TOS PROTOCOL AND PROCEDURE: MEASUREMENT OF HERBACEOUS BIOMASS

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A_DRAFT	03/25/2011	ECO-00280	Initial Draft Release
B_DRAFT	01/13/2014	ECO-01140	Updates from 2013. Will be finalized in next rev.
C	03/24/2014	ECO-01664	Production release, template change, and other changes as detailed in Appendix C
D	04/10/2014	ECO-01792	Updated Appendix D with site-specific information
E	10/01/2014	ECO-02309	Migration to new protocol template
F	8/24/2015	ECO-02532	⌡ New guidance for determining WST biomass to clip ⌡ Streamlined SOP C by removing information already provided in SOP B and improving reference to SOP B. ⌡ Created new SOP F 'Herbaceous Clip for Biogeochemistry' that includes grinding and subsampling for chemical analysis ⌡ Added timing information for SOP F to Section 4 ⌡ Added SOP H with shipping information for biogeochemistry samples; added Appendix F with supporting information for SOP F. ⌡ Updates from FOPS feedback: sorting WST, accounting for Toxicodendron mass, explanation of MODIS data in site-specific Appendix. ⌡ Section 4: Clarified intended temporal sampling strategy at agricultural sites with multiple crop rotations.
G	01/31/2017	ECO-04401	⌡ Updated standardized text throughout document to match current TOS Protocol template. ⌡ Added 'Definitions' table to Section 2.4 ⌡ Removed Herbaceous Biomass for Biogeochemistry SOP. This SOP is now part of the Canopy Foliar Chemistry protocol. ⌡ Information for sampling agricultural sites removed, and is now referenced in NEON.DOC.001714 (Ag SOP). ⌡ Oven temperature standardized with other TOS protocols (65 ˚C). ⌡ Clarified that exclosures are not used in Tower Plots that support Plant Diversity and Biogeochemistry. ⌡ Added instructions when exclosure is placed in incorrect

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
			location in new troubleshooting table.) Added missing sampling dates to APPENDIX D, and clarified start date criteria in Section 4.2

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1 OVERVIEW

1.1 Background

Herbaceous vegetation is operationally defined in this protocol as non-woody plants (i.e. grasses, sedges, forbs, some bryophytes, and non-woody vines such as *Convolvulus spp.* and certain *Rubus spp*.), as well as woody-stemmed plants with diameter at decimeter height (ddh) < 1 cm at the time of sampling. The net primary productivity (NPP) of this plant group dominates the total NPP of grassland sites, and can contribute significantly to NPP in savannahs and some forests, even though total herbaceous biomass is low relative to that of large woody stems.

Understanding long-term trends in herbaceous community structure and biomass is very important in grazed ecosystems where these plants constitute a critical food source for wildlife and livestock. In addition, members of the herbaceous plant community can respond relatively rapidly to various global change drivers. For example, it is predicted that cool-season C3 graminoids may decrease in abundance relative to warm-season C4 graminoids in more northern latitudes as global temperatures and CO_2 concentrations continue to rise, and water availability becomes more variable.

It is standard practice for herbaceous biomass and productivity to be assessed via clip harvests, followed by sorting clipped material into current-year and previous years' growth in order to estimate annual NPP for this plant growth form. Current-year growth is often sorted by species into additional categories based on plant functional traits – e.g. cool-season vs. warm-season graminoids, or leguminous vs. non-leguminous forbs. In order to engender cross-compatibility with existing research, NEON will sort clipped biomass into functional categories that are broadly similar to those employed by the global Nutrient Network research group (http://www.nutnet.umn.edu/exp_protocol).

In sites where grazing is an important part of the management practice, it is standard practice to use grazing exclosures to estimate the productivity that is consumed by grazing herbivores. NEON will employ a standard approach where clip-harvests are performed with paired grazed/exclosed areas per plot.

1.2 Scope

This document provides a change-controlled version of Observatory protocols and procedures. Documentation of content changes (i.e. changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

1.2.1 NEON Science Requirements and Data Products

This protocol fulfills Observatory science requirements that reside in NEON's Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON's document repository, or upon request.

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products, and are documented in the NEON Scientific Data Products Catalog (RD[03]).

1.3 Acknowledgments

Thanks to Daniel Milchunas of Colorado State University and Mary Ashby of the Central Plains Experimental Range USDA-ARS for valuable advice and insight.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.004300	EHSS Policy, Program and Management Plan
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.000914	NEON Science Design for Plant Biomass and Productivity
AD[06]	NEON.DOC.004104	NEON Science Performance QA/QC Plan

2.2 Reference Documents

Reference documents contain information that supports or complements the current document. Examples include related protocols, datasheets, or general-information references.

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Level 1, Level 2 and Level 3 Data Products Catalog
RD[04]	NEON.DOC.001271	NEON Protocol and Procedure: Manual Data Transcription
RD[05]	NEON.DOC.001574	Datasheets for TOS Protocol and Procedure: Measurement of Herbaceous Biomass
RD[06]	NEON.DOC.005005	Level 0 Data Products Catalog
RD[07]	NEON.DOC.000987	Measurement of Vegetation Structure
RD[08]	NEON.DOC.001788	Grazing Exclosure Assembly Instruction
RD[09]	NEON.DOC.001920	NEON Raw Data Ingest Workbook for TOS Herbaceous Plant Biomass
RD[10]	NEON.DOC.014038	TOS Protocol and Procedure: Core Sampling for Plant Belowground

		Biomass
RD[11]	NEON.DOC.001024	TOS Protocol and Procecure: Canopy Foliage Chemistry and Leaf Mass per Area Sampling
RD[12]	NEON.DOC.001717	TOS Standard Operating Procedure: TruPulse Rangefinder Use and Calibration
RD[13]	NEON.DOC.001714	TOS Standard Operating Procedure: Measurement of Aboveground Productivity for Agricultural Crops
RD[14]	NEON.DOC.001716	TOS Standard Operating Procedure: Toxicodendron Biomass and Handling

2.3 Acronyms

Acronym	Definition
ddh	Diameter at decimeter height
NPP	Net Primary Productivity

2.4 Definitions

Common terms used throughout this document are defined here, in alphabetical order.

Table 1. Definitions for common terms used throughout the Herbaceous Biomass protocol.

Term	Definition
clip cell	A 3m x 0.5m rectangular area within a plot that supports clip harvest sampling of herbaceous biomass; the long-edge of the cell is always oriented north/south.
clip list	A randomized list of clip cells for each 20m x 20m plot or subplot, provided by NEON Science. Working down the list through time ensures that selected clip harvest locations will generate an unbiased estimate of herbaceous biomass every bout.
clip strip	A 2m x 0.1m rectangular area, typically centered within each clip cell, in which the actual clip harvest takes place. Coordinates provided in clip lists correspond to the SW corners of clip strips.
exclosure	Portable structures made of wire mesh, and sometimes with a rigid support frame, that exclude herbivores from consuming herbaceous biomass in systems managed for grazing. Data from both exclosed and non-exclosed areas allow estimates of herbaceous biomass consumption, needed to calculate net primary productivity in grazed systems.

3 METHOD

Herbaceous biomass clip-harvests occur within randomly located clip-harvest strips located in 20m x 20m plots or subplots. The goal of the clip-harvesting procedure is to estimate the amount of herbaceous biomass produced within the delineated clip strip area. This means that only those herbaceous plants whose stems enter the ground within the clip strip are clipped (exceptions to this are woody-stemmed plants with diameter at decimeter height [ddh] < 1 cm; the SOPs describe in more detail how to deal with

these plants). There will typically be one clip-harvest per plot or subplot per sampling event, although sites managed for grazing receive two clips per plot or subplot per bout; see SOP C.

There are two types of plots where clip-harvests will occur: Distributed Plots and Tower Plots. Clip-harvests in Distributed and Tower Plots are organized into 3m x 0.5m gridded, numbered "cells" that cover the available sampling area within the plot. Within a cell, technicians perform clip-harvests in north/south-facing strips with dimensions of 2m x 0.1m (**Figure 1**). Those cells that overlap 1 m^2 and 10 m^2 nested subplots are omitted from clip-harvest sampling. Relative coordinates are assigned to the Southwest corner of each clip strip, which enable technicians to find the desired clip strip location for a given sampling bout. For reference, the Southwest corner of each 20m x 20m plot or subplot is defined as (0,0), and the Northeast corner of the plot or subplot is (20,20) (**Figure 1**). Within Distributed Plots, the herbaceous biomass and productivity clip-harvest protocol is carried out only in non-forested plots with ≥ 50% herbaceous cover as seen from the air. Forested plots are considered to be those with NLCD Class = deciduous forest, mixed forest, or evergreen forest.

Clip harvests in 20m x 20m Tower Plots will be carried out identically to those performed in Distributed Plots, with the exception that all plots are harvested regardless of NLCD vegetation type. For Tower Plots 40m x 40m and larger, the herbaceous clip-harvest protocol is implemented in two randomly selected 20m x 20m subpots per plot (**Figure 2**). Again, similar to clip-harvesting in Distributed Plots, 1 m^2 and 10 m^2 nested subplots are not clip-harvested in Tower Plots, but larger sized nested subplots within 40m x 40m and larger Tower Plots may support clip-harvesting.

