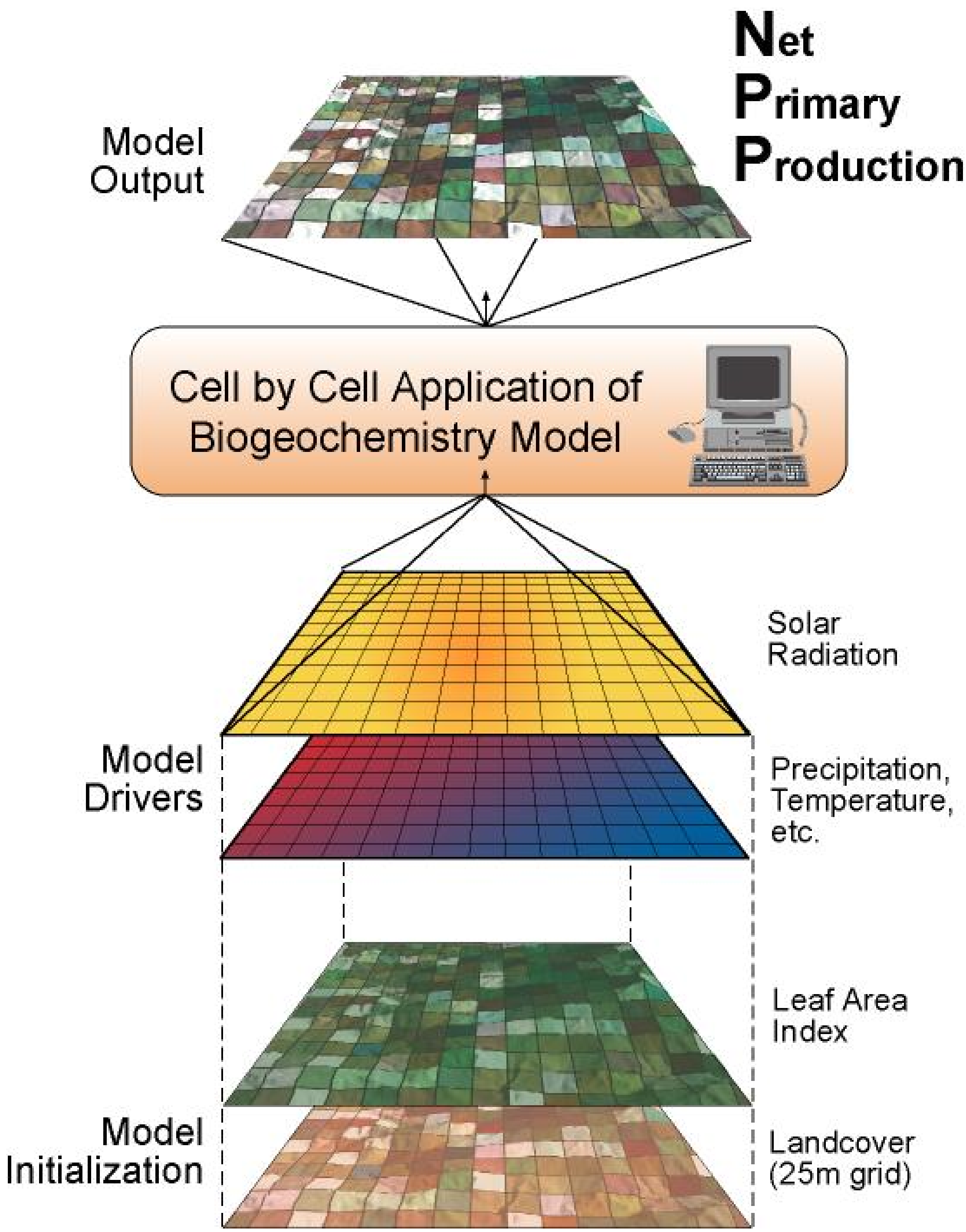


Figure 1.2. Conceptual model illustrating the approach used by BigFoot scientists to model vegetation characteristics for the validation of MODLand products.



the tallgrass prairie [Konza Prairie (KONZ)] and temperate forest [Harvard Forest (HARV)] study areas in 2000 and 2001. Differences between BigFoot and MODLand NPP products will be evaluated in terms of the differences in spatial resolution of the analysis, the differences in vegetation classification system, and the differences in epsilon, the light use efficiency factor, as used in the MODLand NPP algorithm and as derived from BigFoot NPP simulations.

Sites

The primary goal of BigFoot is MODIS product validation. To that end, we will compare fine-grained gridded surfaces developed within our project to MODIS coarse-grained surfaces. We want to know under what sets of conditions these surfaces both correspond and diverge. In particular, the effect of fine-grained cover type heterogeneity, the generalization of land cover classes, and the derivation of production efficiency factors will be evaluated. Comparisons of co-located grid cells within each site are one level of validation, whereas a comparison of grid cell summaries across sites is another. Theoretically, it is possible that not a single MODIS cell estimates land cover, LAI, and NPP accurately, but that at the multi-cell level within a site, MODIS does accurately represent these variables. This latter level of validation is critical as a first determination of how well MODIS products provide accurate estimates across sites (e.g., globally).

Several factors were considered in site selection, including BigFoot objectives, representation across the range of biomes, budgetary and logistical constraints, and relative cost of potential sites within the overall budget. BigFoot is attempting to be as consistent as possible with Earth Observing System (EOS) validation goals and objectives; thus, an additional criterion was that the sites have an active eddy flux tower.

A total of four sites were selected for the BigFoot study: a boreal forest (NOBS), a temperate hardwood forest (HARV), a midwestern cropland (AGRO), and tallgrass prairie grassland (KONZ). The boreal evergreen conifer forest site is the Boreal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) old black spruce site (NOBS) near Thompson, Manitoba, Canada. Drs. S. Wofsy, Harvard University, and Mike Goulden, University of California—Irvine, oversee the operation of the flux tower at the site. The temperate crop site has alternate crops of corn and soybean; it is located near Champaign-Urbana, Illinois. Dr. Tilden Meyers, National Oceanic and Atmospheric Administration (NOAA), oversees the flux tower at the site. The site is also used for Global Energy and Water Cycle Experiment (GEWEX) validation. The tallgrass prairie site is located at Konza Prairie near Manhattan, Kansas. The site is part of the U.S. Long-Term Ecological Research (LTER) network. Dr. Jay Ham, Kansas State University, oversees the flux tower at the site. The temperate hardwood forest site is located at the Harvard Forest, near Petersham, Massachusetts, and is also part of the U.S. LTER network. Dr. Steve Wofsy, Harvard University, oversees the operation of the flux tower.

Field LAI and NPP Measurements

At each site a 25-km^2 area has been identified using ETM+ imagery. The general sample design is a nested approach that provides a greater number of sample locations for easily measured characteristics (i.e., vegetation cover and LAI) and fewer sample locations for more laborious measurements (i.e., NPP_A and NPP_B). The sampling design is primarily an irregular spatial series, sometimes referred to as a systematic spatial-cluster design (Figure 1.3). The design is a spatial application of a time series, with the tessellation unit defined as the number of sample points over a predetermined distance. Using the vegetation cover, LAI, f_{APAR}, or NPP data from this sampling design, a variogram (a plot of autocorrelation coefficient values in ordinate versus distance) can be constructed to determine the following: autocorrelation intensity, the size of the zone of influence, and the type of spatial pattern. The shape of the variogram provides insight into spatial pattern and underlying processes that influence vegetation cover, LAI, and NPP. This complex sampling design is an efficient sampling design (Fortin et al. 1989), but it requires a pair of real-time, differential processing Global Positioning System (GPS) units to accurately locate the plots in the field. Plots will be located in all vegetation cover classes within the 25-km^2 grid to ensure adequate coverage (Figure 1.3).

We will make direct and indirect estimates of LAI at each site. Direct measurement approaches will include periodic area harvest for the crop and prairie ecosystems or application of allometric equations to tree diameter data for the forest sites. LAI will be estimated indirectly using optical approaches (Gower and Norman 1991, Fassnacht et al. 1994, Chen et al. 1997). Gower and Campbell (or colleagues) will visit each site a minimum of three times each year and determine LAI for the major land cover types using Li-Cor LAI-2000 Plant Canopy Analyzers. LAI will be calculated at all sites as

$$LAI = (1-\alpha)\ Le\ \gamma_E / \Omega_E,$$

where

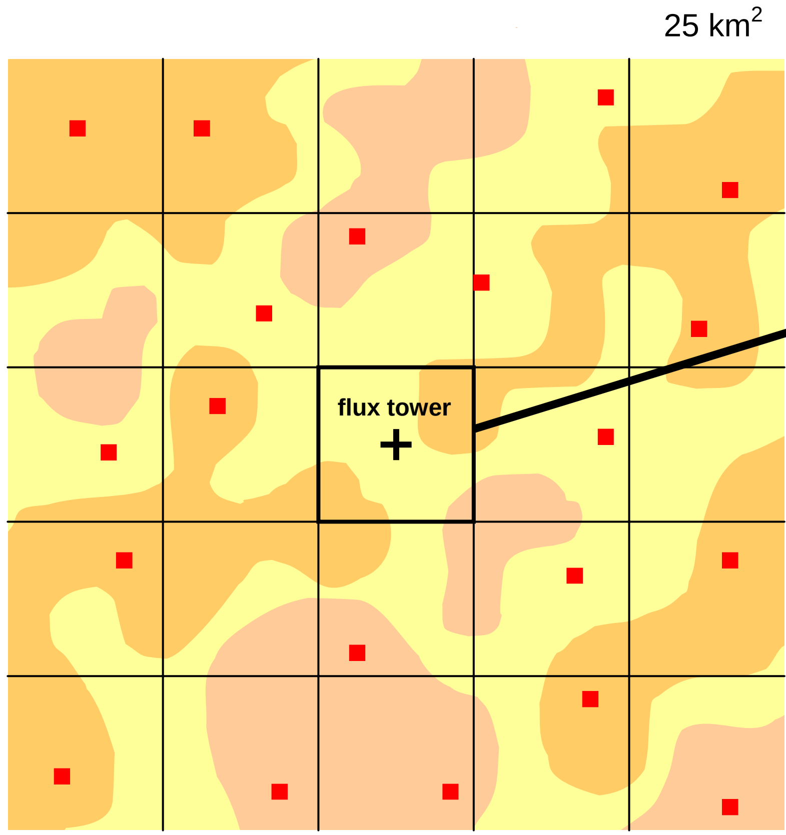
α = ratio of wood area to total plant area (wood + foliage area) and can be determined in forests from allometric relationships or using a multiband image analyzer (Gower et al. 1999);

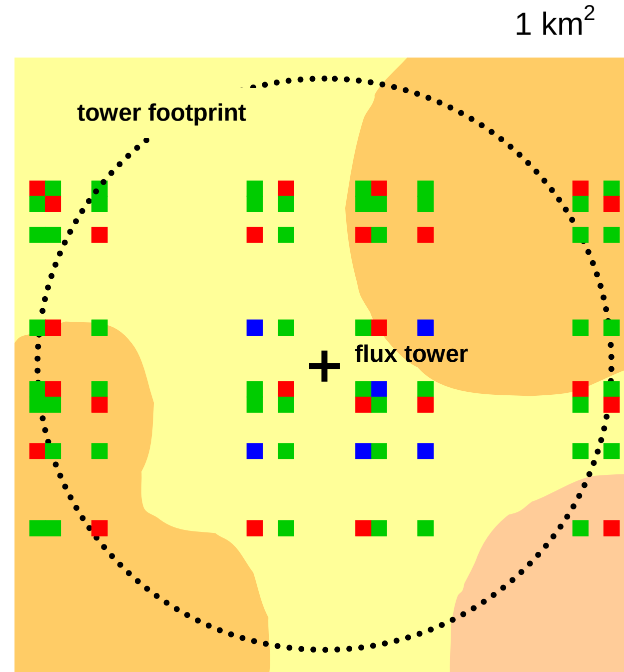
Le = effective leaf area index, which is commonly measured by instruments like the Li-Cor LAI 2000;

γ_E = needle-to-shoot area ratio, which quantifies clumping at the shoot level and increases as clumping increases. $\gamma_E = A_n/A_s$, where A_n is the ratio of one half the total area (all sides) of needles in a shoot and A_s is one half the total shoot area.

Ω_E = clumping correction factor for clumping at the branch-to-tree level.

Figure 1.3. BigFoot field sampling design.





Twenty plots (25 x 25 m in size) will be placed outside the tower footprint and within a 25-km^2 grid. The plots will be arranged in a deliberate fashion such that each of the major cover types is represented (i.e., stratified by cover type). The purpose is to verify that cover type-specific qualities hold over multi-kilometer distances and to address surface features that influence the 25-km^2 MODIS surface but are not necessarily present within the tower footprint.

Eighty plots will be arranged in a systematic spatial cluster design near the tower footprint. The purpose is to allow intensive measurements within the tower footprint and determine the degree and scale of spatial autocorrelation among cover type qualities.

- Extent is set by *a priori* predictions of the range of autocorelation among cover type qualities.
- Resolution (plot size) is set at 25 x 25 m by LANDSAT pixel size.
- Pattern and plot number is set by the number of cover types present and *a priori* predictions of their spatial arrangement.

Plots will be sampled at three levels of intensity:

- 3rd order plot: species comp, aboveground biomass, LAI, and f_{APAR}
- 2nd order plot: above plus aboveground productivity (NPP_A)
- 1st order plot: above plus below ground productivity (NPP_B)

Measurement of these parameters will be done following the protocol described in Fassnacht et al. (1994) and Chen et al. (1997). Results of all data analysis shoot architecture measurements and indirect estimates of LAI will be provided to site investigators. Estimates from these standard, well-established methods will be correlated to other LAI estimates obtained from either direct or indirect methods by site investigators. This approach has been used successfully in BOREAS (Chen et al. 1997). Average values by land cover class of specific leaf area and percent N in foliage will also be determined.

Net primary production is defined as the sum of the annual biomass production of each tissue (e.g., wood, foliage, roots). Various methods are used to estimate NPP_A and NPP_B, with some more suitable for small-stature vegetation communities (i.e., grasslands, tundra, agriculture crops) than for large-stature forests. We will estimate NPP using the following equation:

$$NPP = NPP_W + NPP_F + NPP_{CR} + NPP_{FR} + NPP_U + NPP_{GC} \quad , \qquad (1)$$

where

W = aboveground wood (e.g., stem + branches),
F = foliage,
CR = coarse roots,
FR = fine roots,
U = understory,
GC = ground cover (e.g., mosses and sphagnum).

Herbivory generally constitutes <10% NPP in forest ecosystems (Schowalter et al. 1986) and will be ignored in this study, but losses of NPP to herbivory and harvest must also be accounted for in the prairie and agriculture ecosystems. Aboveground woody biomass (e.g., stem and branch) and coarse root biomass will be estimated from allometric equations that correlate component biomass to an independent variable, usually diameter or basal area at breast height (1.3 m). Woody biomass increment is determined from radial growth, measured using increment cores. Numerous abiotic and biotic factors have been shown to influence the allometric coefficients for new foliage biomass; therefore, we will estimate new foliage production from annual leaf litterfall detritus production for forests where site- and species-specific allometric equations are not available (Gower et al. 1999). This approach assumes the canopy biomass is in steady state. In the case of the agroecosystems and prairie we will use clip plots throughout the growing season to quantify biomass production.

Total foliage biomass and leaf area equations will be from the literature (e.g., Gower et al. 1999). Where appropriate, biomass and leaf area data for harvested trees of the same species, but from different sites, will be composited and a generalized regression equation will be used. NPP_A of the shrub and herbaceous layers will be quantified using clip plots. NPP_A of bryophytes at the NOBS site will be estimated using crank wires for sphagnum and ingrowth mesh plots (MPs) for feathermoss; these methods were used successfully in BOREAS (Gower et al. 1997, K. Bisbee unpublished data).

Fine root NPP and mortality will be estimated using minirhizotrons (Steele et al. 1997). Because of the large costs associated with obtaining and processing these data to calculate NPP_B, we will restrict our analysis to a maximum of the two dominant vegetation cover types at each site. Twenty-five minirhizotrons will be installed in each ecosystem, and fine root growth will be measured for 2 years. Coarse root NPP will be estimated from allometric equations (Steele et al. 1997).

Land Cover and LAI Surfaces

The goal of this part of the research is to develop high-quality surfaces of land cover and LAI for use both for initializing the fine-grained NPP models and for comparison with MODLand surfaces that have the same two variables. To develop these two surfaces, we expect to use ETM+ data but will use Themataic Mapper (TM) data if no ETM+ data are available in a timely manner. Gower's field observations of land cover types and of LAI will be used to develop the surfaces. Independent field observations of cover and LAI will be used to characterize mapping errors associated with the generated cover and LAI surfaces.

To generate the land cover surfaces for each site, Cohen will conduct a field survey of cover types. For a given site, aerial photos, existing satellite imagery, and extant cover and ancillary data obtained from various sources will be examined in the lab prior to the field survey. This will familiarize Cohen with the sites and will result in a preliminary set of georeferenced points that will be visited in the field. This set will consist of a representative number of each important cover type and examples of apparent anomalies to the general set of cover types present. Consultation with site-level collaborators will ensure that Cohen has a good sense of the conditions at each site before visiting the sites. In the field, Cohen will use a borrowed real-time GPS instrument to record the locations of all points visited.

The ETM+ data will be atmospherically corrected and georeferenced in accordance with the methods, and with the assistance of software and expertise, of the MODLand Science Team. For each site, we plan to use multiseasonal imagery if it is available. First, an unsupervised classification of image data will be conducted to separate a vegetation/soil class from other classes, such as open water, rock outcrops, and non-biomass-producing anthropogenic features (Cohen et al. 1995). This single vegetation/soil cover class will be stratified into a series of classes consistent with a given site's characteristics, using a combination of statistical methods as appropriate to derive either class-level or continuous estimates (Cohen et al. unpublished data). One important land cover variable to be derived for all sites is (growing season) maximum percent vegetation cover. An additional, related characterization will be the percent vegetation cover before commencement of the local growing season. For forested classes we will model percent hardwood versus conifer and a structural variable, such as dominant and co-dominant tree size or stand age (Cohen and Spies 1992, Cohen et al. 1995, Maiersperger et al. in review, Thomlinson et al. in review). Similar stratification logic will be used for the cropland and grassland sites, as relevant for those sites. To test the effect of land-cover generalization on NPP estimates, we will also generate a separate cover map for each site, based on MODIS land cover classes [e.g., International Geosphere-Biosphere Programme (GBP)].

At least two different maximum LAI maps will be created for each site. The first will be based on regression modeling to relate LAI to spectral vegetation indices (SVIs) (e.g., Fassnacht et al. 1997), and the second on a “paint-by-numbers” approach that involves assignment of LAI mean and variance values to class labels for individual map cells (S. Goetz et al. unpublished data). SVIs are notorious for their asymptotic nature in relation to LAI (above about 3; e.g., Chen and Cihlar 1996, Goetz 1997), and as several of the sites have LAIs in excess of 3, these relationships will be weak for higher LAI values. The paint-by-numbers approach is designed to avoid this limitation of spectral vegetation indices. Spatial statistics will also be used to examine correlations between LAI and other environmental variables; this information may also be used to create spatial LAI maps. If feasible, a third LAI map will be created for each site. This map would be based on a stratification of low and high LAI values, and then the derivation of two separate SVI-LAI relationships, one for each range of LAI values. One-half of the field measurements of LAI will be used to develop the LAI surfaces; the other half will be used to evaluate errors in the surfaces.

A thorough characterization of errors will be conducted for each LAI and land cover surface generated. For land cover, all points observed by Gower in the field will be used. For LAI, only one-half of the field data is available, as the other half was used to develop the surfaces.

NPP Surfaces

Two process-based NPP models (PnET and Biome-BGC) will be run in a spatially distributed mode over a 25-m grid for the 25-km^2 study area at each site (Figure 1.2). Georeferencing will be done in the coordination with the MODLand Science Team. The models will be implemented in the C programming language with an interface to the spatial data using Image Processing Workbench (IPW) code. IPW is Unix-based public domain software supported by the U.S. Geological Survey.

The most critical spatially varying model inputs are land cover type, LAI, climate variables, and soil water-holding capacity (WHC). The LAI maps will provide the seasonal maximum LAI for each cell. LAI will be used to derive maximum fine root biomass and sapwood biomass (in the case of forests) using allometric relationships (Ryan et al. 1991, Hunt et al. 1996). The seasonal trend in LAI and fine root biomass will be determined by the phenology component of the models. For WHC, an initial average value for each site will be obtained from the WHC surface generated by the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP) (Kittell et al. 1995). Where local digital maps of soil texture and depth to bedrock are available at a finer spatial resolution, this information will be used to create an alternative WHC surface.

The daily climate variables required to run the models are maximum temperature, minimum temperature, solar radiation (total short-wave and photosynthetically active), precipitation, and daytime average vapor pressure. The meteorological data to generate these climate surfaces will be based on measurements at the flux towers. FLUXNET is planning to maintain a website with filled-in time series climate data for each FLUXNET site. For sites with significant terrain, the Mountain Climate Simulator (MTCLM) model (Running et al. 1987) will be used with a 30-m digital elevation model to simulate the climate across the landscape. Model runs will be made for calendar years 1999, 2000, and 2001, depending on the timing of the NPP measurements.

Validation at the daily and weekly time step will be made using the tower flux estimates for gross primary production (GPP) (GPP = daytime net ecosystem exchange – daytime ecosystem respiration). The BigFoot GPP estimates will be spatially averaged over the tower footprint [up to several square kilometers (km^2)]. If pertinent information about daily shifts in the position and size of the footprint are provided by FLUXNET micrometeorologists, an effort will be made to use that information in the 2-D modeling scheme to refine the relevant C flux estimates. Validation (error assessment) at the annual time step for NPP_A will be made by comparing model-simulated NPP_A with measured NPP_A at 40 locations. In some cases, additional NPP_A measurements are being made at these sites by other researchers, and these plots will be used for validation purposes as well. Modeled NPP will be separated by leaf litter production, fine root production, and wood production. The estimate for fine root production will be validated only for the grid cell containing the flux tower.

