Section 5

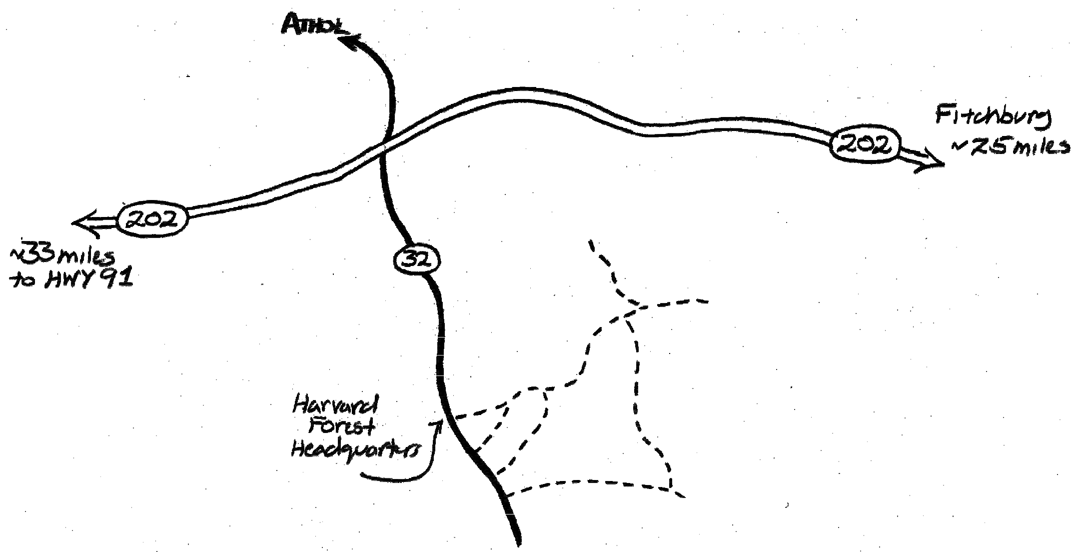
Study Site and Measurement Plan for Harvard Forest, (HARV)
Petersham, Massachusetts

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.

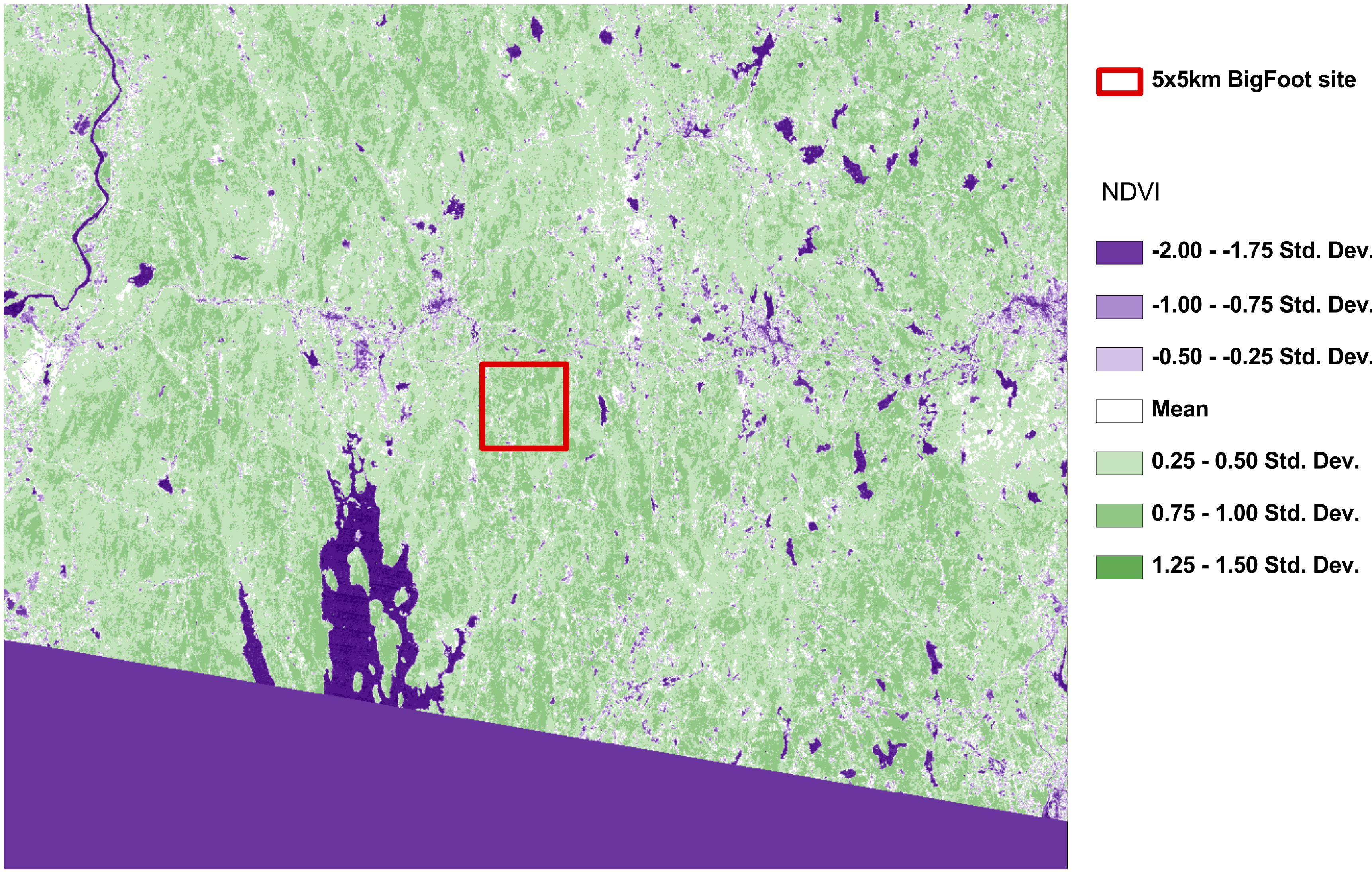
The intensive sampling at the HARV site will be centered on the eddy flux tower. Positioning of the intensive sampling grid in this manner will not place any plots too close to the flux tower (nearest plot >50 m away). Moreover, this positioning minimizes interference with Carol Barford's research plots.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