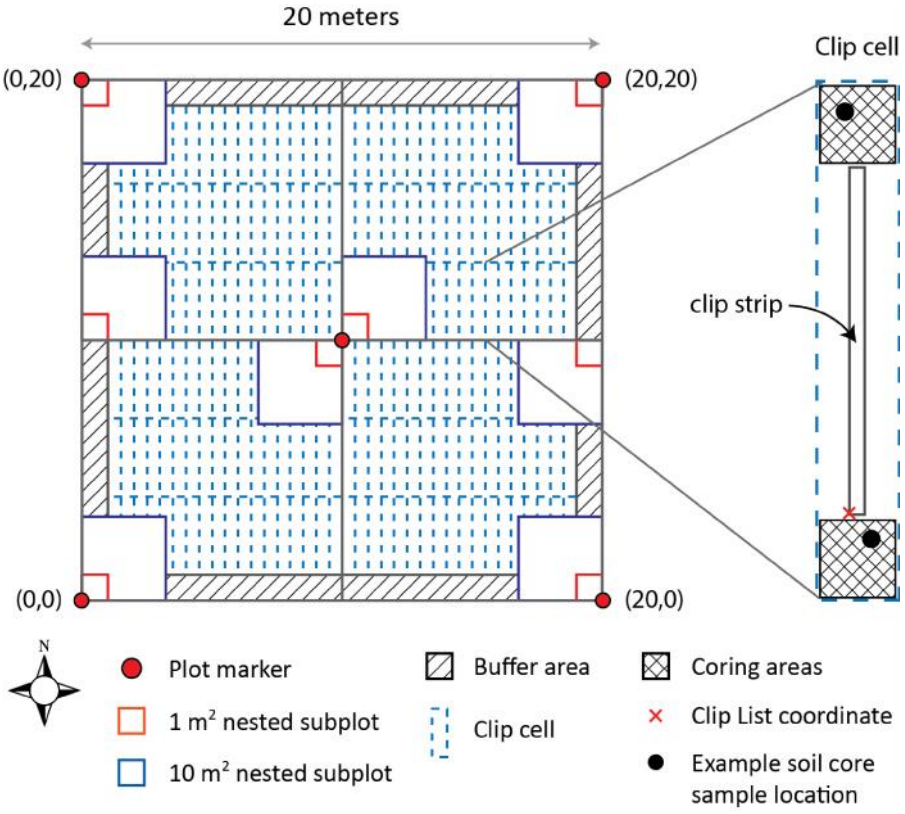

Figure 1. A Distributed Plot showing the locations of 3m x 0.5m clip "cells" (dashed blue lines) that contain potential 2m x 0.1m clip strips. Coordinates corresponding to the SW corner of the clip strip (red 'X' in blowup) are provided to technicians in plot-specific Clip Lists. Clip List coordinates are always relative to the SW corner of the plot (0,0).

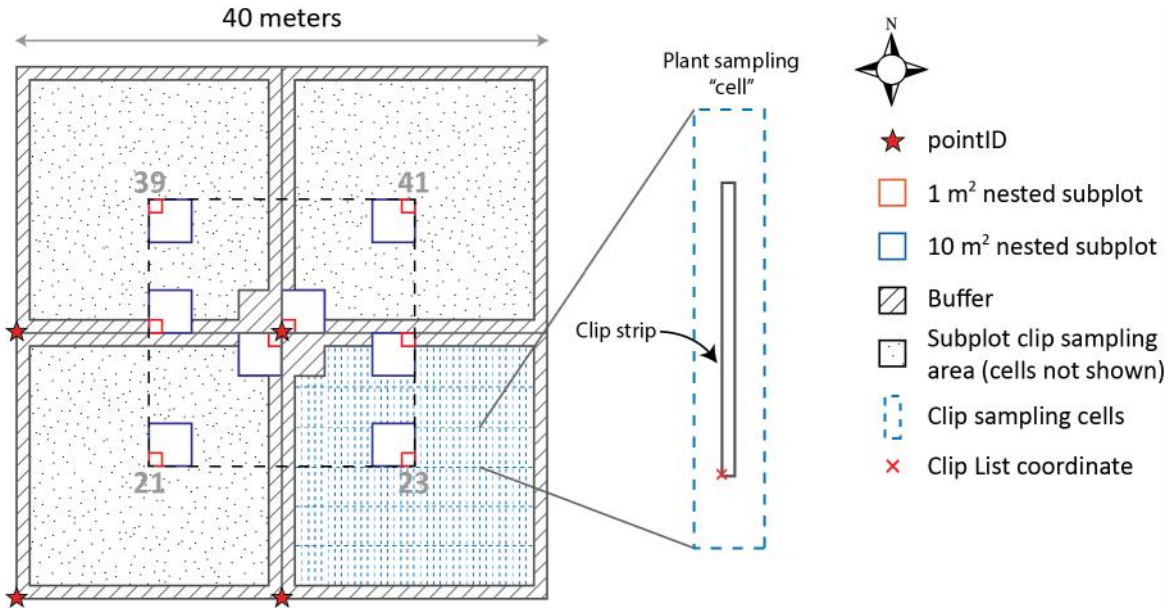

Figure 2. A 40m x 40m Tower Plot showing the location of 3m x 0.5m clip-harvest cells (dashed blue lines) within a 20m x 20m subplot. Cells from the other subplots have been omitted for clarity. The clip strip coordinates provided to technicians (red 'X') are supplied on a per subplot basis. Clip List coordinates are always relative to the SW corner of subplots (red stars). Note that a standard 20m x 20m plot is superimposed over the centroid; this configuration allows for standardized Plant Diversity sampling to occur in a randomly selected subset of 40m x 40m Tower Plots. The super-imposed Plant Diversity plot does not affect implementation of Herbaceous Biomass sampling, though technicians must avoid trampling 1 m^2 nested subplots used for Plant Diversity work.

To determine a clip-harvest location within a given sampling bout, technicians are provided with a randomized list of potential clip strip coordinates for each 20m x 20m plot or subplot (referred to as "Clip Lists" hereafter). An excess number of potential clip-harvest locations within a particular plot or subplot are randomly determined a priori by NEON Science, with the knowledge that not all potential locations will be suitable for clip-harvesting. That is, there may be obstacles such as rocks, trees, ant nests, etc. at any given location that will prevent carrying out a clip-harvest. Technicians should work down this list through time on a per plot or subplot basis, crossing off harvested and rejected strips on the list as work progresses from bout to bout, so that re-sampling of a given clip strip over the lifetime of the Observatory is minimized or eliminated.

LINKED PROTOCOLS: HERBACEOUS BIOMASS AND BELOWGROUND BIOMASS

In Tower plots, the Herbaceous Biomass and Belowground Biomass Core (RD[10]) protocols are spatially linked, and Belowground Biomass Coring should co-occur in the same clip cell used for the peak aboveground biomass clip harvest. The Clip List should indicate whether the Belowground Biomass Core protocol has been implemented before the peak biomass clip; if the the Belowground Core sampling precedes the peak biomass clip, always clip peak biomass from the cell used for Core sampling.

Upon arriving at a plot, it is the field technician's responsibility to first locate the proposed random clip-harvest location, assess its suitability (rejecting and moving on to the next location if necessary), delineate the area for harvesting, and then perform the clip-harvest and biomass sorting. Within each plot or subplot, harvest strips are moved each year to minimize effects of harvest on subsequent biomass data. Additional clip-harvest bouts are required if grazing exclosures are employed at the site. Instructions for utilizing exclosures are provided in SOP C.

Once field work is complete at the plot, technicians must keep harvested biomass cold until sort checking is performed. Best practice is to place clipped biomass into a cooler containing -20 ˚C cold packs immediately after clipping: keeping clipped biomass cold is critical to prevent wilting, so that species' diagnostic features are preserved. Within 24-h of harvest, the same technicians who harvested and sorted the biomass in the field must then check each bag of clipped material to make sure that sorting was done properly, and in particular, that no previous years' biomass is mixed with current-year biomass. Sorted biomass is then either returned to the cooler with fresh -20 ˚C cold packs, or oven-dried as soon as possible in the laboratory and weighed.

Properly accounting for grazing, the contribution of different plant growth forms to overall aboveground biomass (sorting biomass to sub-shrubs, graminoid functional type, etc.), and determining whether biomass was produced in the current year or a previous year are the most important requirements for generating quality data from this field work.

Standard Operating Procedures (SOPs), in Section 7 of this document, provide detailed step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process clipped herbaceous biomass, field technicians **must** follow the protocol and associated SOPs. Use NEON's problem reporting system to resolve any field issues associated with implementing this protocol.

The value of NEON data hinges on consistent implementation of this protocol across all NEON domains, for the life of the project. It is therefore essential that field personnel carry out this protocol as outlined in this document. In the event that local conditions create uncertainty about carrying out these steps, it is critical that technicians document the problem and enter it in NEON's problem tracking system.

Quality assurance will be performed on data collected via these procedures according to the NEON Science Performance QA/QC Plan (AD[06]).

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

A given sampling bout should ideally be concluded within 10-14 days of initiation (Table 2), so that the plant community does not change appreciably during the time that all target plots are sampled. This guideline ensures that data collected across all plots within a given bout are comparable. The number of field technicians assigned to the clip-harvesting task should be optimized so that this goal is feasible. Herbaceous biomass clip-harvests must be performed within Tower Plots on an annual basis, and sampling these plots is a priority.

HELPFUL HINT: COORDINATING WITH PLANT DIVERSITY PROTOCOL

If Plant Diversity sampling is scheduled to occur prior to clip-harvest sampling in a given sampling year, it may be helpful to identify and demarcate a suitable clip strip prior to performing Plant Diversity sampling.