Validation at the daily and weekly time steps for modeled evapotranspiration (ET) will be made in parallel with the daily and weekly C flux estimates. Where streamflow data are available, the monthly and annual simulated streamflow will be compared with field measurements. An additional opportunity for validation of site water balance will be available at the BOREAS and crop sites, where soil moisture is being monitored using time domain reflectometry.

BigFoot/MODLand

The MODLand land cover product will be at a spatial resolution of 1 km and follow the IGBP classification system. BigFoot will produce 25-m land cover maps also based on the IGBP classification and 25-m land cover maps using site-specific classification schemes. Differences between the MODLand land cover products and the BigFoot IGBP-based land cover maps will be evaluated in terms of the proportional estimation error for each land cover class (Moody and Woodcock 1995) and the overall percentage difference at each site. For each site, evaluation of the BigFoot site-specific land cover map and the MODLand IGBP-based map will be in terms of the frequency distribution of the BigFoot cover types within each MODLand cover type. For LAI and NPP comparisons, there will be a direct overlay of the BigFoot and MODLand surfaces, and the differences will be determined for each 25 x 25 m grid cell.

Several scaling exercises will be performed to investigate causes of observed differences between BigFoot and MODLand NPP surfaces. To evaluate the role of spatial resolution, the BigFoot 25-m grids for input variables will be aggregated to resolutions of 250, 500, and 1000 m^2. Model runs will then be made at each spatial resolution, and comparisons of simulated NPP at the different resolutions (including 25 m^2) will be made with each other and with the MODLand 1-km NPP products. We hypothesize that there may be a fundamental grain size for each study site, above which error rates for NPP predictions accelerate. To evaluate the effect of the difference in land cover classification scheme (IGBP vs. site-specific), the models will be run at the 25-m resolution with only the land cover map varying. Results of model runs using the two land cover classification schemes will then be compared. To evaluate the differences between light-use-efficiency factors (epsilons) employed in the MODLand NPP algorithm and the corresponding epsilons from the climate data [incident photosynthetically active radiation (PAR)] and the BigFoot NPP models, the epsilon surfaces from each NPP model will be overlain with the MODLand epsilon surface.

Project Management

Cohen is the overall project leader, and as such, is responsible for making certain the project is effectively integrated. Cohen will supervise one Oregon State University research assistant, and together they will conduct the image processing and related analytical and scaling activities associated with land-cover and LAI surfaces. Gower is responsible for collection and analyses of ground data and for supervision of the University of Wisconsin personnel. Reich is responsible for 1-D modeling at each of the field points where NPP data are collected and for supervision of University of Minnesota personnel. Turner will conduct the 2-D spatial modeling and scaling-related activities associated with NPP and will supervise other Oregon State University research assistants. Although the comparison of gridded surfaces with MODIS surfaces will be led by Cohen, the integrative nature of this activity will require close interaction between the full BigFoot group and relevant MODLand scientists.

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Section 2

Study Site and Measurement Plan for Northern Old Black Spruce (NOBS) Study Area, Thompson, Manitoba, Canada

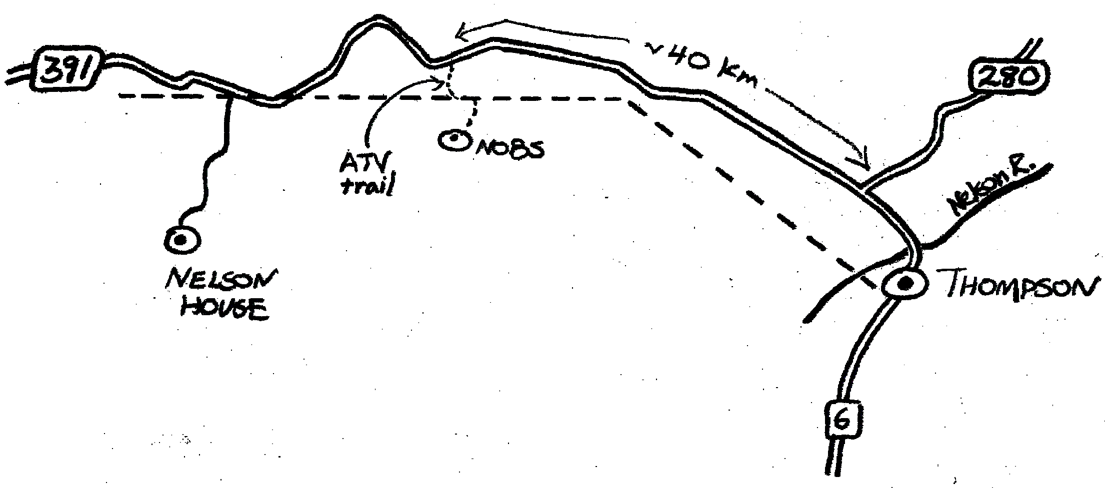
NOBS

Directions to Site

From Thompson, Manitoba

1. Leave Thompson northwest on Road 391, crossing the Burntwood River and passing the airport.
2. Continue west on Road 391 for approximately 36 km past Gillam (Road 280).
3. The trailhead to NOBS is visible on the south side of the road just before the crest of the hill. Trailhead is marked with red/white striped flagging, and an orange utility garage sits just inside the forest.
4. Follow trail to the power line right-of-way (approx. 4 km) and make a left at power line.
5. Travel east along the power line right-of-way until trail enters the forest again (approx. 1 km). Entry point is marked with red/white striped flagging.
6. Continue south along trail past the power station to the research huts and flux tower (approx. 3 km).

Note: The trail from Road 391 to the site is largely paved with spruce planks. It is best traveled by Argo™ when wet and ATV when dry. It is not hard to follow and can be walked in about 1½ hours.



NOBS

Major Cover Types

Major cover types encountered in BigFoot study site

1. Muskeg (open-canopy black spruce)
2. Black spruce (closed-canopy black spruce)
3. Aspen
4. Wetlands
5. Jack pine

Cover type qualifiers

1. Burned
2. Unburned

Cover type descriptions

Muskeg

Acronym:	MSKG
Overstory:	dominated by black spruce often mixed with tamarack
Understory:	sparse to heavy cover of Labrador tea, *Vaccinium* spp., and willow spp.
Ground cover:	predominately sphagnum with feathermoss and reindeer lichen
Vegetation structure:	ground cover hummocky; canopy sparse; trees often stunted (1–6 m tall)
Land form:	flat, low-lying, occasionally flooded
Comments:	Muskeg is very abundant in NOBS. There exists a gradual transition between muskeg and closed-canopy black spruce–feathermoss forests; demarcation is unavoidably arbitrary.

Black spruce

Acronym:	BLSP
Overstory:	dominated by black spruce occasionally mixed with eastern larch (Tamarack). Low-level occurrence of balsam poplar and jack pine
Understory:	sparse coverage of Labrador tea, *Vaccinium* spp.
Ground cover:	predominately feathermoss
Vegetation structure:	ground cover flat (not hummocky); canopy closed; trees not stunted (6–9 m tall)

Land form:	flat, low-lying, but never flooded
Comments:	This cover type is very abundant in NOBS. Transition between muskeg and closed-canopy black spruce–feathermoss forests is gradual; demarcation is unavoidably arbitrary.

Aspen

Acronym:	ASPN
Overstory:	dominated by trembling aspen. Low-level occurrence of white spruce, balsam poplar, black spruce, and jack pine
Understory:	green alder and hazel spp.
Ground cover:	very little moss or forbs present
Vegetation structure:	canopy closed, trees often tall (12–15 m), hazel and alder often forming second closed canopy at 1–2 m
Land form:	uplands
Comments:	Several patches occur at NOBS, but they are small and infrequent.

Wetland

Acronym:	WTLD
Overstory:	scattered bog birch and eastern larch
Understory:	open water lined with willow, Labrador tea, and marsh grasses
Ground cover:	mosses
Land form:	flooded lowlands, creek margins, and beaver ponds
Comments:	This is a difficult community to describe because it includes both flooded peatlands (oligotrophic fens dominated by aquatic sphagnum spp., *Vaccinium*, and Labrador tea) as well as the marshy borders of creeks and beaver ponds (marshes containing willows and sedges). Despite the range of plant communities in this cover type they are grouped together because of their similar structure.

Jack pine

Acronym:	JKPN
Overstory:	dominated by jack pine. Low-level occurrence of white spruce, balsam poplar, black spruce, and trembling aspen

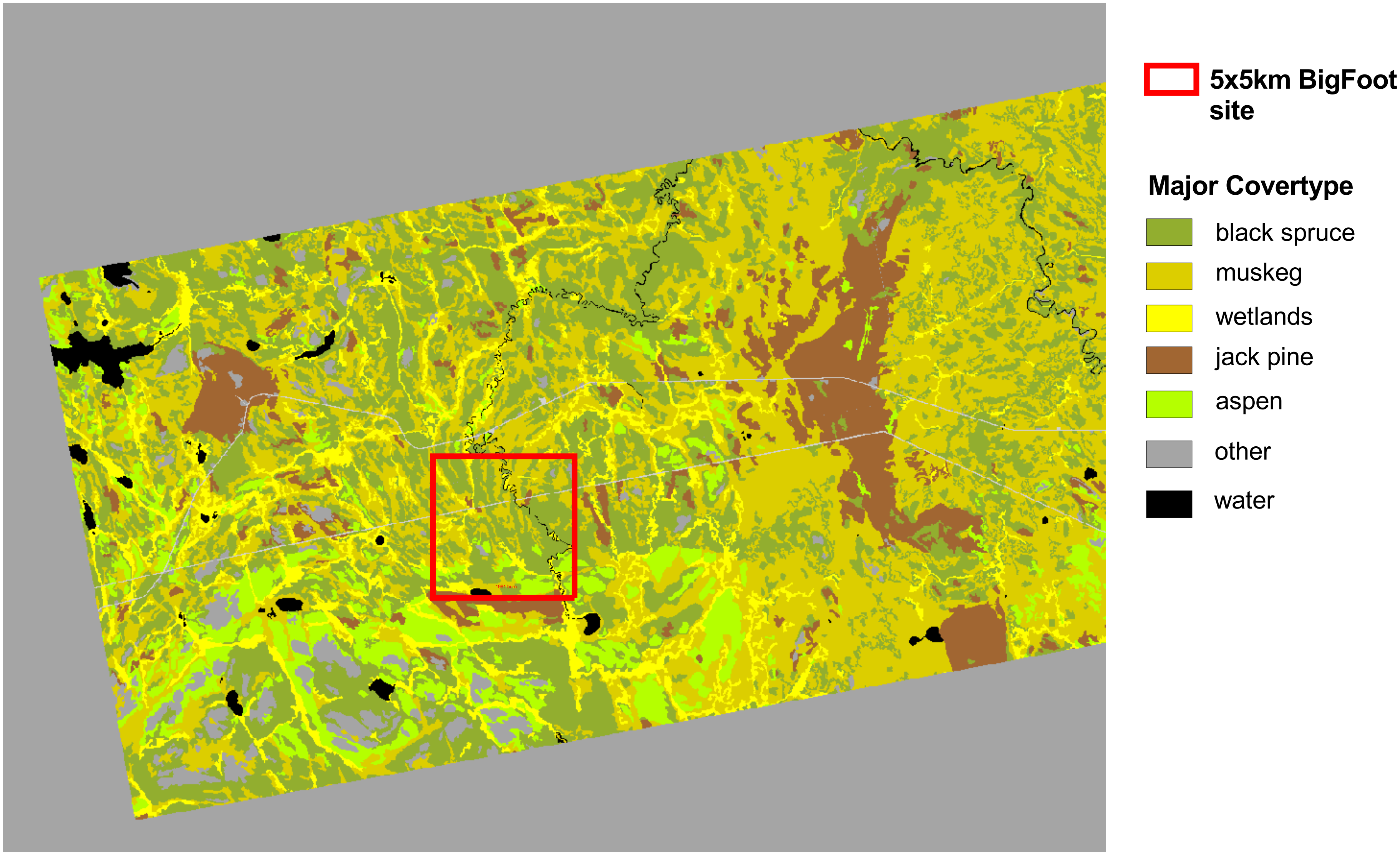
Understory:	sparse coverage of Labrador tea, *Vaccinium* spp., and occasional patches of green alder
Ground cover:	sparse to complete coverage by reindeer lichen; sparse coverage by feathermoss
Canopy architecture:	canopy closed, trees often tall (10–12 m tall)
Land form:	uplands, sandy soils
Comments:	This cover type is very rare at NOBS except for regeneration stands in a 1981 burn at the southern edge of the site.

Cover type qualifiers and additional comments

A large fire burned a 150-km^2 area on the southern boundary of the NOBS BigFoot study area in 1981. A few of the extensive plots on the south end of the 5 x 5 km grid occur in this burn. These plots are classified according to their current plant community (i.e., MSKG, BLSP, WTLD, ASPN, or JKPN), but their status as burned will also be recognized as a cover type qualifier, since the burn influences the species composition, LAI, f_{APAR}, and NPP.

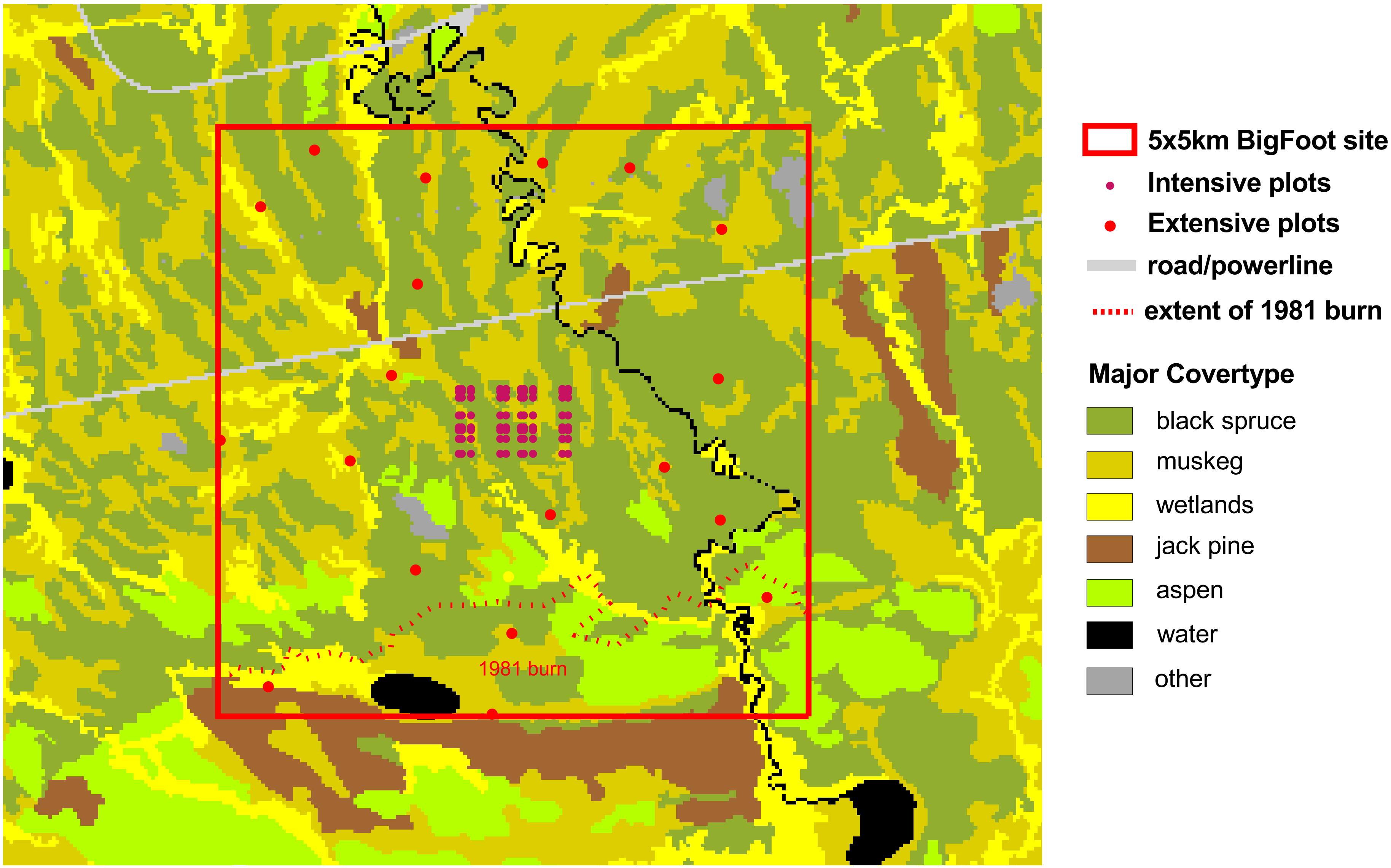
Cover type maps (see Figures 2.1 and 2.2) for the NOBS BigFoot study area were constructed from aerial photography by the Manitoba Department of Natural Resources (MDNR) in 1988 and are available as rastor maps from the BOREAS Information System (BORIS) database (Beth Nelson, BOREAS Data Manager, NASA Goddard Space Flight Center). The map is a high-quality map and recognizes over 100 vegetation cover types. Based on our on-ground experience, the map is accurate. Table 2.1 shows how the five BigFoot cover types correspond to cover types recognized by the Manitoba Department of Natural Resources map.

Figure 2.1. Major land cover types for the NOBS study area and surrounding region.



BOREAS data product created from aerial photography (1988) by the Manitoba Department of Natural Resources; modified to show major land cover classifications.

Figure 2.2. Location of study plots in the NOBS Bigfoot study site.



BOREAS data product created from aerial photography (1988) by the Manitoba Department of Natural Resources; modified to show major land cover classifications.

Table 2.1. Relationship between the five BigFoot NOBS cover types and the cover types recognized in the Manitoba Department of Natural Resources (MDNR) map. Number of pixels refers to number of pixels in the 5 x 5 km BigFoot study area

BigFoot cover type	MDNR subcategories	Cover type*	Number of MDNR pixels
BLSP	black spruce w/pine	BS/JP	16
		BS/JP/TA	45
	black spruce w/broad leaves	BS/TA	42
		BS/BA	55
		BS/WS/TA	47
		BS/WB	44
		WS/TA	43
	black spruce	BS	12
		BS/EL	17
MSKG	muskeg w/trees	treed muskeg	101
	open muskeg	clear muskeg	103
WTLD	willow marsh	willow	73
	beaver ponds and fens	flooded lands	121
ASPN	aspen w/pine	TA/JP	61
	Aspen	TA	31
	aspen w/spruce	TA/BS/JP	66
		TA/BS	62
		BA/BS	72
JKPN	jack pine	JP	11
	jack pine w/aspen	JP/TA	41
		JP/BS/TA	46
	jack pine w/spruce	JP/BS	15

* BS = black spruce; JP = jack pine; TA = trembling aspen; BA = balsam popular; WS = white spruce; EL = eastern larch.

NOBS

Plot Placement Rationale

Positioning of intensive sampling grid

The intensive sampling grid, or flux tower footprint, will consist of 80 individual plots arranged in a systematic spatial cluster design (Figures 2.2 and 2.3). Each plot is 25 x 25 m. The 80-plot grid extends 925 m east to west and 550 m north to south. The purpose of the intensive sampling grid is to characterize the land cover, species composition, LAI, f_{APAR}, and NPP for the footprint of the tower and determine the degree and scale of spatial autocorrelation among land cover type, LAI, f_{APAR}, and NPP.

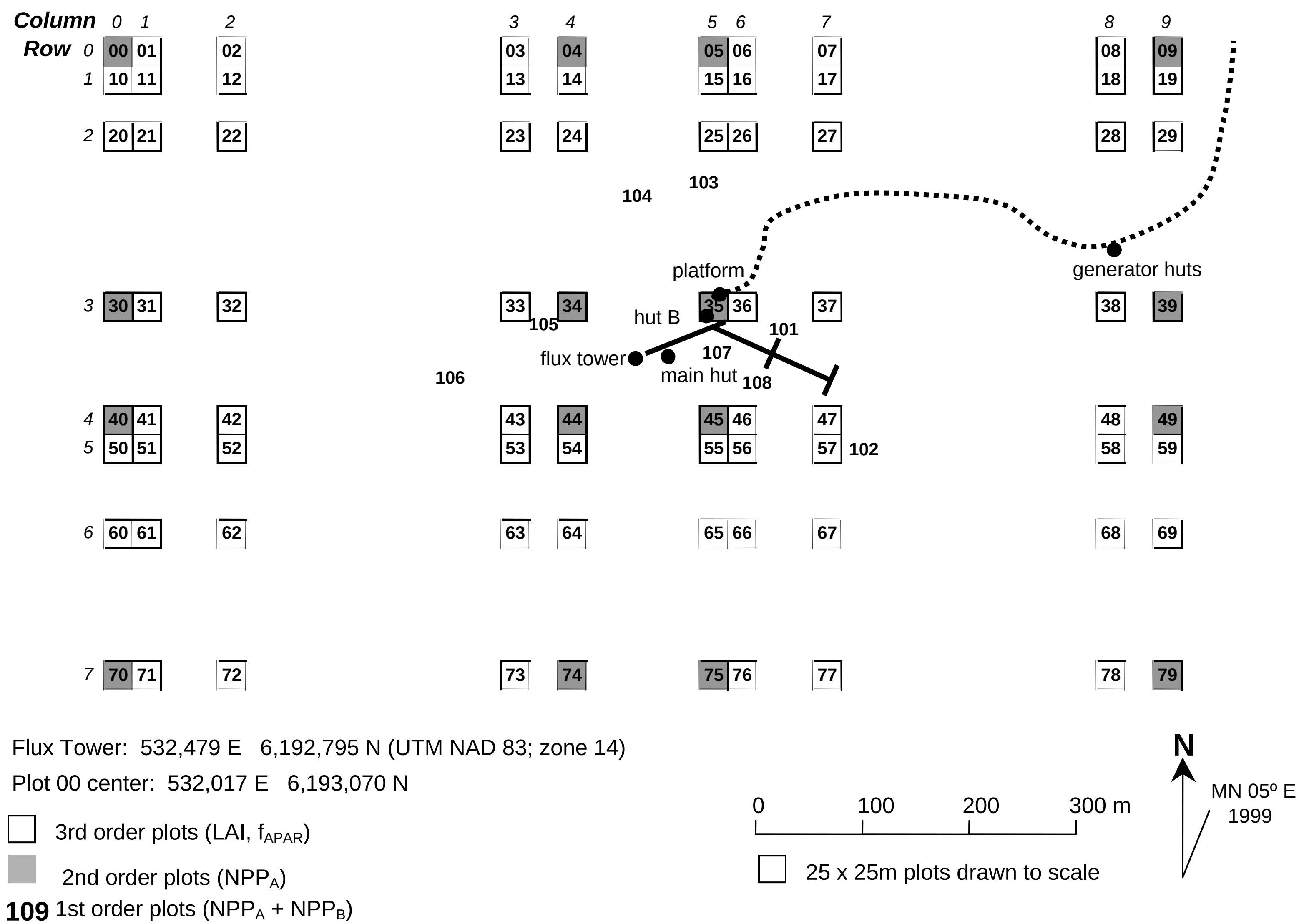
The intensive sampling grid at the NOBS site will be centered on the eddy flux tower. Positioning of the intensive sampling grid in this manner will not place any plots too close to the flux tower (nearest plot >50 m away).