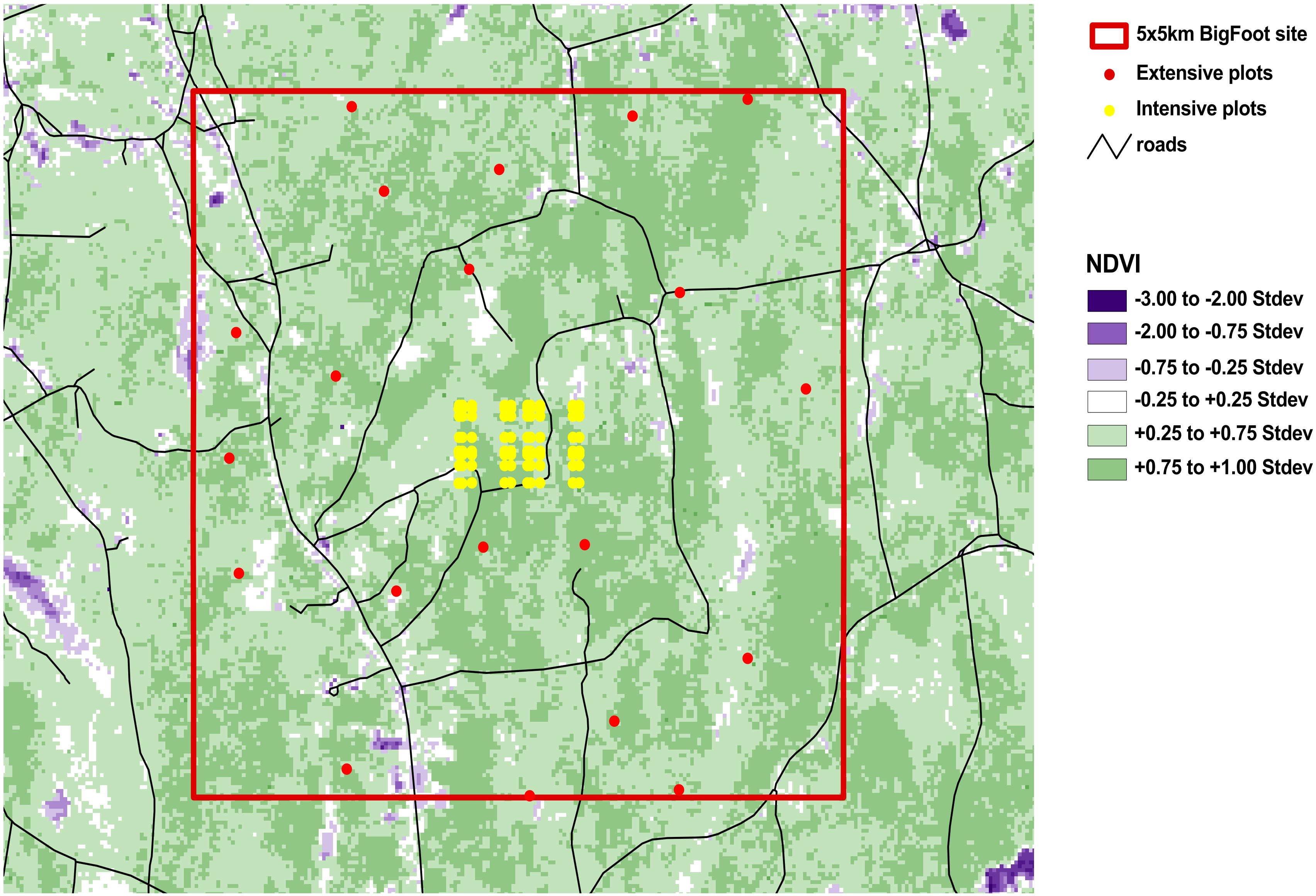
The 5 x 5 km study area will be centered on the flux tower. The 20 external plots will be randomly stratified throughout the 5 x 5 km study area such that plots will be at least 600 m from each other. Two of the original 20 random plots were relocated to new random locations because they occurred in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