- This will ensure that the clip strip is not trampled during diversity sampling.
- Should clip-harvest occur before Plant Diversity sampling:
  - Take care to avoid trampling 1 m^2 nested subplots used for Plant Diversity % cover measurements; and
  - Reject potential clip strips that contain rare or uncommon plants.

After herbaceous plants are clipped from a given clip strip, the following points are critical with respect to timing:

- Place clipped biomass immediately into a cooler, and keep stored cool until it can be placed in a drying oven.
- Check field-sorted biomass for sorting accuracy within 24 h of harvest.
- On the “Field” datasheet, record the date and time that the samples were placed into cold storage after being clipped in the field, and the date and time that the samples were placed in the drying oven. These data will enable automatic calculation of the number of hours that samples were kept in cold storage.

The frequency and timing of herbaceous biomass clip-harvests depends on the type of site being sampled, as well as the type of plots sampled within the site (Table 2).

Table 2. Sampling frequency and timing guidelines for herbaceous biomass clip-harvesting based on sampling type and plot type.

Sampling Type	Plot Type	Plot Number	# Events per Sampling Year	Yearly Interval[1]	Sampling Start	Sampling Stop
Agricultural	See the Agricultural Biomass SOP (RD[13])					
Ungrazed (SOP B)	Distributed, Gradient (non-forest NLCD types only)	n=20 (max)	1X per sampling year	Every 3y (one site per domain per year)	Peak biomass (APPENDIX D provides site-specific dates)	Within 14d of sampling start
	Tower	n=20 or n=30[2]	1X or 2X per sampling year	Annual	Peak biomass[3] (APPENDIX D provides site-specific dates)	Within 14d of sampling start[4]
Grazed[5] (SOP C)	Distributed, Gradient (non-forest NLCD types only)	Approach utilized is identical to that used at ungrazed sites.				
	Tower	n=20 or n=30[3]	Every 4 weeks (i.e., a maximum of 4 weeks elapses between bout completion dates)	Annual	Deploy exclosures 10-14d before animal stocking; first clip is 4 weeks after deployment	Senescence

[1] The schedule determining which years a protocol is implemented; all sites in a domain are sampled at the given interval, unless otherwise indicated; 'annual' means a protocol is implemented every year, 'every 3 y' means there are two 'off' years following every 'on' year. This field DOES NOT indicate the number of times within an 'on' year the protocol should be implemented; intra-year frequency is provided in the '# Events per Sampling Year' field.

[2] Plot number may be reduced following initial data collection at a given site.

[3] When two clip-harvests are performed per year, Sampling Start is per bout. For example, there would be one Sampling Start date for an early season peak in cool-season graminoid biomass (May), followed by another Sampling Start date for a late-season peak in warm-season graminoid biomass (August).

[4] When two clip-harvests are performed per year, "Sampling Stop" is per bout.

[5] Grazed ecosystems are defined as those actively managed for livestock grazing. The 4 wk sampling interval should only be applied when exclosures are present and livestock are present.

4.2 Criteria for Determining Onset and Cessation of Sampling

Site-specific sampling start guidance is provided in Appendix D. In general, bouts should be scheduled to begin within a 2 week window that starts with the provided 'Start Date,' and a given bout should be completed no later than 14 days after the date the bout was started. It is incumbent upon Field Operations to schedule sampling onset dates in accordance with provided guidance.

4.3 Timing for Laboratory Processing and Analysis

Because herbaceous biomass continues to be biologically active after clipping and before drying (i.e. plant cells continue to respire and therefore lose mass), it is important to place clipped samples into the drying oven as soon as possible after clipping occurs. Ideally, samples will be placed in the drying oven within 24 h of clipping in the field, and must be kept in cold storage the entire time between clipping in the field and drying in the laboratory. Keeping samples in cold storage mitigates mass loss by slowing cellular activity. However, when it is not possible to dry samples in the laboratory within 24 h of clipping, it is acceptable to keep samples in cold storage for up to a maximum of 5 days following clipping.

Once samples are dry, they may be weighed immediately (SOP E.1), or placed in temporary storage prior to weighing. There are no scientific limits on the time oven-dried samples may be placed in temporary storage prior to weighing and processing. However, samples should be stored temporarily for no more than 30 days to prevent backlogs from forming (SOP E.1).

4.4 Sampling Timing Contingencies

Table 3. Herbaceous Biomass sampling delay contingency decisions.

Delay/Situation	Action	Outcome for Data Products
Hours	If delay prevents completion of clip-harvest strip: 1. Ensure all small bags of sorted biomass are labeled, 2. Place small bags into a 25# bag and label, Resume harvest of same clip-harvest strip ASAP	No adverse outcome.
	If delay occurs between plots, resume harvest of next clip-harvest strip ASAP.	
1-7 days	If delay prevents completion of clip-harvest strip: 1. Ensure all small bags of sorted biomass are labeled, 2. Place small bags into a 25# bag and label, 3. Store already clipped biomass in a cooler/refrigerator (okay), or oven-dry as	May create potential change in observed NPP, and may increase uncertainty in consumption estimates at grazed sites. May also be difficult to complete clip harvest of all plots in 10-14 day

Delay/Situation	Action	Outcome for Data Products
	per protocol (best), 4. Resume harvest of same clip-harvest strip ASAP with new labeled bags, and 5. Combine dried biomass per functional group for weighing when all biomass is dry.	window if delay approaches 7 days.
	If delay occurs between clip-harvest strips, resume harvest of next strip ASAP.	
8-13 days or longer	If delay prevents completion of clip-harvest strip: 1. Ensure all small bags of sorted biomass are labeled, 2. Place small bags into a 25# bag and label, 3. Store already clipped biomass in a cooler/refrigerator (okay), or oven-dry as per protocol (best), 4. Resume harvest of same clip-harvest strip ASAP with new labeled bags, and 5. Combine dried biomass per functional group for weighing when all biomass is dry.	More uncertainty in biomass and NPP estimates, especially in grazed systems. Aboveground biomass per unit area may change in the field over this length of time.
	If delay occurs between clip-harvest strips, resume harvest of next strip ASAP	

4.5 Criteria for Reallocation of Sampling Within a Site

Herbaceous Biomass sampling will occur on the schedule described above at up to 20 randomly selected Distributed Plots (plot selection is determined by NEON Science), and all Tower Plots per site. Ideally, sampling will occur at these sampling locations for the lifetime of the Observatory (core sites) or the duration of the site's affiliation with the NEON project (relocatable sites). However, circumstances may arise that require that sampling within a site be shifted from one particular location to another. In general, sampling is considered to be compromised when sampling at a location becomes so limited that data quality is significantly reduced. If sampling at a given plot becomes compromised, a problem ticket should be submitted by Field Operations to Science.

There are two main pathways by which sampling can be compromised. Sampling locations can become inappropriately suited to answer meaningful biological questions (e.g., a terrestrial sampling plot becomes permanently flooded). Alternatively, sampling locations may be located in areas that are logistically impossible to sample on a schedule that that is biologically meaningful.

For Herbaceous Biomass clip-harvest sampling, criteria for considering a plot compromised depend on plot type:

- Distributed Plots: These plots are sampled every 3 y; if sampling cannot be completed for 2 consecutive bouts then the plot should be considered compromised.
- Tower Plots: If more than 50% of bouts over 3 consecutive years cannot be completed for a given plot, it may be considered compromised for this protocol.

5 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices.

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the Operations Field Safety and Security Plan (AD[02]) and EHSS Policy, Program and Management Plan (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

A laser rangefinder/hypsometer/compass instrument may be used to navigate to clip cells within plots. Safety considerations for this instrument include:

- Avoid staring directly at the laser beam for prolonged periods. The rangefinder is classified as eye-safe to Class 1 limits, which means that virtually no hazard is associated with directly viewing the laser output under normal conditions. As with any laser device, however, reasonable precautions should be taken in its operation. It is recommended that you avoid staring into the transmit aperture while firing the laser.
- Never attempt to view the sun through the scope. Looking at the sun through the scope may permanently damage the eyes.

Additional safety issues associated with this field procedure include potential exposure to *Toxicodendron* oils (discussed in APPENDIX F, AD[02] and RD[14]).

6 PERSONNEL RESOURCES

6.1 Equipment

The following equipment is needed to implement the procedures in this document. Equipment lists are organized by task. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.