Positioning of extensive sampling plots

The extensive sample plots will consist of twenty 25 x 25 m plots randomly stratified throughout the 5 x 5 km study area (Figure 2.2). The purposes of the extensive sample plots are to verify that cover type-specific characteristics hold over multi-kilometer distances and to address surface features that influence the 25-km^2 MODIS surface but are not necessarily present within the tower footprint.

The 5 x 5 km study area will be centered on the flux tower. The 20 external plots will be randomly stratified throughout the 5 x 5 km study area such that plots are at least 600 m from each other. Four of the original 20 locations were repositioned to new locations because they were in lakes, creeks, or nonrepresentative land cover types. Aquatic ecosystems are an important component of the northern boreal landscape, but characterizing these ecosystems is beyond the scope of this project.

Figure 2.3. Location of intensive study plots surrounding NOBS flux tower.



NOBS

Sampling Intensity Among Plots

According to the BigFoot sampling design, each of the 25 x 25 m plots will be sampled at one of three levels of intensity. For the NOBS site, the distribution of sampling intensity among plots will be as follows:

Sampling Intensity	Vegetation Characteristics	Number of plots (of 108 total plots)
3rd order	Vegetation cover, species composition, plant biomass, leaf area index (LAI), and f_{APAR}	56
2nd order	3rd-order measurements + aboveground net primary productivity (NPP_A)	44
1st order	2nd-order measurements + belowground net primary productivity (NPP_B)	8

Assignment of second-order plots

All 20 of the extensive plots (plot numbers 80–99) will be assigned second-order status. In addition, 24 of the 80 intensive plots will be assigned second-order status. The 24 second-order plots will be chosen from the 80 intensive plots to maximize their distance from each other and minimize autocorrelation among plots.

Assignment of third-order plots

Excluding the second-order plots, the remaining 56 plots in the intensive plot grid will be third-order plots.

Assignment of first-order plots

Eight plots will be assigned first-order status for belowground NPP measurements because of the labor costs associated with the measurement of fine root NPP. Four separate plots will be sampled to estimate fine root NPP for a given cover type; the eight plots are evenly distributed between the two most abundant cover types.

At the NOBS site, four first-order plots will be located in closed-canopy black spruce, and four first-order plots are located in open-canopy black spruce muskeg. Since these plots were initiated prior to establishing the BigFoot sampling grid, they do not share a position with any of the BigFoot plots 00–99 and are labeled 100–107. (See Table 2.2.)

Table 2.2. NOBS plot locations and descriptions

Plot Number	UTM zone 14 NAD 83 Easting*	UTM zone 14 NAD 83 Northing	Cover type**	Sampling intensity	Comments***
00	532016.653	6193070.418	MSKG	2	
01	532041.653	6193070.418	BLSP	3	
02	532116.653	6193070.418	BLSP	3	
03	532366.653	6193070.418	BLSP	3	
04	532416.653	6193070.418	BLSP	2	
05	532541.653	6193070.418	MSKG	2	
06	532566.653	6193070.418	MSKG	3	
07	532641.653	6193070.418	BLSP	3	
08	532891.653	6193070.418	BLSP	3	
09	532941.653	6193070.418	BLSP	2	
10	532016.653	6193045.418	MSKG	3	
11	532041.653	6193045.418	BLSP	3	
12	532116.653	6193045.418	BLSP	3	
13	532366.653	6193045.418	BLSP	3	
14	532416.653	6193045.418	BLSP	3	
15	532541.653	6193045.418	MSKG	3	
16	532566.653	6193045.418	MSKG	3	
17	532641.653	6193045.418	BLSP	3	
18	532891.653	6193045.418	BLSP	3	
19	532941.653	6193045.418	BLSP	3	
20	532016.653	6192995.418	BLSP	3	
21	532041.653	6192995.418	BLSP	3	
22	532116.653	6192995.418	BLSP	2	
23	532366.653	6192995.418	BLSP	2	
24	532416.653	6192995.418	BLSP	3	
25	532541.653	6192995.418	BLSP	3	
26	532566.653	6192995.418	BLSP	3	
27	532641.653	6192995.418	BLSP	2	
28	532891.653	6192995.418	BLSP	2	
29	532941.653	6192995.418	BLSP	3	
30	532016.653	6192845.418	BLSP	2	
31	532041.653	6192845.418	MSKG	3	
32	532116.653	6192845.418	BLSP	3	
33	532366.653	6192845.418	BLSP	3	
34	532416.653	6192845.418	BLSP	2	
35	532541.653	6192845.418	MSKG	2	
36	532566.653	6192845.418	MSKG	3	
37	532641.653	6192845.418	MSKG	3	
38	532891.653	6192845.418	BLSP	3	
39	532941.653	6192845.418	BLSP	2	
40	532016.653	6192745.418	BLSP	2	
41	532041.653	6192745.418	BLSP	3	
42	532116.653	6192745.418	MSKG	3	
43	532366.653	6192745.418	BLSP	3	
44	532416.653	6192745.418	BLSP	2	
45	532541.653	6192745.418	BLSP	2	
46	532566.653	6192745.418	BLSP	3	
47	532641.653	6192745.418	MSKG	3	
48	532891.653	6192745.418	BLSP	3	

Table 2.2 (continued)

Plot Number	UTM zone 14 NAD 83 Easting*	UTM zone 14 NAD 83 Northing	Cover type**	Sampling intensity	Comments***
49	532941.653	6192745.418	BLSP	2	
50	532016.653	6192720.418	BLSP	3	
51	532041.653	6192720.418	BLSP	3	
52	532116.653	6192720.418	MSKG	3	
53	532366.653	6192720.418	BLSP	3	
54	532416.653	6192720.418	BLSP	3	
55	532541.653	6192720.418	BLSP	3	
56	532566.653	6192720.418	BLSP	3	
57	532641.653	6192720.418	MSKG	3	
58	532891.653	6192720.418	BLSP	3	
59	532941.653	6192720.418	BLSP	3	
60	532016.653	6192645.418	BLSP	3	
61	532041.653	6192645.418	BLSP	3	
62	532116.653	6192645.418	MSKG	2	
63	532366.653	6192645.418	BLSP	2	
64	532416.653	6192645.418	BLSP	3	
65	532541.653	6192645.418	BLSP	3	
66	532566.653	6192645.418	BLSP	3	
67	532641.653	6192645.418	BLSP	2	
68	532891.653	6192645.418	BLSP	2	
69	532941.653	6192645.418	BLSP	3	
70	532016.653	6192520.418	BLSP	2	
71	532041.653	6192520.418	BLSP	3	
72	532116.653	6192520.418	BLSP	3	
73	532366.653	6192520.418	BLSP	3	
74	532416.653	6192520.418	BLSP	2	
75	532541.653	6192520.418	BLSP	2	
76	532566.653	6192520.418	BLSP	3	
77	532641.653	6192520.418	BLSP	3	
78	532891.653	6192520.418	MSKG	3	
79	532941.653	6192520.418	BLSP	2	
80	529994.213	6192634.148	MSKG	2	
81	530337.153	6194614.408	WTLD	2	
82	530403.203	6190541.898	WTLD	2	in 1981 burn
83	530793.113	6195093.608	BLSP	2	
84	531094.123	6192458.308	WTLD	2	
85	531444.823	6193184.088	MSKG	2	
86	531640.823	6191580.828	BLSP	2	
87	531666.063	6193958.858	BLSP	2	
88	531735.323	6194857.528	MSKG	2	
89	532297.153	6190311.528	MSKG	2	in 1981 burn
90	532407.583	6191502.858	ASPN	2	
91	532462.233	6190995.528	MSKG	2	in 1981 burn
92	532725.933	6194986.678	MSKG	2	
93	532791.023	6192003.328	BLSP	2	
94	533463.453	6194942.678	BLSP	2	
95	533755.243	6192407.348	MSKG	2	

Table 2.2 (continued)

Plot Number	UTM zone 14 NAD 83 Easting*	UTM zone 14 NAD 83 Northing	Cover type**	Sampling intensity	Comments***
96	534213.713	6193154.978	BLSP	2	
97	534226.783	6191956.048	BLSP	2	
98	534241.553	6194421.418	MSKG	2	
99	534622.943	6191301.818	ASPN	2	in 1981 burn
100	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
101	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
102	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
103	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
104	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
105	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
106	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
107	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
GPS base	532541.913	6192844.748			

* UTM = Universal Transverse Mercator; NAD = North American Datum.
** MSKG = muskeg; BLSP = black spruce; WTLD = wetland; ASPN = aspen.
*** NPP_B = belowground net primary production.

NOBS

Vegetation Characteristics to be Measured

According to the BigFoot objectives it is necessary to quantify vegetation cover, LAI, f_{APAR}, and aboveground biomass for each 25 x 25 m plot and aboveground and belowground NPP for a subset of plots. Each of these characteristics has multiple components that require separate measurement. Below is a list of the 20 vegetation characteristics to be measured (in at least some of the plots), followed by Table 2.3, describing the protocol for taking each of the measurements.

Aboveground Biomass (all plots)

1. moss layer
2. understory
3. small tree wood and leaf
4. large tree wood and leaf

Belowground Biomass (1st-order plots only)

5. coarse roots
6. fine roots

Aboveground NPP (2nd- and 1st-order plots only)

7. moss production
8. understory wood production
9. small tree wood production
10. large tree wood production
11. total foliage production

Belowground NPP (1st-order plots only)

12. coarse root production
13. fine root production

Leaf Area Index and Vegetation Cover (all plots)

14. leaf area index measured optically
15. leaf area index measured using allometric equations
16. f_{APAR} measured optically
17. vegetation cover

Scaling parameters (sitewide averages will be measured in six of the exterior 2nd-order plots)

18. moss mass per ground area
19. specific leaf area of dominant canopy species
20. leaf N concentration of dominant canopy species

Table 2.3. Vegetation sampling methodology for NOBS

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
1) Moss mass	Feathermoss and sphagnum	Visual estimate of % ground cover in subplots is multiplied by average mass of moss per unit area (measurement no. 16)	5	0.25–4.00 m^2 (depending on moss patch size)	Midsummer	
2) Understory mass	Labrador tea, rose spp., *Vaccinium* spp.	Clip at base, dry, and weigh all understory in subplot	5	0.25 m^2	Midsummer	
3) Small tree mass	Black spruce and larch <2.5 cm DBH*	Count stems and basal diameter in subplots and scale to tree mass w/ allometric equations	5	1–25 m^2 depending on tree density (enough to get 4 trees/ subplot)	Midsummer	
4) Large tree above-ground mass	Black spruce, larch >2.5 cm DBH*	Variable-radius plots to count stems by size; stem counts scaled to tree mass w/ allometric equations	1	Variable-radius prism plot	Pre- and post-growing season	
5) Coarse root mass	Tree roots >2 mm in diameter	Variable-radius plots to count stems by size; stem counts scaled to root mass w/ allometric equations	1	Not applicable	Midsummer	Derived from the same prism sweep data above

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
6) Fine root mass	Root 2 mm or less in diameter	The inside of clear tubes inserted into ground are periodically viewed with a digital camera. Area of fine roots seen in images are scaled to mass/area	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	Size cutoff and scaling factors depend on further methods development
7) Moss growth	Feathermoss and sphagnum	Vertical growth measured in subplots; growth through plastic mesh for feathermoss, past vertical wire gauges for sphagnum	0–8	moss screens = 0.01 m^2; sphagnum gauges clustered in 0.25-m^2 clumps	Gauges set at either spring thaw or fall freeze; growth measured 1 and/or 2 years later	Number of mesh plots or wire gauges dependent on ground cover composition
8) Understory stem growth	New stem of Labrador tea, rose spp., *Vaccinium* spp.	Based on bud scarring, new stem growth is separated from the understory biomass samples and weighed	5	0.25 m^2	After growing season for which NPP is calculated	Sampled from the same plots used to determine small tree mass

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
9) Small tree wood growth	Annual stem and branch growth of spruce and larch <2.5 cm DBH	Radial increment of tree determined from stem cores or disks; increment scaled to stem growth w/allometric equations	4	1–25 m^2, depending on tree density (enough to get 4 trees/subplot)	After growing season for which NPP is calculated	Sampled from the same plots used to determine small tree mass
10) Large tree stem growth	Annual stem and branch growth of spruce and larch >2.5 cm DBH	Radial increment of trees counted in prism sweep determined from cores taken at BH; Increment scaled to stem growth w/ prism factor and allometric equations	1	Variable-radius prism plots	After growing season for which NPP is calculated	Same trees used to determine aboveground biomass
11) Foliage NPP	Leaves senesced from (and presumed grown in) canopy over one growing season New foliage produced	Litter traps: foliage detritus = new foliage production (2) Allometric equations used to estimate new foliage	5	0.25-m^2 litter traps	Litter collected over the growing season for which NPP is calculated	In deciduous plots, leaflitter is annual foliar production. In evergreen plots, steady stasis between foliar growth & senescence must be assumed

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
12) Coarse root NPP	Annual growth in roots >2 mm in diameter	Calculated as an allometric function of aboveground stem growth (measure no. 10)	1	Variable-radius prism plots	After growing season for which NPP is calculated	Same trees used to determine aboveground biomass
13) Fine root NPP	Fine root tips <2 mm	The insides of clear tubes inserted into ground are periodically viewed with a digital camera; increase in area of fine roots is scaled to biomass using mass/area constants	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	Σ new fine root length for each root diameter class x mass/area coefficient
14) LAI (optical)	½ total leaf area in canopy per unit ground area	Measured at points in plot using LAI 2000 (LAI computed from sunlight attenuation as it passes through canopy)	5	Point samples	4 times seasonally	
15) LAI (allometry)	½ total leaf area in canopy per unit ground area	Foliar mass (determined allometrically from prism sweeps) is scaled to area using specific leaf area (area/mass)	1	Variable-radius prism plots	Any time	In deciduous stands, litterfall can be used to estimate LAI

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
16) f_{APAR}	Fraction of light absorbed by canopy	Measured at points in plot using LAI 2000 (computed from same measurement as LAI)	5	Point samples	4 times seasonally	
17) Vegetation cover	Vertical projection of vegetation to ground area	Mean crown completeness using digital true-color camera	5	1 m^2	Midsummer	
18) Moss mass per ground area	Dry mass of moss per unit ground area at 100% coverage	Moss samples are collected from a fixed area in which moss grows with 100% coverage; living tissue is separated, dried, and weighed	5		Midsummer	This is used to scale moss coverage to moss mass. Sitewide averages will suffice

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
19) Specific leaf area	Leaf area per unit leaf mass by species	For broad leaves, fresh leaves are weighed and measured with a leaf area meter; for needle leaves, leaf volume is determined gravimetrically, converted to area using shape-specific geometric constants		5 trees of each dominant species	Midsummer	Sitewide averages
20) Leaf nitrogen concentration	% nitrogen by mass of leaves from dominant tree species	Fresh leaves are dried, digested by Kjeldahl incubation, and colormetrically analyzed for nitrogen		5 trees of each dominant species	Midsummer	Sitewide averages

* DBH = diameter at breast height.

NOBS

Subplot Placement

The 25 x 25 m plot is the experimental unit. In the final analyses, each plot produces only *one* value for each characteristic parameter measured. When appropriate, multiple fixed-area subplots will be used to sample variation within each plot. The subplots are positioned in the 25 x 25 m plot such that

1. they are spatially stratified throughout the plot and not clustered in one area,
2. they are simple and convenient to deploy in the field, and
3. they do not interfere with one another.

The subsamples will be located in a regular pattern in each plot based on the cardinal compass directions. The protocol for the subplot placement of subsamples at NOBS is illustrated in Figure 2.4 and described in Table 2.4.

Figure 2.4. Placement of NOBS subsamples.

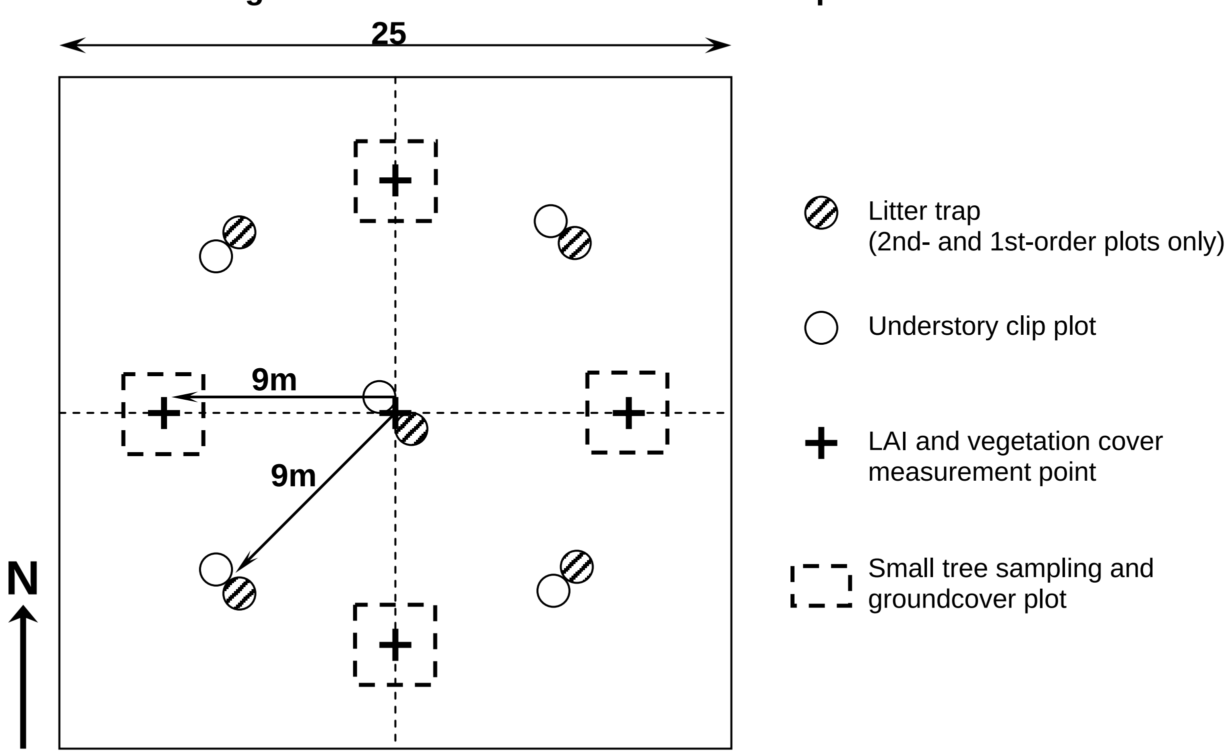


Table 2.4. Subplot placement protocol for NOBS

Subplot	Number of subplot	Position in 25 x 25 m plot
Understory clip plots	5	One positioned near plot center and four more positioned 9 m NW, NE, SE, and SW from plot center
Litter traps (2nd- and 1st-order plots only)	5	Placed adjacent to the understory clip plots
Small tree stem survey plots	4	Four fixed-area subplots centered at points 9 m N, S, E, and W from plot center
Moss groundcover survey plots	1	Visual survey made from plot center
Variable-radius plots	1	One prism plot made from plot center
LAI and vegetation cover sample points	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center
Minirhizotrons (1st-order plots only)	5	Placed adjacent to the understory clip plots (or anywhere they can be installed)
Feathermoss growth plots	0–8	Up to eight feathermoss screens stratified among the patches of pure feathermoss
Sphagnum growth wires	0–5	Up to five sets of sphagnum growth wires stratified among the sphagnum hummocks in the plot

NOBS

Tentative 1999 Field Calendar

Month	Week	Day of year	Measurements
May	2–4	130	Survey in plots, install moss gauges and litter traps, measure LAI, and take root images Snow melts mid-April
June	4	174	Measure LAI and vegetation cover, take root images
Aug.	1–3	211	Measure LAI and vegetation cover, take root images, sample understory, begin surveying trees Full flush occurs at this period
Oct.	1–2	271	Measure LAI and vegetation cover, take root images, finish surveying trees, clip moss

In the summer of 2000, a new set of LAI measurements, root images, litter collections, and moss growth measurements will be taken on similar dates. Tree surveys will not need to be repeated. Tree cores will be collected at the end of the year 2000 growing season to estimate aboveground NPP.

NOBS

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Section 3

Study Site and Measurement Plan for Konza Prairie (KNOZ), Manhattan, Kansas

KONZ

Directions to Site

From Interstate 70, Kansas

1. Take exit 313 off Interstate 70 onto HWY 177 (this is the Manhattan exit).
2. Drive north on HWY 177 to the bridge crossing the Kansas River near Manhattan (about 13.5 km from I-70).
3. Immediately before crossing the bridge, take a left (south) on Riley Rd.
4. Follow Riley Rd. along river valley for about 10 km to Kings Creek.
5. Take the first road (left turn) after crossing Kings Creek to Konza Prairie. Parking area is approximately 1.5 km from turnoff.

KONZ

Major Cover Types

Major cover types encountered in BigFoot study site

1. Tallgrass prairie
2. Shortgrass prairie
3. Shrub community
4. Gallery forest

Cover type qualifiers

1. Cattle grazed
2. Bison grazed
3. Ungrazed
4. Burn frequency

Cover type descriptions

Tallgrass prairie

Acronym:	TGPR
Species:	big bluestem, Indian grass, little bluestem, switchgrass, and other forbs
Architecture:	1–1.5 m tall at full flush
Land form:	bottomlands, deep soils, unexposed aspects
Comments:	A wide, poorly defined gradient exists between the tallgrass and shortgrass prairies.