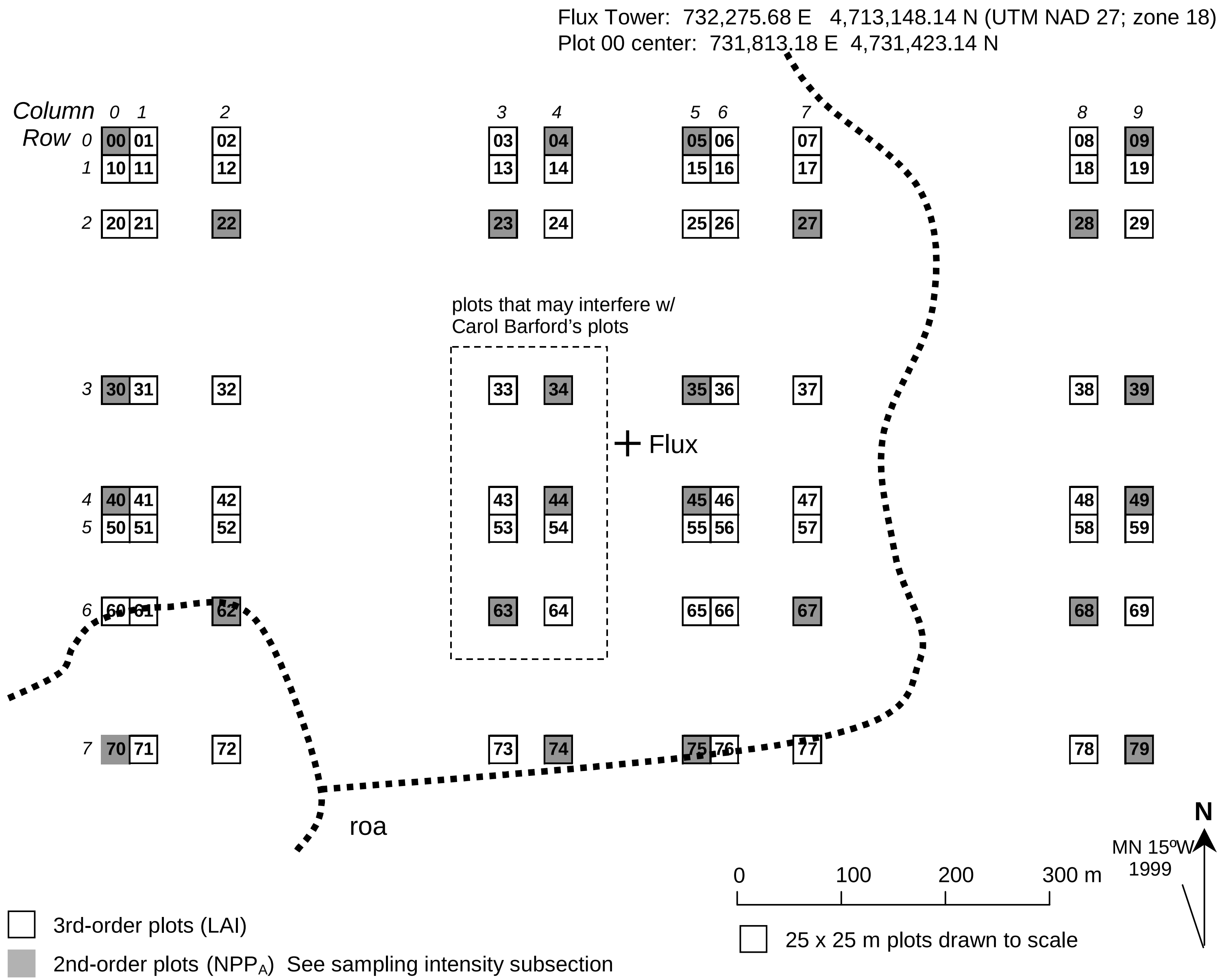


Table 5.1. HARV plot locations and descriptions

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.

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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

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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	