See also APPENDIX F, section F.1 for equipment related to minimizing exposure to toxic oils from *Toxicodendron spp.*

Table 4. Equipment list – durable items required for per-plot biomass clip harvesting and sorting (quantities are for two technicians)

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Durable Items					
MX100703	S	GPS receiver, recreational accuracy	Navigate to sampling location	1	N
MX100320	S	Compass with mirror and declination adjustment	Locate clip-harvest strips (with measuring tape)	1	N
MX100322	R	Laser Rangefinder, 0.3 m accuracy	Locate clip-harvest strips within plots/subplots; use when plot slope > 20% or brushy	1	N
MX103218	R	Foliage filter	Allow laser rangefinder use in dense vegetation	2	N
MX104359	R	White reflector or reflective tape	Reflective target for laser rangefinder; aids in measuring distance to target accurately	1	N

Item No.	R/S	Description	Purpose	Quantity	Special Handling
EG07570000 EG07570001	R	Grazing exclosure, tall or short grass system	Prevent herbivory at clip location in actively grazed sites		N
	S	Hammer	Install and remove grazing exclosure stakes	1	N
	R	Pruning shear	Clip plants		N
MX106656	R	Magnifier hand-lens, 10X	Aid in species identification	1	N
MX103211	R	Magnifier hand-lens, 20X	Aid in species identification	1	N
MX100358	R	Cold packs	Chill perishable samples in field		N
	R	Pre-marked string and stake sets	Delineate clip harvest strip; polyester cord recommended to minimize stretching with use.		N
MX104361	R	Chaining pins or other suitable anchor	Anchor measuring tapes	2	N
MX100722	R	Measuring tape, minimum 30 m	Locate clip-harvest strips within plots/subplots .Plot slope < 20%; grassland, savannah	1	N
MX100543	R	Ruler, 30 cm	Delineate clip-harvest strip	1	N
	R	Forceps	Identify and sort plants	2	N
	S	Work gloves	Protect hands	2	N

Item No.	R/S	Description	Purpose	Quantity	Special Handling
	R	Cooler	Chill perishable samples in field	1	N
Consumable Items					
	R	Survey marking flag, PVC or fiberglass stake	Delineate sampling area	4	N
MX105089	R	Paper bags, #8[1]	Contain clipped herbaceous biomass, sorted to functional group	50[2]	N
MX103232	R	Paper bags, #25[1]	Organize smaller bags from a given clip strip	10[2]	N
	R	Permanent marker	Label paper bags	2	N
	S	CR123A battery	Spare battery for laser rangefinder	2	N
	S	AA battery	Spare battery for GPS receiver	2	N
Resources					
RD[05]	R	Herbaceous Biomass Field Datasheets	Record sampling metadata		N
	R	Per plot or subplot Clip Lists	Identify random clip strip locations	As needed	N

Item No.	R/S	Description	Purpose	Quantity	Special Handling
	R	Field guide, regional flora reference guide and/or key	Identify leguminous forbs and graminoids to species	1	N

R/S=Required/Suggested

[1] Bag size may be adjusted as necessary based on size/bulk of plants being clipped. For example, sites with tall grasses will require larger bags.
[2] Quantity may be adjusted as necessary based on field experience at a given site.

Table 5. Equipment list – Post-field sampling tasks

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Durable Items					
MX103211	R	Magnifier hand-lens, 20X	Aid in species identification	1	N
MX106656	R	Magnifier hand-lens, 10X	Aid in species identification	1	N
	R	Cooler	Chill perishable samples	1	N
	R	Cold packs	Chill perishable samples	Vari-able	
Resources					
RD[05]	R	Completed Herbaceous Biomass Field Datasheets	Contains field-collected sampling metadata	Vari-able	N
	R	Field guide, regional flora reference guide and/or key	Aid in distinguishing morphologically similar species to functional groups	1	N

R/S=Required/Suggested

Table 6. Equipment list – Processing herbaceous biomass clip-harvest samples in the laboratory

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Durable Items					
MX100230	R	Drying oven	Dry samples	2 (typically)	N
MX100265	R	Balance, 0.01 g accuracy	Weigh samples	1	N
MX100689	R	Weigh boats, large	Contain dried sample while weighing	Variable	N
MX103931	S	Plastic tray	Contain oversized samples while weighing	1	N
Consumable Items					
	R	Pre-printable labels	Label scintillation vials	As needed	N
RD[05]	R	Datasheets: • Lab Drying QC Datasheet • Lab Weighing Datasheet	Recording dry weight of herbaceous biomass	As needed	N

6.2 Training Requirements

All technicians must complete required safety training and protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD[04]).

For the field component of this protocol, technicians must be trained in navigating to points in the field with a GPS and manual methods. Most critically, technicians must be trained to quickly identify common herbaceous species at the sites within the region of employment. Because different herbaceous functional groups can be sensitive indicators of ecosystem responses to global change (e.g. N deposition, warming, rising CO_2), it is very important that field technicians within a domain can accurately and quickly identify C3 and C4 graminoids as well as identify leguminous and non-leguminous forbs within that domain.

Training for both the field and laboratory work must emphasize the importance of consistent, detailed labeling of all samples. ***Improper or inconsistent labeling is the most common and problematic error associated with this work!***

6.3 Specialized Skills

The lead plant technician must possess the demonstrated ability to identify required plants to functional group – either via visual inspection, or via visual inspection in combination with a dichotomous or polyclave key.

- Identification of all leguminous forbs to functional group, in the absence of flowers, is required.
- Identification to species is not required for non-leguminous forbs and woody stemmed plants.
- Identification to species is required for cool-season (C3) and warm-season (C4) graminoid functional groups. Technicians should be able to identify graminoids vegetatively.

Ideally, each team member should know how to use diagnostic traits and a dichotomous or polyclave key to identify unknown species.

6.4 Estimated Time

The time required to implement a protocol will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below is an estimate based on completion of a task by a skilled two-person team (i.e., not the time it takes at the beginning of the field season). Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, a problem ticket should be submitted. Please note that if sampling at particular locations requires significantly more time than expected, NEON Science may propose to move these sampling locations.

An experienced two-person team will require between 1-3 hours to perform clip-harvest sampling within a given clip strip when biomass is sorted to functional group. This time range includes identifying an acceptable clip-harvest location, delineating the clip strip, and clipping qualifying herbaceous biomass. The clip-harvest may take closer to 1 h per plot if herbaceous vegetation is sparse.

For those harvests at sites managed for grazing that are not sorted to functional group, the time required to clip-harvest herbaceous biomass from a clip strip should be between 1-3 hours (including all the tasks described above).

7 STANDARD OPERATING PROCEDURES

SOP A Preparing for Sampling

A.1 Sampling Equipment Preparation and Checklist

Table 7. Sampling equipment preparation checklist

Item	Action
GPS unit	Charge Load target locations
Compass, mirror-sight	Check/set correct declination[1]
Laser rangefinder / hypsometer	⌡ Check battery, charge (if possible) ⌡ Clean lenses with lens cloth or lens tissue (if necessary) ⌡ Check/set correct declination[1]. See RD[12] for details. ⌡ Calibrate tilt-sensor (only necessary after severe drop-shock; see RD[12] for details).
Hand clippers	Clean and sharpen blades (if necessary)
Re-usable cold packs	Place in –20 ˚C freezer
Pre-marked string and stake sets[2]	Fabricate if necessary: 1. Cut 2.5m of ⅛" diameter polyester cord 2. Mark cord at each end with a permanent marker so that the center section of the cord measures exactly 2m between the markings. 3. Tie each end to an 8" or longer tent stake.
Herbaceous Biomass Field Datasheets (RD[05])	Print on all-weather paper
Per plot or subplot Clip Lists[3]	Print on all-weather paper

[1] Declination changes with time and should be looked up annually per site: http://www.ngdc.noaa.gov/geomag-web/

[2] Pre-marked string and stake sets are used to temporarily delineate clip strip boundaries, and require fabrication prior to field work. Each set consists of two tent stakes connected by cord.

[3] Provided separately by Science Operations once plot establishment has been completed.

A.2 Early-season preparation at a grazed site

Grazing exclosures are deployed only within Tower Plots, and one exclosure should be constructed for each 20m x 20m plot or subplot.

- Inspect existing grazing exclosures for wear and damage.
- Construct additional grazing exclosures as needed according to plans outlined in RD[08].
  - The drawings in RD[08] depict two different styles of grazing exclosure, with heights optimized for low-stature grassland vegetation (plants ~ 30cm height), and mid-stature grassland vegetation (plants ~ 1 m height).
  - Choose the exclosure height so that the exclosure height is approximately equal to or just greater than the height of the vegetation.
  - Provide feedback to Science Operations if the assembly document requires updating to include an expanded range of exclosure heights.
- Deploy exclosures within Tower Plots or subplots at least 10-14 days prior to the anticipated onset of grazing.
  - The Field Operations Manager must communicate with the site host to ascertain when grazing begins in a given growing season.
  - For each Tower Plot or subplot, place an exclosure over the first suitable clip strip, and stake the exclosure to the ground.
  - The first sampling bout should be scheduled 4 weeks after the date the exclosures were actually deployed.
  - If exclosures were put in place at the end of the previous growing season, schedule the first bout so that sampling is complete within a maximum of 4 weeks after the actual date of animal stocking. No more than 4 weeks should elapse between the dates when bouts are completed.

Follow steps in SOP C to locate clip-harvest strips and assess suitability.

SOP B Field Sampling Sites Not Managed for Grazing

At non-grazed sites, which are defined here to mean those that are not actively managed for grazing, one clip strip per plot or subplot per bout is harvested. Distributed Plots are harvested once per year at peak biomass (on a 3 y interval), and Tower Plots are harvested annually either once or twice per growing season, depending on whether a particular plant community shows seasonally distinct biomass peaks (e.g. C3 peak in spring, C4 peak in summer).

At non-grazed sites, sorting clipped biomass to functional group is required. If two harvests are performed in Tower Plots, both harvests must be sorted to functional group.

If Plant Diversity sampling occurs prior to Herbaceous Biomass clip-harvest sampling in a given year, identify and demarcate a suitable clip strip prior to performing Plant Diversity sampling. This will ensure that the clip strip is not trampled during Plant Diversity sampling.

LINKED PROTOCOL: BELOWGROUND BIOMASS

- In an 'on' year for the Belowground Biomass Core protocol (RD[10]), accepting/rejecting clip strips should be done with both protocols in mind (**Figure 3**).
  - *Example*: Reject the clip cell if a large rock prevents coring in the North coring area, and clipping is otherwise possible.
- It is highly desirable for accepted clip strips to support both protocols; be consistent across teams, and follow established accept/reject criteria when assessing whether a clip strip is representative of the plot.
- To determine whether coring for Belowground Biomass is theoretically possible in a given clip strip, briefly probe the North and South sampling areas within the clip cell with a chaining pin or equivalent (see **Figure 1** to locate N/S sampling areas within a clip cell).