Shortgrass prairie

Acronym:	SGPR
Species:	blue grama, hairy grama, xeric forbs
Architecture:	10–20 cm tall at full flush
Land form:	exposed ridgetops, shallow claypan soils
Comments:	A wide, poorly defined, gradient exists between the tallgrass and shortgrass prairies.

Shrub community

Acronym:	SHRB
Species:	smooth sumac and *Cornus* spp.
Architecture:	1–2 m tall, very dense, thin stems, closed canopy
Land form:	exposed ridgetops, shallow claypan soils

Comments:	Shrubs form patches in drainage gulches and seeps. Shrub communities also occur adjacent to creeks and as a transition between prairie and forest.

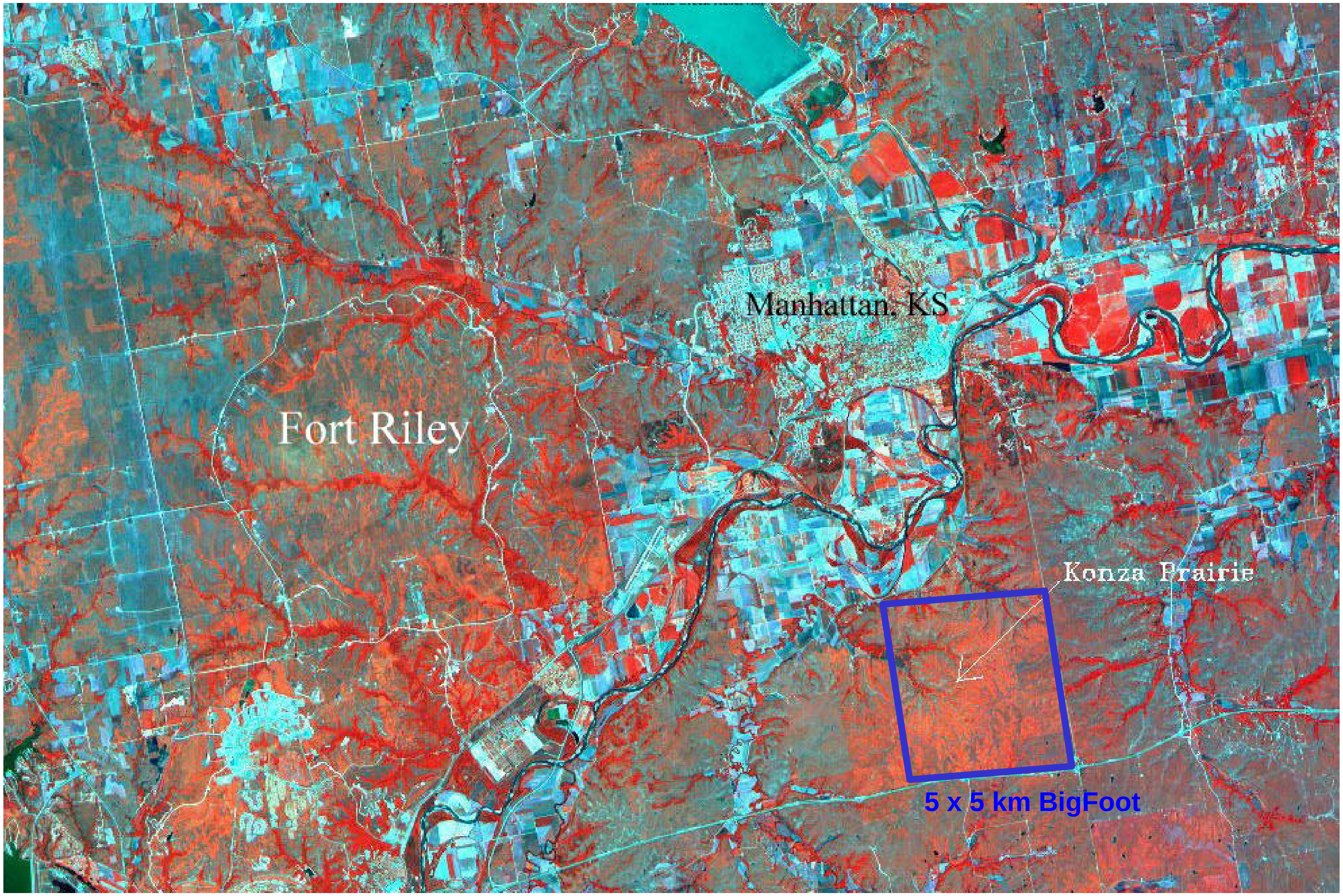
Gallery forest

Acronym:	GALF
Species:	oaks, elm, hackberry, walnut, and hickory
Architecture:	15–20 m tall closed canopy but lots of edge supports; significant understory with open canopy at 3–5 m
Land form:	lowlands, largely riparian
Comments:	This is a diverse community that includes transition communities such as open savanna and shrub. About 6% of Konza is gallery forest.

Cover type qualifiers and additional comments

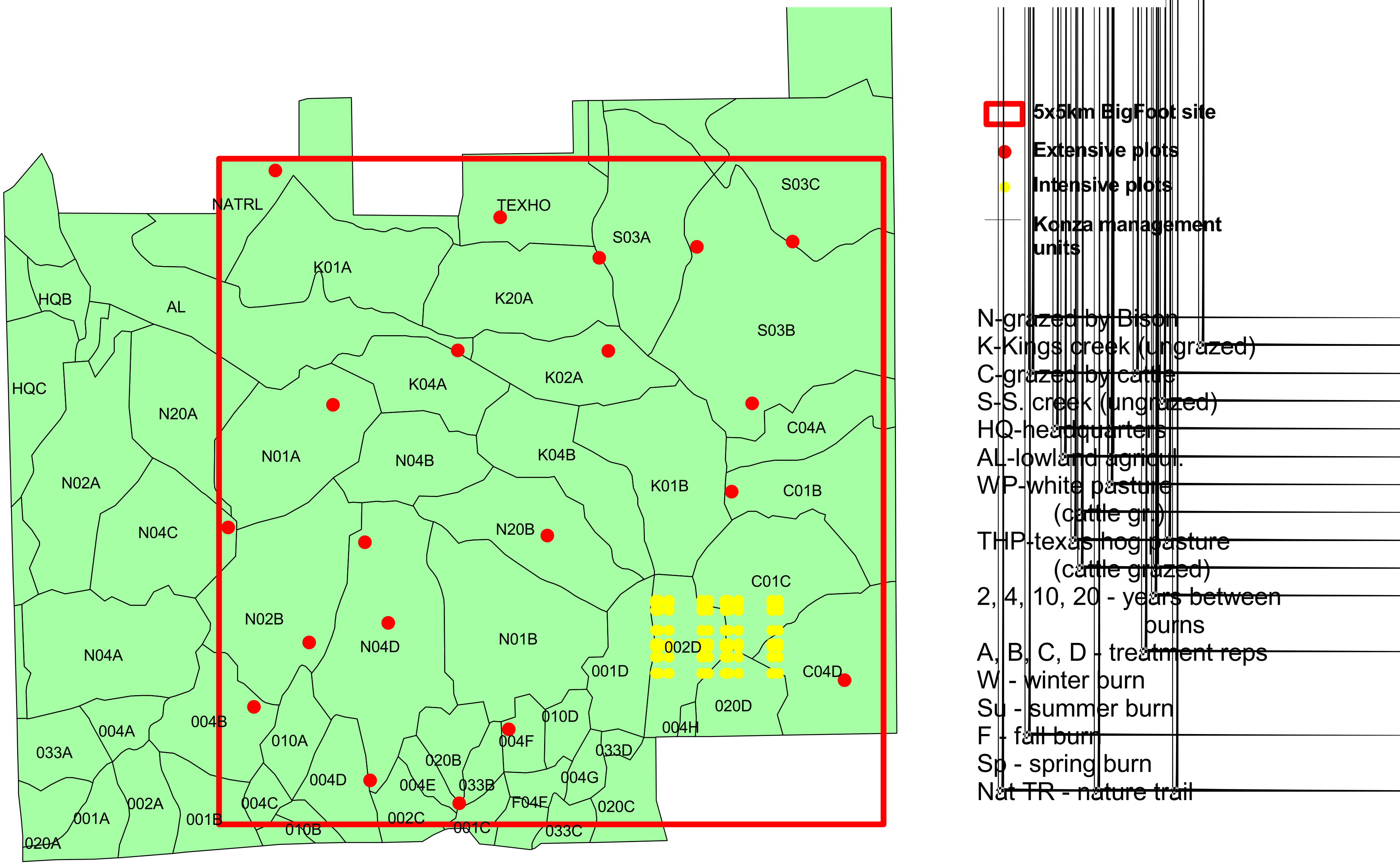
Konza (Figure 3.1) is divided into over 60 managed experimental watersheds. The management practices vary in grazing regime and fire frequency (Figure 3.2). Grazing treatments include cattle grazing, bison grazing, and no grazing. Fire regimes vary by frequency (1-, 2-, 4-, 10-, or 20-year fire cycles) and timing (winter, summer, fall, and spring burning). While not all combinations of burning and grazing regimes are practiced, many are making the Konza landscape very diverse. The BigFoot design cannot sample each of these management areas. The management history of each study plot will be recognized as a cover type qualifier since the management practice will influence species composition, vegetation structure, and function.

Figure 3.1. Location of BigFoot study site in relation to the surrounding landscape.



Konza Prairie Research Natural Area SPOT image obtained from http://climate.konza.ksu.edu/images/spot91b.jpb

Figure 3.2. Location of study plots in Konza Prairie Research Natural Area management units.



Konza Prairie Research Natural Area management unit obtained from ftp://ftp.konza.ksu.edu/pub/arc-infor/wshd.e00.

KONZ

Plot Placement Rationale

Positioning of intensive sampling grid

The intensive sampling grid will consist of 80 individual plots (25 x 25 m) arranged in a systematic spatial cluster design (Figures 3.3 and 3.4; Table 3.1). The 80-plot grid extends 925 m east to west and 550 m north to south. The intensive sampling grid at KONZ will be centered on the eddy flux tower located in the every-other-year burning management unit. The purpose of the intensive sampling grid is to provide accurate characterization of vegetation characteristics for the tower footprint and determine the degree and scale of spatial autocorrelation among land cover types.

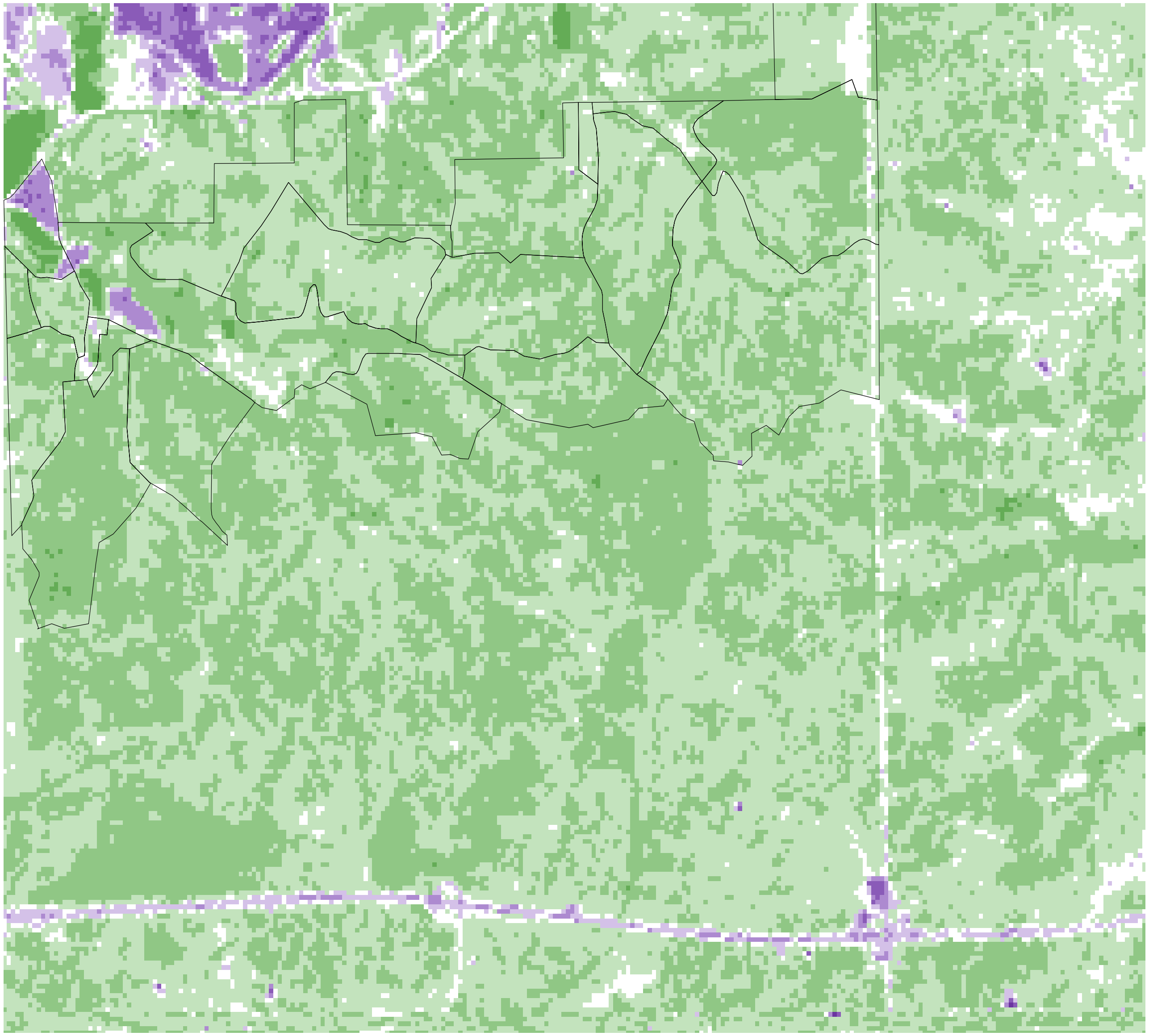
Positioning of the intensive sampling grid in this manner will not place any plots too close to the flux tower (nearest plot >50 m away)

Positioning of extensive sampling plots

The extensive sample plots will consist of 20 individual plots (each measuring 25 x 25 m) randomly stratified throughout the 5 x 5 km study area. The purposes of the extensive sample plots will be to verify that cover type-specific characteristics hold over multi-kilometer distances and to measure vegetation characteristics of unique ecosystems that influence the 25-km^2 MODIS surface but were not present in the tower footprint.

At the KONZ site, the 5 x 5 km BigFoot study area will be centered on the Konza Prairie research area. The 20 external plots will be randomly stratified throughout the 5 x 5 km study area such that plots will be at least 600 m from each other. Four of the 20 random points were relocated to new random locations because the original locations were on farms on which we did not have permission to conduct research or occurred in nonrepresentative land cover types.

Figure 3.3. Location of study plots in relation to a standardized normalized difference vegetation index (NDVI) image for the Konza Prairie.



NDVI calculated from LandSat TM Image

Figure 3.4. Location of intensive study plots surrounding KONZ flux tower.

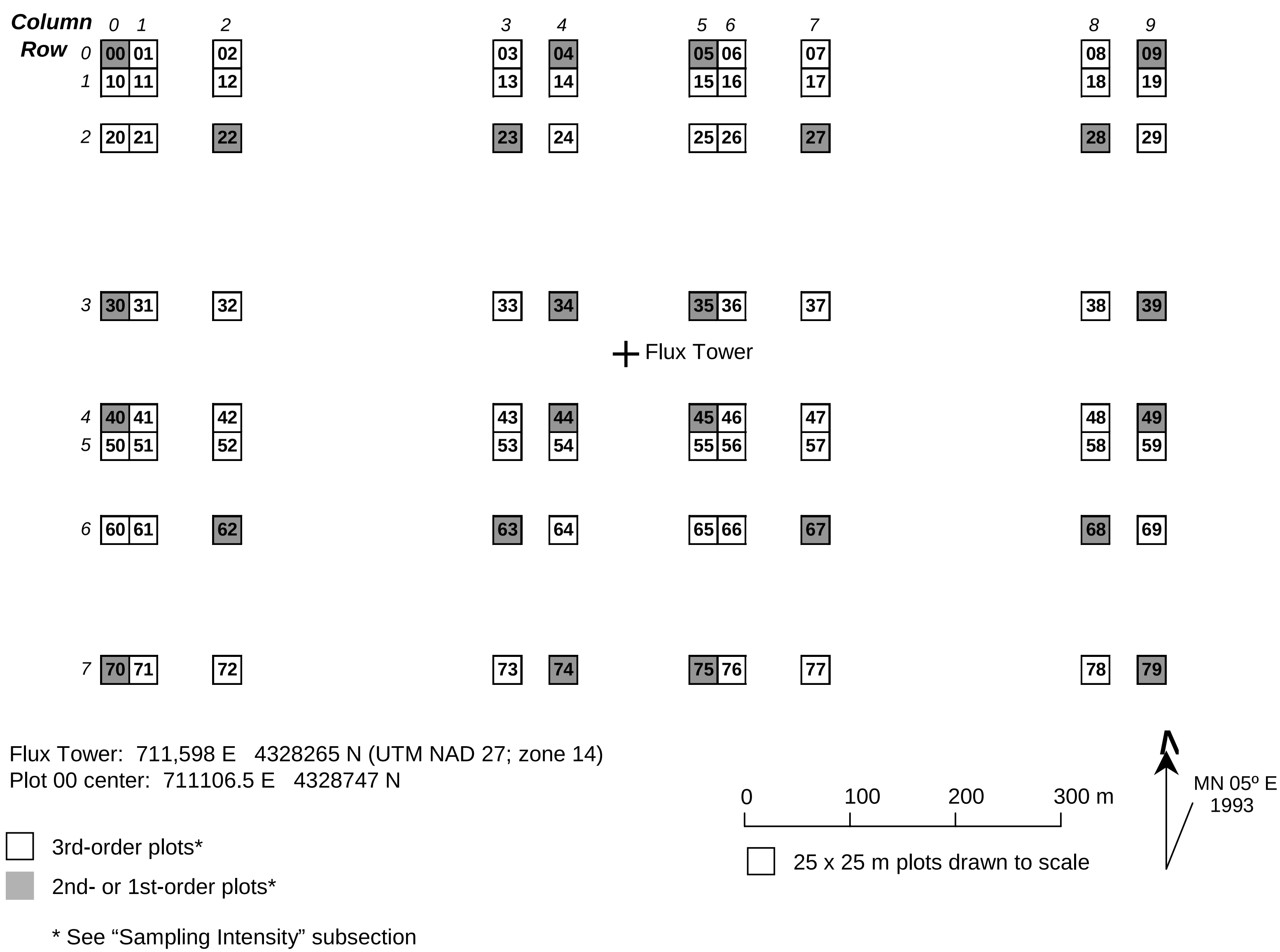


Table 3.1. KONZ plot locations and descriptions

Plot number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity**	Comments
00	711,106.50	4,328,747.00		2	
01	711,131.50	4,328,747.00		3	
02	711,206.50	4,328,747.00		3	
03	711,456.50	4,328,747.00		3	
04	711,506.50	4,328,747.00		2	
05	711,631.50	4,328,747.00		2	
06	711,656.50	4,328,747.00		3	
07	711,731.50	4,328,747.00		3	
08	711,981.50	4,328,747.00		3	
09	712,031.50	4,328,747.00		2	
10	711,106.50	4,328,722.00		3	
11	711,131.50	4,328,722.00		3	
12	711,206.50	4,328,722.00		3	
13	711,456.50	4,328,722.00		3	
14	711,506.50	4,328,722.00		3	
15	711,631.50	4,328,722.00		3	
16	711,656.50	4,328,722.00		3	
17	711,731.50	4,328,722.00		3	
18	711,981.50	4,328,722.00		3	
19	712,031.50	4,328,722.00		3	
20	711,106.50	4,328,672.00		3	
21	711,131.50	4,328,672.00		3	
22	711,206.50	4,328,672.00		2	
23	711,456.50	4,328,672.00		2	
24	711,506.50	4,328,672.00		3	
25	711,631.50	4,328,672.00		3	
26	711,656.50	4,328,672.00		3	
27	711,731.50	4,328,672.00		2	
28	711,981.50	4,328,672.00		2	
29	712,031.50	4,328,672.00		3	
30	711,106.50	4,328,522.00		2	
31	711,131.50	4,328,522.00		3	
32	711,206.50	4,328,522.00		3	
33	711,456.50	4,328,522.00		3	
34	711,506.50	4,328,522.00		2	
35	711,631.50	4,328,522.00		2	
36	711,656.50	4,328,522.00		3	
37	711,731.50	4,328,522.00		3	
38	711,981.50	4,328,522.00		3	
39	712,031.50	4,328,522.00		2	
40	711,106.50	4,328,422.00		2	
41	711,131.50	4,328,422.00		3	
42	711,206.50	4,328,422.00		3	
43	711,456.50	4,328,422.00		3	
44	711,506.50	4,328,422.00		2	
45	711,631.50	4,328,422.00		2	

Table 3.1 (continued)

Plot Number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity**	Comments
46	711,656.50	4,328,422.00		3	
47	711,731.50	4,328,422.00		3	
48	711,981.50	4,328,422.00		3	
49	712,031.50	4,328,422.00		2	
50	711,106.50	4,328,397.00		3	
51	711,131.50	4,328,397.00		3	
52	711,206.50	4,328,397.00		3	
53	711,456.50	4,328,397.00		3	
54	711,506.50	4,328,397.00		3	
55	711,631.50	4,328,397.00		3	
56	711,656.50	4,328,397.00		3	
57	711,731.50	4,328,397.00		3	
58	711,981.50	4,328,397.00		3	
59	712,031.50	4,328,397.00		3	
60	711,106.50	4,328,322.00		3	
61	711,131.50	4,328,322.00		3	
62	711,206.50	4,328,322.00		2	
63	711,456.50	4,328,322.00		2	
64	711,506.50	4,328,322.00		3	
65	711,631.50	4,328,322.00		3	
66	711,656.50	4,328,322.00		3	
67	711,731.50	4,328,322.00		2	
68	711,981.50	4,328,322.00		2	
69	712,031.50	4,328,322.00		3	
70	711,106.50	4,328,197.00		2	
71	711,131.50	4,328,197.00		3	
72	711,206.50	4,328,197.00		3	
73	711,456.50	4,328,197.00		3	
74	711,506.50	4,328,197.00		2	
75	711,631.50	4,328,197.00		2	
76	711,656.50	4,328,197.00		3	
77	711,731.50	4,328,197.00		3	
78	711,981.50	4,328,197.00		3	
79	712,031.50	4,328,197.00		2	
80	710,321.30	4,329,030.30		2	
81	710,780.30	4,330,416.20		2	
82	708,110.00	4,327,739.30		2	
83	712,170.80	4,331,239.60		2	
84	709,123.70	4,328,370.50		2	
85	711,865.50	4,330,022.40		2	
86	712,562.90	4,327,942.40		2	
87	708,273.40	4,331,775.10		2	
88	709,966.20	4,331,424.50		2	
89	708,705.60	4,330,013.90		2	
90	708,527.20	4,328,225.70		2	

Table 3.1 (continued)

Plot Number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity**	Comments
91	708,947.00	4,328,979.20		2	
92	710,029.30	4,327,572.30		2	
93	709,659.40	4,327,016.90		2	
94	710,711.70	4,331,117.80		2	
95	708,986.90	4,327,189.30		2	
96	711,449.30	4,331,198.60		2	
97	711,711.50	4,329,359.10		2	
98	709,647.90	4,330,422.00		2	
99	707,917.80	4,329,090.10		2	

* UTM (Universal Transverse Mercator) NAD27 (projected as tower location given us by Konza) zone 14.