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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.

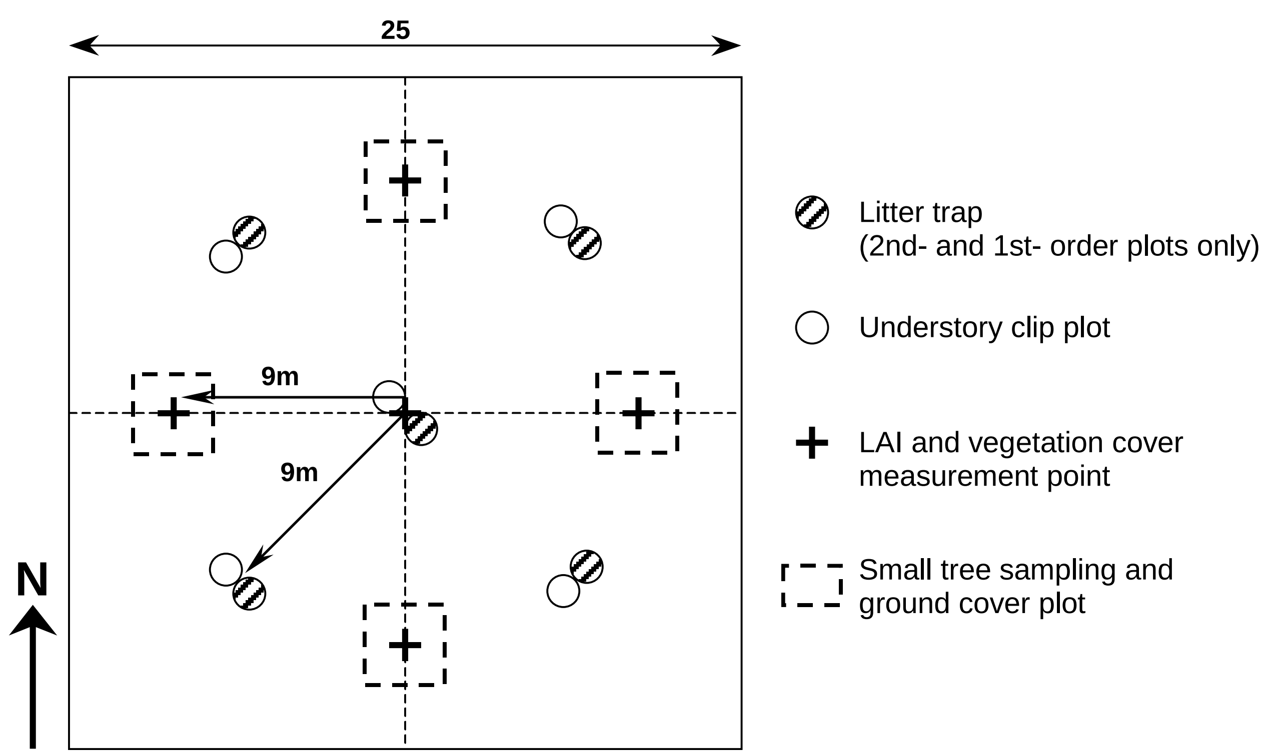

Table 5.3. Subplot placement protocol for HARV

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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