B.1 Sample Collection in the Field

1. Navigate to the plotID to be sampled (using the GPS if necessary).
2. Use the plot- or subplot-specific Clip List to identify the first potential clip strip location that has not already been sampled or rejected.
   - The Clip List provides the randomized list of potential clip strips per plot or subplot. Where relevant, subplot number is included in the file name and is also provided as a field in the spreadsheet.
   - The Clip List is also updated by NEON technicians to provide a record of which clip strips have already been harvested or rejected.
   - For Tower plots 40m x 40m and larger, herbaceous biomass sampling is performed in a randomly selected subset of available subplots.

- Clip Lists are only provided for these randomly selected subplots.

3. Locate the relative X,Y-coordinates of the clip strip SW corner within the plot or subplot. The procedure used to locate the X-coordinate depends on the value of the relative Y-coordinate and the different procedures are detailed below:

4. If the 'offsetNorthing' coordinate for the clipID is < 10:

a. Run a tape East/West along the south edge of the plot or subplot between the (0,0) → (20,0) plot markers (Figure 1), and stretch the tape taut.*

b. Place a pin flag at the desired relative X-coordinate (offsetEasting).

c. Standing directly over the pin flag that was just placed at the X-coordinate, use either a compass and tape, or the TruPulse in **HD** mode with a reflective surface, to locate the Y-coordinate (offsetNorthing).

- Make sure the azimuth is as close to 0˚ as possible (True North) when finding the Y-coordinate (see **Figure 1**).
- Avoid trampling the potential clip-harvest strip as much as possible.

d. Place a pin flag at the clip strip (X,Y) location; this point corresponds to the SW corner of the clip strip.

5. If the 'offsetNorthing' coordinate for the clipID is > 10:

a. Run a tape* East/West from the plot centroid (10,10) to either the (0,10) position or the (20,10) position (**Figure 1**):

offsetEasting	Tape Layout[1]
1 < offsetEasting < 10	From (10,10) to (0,10)[1]
10 < offsetEasting < 20	From (10,10) to (20,10)[1]

[1] Use a compass or the TruPulse in **AZ** mode to guide the tape along the correct azimuth. For plots < 20% slope and lacking brush, an additional tape can be run N/S connecting the SW/NW or SE/NE plot markers to help find the (0,10) and (20,10) points if desired.

b. Place a pin flag at the desired relative X-coordinate (offsetEasting).

c. Standing directly over the pin flag that was just placed at the X-coordinate, use either a compass and tape, or the TruPulse in **HD** mode with a reflective surface, to locate the Y-coordinate (offsetNorthing).

- Make sure the azimuth is 0˚ (True North) when shooting the TruPulse to find the Y-coordinate.
- Avoid trampling the potential clip strip as much as possible.

d. Place a pin flag at the clip strip (X,Y) location; this point corresponds to the SW corner of the clip strip.

BEST PRACTICE TIPS

- If the plot slope is > 20 %, or there is significant brush or obstacles that prevent accurately stretching a tape, the laser rangefinder can be used in **HD** mode to place the initial pin flags relative to the plot markers.
- Plot slope can be quickly estimated using the inclinometer in the rangefinder unit (**INC** mode).

6. Assess whether the clip cell is suitable and representative, and accept or reject the clip cell (see **Figure 3** flow-chart).

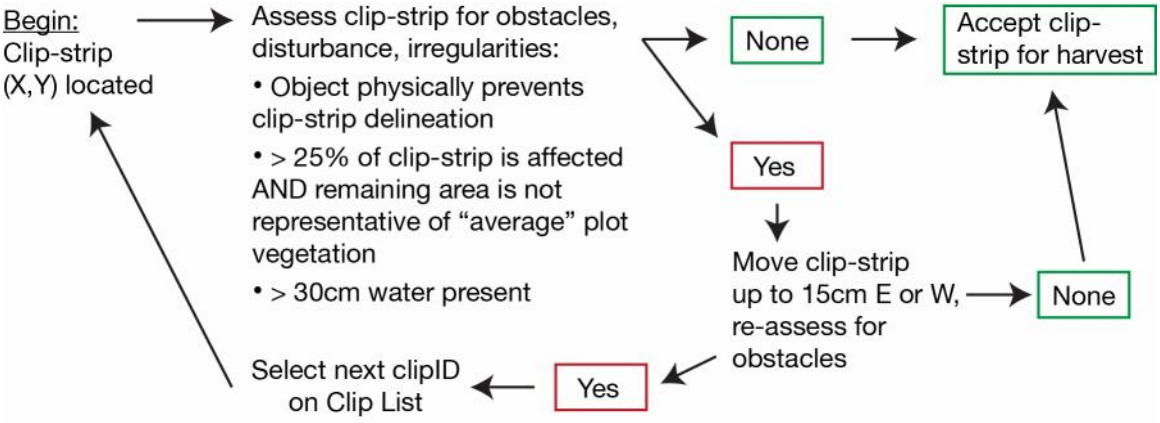

Figure 3. Flow chart to guide assessing potential clip cells for clip-harvest suitability.

- Obstacles, disturbances, and/or irregularities may include trees, large rocks, ant nests, downed logs, etc.
- Strips should also be rejected if clipping a particular plant specimen in the strip would influence plot-level diversity. That is, the plant in question exists nowhere else in the plot or subplot.
  - If a rare or uncommon plant exists within the clip cell, use code 4 to temporarily reject, and re-assess for clipping in a future year.
- If ≥ 3 consecutive potential clip cells are rejected as 'unrepresentative,' it is necessary to consider recalibrating the working definition of 'representative.'

7. **If the clipID is rejected, record why in the "status" column on the Clip List, select the next clipID on the list, and return to step (3) above. Otherwise, update the "status" column and proceed to step (6).** Update the "status" column in the Clip List using codes in

8. Table **8**.

Table 8. Codes to document acceptance/rejection of clip strips on the list of clip strip coordinates.

Code	Definition
0	Rejected; disturbance, obstacle, and/or irregularity encountered within the clipID cell
1	Accepted, no exclosure
2	Accepted, exclosure
3	Rejected temporarily, inundated
4	Rejected temporarily, uncommon plant
5	Co-located belowground biomass core sampling
6	Accepted for Bryophyte Productivity net harvest

9. Delineate the accepted clip strip for harvesting.
    a. Using one of the pre-marked string and stake sets, line up one of the marks with the pin flag, and push one stake into the ground.
    b. Stretch the string and second stake from the South to the North end of the clip strip, using the compass or the TruPulse to orient the string in a North/South direction.
    c. Keep the compass or TruPulse at least 50 cm from non-aluminum metal plot markers, eyeglasses, wristwatches, tent stakes, etc.
    d. Use a ruler to place the second string-and-stake set 10 cm to the right (east) of the first set. Check that the distance between the two strings is exactly 10 cm at both ends of the clip strip.
    e. The two sets of marks on the two string-and-stake sets now clearly delineate a 2m x 0.1m area for clip-harvesting.
10. If there is no herbaceous biomass in a clip strip, AND the clip strip is deemed representative of the plot:
    - Record 'targetTaxaPresent = N' in the **remarks** field.
11. Using a permanent marker, label 8# kraft paper bags with the information below (use larger bags if vegetation is large-stature; if vegetation is wet, cloth bags may be used).
    - **boutNumber**; use *XX* format, where XX is the bout number assigned by Field Operations, e.g. '01'. Values of **boutNumber** reset every year.
    - **date**; use *YYYYMMDD* format
    - **clipID**; as provided in Clip List; use "*plotID_clipCellNumber"* format, e.g. CPER_001_0126
    - **bagCount**; the total # of bags generated from a given clipID, does not include OSD since OSD bags are discarded after the sort-check.

Table 9. Herbaceous clip-harvest functional groups with corresponding herbGroup codes, descriptions of functional groups, and clipping guidelines.

herb Code	Description	Clipping Guidelines
ALL	Clipped herbaceous biomass is only sorted to remove OSD; use for non-peak-biomass harvests at sites managed for grazing with more than one sampling bout per growing season	Clip 1-2 cm above the ground; plants < 1-2 cm tall are ignored.
BRY	Bryophytes; lichens are not part of this group, and are ignored	Clip only species that show distinct annual growth, and only clip current year growth
CSG	Cool-season graminoids; includes all grasses, sedges, rushes, etc. with the C3 photosynthetic pathway	Clip 1-2 cm above the ground; plants < 1-2 cm tall are ignored. DO NOT clip the crowns of perennial graminoids, as this will damage or kill the plant (**Figure 4**)
WSG	Warm-season graminoids; includes all grasses, sedges, rushes, etc. with the C4 photosynthetic pathway	Clip 1-2 cm above the ground; plants < 1-2 cm tall are ignored. DO NOT clip the crowns of perennial graminoids, as this will damage or kill the plant (**Figure 4**)
LFB	Leguminous forbs; includes all herbaceous annual and perennial members of the Fabaceae family	Clip tissue produced in the current year; DO NOT clip any aboveground perennial parts. Plants < 1-2 cm tall are ignored.
FRB	Non-leguminous herbaceous annual and perennial forbs	Clip tissue produced in the current year; DO NOT clip any aboveground perennial parts. Plants < 1-2 cm tall are ignored.
WST	Woody-stemmed plants with ddh < 1 cm	Treat nodes where current-year woody growth emerges from previous years' woody growth as a "rooting point". Clip only leaves and twigs produced in the current year attached to nodes that lie within the clip strip. Harvested current-year material may leave the clip strip so long as the node lies within it. It is not necessary for the actual rooting point to lie within the clip strip. See training materials for example diagram.
OSD	Old standing dead material produced in a previous growing season	Make sure standing dead material produced in the *current* growing season is sorted into the correct group above.