** Six of the 2nd-order plots will be upgraded to 1st-order plots (NPP_B plots) at the time of tube installation.

KONZ

Sampling Intensity Among Plots

According to the BigFoot sampling design, each of the 25 x 25 m plots will be sampled at one of three levels of intensity:

Sampling intensity	Parameters quantified	Number of plots (of 100 total plots)
3rd-order	Vegetation cover, species composition, plant biomass, leaf area index (LAI), and fraction absorbed photosynthetic active radiation (f_{APAR})	56
2nd-order	3rd-order measurements + aboveground net primary productivity (NPP_A)	38
1st-order	2nd-order measurements + aboveground net primary productivity (NPP_B)	6

Assignment of second-order plots

All 20 of the extensive plots (plot numbers 80–99) will be assigned second-order status. In addition, 24 of the 80 intensive plots will be assigned second-order status. These 24 second-order plots were chosen from the 80 intensive plots in a manner that maximizes the distance among plots in an attempt to minimize autocorrelation among plots.

Assignment of first-order plots

Fine root NPP will be measured on only six first-order status plots because of the large labor costs of measuring fine root NPP. Three replicate plots in each of the two most abundant cover types will be sampled to estimate fine root NPP for Konza. Each first-order plot will be located in an independent vegetation community (i.e., separated by at least one other community).

At the KONZ site, three first-order plots will be located in shortgrass prairie and three plots located in gallery forest. Five minirhizotrons will be installed in each first-order plot. The plots to be selected will be unknown until the plots are surveyed and established, which will occur in the summer of 1999.

Assignment of third-order plots

The remaining 50 plots will be third-order status plots. The distribution of first-, second-, and third-order plots will be 56, 38, and 6, respectively.

KONZ

Vegetation Characteristics to be Measured

According to the BigFoot objectives it is necessary to quantify vegetation cover, LAI, f_{APAR}, and aboveground biomass for each 25 x 25 m plot and aboveground and belowground NPP for a subset of plots. Each of these characteristics has multiple components that require separate measurement. Below is a list of the 20 vegetation characteristics to be measured (in at least some of the plots), followed by Table 3.2, describing the protocol for taking each of the measurements.

Aboveground Biomass (all plots)

1. moss layer
2. understory
3. small tree wood and leaf
4. large tree wood and leaf

Belowground Biomass (1st-order plots only)

5. coarse roots
6. fine roots

Aboveground NPP (2nd- and 1st-order plots only)

7. moss production
8. understory stem production
9. small tree stem production
10. large tree stem production
11. total foliage production

Belowground NPP (1st-order plots only)

12. coarse root production
13. fine root production

Leaf Area Index and Vegetation Cover (all plots)

14. leaf area index measured optically
15. leaf area index measured using allometry (for forests only)
16. f_{APAR} measured optically
17. vegetation cover

Scaling parameters (sitewide averages may be adequate measured in six of the exterior 2nd-order plots)

18. moss mass per ground area
19. specific leaf area of dominant canopy species
20. leaf N concentration of dominant canopy species

Table 3.2. Vegetation sampling methodology for KONZ*

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
1) Moss mass	Feather moss or sphagnum					Not significant at KONZ
2) Understory mass	Grasses, forbs, and small shrubs	Clip at base, dry, and weigh all understory in subplot	10	0.05 m^2	4 times per year	Details regarding the accurate annual sampling of prairie species not yet fully determined
3) Small tree mass	Sumac, *Cornus*, and saplings <2.5 cm DBH**	Count stems and basal diameter in subplots and scale to tree mass w/ allometric equations	5	1–25 m^2 depending on tree density (enough to get 4 trees/subplot)	Midsummer	Plot surveys in 1999 will help make distinction between understory shrubs and small trees
4) Large tree aboveground mass	Oaks, elms, and other trees >2.5 cm diameter	Plot-centered prism plots to count stems by size; stem counts scaled to tree mass w/ allometric equations	1	Variable-radius prism plots	Midsummer	
5) Coarse root mass	Tree roots >2.5 mm diameter	Plot-centered prism sweep to count stems by size; stem counts scaled to root mass w/ allometric equations	1	Variable-radius prism plots	Midsummer	Methods for coarse root measurement in grasses undetermined

Table 3.2 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
6) Fine root mass	Root 2 mm or less in diameter	The inside of clear tubes inserted into ground are periodically viewed with a digital camera. Area of fine roots seen in images are scaled to mass/area using gravimetric constants	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	Size cutoff and scaling factors depend on further methods development
7) Moss growth						No significant at KONZ
8) Understory stem growth	New stem growth of small perennials	Based on bud scarring, new stem growth is separated from the understory biomass samples and weighed	5	0.25 m^2	After growing season for which NPP is calculated	Sampled from the same plots used to determine small tree mass
9) Small tree wood NPP	Annual stem and branch growth of sumac, *Cornus*, and tree saplings <2 cm DBH	Radial increment of tree determined from basal cores or disks; increment scaled to stem growth w/allometric equations	4	1-25 m^2 depending on tree density (enough to get 4 trees/subplot)	After growing season for which NPP is calculated	Sampled from the same plots used to determine small tree mass
10) Large tree wood NPP	Annual bole and branch growth of oak, elm, and other trees >2 cm DBH	Radial increment of trees counted in prism plots determined from cores taken at BH; increment scaled to stem growth w/ prism factor and allometric equations	1	Variable-radius plots	After growing season for which NPP is calculated	Same trees used to determine aboveground biomass

Table 3.2 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
11) Foliage NPP	Leaves senesced from (and presumed grown in) canopy over one growing season	Litter traps for shrub and forest ecosystems; clip plots for prairie ecosystems	5	0.25-m^2 litter traps	Litter collected over the growing season for which NPP is calculated	Details regarding the accurate sampling of prairie species not yet fully determined
12) Coarse root NPP	Annual growth of roots >2 mm diameter	Calculated as an allometric function of aboveground stem growth (meas. no. 10)	1	Variable-radius plots for trees	After growing season for which NPP is calculated	Allometry for shrub and forest ecosystems not relevant for prairies
13) Fine root NPP	Roots <2 mm diameter	The insides of clear tubes inserted into ground are periodically viewed with a digital camera; gross increase in area of fine roots seen in images is scaled to mass/area using constants	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	
14) LAI (optical)	½ total leaf area in canopy per unit ground area	Measured at points in plot using LAI 2000 (LAI computed from sunlight attenuation as it passes through canopy)	5	Point samples	4 times seasonally	
15) LAI (allometry)	½ total leaf area in canopy per unit ground area	Foliar mass values are scaled to area using species-specific specific leaf area values (meas. no. 18)	1	Variable-radius plots	Any time	Forest and shrub communities only

3-17

Table 3.2 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
16) f_{APAR}	Fraction of PAR absorbed by canopy	Measured at points in plot using LAI 2000 (computed from same measurement as LAI)	5	Point samples	4 times seasonally	
17) Vegetation cover	Vertical projection of vegetation to ground area	Mean crown completeness using digital true-color camera	5	1 m^2	Midsummer	
18) Moss mass per ground area						No significant moss component at KONZ
19) Specific leaf area	Leaf area per unit leaf mass by species	Fresh leaves are weighed and measured with a leaf area meter				Sitewide averages will be determined by taking leaf samples only at selected plots
20) Leaf nitrogen concentration	% nitrogen by mass of leaves from dominant tree species	Fresh leaves are dried, digested by Kjeldahl incubation, and colormetrically analyzed for nitrogen				Sitewide averages will be determined by taking leaf samples at only a few selected plots

* Grassland plots will require only a subset of these measurements.
** DBH = diameter at breast height.

KONZ

Subplot Placement

The 25 x 25 m plot is the experimental unit. In our final analysis each plot will yield *one* value for each vegetation characteristic measured. Where appropriate, multiple fixed-area subplots will be sampled within each plot. The subplots are positioned in the 25 x 25 m plot such that

1. they are spatially stratified throughout the plot and not clustered in one area,
2. they are simple and convenient to deploy in the field, and
3. they do not interfere with one another.

The subplots will be established in a regular pattern in each plot based on the cardinal compass directions. Figures 3.5 and 3.6 and Tables 3.3 and 3.4 illustrate the protocol for placing subplots in both forested and grassland plots at KONZ.

Figure 3.5. Placement of KONZ grassland plots

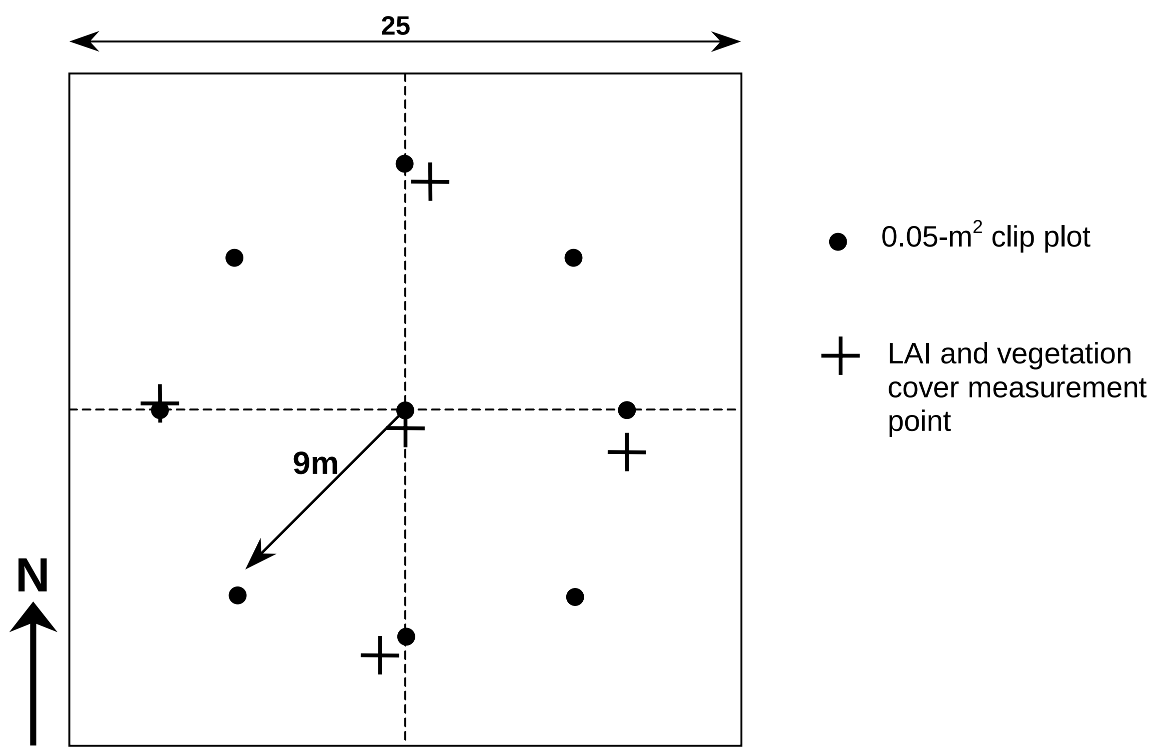


Figure 3.6. Placement of KONZ forested plots

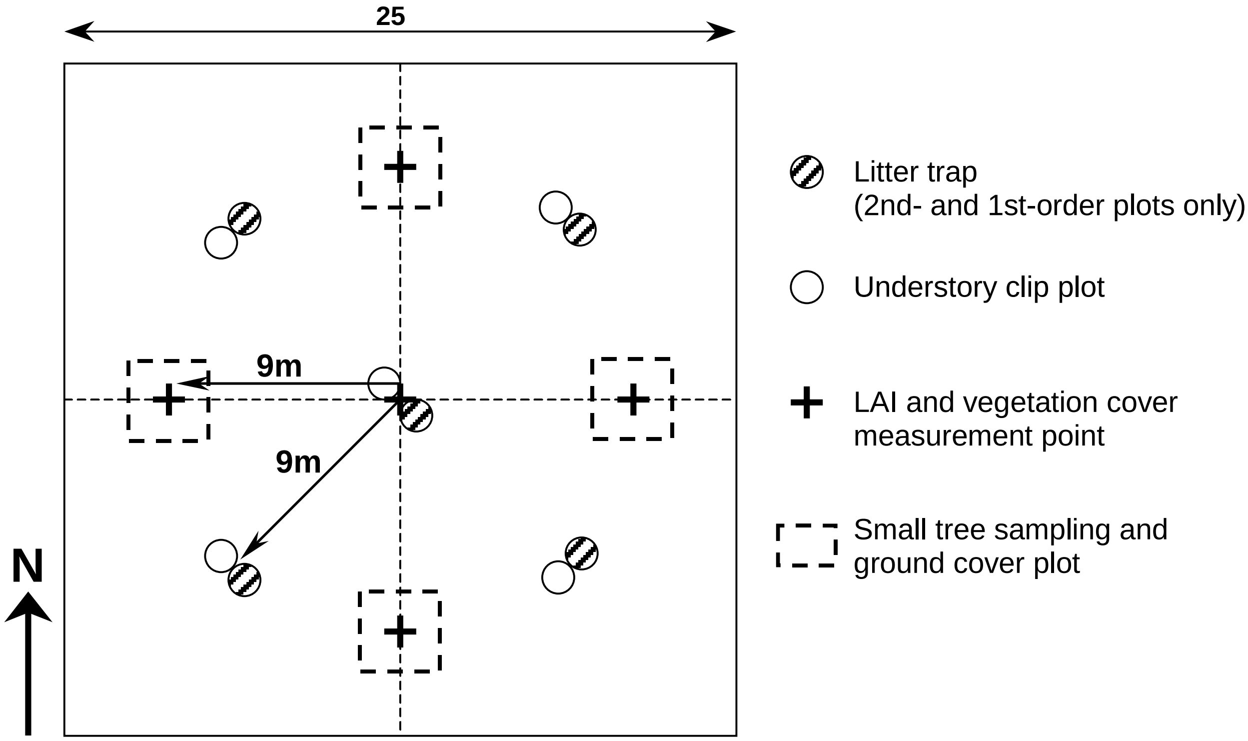


Table 3.3. Subplot placement protocol for KONZ grassland plots

Subplot	Number of subplots	Position in 25 × 25 m plot
Vegetation clip plot	9	One clip plot near plot center and eight more 9 m N, NE, E, SE, S, SW, and W, from plot center. These locations should be only approximate so as to afford multiple samples a year w/o clipping the same place twice
LAI and vegetation cover sample points	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center
Minirhizotron tubes (1st-order plots only)	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center (or anywhere they can be installed)

Table 3.4. Subplot placement protocol for KONZ forested plots

Subplot	Number of subplots	Position in 25 $\times$ 25 m plot
Understory clip plots	5	One positioned near plot center and four more positioned 9 m NW, NE, SE, and SW from plot center
Litter traps (2nd- and 1st-order plots only)	5	Placed adjacent to the understory clip plots
Small tree stem survey plots	4	Four fixed-area subplots centered at points 9 m N, S, E, and W from plot center
Variable-radius plots	1	One variable-radius plot made from plot center
LAI and vegetation cover sample points	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center
Minirhizotrons (1st-order plots only)	5	Placed adjacent to the understory clip plots (or anywhere they can be installed)

KONZ

Tentative 1999 Field Calendar

Month	Week	Day of year	Measurements
July	2	185	Survey in plots and install minirhizotrons

Full field campaigns will occur in 2000 and 2001.

KONZ

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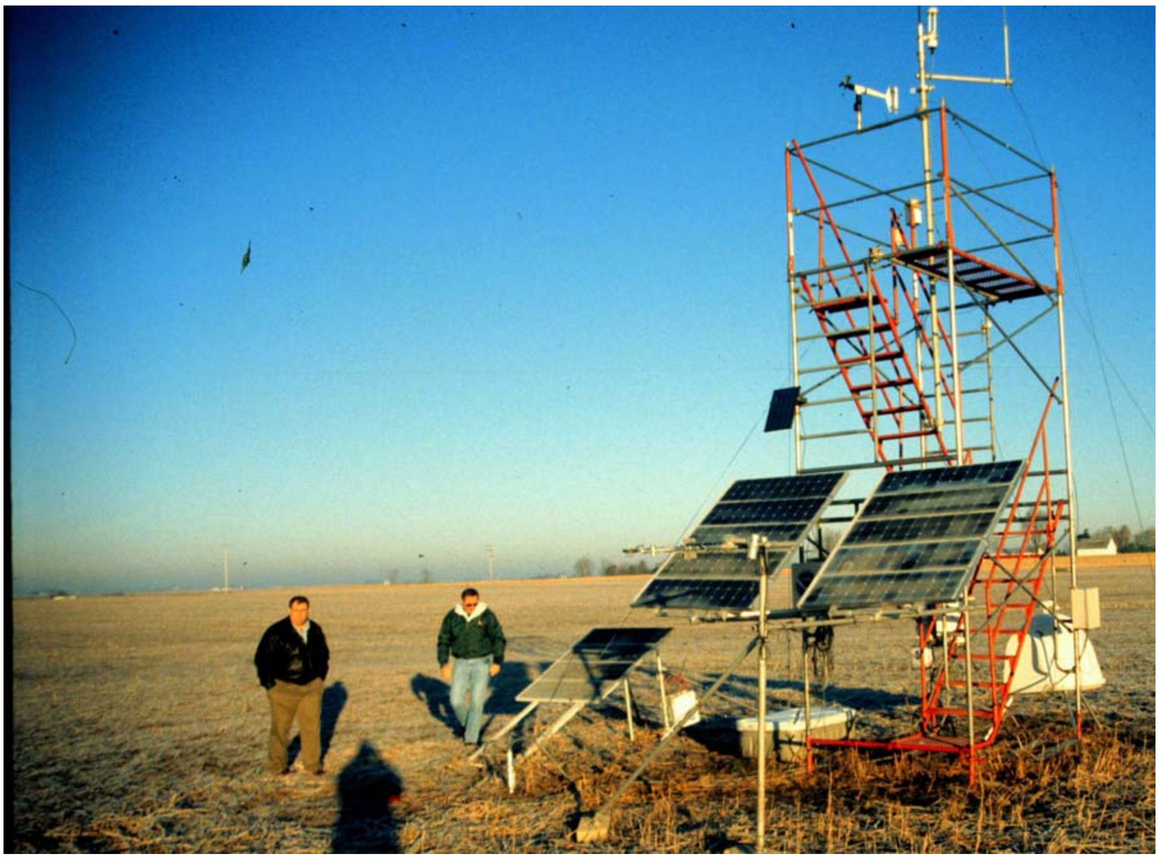
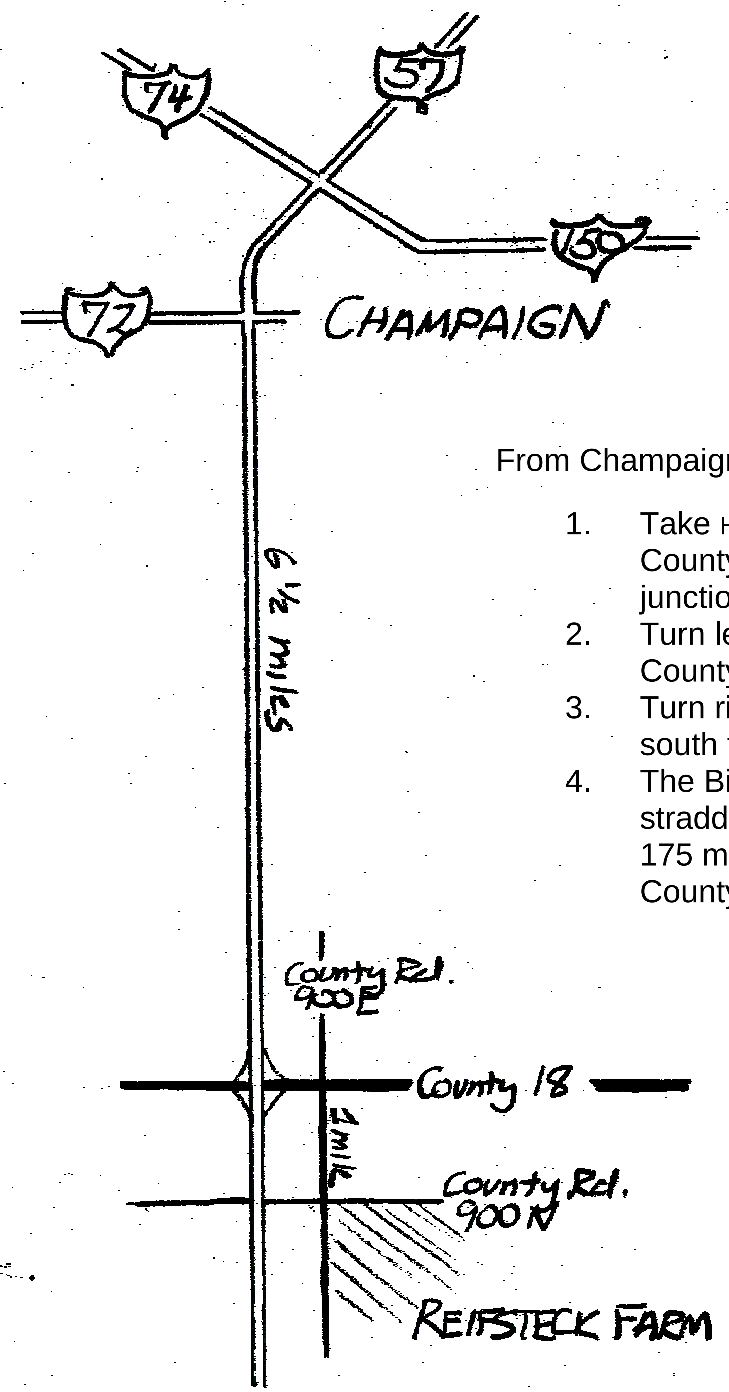
Section 4

Study Site and Measurement Plan for Agricultural Cropland (AGRO), Champaign, Illinois



AGRO

Directions to Site



From Champaign, Illinois

1. Take HWY 57 south of town to County HWY 18 (9 km south of junction with HWY 72)
2. Turn left and drive east on HWY 18 to County Rd. 900E (0.8 km)
3. Turn right on Rd. 900E and drive south to County Rd. 900N (1.5 km)
4. The BigFoot intensive sampling grid straddles County Rd. 900E about 175 m south of the intersection with County Rd. 900N

AGRO

Major Cover Types

Major cover types encountered in BigFoot study area

1. Corn
2. Soybean
3. Fallow

Cover type qualifiers

1. Time of planting

Cover type descriptions

Corn

Acronym:	CORN
Species:	corn
Architecture:	closed-canopy row crop growing >2 m tall by late summer
Comments:	Roughly half of the row crops planted on the site will be corn.