12. If required to facilitate clipping, remove any cactus biomass lying within the clip strip. If the individual is rooted within the clip strip, clip off the cactus plant at the soil level. ***Only clip cactus plants that prevent access to herbaceous biomass that must be clipped.***

) Dispose of the cactus biomass outside of the plot.

13. Clip and sort all herbaceous aboveground biomass rooted within the clip strip into the functional groups in

14. Table **9**. See Table 10 at end of this SOP for common points of confusion and guidelines for problem plants.

- Do **NOT** clip herbaceous vegetation that passes through/leans over the clip strip but is not rooted in the strip (this includes non-woody vines; WST group is an exception, see below).
- **DO** clip all herbaceous biomass of plants rooted within the strip > 1-2 cm in height. That is, include leaves in the harvest that exit the strip but originate from stems rooted within the strip.
- **DO** clip leaves and twigs of woody stemmed plants with ddh < 1cm that are produced in the current year AND originate from nodes that fall within the clip strip. It is not necessary that the individuals are rooted in the clip strip as long as the most recent node from which they originated falls within the strip.
- Working in pairs, technicians may split the clipping labor one of two ways:
    - Divide the 2 m clip strip into 1 m sections, label two bags for each herbGroup so that each technician has a set of bags, and then combine the biomass for each herbGroup when clipping is finished.
    - Divide the clipping labor among the herbGroups. For example, one technician clips cool- and warm-season graminoids while second technician clips leguminous and non-leguminous forbs.

BEST PRACTICE TIPS

- Target one herbGroup at a time.
- Clip slowly, and immediately sort clipped vegetation into labeled bags.
- Place full bags immediately into a cooler with cold packs.

15. When clipping is finished, group all bags from the current clipID into a larger 25# bag and return to the cooler.

16. Record required per clip cell sampling data in the Field Data table:
    - **boutNumber**; use *XX* format, where XX is the bout number assigned by Field Operations, e.g. '01'. Values of **boutNumber** reset every year.
    - **plotID**; use SITE_XXX format, where XXX is unique to each plot.
    - **subplotID**; for all Distributed Plots and 20m x 20m Tower Plots, subplotID = 31. For 40m x 40m Tower Plots, subplotID = 21, 23, 39, or 41
    - **clipCellNum**; use XXX format. This number is the last 3 digits of the clipID from the Clip List.
    - **clipDimension**; the dimensions of the clip strip. Should be 2.0m x 0.1m; other dimensions are employed only during Agricultural Biomass sampling (RD[13]).
    - **clipDate**; use *YYYYMMDD* format

- **time**; use HH:mm, 24-h time format. This is the ***local*** time the sample was placed in the cooler after clipping.
- **exclosure**; record 'Y/N' to indicate whether an exclosure is present over the clip strip or not.
- **bagCount**; the total number of bags generated from the clip strip. Used for sample tracking purposes.
- **remarks**; technician entered observations. E.g., 'Clip strip seasonally submerged in 10 cm water.'

17. If there is no biomass associated with a given herbGroup, be sure to record so it is clear that a given herbGroup was not forgotten.
    - If using paper data sheets, record in the remarks field, 'absent = XXX, YYY' etc., where XXX and YYY are the 3-letter codes for the absent herbGroups.

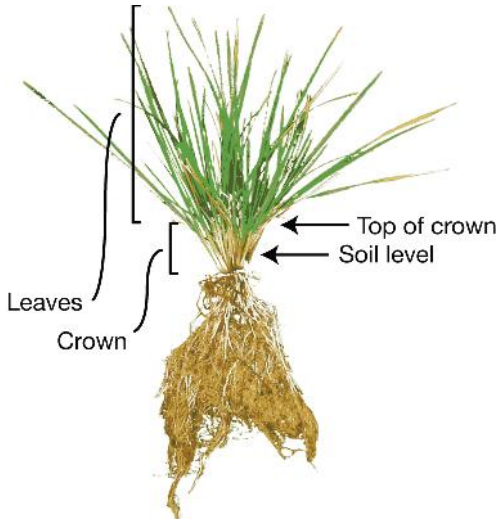

Figure 4. A perennial graminoid, showing the location of crown material relative to leaves and the soil surface

B.2 Points of Confusion

Table 10. Additional guidelines for plant growth forms that require special handling or consideration.

Growth Form	Guidelines
Barrel- and saguaro-type cactus species	DO NOT CLIP; clip around these plants.
Cholla- and pad-type cactus species	DO NOT CLIP for biomass; these plants are counted and measured with the Vegetation Structure protocol. Clip and remove pad cactus only if their presence hinders the removal of other herbaceous functional groups.
Toxicodendron spp.	Handle according to procedure in APPENDIX F and RD[14].
Agave, Yucca, and related species	DO NOT CLIP; these plants are counted and measured with the Vegetation Structure protocol
Ferns	DO NOT CLIP; these plants are counted and measured with the Vegetation Structure protocol
Clumped plants (caespitose graminoids, large rosette forbs, etc.)	Clip only the part of the clump that is rooted within the clip strip. See training materials for examples.
Litter, prostrate on the ground	Ignore; prostrate litter material produced in a previous year is not sampled as part of this protocol.
Evergreen herbaceous plants for which distinguishing current-year from past-year growth is difficult	Do your best to distinguish current-year from past-year growth, and be conservative. Make sure all technicians make consistently similar decisions when clipping.
Epiphytes	DO NOT CLIP
Multiple rooting points, at least one of which is in the clip strip	Only clip biomass associated with rooting points located within the strip.
WST that are leguminous (N fixers)	Leguminous WST should be grouped in with the leguminous forb functional group (LFB); the functional aspect of the grouping is more important than the morphological aspect.
Small sub-shrubs (e.g., Ericaceous plants) that are difficult to differentiate between WST or FRB	Use the USDA plants database as a consistent means of determining the growth form for a given species. If denoted a ‘shrub’ or ‘sub-shrub’ by USDA, classify as WST.

B.3 Sample Preservation

- Keep paper bags with clipped vegetation in a cooler with cold packs to minimize wilting and to preserve diagnostic features for the post-harvest sort-check.
- Change cold packs for fresh ones every 12 h or transfer to a 4 ˚C refrigerator if a drying oven is not immediately available.
- Transfer bags to the drying oven as soon as possible after the post-harvest sort-check. Monitor drying progress with the “Lab Drying QC” datasheet.

IMPORTANT: Record the **clipDate** and **time** on the “Field” datasheet AND **ovenInDate** and time on both the sample bags and the “Lab Weighing” datasheet so that the number of hours the bags were stored cold can be automatically calculated.

SOP C Field Sampling with Grazing Management

At "grazed" sites, which are defined here to mean those that are actively managed for grazing, two clip strips per plot or subplot per bout are harvested. One clip strip per plot or subplot is protected from grazing with a grazing exclosure, and the second clip strip per plot or subplot is exposed to the managed level of grazing pressure. Exclosures should be placed at a suitable random grid-cell location prior to grazing onset in the current season. After each clip-harvest sampling event, the exclosure is moved to the next suitable random location, and clipping occurs on a 4 week interval. A 4 week clipping interval is ONLY employed when livestock are present.

EXCLOSURE DEPLOYMENT RESTRICTION:

Exclosures must NOT be deployed in the 4 Tower Plots that support Plant Diversity and Biogeochemistry sampling (soil and canopy). Ferrous metals may interfere with soil biogeochemistry measurements.

Additionally, there are several common scenarios that affect the deployment of grazing exclosures at sites managed for grazing (**Table 11**):

Table 11. Appropriate exclosure strategies for different grazing management scenarios.

Grazing Management Scenario	Exclosure Strategy
Animals are stocked after senescence has occurred, and removed before plants begin to grow again the next season	Not necessary to deploy exclosures
A portion, but not all, of the Tower Plots are managed for grazing	⟩ Place exclosures only over those Tower plots that are actively managed for grazing. ⟩ The peak biomass clip that is sorted to functional group is clipped at the same time as other Tower Plots.
A portion of the Tower Plots, or all of the Tower Plots, are grazed intermittently	⟩ At the beginning of the season, deploy exclosures in all Tower Plots that may be grazed. If it is unclear which Tower Plots will be grazed, be conservative and install exclosures. ⟩ Actively monitor presence of livestock, and begin every 4 week clipping in a given plot the next bout after livestock arrive. ⟩ Clipping under exclosures is not required for a given plot if livestock have been absent from the plot for the entirety of the previous 4 weeks.
Animals are stocked year-round	Deploy grazing exclosures year-round, even if sampling bouts cannot be performed in the absence of seasonal labor.

At grazed sites, most bouts are only sorted to remove the 'OSD' functional group. Sorting clipped biomass to additional functional groups is only required for one harvest per year, and the harvest that is sorted to all functional groups should be selected to coincide with peak biomass. If there are multiple biomass peaks, choose the time point with the highest peak biomass for functional group sorting. All other harvests are not sorted to functional group, and are assigned **herbGroup** = 'ALL'.