Soybean

Acronym:	SOYB
Species:	soybean
Architecture:	closed-canopy row crop growing 50 to 75 cm tall by late summer
Comments:	Roughly half of the row crops planted on the site will be soybean.

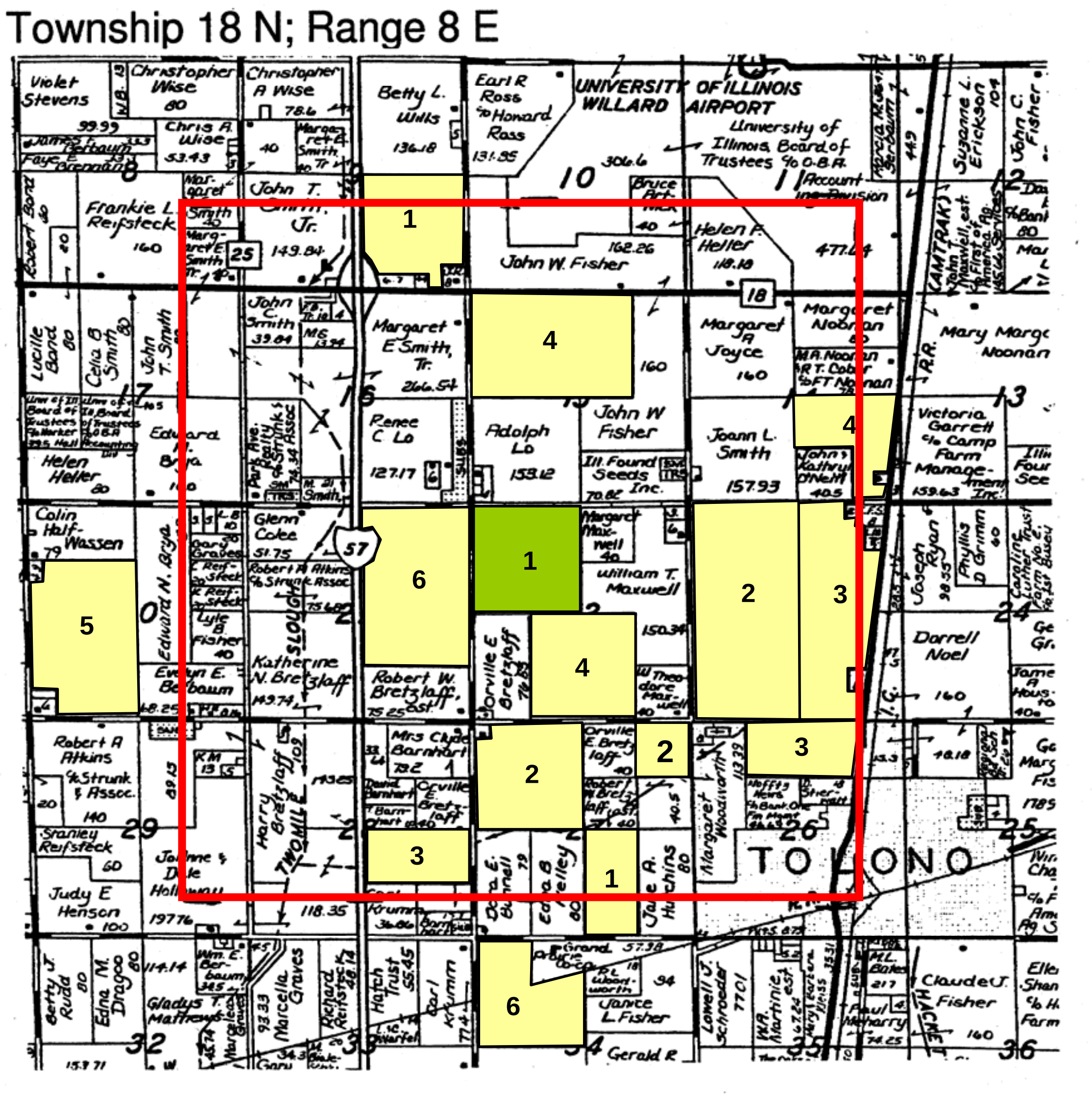
Fallow

Acronym:	FALO
Species:	hay, grasses
Architecture:	grassland of variable height
Comments:	Only a small proportion of the site (<5%) is fallow.

Cover type qualifiers and additional comments

The BigFoot extensive research plots will be stratified among many farms (see Figure 4.1), each of which may have unique planting and harvest dates. The timing of planting and harvest for each study plot will be recognized as a cover type qualifier since crop phenology (especially early in the season) influences vegetation cover, f_{APAR}, and LAI.

Figure 4.1. Land ownership at AGRO study site



Reifsteck Farm (flux tower site)
Other farms associated with study
Perimeter of 25 km^2 BigFoot study area

Land owners by number

John Reifsteck	1007 County Rd 900 E Champaign, IL 61822	217-359-5856
Forest Brewer	1038 County Rd 800 N Tolono, IL 61880	217-485-4760
Dale Stierwalt	827 US Rt 45 Tolon, IL 61880	217-485-8925
Ron Fisher	913B US Rt 45 Tolon, IL 61880	217-485-5684
Steve Stierwalt	323 County Rd 700 N Sadorus, IL 61872	217-564-2344
Roger Woodworth	831 County Rd 900 N Tolono, IL 61880	217-485-5126

AGRO

Plot Placement Rationale

Positioning of intensive sampling grid

The intensive sampling grid will consist of 80 individual plots (25 x 25 m) arranged in a systematic spatial cluster design. The 80-plot grid extends 925 m east to west and 550 m north to south. The purpose of the intensive sampling grid is to provide accurate characterization of vegetation characteristics for the tower footprint and determine the degree and scale of spatial autocorrelation among land cover types.

The intensive sampling grid will be positioned at the AGRO site such that most of the plots will occur in John Reifsteck's farm (NW corner of sec. 22 T18N, R8E). This meant centering the grid N/S in the above-mentioned quarter section. Because the E/W dimensions of the grid do not fit into a quarter section, the grid was shifted west such that grid columns 0, 1, and 2 occur in Roger Woodworth's farm (NE corner of sec. 21 T18N, R8E). County Highway 900E runs N/S evenly between grid columns 2 and 3. Positioning of the intensive sampling grid in this manner will not place any plots too close to the flux tower (nearest plot >50 m away).

Positioning of extensive sampling plots

The extensive sample plots will consist of 20 individual plots (each measuring 25 x 25 m) randomly stratified throughout a 5 x 5 km study area. The extensive sample plots will be used to verify that land cover type-specific characteristics hold over multi-kilometer distances and to address surface features that influence the 25-km^2 MODIS surface but are not necessarily present within the tower footprint.

Placement of the extensive plots is somewhat restricted at the AGRO site because all the land is privately owned. The 5 x 5 km study area will be centered on the intensively sampled Reifsteck farm. In addition, we have received permission to work on 11 other farms within the 5 x 5 km study area (see Figures 4.1 and 4.2; Table 4.1). The 20 external plots will be subjectively stratified throughout these farms to maximize the distance between any two plots and the overall extent. Each field plot will be placed just far enough off the access road to avoid edge effect (70 m in most cases).

Figure 4.2. Location of study plots in the AGRO BigFoot study site.

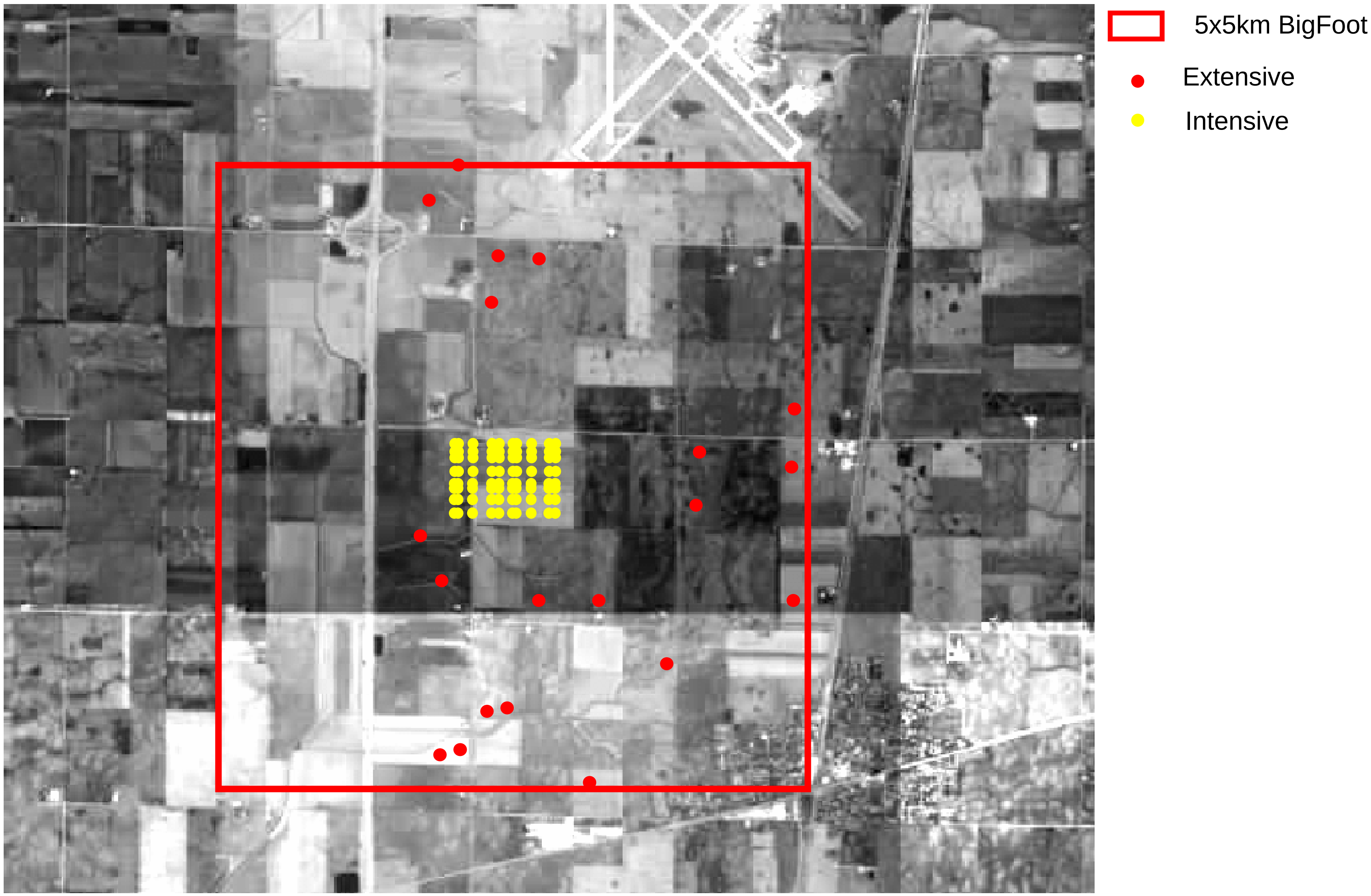


Table 4.1. AGRO plot locations and descriptions

Plot number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity	Comments
00	389295.40	4429570.60		2	Woodworth farm
01	389320.40	4429570.60		2	Woodworth farm
02	389395.40	4429570.60		2	Woodworth farm
03	389645.40	4429570.60		2	Riefsteck farm
04	389695.40	4429570.60		1	Riefsteck farm
05	389820.40	4429570.60		2	Riefsteck farm
06	389845.40	4429570.60		2	Riefsteck farm
07	389920.40	4429570.60		2	Riefsteck farm
08	390170.40	4429570.60		2	Riefsteck farm
09	390220.40	4429570.60		1	Riefsteck farm
10	389295.40	4429545.60		2	Woodworth farm
11	389320.40	4429545.60		2	Woodworth farm
12	389395.40	4429545.60		2	Woodworth farm
13	389645.40	4429545.60		2	Riefsteck farm
14	389695.40	4429545.60		2	Riefsteck farm
15	389820.40	4429545.60		2	Riefsteck farm
16	389845.40	4429545.60		2	Riefsteck farm
17	389920.40	4429545.60		2	Riefsteck farm
18	390170.40	4429545.60		2	Riefsteck farm
19	390220.40	4429545.60		2	Riefsteck farm
20	389295.40	4429495.60		2	Woodworth farm
21	389320.40	4429495.60		2	Woodworth farm
22	389395.40	4429495.60		2	Woodworth farm
23	389645.40	4429495.60		2	Riefsteck farm
24	389695.40	4429495.60		2	Riefsteck farm
25	389820.40	4429495.60		2	Riefsteck farm
26	389845.40	4429495.60		2	Riefsteck farm
27	389920.40	4429495.60		2	Riefsteck farm
28	390170.40	4429495.60		2	Riefsteck farm
29	390220.40	4429495.60		2	Riefsteck farm
30	389295.40	4429345.60		2	Woodworth farm
31	389320.40	4429345.60		2	Woodworth farm
32	389395.40	4429345.60		2	Woodworth farm
33	389645.40	4429345.60		2	Riefsteck farm
34	389695.40	4429345.60		2	Riefsteck farm
35	389820.40	4429345.60		1	Riefsteck farm
36	389845.40	4429345.60		2	Riefsteck farm
37	389920.40	4429345.60		2	Riefsteck farm
38	390170.40	4429345.60		1	Riefsteck farm
39	390220.40	4429345.60		2	Riefsteck farm
40	389295.40	4429245.60		2	Woodworth farm
41	389320.40	4429245.60		2	Woodworth farm
42	389395.40	4429245.60		2	Woodworth farm
43	389645.40	4429245.60		2	Riefsteck farm
44	389695.40	4429245.60		2	Riefsteck farm
45	389820.40	4429245.60		2	Riefsteck farm

Table 4.1 (continued)

Plot Number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity	Comments
46	389845.40	4429245.60		2	Riefsteck farm
47	389920.40	4429245.60		2	Riefsteck farm
48	390170.40	4429245.60		2	Riefsteck farm
49	390220.40	4429245.60		2	Riefsteck farm
50	389295.40	4429220.60		2	Woodworth farm
51	389320.40	4429220.60		2	Woodworth farm
52	389395.40	4429220.60		2	Woodworth farm
53	389645.40	4429220.60		2	Riefsteck farm
54	389695.40	4429220.60		2	Riefsteck farm
55	389820.40	4429220.60		2	Riefsteck farm
56	389845.40	4429220.60		2	Riefsteck farm
57	389920.40	4429220.60		2	Riefsteck farm
58	390170.40	4429220.60		2	Riefsteck farm
59	390220.40	4429220.60		2	Riefsteck farm
60	389295.40	4429145.60		2	Woodworth farm
61	389320.40	4429145.60		2	Woodworth farm
62	389395.40	4429145.60		2	Woodworth farm
63	389645.40	4429145.60		2	Riefsteck farm
64	389695.40	4429145.60		2	Riefsteck farm
65	389820.40	4429145.60		2	Riefsteck farm
66	389845.40	4429145.60		2	Riefsteck farm
67	389920.40	4429145.60		2	Riefsteck farm
68	390170.40	4429145.60		2	Riefsteck farm
69	390220.40	4429145.60		2	Riefsteck farm
70	389295.40	4429020.60		2	Woodworth farm
71	389320.40	4429020.60		2	Woodworth farm
72	389395.40	4429020.60		2	Woodworth farm
73	389645.40	4429020.60		2	Riefsteck farm
74	389695.40	4429020.60		1	Riefsteck farm
75	389820.40	4429020.60		2	Riefsteck farm
76	389845.40	4429020.60		2	Riefsteck farm
77	389920.40	4429020.60		2	Riefsteck farm
78	390170.40	4429020.60		2	Riefsteck farm
79	390220.40	4429020.60		1	Riefsteck farm
80	389449.76	4431831.61		2	Riefsteck 9 SE
81	389317.63	4431555.49		2	Riefsteck 9 SE
82	389649.01	4431261.14		2	Fisher 15 NW
83	389850.40	4431235.15		2	Fisher 15 NW
84	389639.21	4431080.13		2	Fisher 15 NE
85	389178.27	4428900.30		2	Fisher 14 SE
86	389274.53	4428716.25		2	Brewer 23 NW
87	389588.71	4427427.81		2	Stierwalt 23 NE
88	389736.87	4427440.06		2	Brewer 23 SW
89	389454.17	4427069.31		2	Stierwalt 23 SE

Table 4.1 (continued)

Plot Number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity	Comments
90	389350.62	4427044.78		2	Woodworth 21 SW
91	390429.16	4426795.86		2	Woodworth 21 SW
92	to be determined	to be determined		2	Fisher 22 SW
93	390654.26	4428232.05		2	Fisher 22 SE
94	to be determined	to be determined		2	Stierwalt 28 SE
95	391219.13	4429550.22		2	Stierwalt 28 SE
96	391221.50	4429209.01		2	Brewer 27 NW
97	to be determined	to be determined		2	Brewer 27 NW
98	392021.94	4429528.52		2	Brewer 27 NE
99	392006.37	4429795.91		2	Riefsteck 27 SE
AGRO Base	389521.28	4431541.29			
AGROSEC1	391943.74	4429677.49			
AGROSEC2	390597.37	4429718.91			

* UTM (Universal Transverse Mercator) NAD (North American Datum) 83 zone 16.

AGRO

Sampling Intensity Among Plots

According to the BigFoot sampling design (Figure 4.3), each of the 25 x 25 m plots will be sampled at one of three levels of intensity. At the AGRO site, however, there is no distinction between 2nd- and 3rd-order plots because aboveground biomass equals aboveground productivity. The assignment of sampling intensity among plots is as follows:

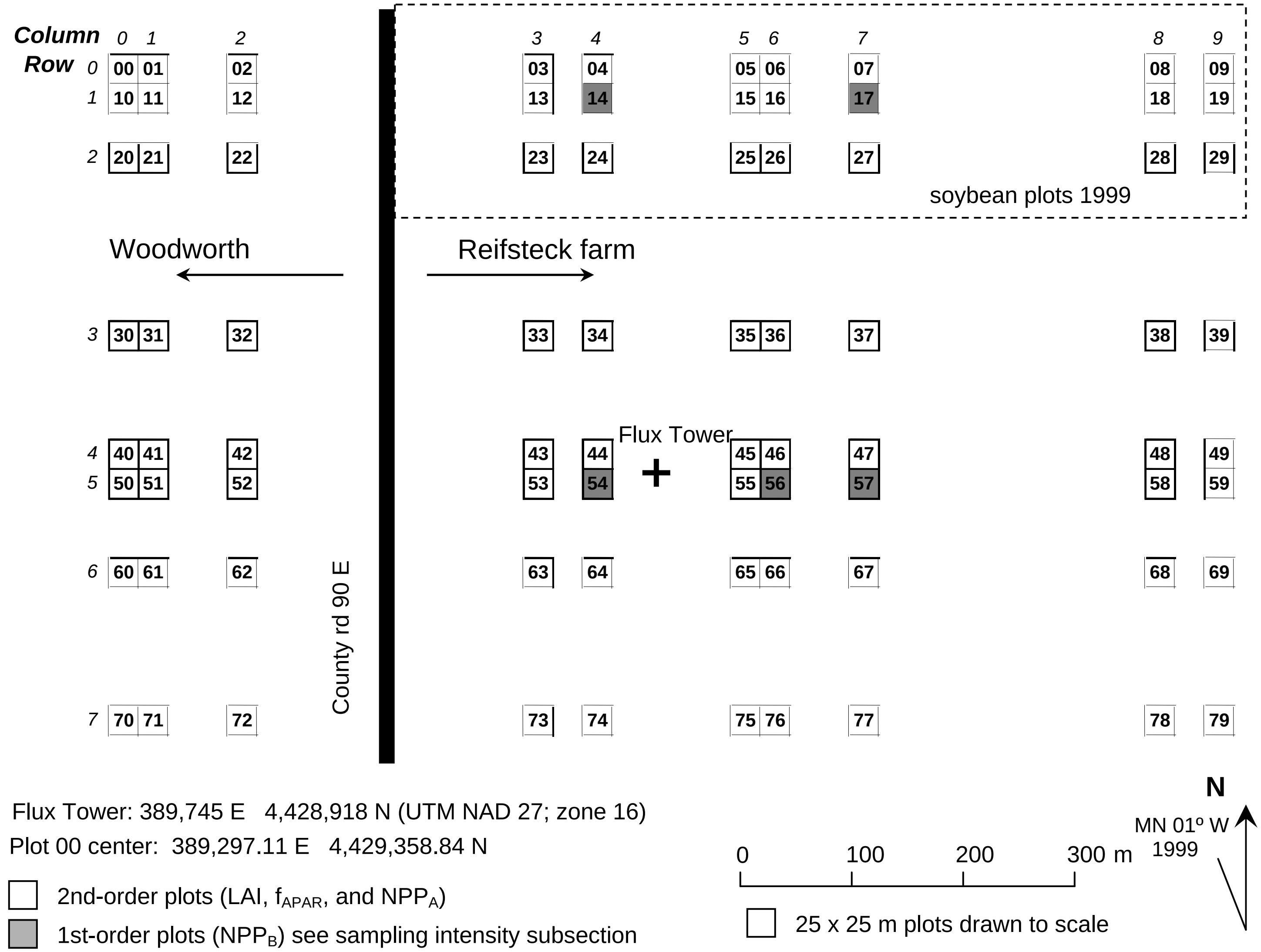
Sampling intensity	Parameters quantified	Number of plots (of 100 total plots)
3rd order	Vegetation cover, species composition, plant biomass, LAI, and f_{APAR}	0
2nd order	NPP_A	94
1st order	Net primary productivity (NPP_A + NPP_B)	6

Assignment of first-order plots

Fine root NPP will be measured in only six plots with first-order status because of the large labor costs. Three separate plots will be sampled to estimate fine root NPP for each of the two major vegetation types. In choosing the first-order plots we will attempt to maximize their independence from each other.

At the AGRO site, three plots will be located in corn crop areas and three plots in soybean crop areas. Five minirhizotrons will be installed in each of the replicate plots. Which of the plots will be first-order plots will not be determined until the row crops are planted.

Figure 4.3. Location of intensive study plots surrounding AGRO flux tower.



AGRO

Vegetation Characteristics to be Measured

Vegetation cover, LAI, f_{APAR}, and aboveground biomass will be estimated for each 25 x 25 m plot; and NPP_A and NPP_B will be estimated for a subset of plots. The diversity of plant growth forms present in the other BigFoot sites makes it necessary to compartmentalize these characteristics into multiple components and apply a unique measurement technique to each. However, the AGRO site is composed of annual monoculture crops (corn and soybean), greatly simplifying the measurement approach.

Below is a list of the 10 vegetation characteristics to be measured in the AGRO plots, followed by Table 4.2, describing the protocol for taking each of the measurements.

Biomass and NPP Components

1. Crop stems per unit area
2. Aboveground mass of crop plant per stem
3. Belowground mass of crop plant per stem
4. Fine root NPP

Canopy Characteristics

5. LAI (measured optically)
6. LAI (measured directly)
7. f_{APAR} (measured optically)
8. Specific leaf area
9. Leaf nitrogen content
10. Vegetation cover

Table 4.2. Vegetation sampling methodology for AGRO

Measurement	Example	Method	Sample number	Timing	Comments
1) Density of crop stems	Corn or soybean	Count the number of stems per 5 m of crop row and the number of crop rows per 25 m	4 counts per field	Once after sprouting and once after spring mortality	
2) Aboveground mass of crop per stem	Corn or soybean	A single stem will be removed from soil w/ roots, dried, separated from roots, and weighed	4 stems per plot	6 times over the season	A total of 24 stems will be removed from each 25 x 25 m plot over the entire growing season
3) Belowground mass of crop per stem	Corn or soybean	Roots separated from above-mentioned sample will be weighed	Same 4 stems per plot	6 times over the season	
4) Fine root NPP	Corn or soybean	The minirhizotrons are periodically viewed with a digital camera. Gross increase in area of fine roots seen in images is scaled to mass/area using gravimetric constants	5 tubes per plot (2-D images totaling 30 cm each)	6 times over the season	Only 6 of 100 plots will receive minirhizotrons
5) LAI (optical)	½ total leaf area in canopy per unit ground area	Measured at points in plot using LAI 2000 (LAI computed from sunlight attenuation as it passes through canopy)	5 points	6 times over the season	

Table 4.2 (continued)

Measurement	Example	Method	Sample number	Timing	Comments
6) LAI (allometry)	½ total leaf area in canopy per unit ground area	Before drying, leaves from the harvested plant will be sent through a leaf area meter to determine average ½ leaf area per stem. This value will be scaled to plot using the stems per plot values	Same 4 stems per plot	6 times over the season	
7) f_{APAR}	Fraction of PAR absorbed by canopy	Measured at points in plot using LAI 2000 (computed from same measurement as LAI)	5 points	6 times over the season	
8) Vegetation cover	Vertical projection of vegetation to ground-cover	Mean crown completeness using digital true-color camera	5	1 m^2	
9) Specific leaf area	Leaf area per unit leaf mass by species	Fresh leaves are weighed and measured with a leaf area meter			Sitewide averages will be determined by taking leaf samples only at selected plots
10) Leaf nitrogen concentration	% nitrogen by mass of leaves from dominant tree species	Fresh leaves are dried, digested by Kjeldahl incubation, and colormetrically analyzed for nitrogen		3 times seasonally	Sitewide averages will be determined by taking leaf samples only at a selected few plots

AGRO

Subplot Placement

The 25 x 25 m plot is the experimental unit. In our final analyses each plot will yield only *one* value for each vegetation characteristic. Where appropriate, multiple fixed-area subplots will be sampled within each plot to better characterize spatial heterogeneity. The subplots are positioned in the 25 x 25 m plot such that

1. they are spatially stratified throughout the plot and not clustered in one area,
2. they are simple and convenient to deploy in the field, and
3. they do not interfere with each other.

The subsamples will be located in a regular pattern in each plot based on the cardinal compass directions. The protocol for the subplot placement of subsamples at AGRO is illustrated in Figure 4.4 and described in Table 4.3.

Figure 4.4. Placement of AGRO subsamples.

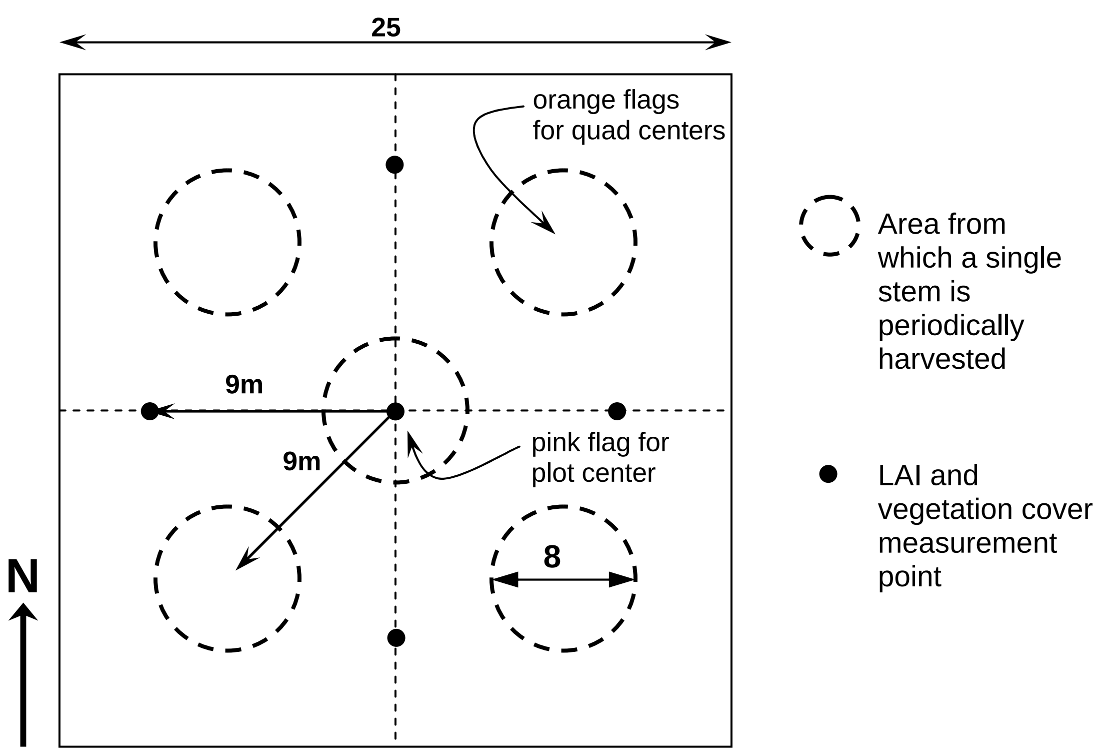


Table 4.3. Subplot placement protocol for AGRO

Subplot	Number of subplots	Position in 25 x 25 m plot
Stem clip location	4	One stem in each of four fixed-area regions centered at points 9 m N, S, E, and W from plot center
LAI and vegetation cover sample points	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center
Minirhizotrons (1st-order plots only)	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center (or anywhere they can be installed)

A tentative field schedule is provided on the following page.

AGRO

Tentative 1999 Field Calendar

Month	Week	Day of year	Measurements
April	2	106	Survey in plots and install minirhizotron tubes just after crops are planted
May	3	136	Take LAI, take root images, and harvest sample plants (1 of 7 times in season)
June	1	151	Take LAI, take root images, and harvest sample plants (2 of 7 times in season)
June	3	166	Take LAI, take root images, and harvest sample plants (3 of 7 times in season)
July	1	181	Take LAI, take root images, and harvest sample plants (4 of 7 times in season) Peak tassel anticipated
July	4	204	Take LAI, take root images, and harvest sample plants (5 of 7 times in season)
Aug.	3	235	Take LAI, take root images, and harvest sample plants (6 of 7 times in season)
Sept.	3	263	Take LAI, take root images, and harvest sample plants (7 of 7 times in season); remove minirhizotron tubes just prior to harvest

These dates are dependent on the farmers’ planting schedule, which in turn is dependent on the weather.

Measurements will be repeated in 2000 on or near the same dates.

AGRO

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Section 5

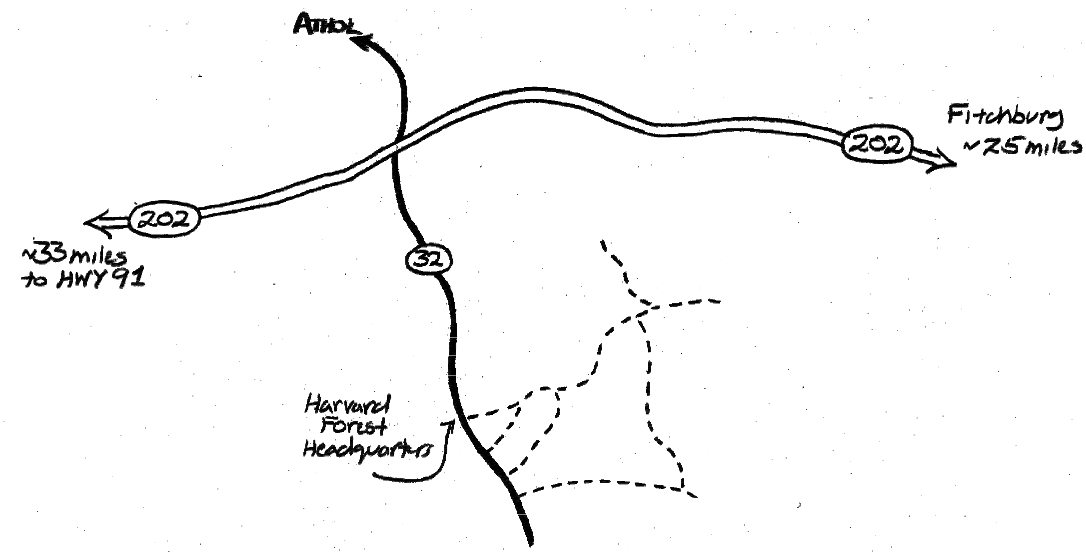
Study Site and Measurement Plan for Harvard Forest, (HARV) Petersham, Massachusetts

HARV

Directions to site

From Highway 202, between Fitchburg, Massachusetts, and I-91

1. Turn south onto HWY 32 from HWY 202 (opposite from turn to Athol)
2. Drive south on HWY 32 to sign for Harvard forest (about 4 km)



HARV

Major Cover Types

Major cover encountered in BigFoot study site

1. Eastern hardwoods
2. Eastern hemlock
3. Red pine
4. Oldfield meadow

Cover type qualifiers

1. Disturbed (clearcut)
2. Undisturbed

Cover type descriptions

Eastern hardwoods

Acronym:	EHWD
Overstory:	dominated by sugar maple mixed with red oak, ash, basswood, and beech
Understory:	saplings of shade-tolerant tree species and *Vaccinium* spp
Ground cover:	grasses and forbs belonging to the “Canadian carpet” community
Land form:	uplands
Comments:	The fall 1999 visit to HARV will allow us to better describe this community.

Eastern hemlock

Acronym:	HEML
Overstory:	eastern hemlock with remnant red oak
Understory:	hemlock saplings
Ground cover:	sparse cover of grasses and forbs belonging to the “Canadian carpet” community
Land form:	uplands to lowlands
Comments:	The fall 1999 visit to HARV will allow us to better describe this community.

Red pine

Acronym:	RDPN
Overstory:	red pine
Understory:	red pine saplings
Ground cover:	sparse cover of grasses and forbs
Land form:	uplands
Comments:	The fall 1999 visit to HARV will allow us to better describe this community.

Oldfield meadow

Acronym:	OLDF
Overstory:	none
Understory:	grasses, shrubs
Comments:	This cover type is largely the result of anthropogenic disturbance. Additional visits to HARV will allow us to better describe this community.

Cover type qualifiers and additional comments

A clearcut planned for 1999 will occur on a portion of the private land occurring within the HARV BigFoot study area, affecting one or more of the extensive plots. These plots will be classified according to their current vegetation cover, but their status as clearcut will also be recognized as a cover type qualifier, since the cutting influences the vegetation structure and function.

HARV

Plot Placement Rationale

Positioning of intensive sampling grid

The intensive sampling grid will consist of 80 individual plots (25 x 25 m) arranged in a systematic spatial cluster design (Figures 5.1, 5.2, and 5.3; Table 5.1). The 80-plot grid extends 925 m east to west and 550 m north to south. The purpose of the intensive sampling grid is to provide vegetation characteristics for the tower footprint and determine the degree and scale of spatial autocorrelation among land cover type qualities.

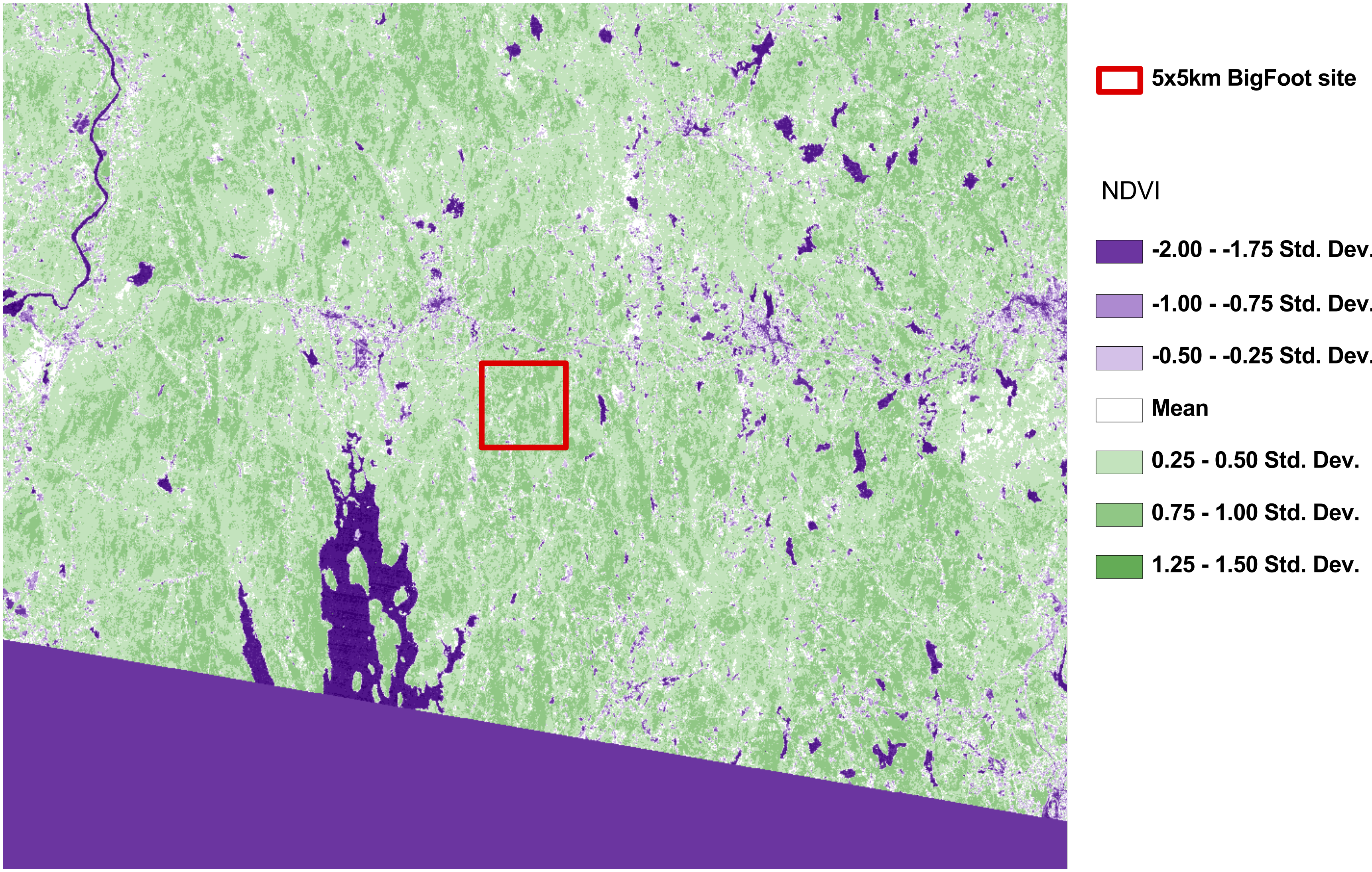
The intensive sampling at the HARV site will be centered on the eddy flux tower. Positioning of the intensive sampling grid in this manner will not place any plots too close to the flux tower (nearest plot >50 m away). Moreover, this positioning minimizes interference with Carol Barford's research plots. The six BigFoot plots that fall in the same area as Carol Barford's plots can be eliminated if necessary.

Positioning of extensive sampling plots

The 20 extensive sample plots (25 x 25 m) will be randomly stratified throughout the 5 x 5 km study area (Figures 5.2 and 5.3). The extensive sample plots will be used to verify that cover type-specific characteristics hold over multi-kilometer distances and to measure vegetation characteristics of ecosystems that influence the 25-km^2 MODIS surface but are not adequately sampled in the tower footprint.

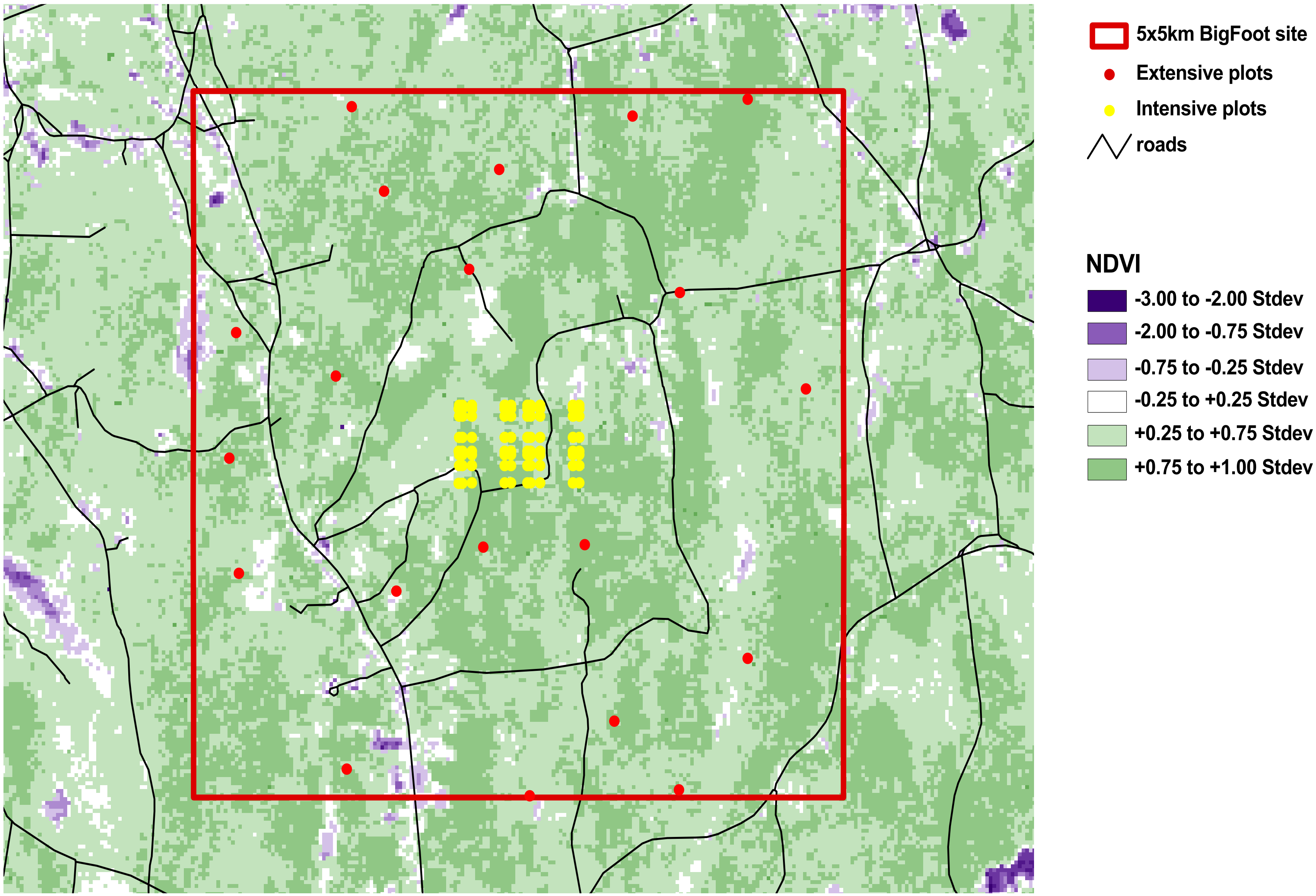
The 5 x 5 km study area will be centered on the flux tower. The 20 external plots will be randomly stratified throughout the 5 x 5 km study area such that plots will be at least 600 m from each other. Two of the original 20 random plots were relocated to new random locations because they occurred in lakes or residential areas.