C.1 Sample Collection in the Field

1. Navigate to the plotID to be sampled (using the GPS if necessary).
2. ***You will sample two clip strips per plot.*** The first clip strip is the one underneath the grazing exclosure that was previously put in place. The second clip strip location will be selected from the Clip List provided by Science.
   - The Clip List provides the randomized list of potential clip-harvest strips per plot or subplot, and also indicates which clip strips have already been harvested or rejected.
3. ***For the clip strip without an exclosure:*** Locate the SW corner of the clip strip using the method described in SOP B.
4. ***For both clip strips:*** Perform the clip-harvest as indicated in SOP B.
   - For all bouts ***except*** the peak biomass bout(s), record herbGroup = 'ALL'
   - For the peak biomass bout(s), sort the clip to herbGroup.
   - For all bouts, OSD must be sorted from biomass produced in the current year.
5. When you are finished harvesting the clip strip that was protected by the grazing exclosure, move the exclosure to the next suitable clip strip location on the Clip List.
6. Stake the exclosure to the ground, and proceed to the next plot.

C.2 Troubleshooting

Table 12. Potential issues encountered during Herbaceous Biomass sampling at grazed sites, and issue resolution.

Issue	Resolution
Exclosure placed over > 1 clip cell	Clip herbaceous biomass from a clip strip centered under the exclosure, and mark the affected cells as sampled on the Clip List.
Exclosure placed over incorrect clip cell(s)	Clip herbaceous biomass under the exclosure, and mark the affected cell(s) as sampled on the Clip List.
Exclosure placed within buffer area	- Do not clip herbaceous biomass, as there is no clipID for this location. - Move exclosure to next suitable clip cell on the Clip List.
Exclosure placed over 10 m^2 nested subplot	- If nestedSubplot supports Plant Diversity: Avoid trampling, do NOT clip, and move exclosure to next suitable clip cell on the Clip List. - If nestedSubplot does NOT support Plant Diversity: Clip herbaceous biomass, and look up the clipCellNumber from APPENDIX G.

SOP D Post-Field Sampling Tasks

D.1 Check Sorting of Clipped Biomass

The objectives for this task are:

- ***Within 24-h of harvest,*** check bags of field-sorted biomass for sorting accuracy.
- Remove any litter produced in a previous year from material produced in the current year. The most common error, particularly for clip-harvests performed late in the growing season, is to confuse material that was produced in the current year and has already died with material that was produced in a previous year.
- Remove any material produced in the current year that belongs in another biomass group. For example, leguminous forbs should not be mixed with non-leguminous forbs.
- It is not necessary to check sorting accuracy for bags with herbGroup = OSD. The OSD material is used as a reference during the laboratory sort-check, and is then discarded.

To sort-check clipped biomass:

1. Select a 25# kraft bag (or bags) containing all of the biomass from a given clipID.
2. Make sure that all bags from a given clipID are collated in the correct 25# kraft bag(s).
3. Choose a smaller bag containing clipped biomass from one herbGroup only, and carefully check the biomass that was sorted in the field.
4. Set aside biomass that does not belong in the bag into separate piles (i.e. one pile for each herbGroup).
5. Place any previous years' litter into the "OSD" bag.
6. Place sorted, checked biomass back into the original bag.
7. Clean the work area of any debris, and proceed to the next herbGroup from the same clipID, sorting again as in step (3).
8. Once all herbGroups have been checked for sorting accuracy, place piles of resorted biomass into the appropriately labeled herbGroup bags, and place all smaller bags back into the 25# bag(s).
    - Exception: Discard the OSD bag.
9. Place the 25# bag(s) into the drying oven (SOP E), or return to the cooler for continued temporary storage.
10. Clean the workspace, and proceed to checking herbGroup bags from the next clipID.

BEST PRACTICE TIPS

- The lead plant technician or botanist should spot-check 10% of the re-sorted biomass piles before they are re-bagged.
- Spot-checks from a person skilled in plant species identification is particularly important early in the field season when seasonal field technicians may be less familiar with local flora.

D.2 Refreshing the Sampling Kit

- Make sure the following consumables are available in sufficient quantity for the next round of clip-harvests:
  - Paper bags, 8# and 25# kraft (or the necessary size given site vegetation stature)
  - Rite-in-the-Rain paper for printing field datasheets
  - Permanent markers for labeling bags in the field
- Return cold packs to the -20 ˚C freezer to refresh.

D.3 Equipment Maintenance and Cleaning

- Clean blades of hand clippers with an appropriate solvent (oil, ethanol, water), and dry thoroughly.
- Recharge batteries for the GPS unit (if necessary).
- Recharge batteries for the TruPulse (if applicable).

SOP E Laboratory Processing of Herbaceous Biomass Samples

E.1 Drying and Weighing Clipped Herbaceous Biomass

Clipped herbaceous biomass should be placed in the drying oven as soon as possible following the post-field-sampling sort check. For the standard Herbaceous Biomass clip procedure, only the **dryMass** field is used for data ingest. The **freshMass, subSampleFreshMass,** and **subSampleDryMass** fields are only used for the Agricultural Biomass SOP (RD[13]).

1. Label each 25# bag (with smaller bags for each herbGroup inside) with the date and time it is placed in the drying oven.
   - These data are the **ovenInDate** and time required during data entry.
   - ***Critical step***: Labeling bags allows assessment of how long different batches of bags have been in the oven, especially when harvests from multiple days occupy the same oven.
2. Place labeled 25# bags into a **65 ˚C drying oven for 48h – 120h (2d – 5d)**.
3. After placing bags in the oven, check the drying progress of clipped biomass using a subset of 10 herbGroup samples, and the "Lab Drying QC" datasheet.
4. Check the weight of the same selected subset of n=10 herbGroup sample bags per **ovenInDate** after day 1, 2, 3, etc. Record these weights each day on the "Lab Drying QC" datasheet.
   - Plant material may be weighed WITH the bag for this part of the procedure.
   - Check the drying progress of the heaviest bags; these will likely take the longest to dry.
5. Calculate the difference in weight between the latest two time points for each bag.
6. Samples are dry when the average weight difference between the latest two timepoints = 0 (averaged across all n=10 bags, ± 0.05 g).

DRYING TIPS

- A spreadsheet calculator is useful for calculating the average weight difference. Ask your lead technician how to access the calculator already created by Field Operations staff.
- If there are ≥ 10 25# bags from a single **ovenInDate**, save time and weigh larger 25# bags from a given clipID that contain all of the smaller herbGroup bags for that clipID. It is not necessary to remove and weigh individual bags for a single herbGroup when there are ≥ 10 25# bags (write herbGroup = 'ALL' on the Lab Drying QC Datasheet).
- ***Note:*** It may be more difficult to meet the definition of 'dry', above, when weighing larger 25# bags.

7. Remove bags of dried biomass from the drying oven, and label bags with **ovenOutDate**/Time.
    - Dried plant material should be weighed immediately after removing from the drying oven, as it will absorb moisture from the air if left in ambient room conditions (particularly in humid environments).
        - If using this method, it is helpful to remove bags from the oven and weigh one at a time.
    - Dried samples may also be stored for up to 30 days in ambient room conditions prior to weighing. Samples treated in this manner must be returned to the drying oven for 24 h prior to weighing, and must be weighed as above after removal from the oven.
8. Weigh biomass from each herbGroup from each clipID using a mass balance (0.01g accuracy) and a large weigh boat.
    - Record **dryMass** on the "Lab Weighing" datasheet: nearest 0.01 g, plant material ONLY (without the bag).
    - For large volumes of biomass that do not readily fit into a large weighboat, use the following strategies:
        - Use a large plastic tray (or equivalent) instead of a weigh boat (see equipment list).
        - Crush or chop the biomass to reduce volume so it will fit into a weigh boat.
        - Avoid splitting the biomass into subgroups for weighing, as uncertainty values must be added each time a subgroup is created.
9. Record required metadata for each sample in the "Lab Weighing" datasheet:
    - **clipCellNumber;** last three digits of the clipID
    - **clipDate;** date biomass was clipped in the field
    - **ovenInDate / Time;** date and time (24-h format) the sample was placed in the drying oven
    - **ovenOutDate / Time;** date and time the sample was removed from the drying oven
    - **weighDate;** use *YYYYMMDD* format; date sample was weighed in the laboratory

herbGroup; 3-letter code associated with sorted herbaceous functional groups (

) **Table 9**)

10. Once all weights have been recorded, QA may be performed on a subset of samples (SOP E.2), or return biomass to temporary storage at ambient conditions. Samples in temporary storage can then be weighed for QA as time permits.

E.2 Data Verification and QA

To quantify uncertainty associated with weighing dried biomass, a portion of dried samples are re-weighed by a different technician than the person who originally weighed the biomass.

1. Per unique boutNumber for each site, select 10% of dried, previously weighed samples for re-weighing.
   - If QA weighing does not occur within several hours of the initial weighing, return the selected samples to the drying oven for 24 h prior to QA weighing. In humid environments, samples will pick up moisure from the atmosphere (especially bryophytes).
2. Record QA weight data to the nearest 0.01 g in the **qaDryMass** field of the "Lab Weighing" datasheet.
3. Return plant material to temporary storage until all data have been successfully entered to the NEON database. Once data have been successfully entered and data entry has been QC checked, samples may be discarded.

SOP F Data Entry and Verification

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible; alternatively, devices should be synced immediately upon return to the Domain Support Facility.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times. As a best practice, field data collected on paper datasheets should be digitally transcribed within 7 days of collection or the end of a sampling bout (where applicable). However, given logistical constraints, the maximum timeline for entering data is within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

F.1 Field Datasheets

1. If using paper data sheets and a representative clipID contained no herbaceous biomass, noted as 'targetTaxaPresent = N' in the **remarks** field of the Field Datasheet, enter the following values in the "perbout" ingest table:

   - **targetTaxaPresent** = 'N'

2. Update permanent digital versions of the "clip strip coordinate" lists with "date" and "status" data recorded in the field.