Figure 5.1. Location of HARV study site in relation to the surrounding landscape.



NDVI derived from LandSat TM image obtained from http://www.lternet.edu

Figure 5.2. Location of study plots in relation to a standardized NDVI image for Harvard Forest.



NDVI derived from LandSat TM image obtained from http://www.lternet.edu

Figure 5.3. Location of intensive study plots surrounding HARV flux tower.

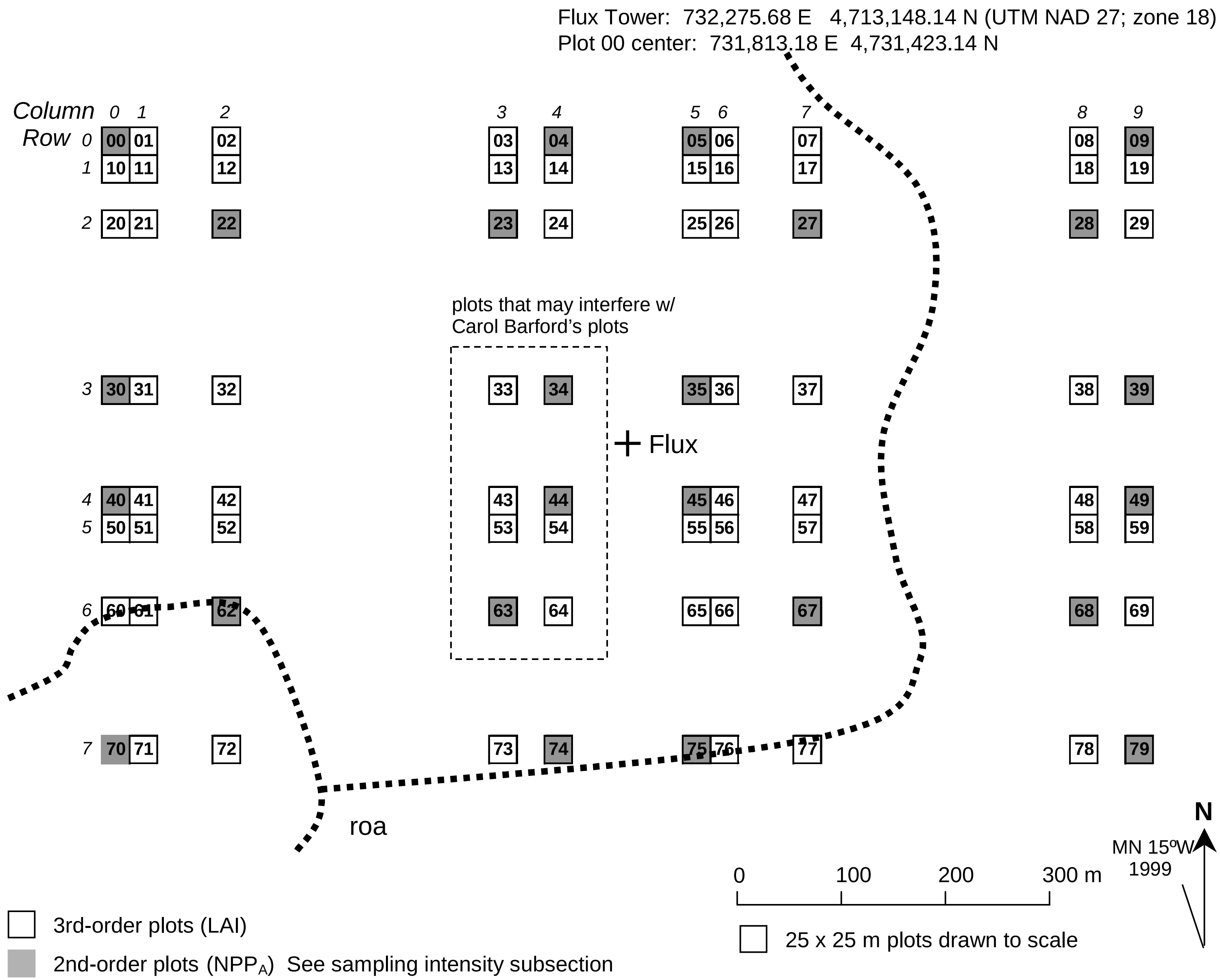


Table 5.1. HARV plot locations and descriptions

Plot number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity**	Comments
00	731,813.18	4,713,423.14		2	
01	731,838.18	4,713,423.14		3	
02	731,913.18	4,713,423.14		3	
03	732,163.18	4,713,423.14		3	
04	732,213.18	4,713,423.14		2	
05	732,338.18	4,713,423.14		2	
06	732,363.18	4,713,423.14		3	
07	732,438.18	4,713,423.14		3	
08	732,688.18	4,713,423.14		3	
09	732,738.18	4,713,423.14		2	
10	731,813.18	4,713,398.14		3	
11	731,838.18	4,713,398.14		3	
12	731,913.18	4,713,398.14		3	
13	732,163.18	4,713,398.14		3	
14	732,213.18	4,713,398.14		3	
15	732,338.18	4,713,398.14		3	
16	732,363.18	4,713,398.14		3	
17	732,438.18	4,713,398.14		3	
18	732,688.18	4,713,398.14		3	
19	732,738.18	4,713,398.14		3	
20	731,813.18	4,713,348.14		3	
21	731,838.18	4,713,348.14		3	
22	731,913.18	4,713,348.14		2	
23	732,163.18	4,713,348.14		2	
24	732,213.18	4,713,348.14		3	
25	732,338.18	4,713,348.14		3	
26	732,363.18	4,713,348.14		3	
27	732,438.18	4,713,348.14		2	
28	732,688.18	4,713,348.14		2	
29	732,738.18	4,713,348.14		3	
30	731,813.18	4,713,198.14		2	
31	731,838.18	4,713,198.14		3	
32	731,913.18	4,713,198.14		3	
33	732,163.18	4,713,198.14		3	Overlap w/Barford’s plot (unsampled here)
34	732,213.18	4,713,198.14		2	Overlap w/Barford’s plot (unsampled here)
35	732,338.18	4,713,198.14		2	
36	732,363.18	4,713,198.14		3	
37	732,438.18	4,713,198.14		3	
38	732,688.18	4,713,198.14		3	
39	732,738.18	4,713,198.14		2	
40	731,813.18	4,713,098.14		2	
41	731,838.18	4,713,098.14		3	
42	731,913.18	4,713,098.14		3	

Table 5.1 (continued)

Plot Number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity**	Comments
43	732,163.18	4,713,098.14		3	Overlap w/Barford's plot (unsampled here)
44	732,213.18	4,713,098.14		2	Overlap w/Barford's plot (unsampled here)
45	732,338.18	4,713,098.14		2	
46	732,363.18	4,713,098.14		3	
47	732,438.18	4,713,098.14		3	
48	732,688.18	4,713,098.14		3	
49	732,738.18	4,713,098.14		2	
50	731,813.18	4,713,073.14		3	
51	731,838.18	4,713,073.14		3	
52	731,913.18	4,713,073.14		3	
53	732,163.18	4,713,073.14		3	Overlap w/Barford's plot (unsampled here)
54	732,213.18	4,713,073.14		3	Overlap w/Barford's plot (unsampled here)
55	732,338.18	4,713,073.14		3	
56	732,363.18	4,713,073.14		3	
57	732,438.18	4,713,073.14		3	
58	732,688.18	4,713,073.14		3	
59	732,738.18	4,713,073.14		3	
60	731,813.18	4,712,998.14		3	
61	731,838.18	4,712,998.14		3	
62	731,913.18	4,712,998.14		2	
63	732,163.18	4,712,998.14		2	Overlap w/Barford's plot (unsampled here)
64	732,213.18	4,712,998.14		3	Overlap w/Barford's plot (unsampled here)
65	732,338.18	4,712,998.14		3	
66	732,363.18	4,712,998.14		3	
67	732,438.18	4,712,998.14		2	
68	732,688.18	4,712,998.14		2	
69	732,738.18	4,712,998.14		3	
70	731,813.18	4,712,873.14		2	
71	731,838.18	4,712,873.14		3	
72	731,913.18	4,712,873.14		3	
73	732,163.18	4,712,873.14		3	
74	732,213.18	4,712,873.14		2	
75	732,338.18	4,712,873.14		2	
76	732,363.18	4,712,873.14		3	
77	732,438.18	4,712,873.14		3	
78	732,688.18	4,712,873.14		3	
79	732,738.18	4,712,873.14		2	

Table 5.1 (continued)

Plot Number	Plot center UTM easting*	Plot center UTM northing*	Cover type	Sampling intensity**	Comments
80	731,332.20	4,712,107.20		2	May need repositioning if in residential yard
81	730,048.30	4,713,050.60		2	
82	731,891.90	4,714,384.80		2	may need repositioning if on road
83	733,511.60	4,714,223.20		2	may need repositioning if on road
84	730,120.20	4,712,233.10		2	
85	732,000.90	4,712,419.70		2	
86	731,946.40	4,713,511.30		2	
87	730,866.10	4,713,631.60		2	
88	730,988.50	4,715,536.00		2	
89	732,780.70	4,712,437.10		2	
90	733,148.90	4,715,470.70		2	
91	730,099.30	4,713,939.00		2	
92	732,121.90	4,715,094.80		2	
93	731,238.70	4,714,938.20		2	
94	732,356.80	4,710,660.90		2	
95	734,481.70	4,713,538.10		2	
96	734,034.20	4,711,630.80		2	
97	733,505.00	4,710,702.60		2	
98	730,951.60	4,710,848.40		2	
99	734,032.80	4,715,589.00		2	

* UTM (Universal Transverse Mercator) NAD (North American Datum) 27 zone 18.

** Six of the 2nd-order plots will be upgraded to 1st-order plots (NPP_B plots) at the time of tube installation. Grid position philosophy: grid centered around flux tower based on location taken by Burrows in 11/98.

HARV

Sampling Intensity Among Plots

According to the BigFoot sampling design, each of the 25 x 25 m plots will be sampled at one of three levels of intensity (Figure 5.3):

Sampling Intensity	Parameters quantified	Number of plots (of 100 total plots)
3rd-order	Vegetation cover, species composition, plant biomass, LAI, and f_{APAR}	56
2nd-order	3rd-order measurements + NPP_A	38
1st -order	2nd-order measurements + NPP_B	6

Assignment of second-order plots

All 20 of the extensive plots (plot numbers 80–99) will be assigned second-order status. In addition, 24 of the 80 intensive plots will be assigned second-order status. The 24 second-order plots were selected from the 80 intensive plots to maximize the distance among plots to minimize autocorrelation among plots.

Assignment of first-order plots

Fine root NPP will be measured in only six first-order plots because of the large labor costs. Three plots will be sampled to estimate fine root NPP for each of the two most abundant cover types. The first-order plots will be selected to maximize independence from each other.

At the HARV site, three plots will be located in mixed hardwood forests and three plots located in hemlock forests. Five minirhizotrons will be installed in each stand. Which of the plots will be selected will not be determined until fall of 1999, when the plots are established.

Assignment of third-order plots

The remaining 50 plots will be third-order plots The distribution of first-, second-, and third-order plots will be 56, 38, and 6, respectively.

HARV

Vegetation Characteristics to be Measured

According to the BigFoot objectives it is necessary to quantify vegetation cover, LAI, f_{APAR}, and aboveground biomass for each 25 x 25 m plot and aboveground and belowground NPP for a subset of plots. Each of these characteristics have multiple components that require separate measurement. Below is a list of the 20 vegetation characteristics to be measured (in at least some of the plots) followed by Table 5.2, describing the protocol for taking each of the measurements.

Aboveground Biomass (all plots)

1. moss layer
2. understory
3. small tree wood and leaf
4. large tree wood and leaf

Belowground Biomass (1st-order plots only)

5. coarse roots
6. fine roots

Aboveground NPP (2nd- and 1st-order plots only)

7. moss production
8. understory wood production
9. small tree wood production
10. large tree wood production
11. total foliage production

Belowground NPP (1st-order plots only)

12. coarse root production
13. fine root production

Leaf Area Index and Vegetation Cover (all plots)

14. leaf area index measured optically
15. leaf area index measured using allometric equations
16. f_{APAR} measured optically
17. vegetation cover

Scaling parameters (site-wide averages will be measured in six of the exterior 2nd-order plots)

18. moss mass per ground area
19. specific leaf area of dominant canopy species
20. leaf N concentration of dominant canopy species

Table 5.2. Vegetation sampling methodology for HARV

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
1) Moss mass	Sphagnum	Visual estimates of % ground cover in subplots are multiplied by average mass of moss per unit area (measurement no. 16)	5	0.25–4.00 m^2 (depending on moss patch size)	Midsummer	Few plots at HARV will require this measurement
2) Understory mass	*Vaccinium* spp., ferns, and tree seedlings	Clip at base, dry, and weigh all understory in subplot	5	0.25 m^2	Midsummer	
3) Small tree mass	Large shrubs and tree saplings <2 cm DBH	Count stems and basal diameter in subplots and scale to tree mass w/ allometric equations	5	1–25 m^2 depending on tree density (enough to get 4 trees/ subplot)	Midsummer	
4) Large tree aboveground mass	Maple, oak, hemlock, and pine >2 cm DBH	Variable-radius plots to count stems by size; stem counts scaled to tree mass w/ allometric equations	1	Variable-radius prism sweep	Midsummer	
5) Coarse root mass	Tree roots >2 mm diameter	Plot-centered prism plot to count stems by size; stem counts scaled to root mass w/ allometric equations	1	Not applicable	Midsummer	Derived from the same prism plot data above

Table 5.2 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
6) Fine root mass	Root 2 mm or less in diameter	The inside of clear tubes inserted into ground are periodically viewed with a digital camera. Area of fine roots seen in images are scaled to mass/area using gravimetric constants	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	
7) Moss NPP	Sphagnum	Growth past vertical wire gauges for one year.	0–8	Sphagnum gauges clustered in 0.25-m^2 clumps	Gauges set at either spring thaw or fall freeze; growth measured 1 and/or 2 years later	Number of mesh plots or wire gauges dependent on abundance and/or presence of moss
8) Understory wood NPP	New stem growth of *Vaccinium* spp., ferns, and tree seedlings	Based on bud scarring, new stem growth is separated from the understory biomass samples and weighed	5	0.25 m^2	After growing season	Sampled from the same plots used to determine small tree mass
9) Small tree wood NPP	Annual bole and branch growth of large shrubs and tree saplings <2 cm DBH	Radial increment of tree determined w/basal cores or disks; increment scaled to stem growth w/ allometric equations	4	1–25 m^2 depending on tree density (enough to get 4 trees/ subplot)	After growing season for which NPP is calculated	Sampled from the same plots used to determine small tree mass

Table 5.2 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
10) Large tree wood NPP	Annual bole and branch growth of maple, oak, hemlock, and pine >2 cm DBH	Radial increment of trees counted in prism plots determined from cores taken at BH; increment scaled to stem growth w/prism factor and allometric equations	1	Variable-radius prism plots	After growing season for which NPP is calculated	Same trees used to determine aboveground biomass
11) Foliage NPP	Leaves senesced from (and presumed grown in) canopy over one growing season	Litter traps to collect annual leaf production; allometric equations used to estimate new foliage	5	0.25-m^2 litter traps	Litter collected over the growing season for which NPP is calculated	In deciduous plots, leaflitter is annual foliar production. In evergreen plots, steady stasis between foliar growth and senescence must be assumed
12) Coarse root NPP	Annual growth in roots >2 mm in diameter	Coarse root biomass allometric equation used to estimate biomass from DBH	1	Variable-radius prism plot	After growing season for which NPP is calculated	Same trees used to determine aboveground biomass

5-16

Table 5.2 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
13) Fine root NPP	Gross growth of root tips <2 mm in diameter	The insides of clear tubes inserted into ground are periodically viewed with a digital camera; gross increase in area of fine roots seen in images is scaled to biomass using mass/area constants	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	
14) LAI (optical)	½ total leaf area in canopy per unit ground area	Measured at points in plot using LAI 2000 (LAI computed from sunlight attenuation as it passes through canopy)	5	Point samples	4 times seasonally	
15) LAI (allometry)	½ total leaf area in canopy per unit ground area	Foliar mass (determined from allometric equations) is scaled to area using species-specific specific leaf area values (meas. no. 18)	1	Variable-radius plots	Any time	In deciduous stands, litterfall can be used as an alternative measure of foliar mass
16) f_{APAR}	Fraction of PAR absorbed by canopy	Measured at points in plot using LAI 2000 (computed from same measurement as LAI)	5	Point samples	4 times seasonally	
17) Vegetation cover	Vertical projection of vegetation to ground area	Mean crown completeness using digital true-color camera	5	1 m^2	Midsummer	

5-17

Table 5.2 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
18) Moss mass per ground area	Dry mass of moss per unit ground area at 100% coverage	Moss samples are collected from a fixed area in which moss grows with 100% coverage. Living tissue is separated, dried, and weighed				This is used to scale moss coverage to moss mass. Sitewide averages will suffice
19) Specific leaf area	Leaf area per unit leaf mass by species	For broad leaves, fresh leaves are weighed and measured using a leaf area meter. For needle leaves, leaf volume by water displacement and volume is converted to area using shape-specific geometric constants				Sitewide averages will be determined by taking leaf samples only at selected few plots
20) Leaf nitrogen concentration	% nitrogen by mass of leaves from dominant tree species	Fresh leaves are dried, digested by Kjeldahl incubation, and colormetrically analyzed for nitrogen				Sitewide averages will be determined by taking leaf samples only at selected plots

HARV

Subplot Placement

The 25 x 25 m plot is the experimental unit. In our final analyses, each plot yields only *one* value for each vegetation characteristic. When appropriate, multiple fixed-area subplots will be sampled within each plot. The subplots are positioned in the 25 x 25 m plot such that

1. they are spatially stratified throughout the plot and not clustered in one area,
2. they are simple and convenient to deploy in the field, and
3. they do not interfere with one another.

The subplots will be established in a regular pattern in each plot using cardinal compass directions. The protocol for the subplot placement of

Figure 5.4. Placement of HARV subsamples.

subsamples at HARV is illustrated in Figure 5.4 and described in Table 5.3.

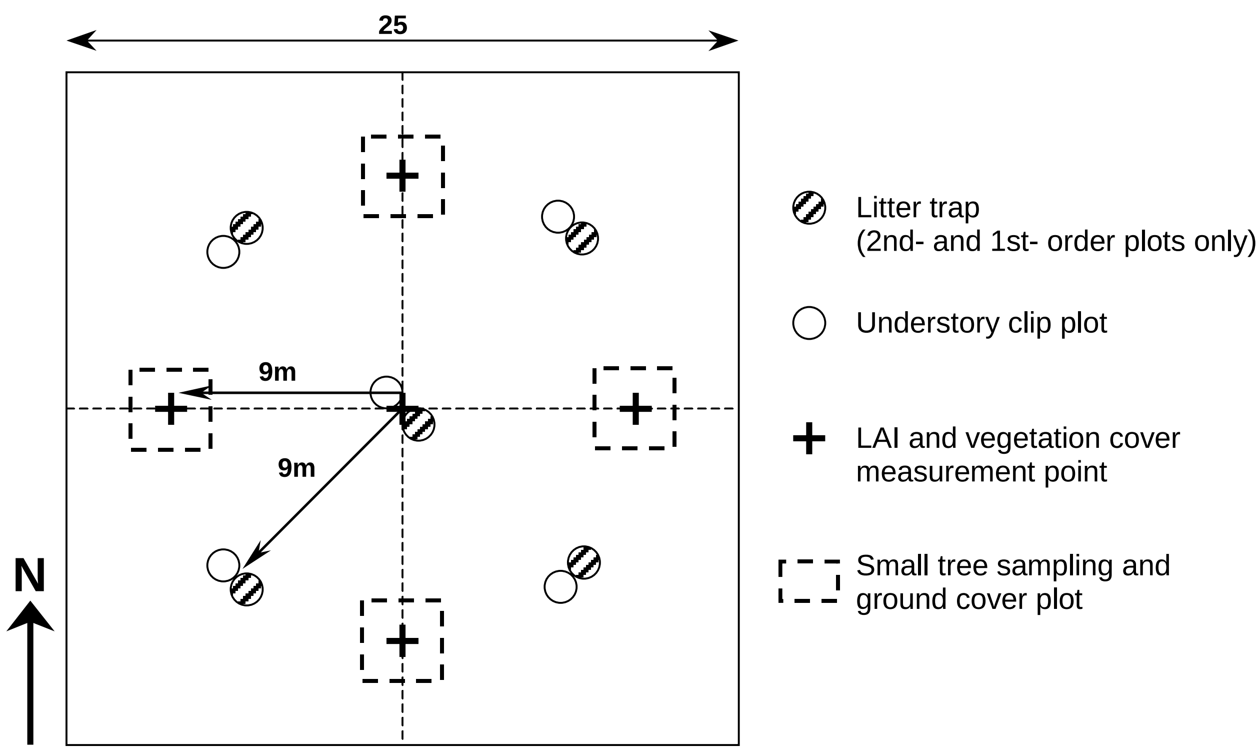


Table 5.3. Subplot placement protocol for HARV

Subplot	Number of Subplots	Position in 25 × 25 m plot
Understory clip plots	5	One positioned near plot center and four more positioned 9 m NW, NE, SE, and SW from plot center
Litter traps (2nd- and 1st-order plots only)	5	Placed adjacent to the understory clip plots
Small tree stem survey plots	4	Four fixed-area subplots centered at points 9 m N, S, E, and W from plot center
Moss ground cover survey plots	1	One prism sweep made from plot center
Variable-radius plots	1	One prism sweep made from plot center
LAI and vegetation cover sample points	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center
Minirhizotrons (1st-order plots only)	5	Placed adjacent to the understory clip plots (or anywhere they can be installed)
Sphagnum growth wires	0–5	Up to five sets of sphagnum growth wires stratified among the sphagnum hummocks present in the plot

HARV

Tentative 1999 Field Calendar

Month	Week	Day of year	Measurements
July	2	189	Survey in plots and install minirhizotron tubes

Plots will be established in summer 1999, and field campaigns will occur in 2000 and 2001.

HARV

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