F.2 Lab Datasheets

- Lab Drying QC data are not transcribed for ingest into the NEON database.
- Transcribe data from the "Lab Weighing" datasheet to the "massdata" ingest table.
  - Consult the herbaceous biomass and productivity data ingest document (RD[09]) for additional information about the appropriate values and formats for each field.
  - If a representative clipID contained no herbaceous biomass in one or more herbGroups (noted in the 'remarks' column of the Field Datasheet), enter the following in the "massdata" ingest table:
    - Enter the appropriate **herbGroup** code
    - Enter '0' in the **dryMass** field

SOP G Sample Shipment

The Herbaceous Biomass protocol does not generate samples that require shipping.

8 REFERENCES

The Nutrient Network Experimental Protocol page (http://www.nutnet.umn.edu/exp_protocol). Accessed 2013-09-19.

APPENDIX A DATASHEETS

Table 13. Datasheets associated with this protocol

NEON Doc. #	Title
NEON.DOC.001574	Datasheets for TOS Protocol and Procedure: Measurement of Herbaceous Biomass

These datasheets can be found in Agile or the NEON Document Warehouse.

APPENDIX B QUICK REFERENCES

B.1 Delineating the Clip Harvest Strip

LOCATE AND ASSESS POTENTIAL CLIP AREA

STEP 1 – Locate southwest corner of sample plot - plot coordinate (0,0)

STEP 2 – Select first available clip strip location from the Clip List. Be sure to check if Belowground Biomass Core sampling has already occurred in the current season, and choose clip strips accordingly.

STEP 3 – Locate the offsetEasting coordinate, anchor and stretch east-west tape, place pin flag.

offsetNorthing coordinate	East-West Tape Location
1.5, 4.5, or 7.5	(0,0) →(20,0)
10.5, 13.5, or 16.5	(0,10) →(20,10)

STEP 4 – Locate the offsetNorthing coordinate with TruPulse in HD mode (azimuth 0°), place pin flag.

STEP 5 – Assess suitability of clip strip. Relocate 15 cm west or east OR reject if not suitable.

STEP 6 – Remove and relocate exclosure to next suitable random location, if applicable.

DELINEATE 0.1 M X 2 M CLIP STRIP

STEP 1 – Place north-south oriented string-and-stake set on west side of clip strip. Use TruPulse to orient string.

STEP 2 – Place second string-and-stake set EXACTLY 10 cm to the east of first set.

STEP 3 – Check distance between strings at both ends with ruler.

CHARACTERIZATION

STEP 1 – If cactus are present, remove and discard only those cactus pads that would physically prevent clipping herbaceous biomass.

B.2 Clipping and Sorting

STEP 1 – Label 8# kraft paper bags (lunchbag size), use multiple bags as needed.

STEP 2 – Clip biomass ROOTED in clip strip area, sorting vegetation into coded bags as you go.

STEP 3 – Record on Field Datasheet the total number of bags harvested per clip strip.

STEP 4 – Place all 8# bags from single clip strip into one 25# bag.

STEP 5 – Store bag in cooler with cold packs (or sealed ice) for transport back to lab.

STEP 6 – Transfer clip bags to 4° C refrigerator in domain lab (if possible).

STEP 7 – Check sorting at end of day or next morning in lab.

STEP 8 – Confer with lead plant technician to check that all biomass is correctly sorted.

STEP 9 – Place clipped biomass in a drying oven as soon as possible after clipping and sorting.

STEP 10 – On the appropriate datasheets, record the clipDate and time biomass was placed in the cooler in the field, as well as the ovenInDate and time biomass was placed in the drying oven.

QUALITY DEPENDS ON PROPER:

- Sorting into groups.
- Separation of previous and current years' growth.
- Labeling of all samples.

CLIPPING GUIDELINES

- Only clip biomass ROOTED in the clip strip area (with the exception of WST).
- Sort clipped vegetation into appropriate bags as you go.
- Clip as close to the ground as possible (i.e., 1-2 cm above ground).
- DO NOT CLIP crowns of perennial grasses, as this will kill or damage the plant.
- Do not clip ANY cactus unless required to access herbaceous vegetation
- Clip qualifying *Toxicodendron spp.* according to APPENDIX F.

APPENDIX C REMINDERS

Collecting Quality Biomass Data with the Clip Harvest Technique

At the plot: Be sure to…

- ☑ Avoid walking on targeted clip area, plant diversity subplots, and area surrounding plot centroid.
- ☑ Assess suitability of potential clip strip and accurately delineate.
- ☑ Relocate exclosure to next suitable location, if applicable.

Label Information

- boutNumber
- date
- clipID
- exclosure (Y or N)
- herbGroup (3 letter code)
- bagNumber (e.g. 2 of 3)

Functional Group Name	Biomass Code
Bryophtyes (not lichens), with discernable annual growth	BRY
Cool-season graminoids (C3)	CSG
Warm-season graminoids (C4)	WSG
Leguminous forbs	LFB
Non-leguminous forbs	FRB
Woody-stemmed plants, ddh < 1.0 cm	WST
Previous years' old standing dead	OSD
Unsorted herbaceous biomass, potentially containing all functional groups	ALL

- ☑ Fill out 'status' for sampled or rejected clip-harvest locations on Clip List

Clip harvesting: Be sure to…

- ☑ Clip and discard pad-forming cactus only if necessary.
- ☑ Fill in Field Datasheet and check that all bags are accounted for.
- ☑ Store bags in cooler or refrigerator at all times prior to oven drying.
- ☑ Check sorting in lab at end of field day or next morning.
- ☑ Confer with lead plant technician to check biomass sorting.

Using the TruPulse: Pay close attention to…

- ☑ Declination – Is it set for your current location?
- ☑ Selection choices in drop-down menu.
- ☑ Battery charge (replace when low-charge indicated).
- ☑ Transcription of measurements onto data sheet.
- ☑ Metal objects – Keep them at least 2 feet away from instrument when using internal compass.

APPENDIX D SITE-SPECIFIC ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

The dates in the table below are estimated from satellite MODIS-EVI phenology data averaged from 2001-2009, and for sites that are not grazed, correspond to the average date after which greenness begins to decrease at each site. By using the average greenness decrease date, we ensure that there is a high probability that all herbaceous biomass has been produced for the current season prior to clipping. For grazed sites, start dates correspond to green-up dates, and it is assumed that cows are present from this point forward. These dates are only a guide, and it is essential that domain staff monitor real-time conditions to determine when to start (and stop) sampling, as described in Section 4 of this protocol.

At sites managed for grazing, Distributed Plots should be clip-harvested at approximately the same peak biomass date that functional groups are sorted in the Tower Plots (see "Additional Sampling Information" field in the table below).

Assessment of grazing management is accurate as of the publication date of this protocol; however, grazing management status may change, and must be assessed by the Domain Manager in consultation with the site host and/or grazing lessees.

Table 14. Site-specific grazing status and per bout sampling start dates for herbaceous clip-harvest.

Domain Number	Site ID	Grazing Mgmt	Bouts per Growing Season*	Sampling Dates*† (MM/dd)	Additional Sampling Information
01	BART	No	1	D: 08/08 T: 08/08	
	HARV	No	1	D: 08/08 T: 08/08	
02	BLAN	No	1	D: 07/29 T: 07/29	Dates are for peak biomass harvested in grazed Dist Plots, and Tower Plots. Dates for cropped Dist Plots in RD[13.]
	SCBI	No	1	D: 08/08 T: 08/08	
	SERC	Yes	1	D: 08/08 T: 3/20-11/20	Mixed Ag and grazed tower and distributed plots. Ag dates provided in RD[13]. Peak biomass sort in grazed Tower Plots same date as Dist Plot clip.
03	DSNY	No	1	D: 07/09 T: 07/09	
	JERC	No	1	D: 08/08 T: 08/08	
	OSBS	No	1	D: 07/09 T: 07/09	
04	GUAN	No	2	D: 10/15 T b1: 05/30 T b2: 10/15	Sampling dates based on precipitation data, not MODIS-EVI; very little change in EVI throughout the year.

Domain Number	Site ID	Grazing Mgmt	Bouts per Growing Season*	Sampling Dates*† (MM/dd)	Additional Sampling Information
	LAJA	Yes	D: 1 T: Every 4 weeks	D: 10/15 T: 01/01 – 12/31	Dates for Ag plots in RD[13]. Non-Ag Dist Plots: dates coincide with autumn wet season. Tower Plots: Peak biomass sort for grazed plots same date as Dist Plots.
05	STEI	No	1	D: 08/03 T: 08/03	
	TREE	No	1	D: 08/03 T: 08/03	
	UNDE	No	1	D: 08/03 T: 08/03	
06	KONA	No	1	D: 07/28 T: see RD[13]	Dist Plots: date is for non-Ag plots; see RD[13] for Ag Dist and Tower Plot dates.
	KONZ	Yes	D: 1 T: Every 4 weeks	D: 07/29 T: 03/31 – 10/27	End sampling by 10/27, or when livestock removed. Tower Plots: Peak biomass sort for grazed plots same date as Dist Plots.
	UKFS	No	1	D: 07/15 T: 07/15	
07	GRSM	No	1	D: 08/03 T: 08/03	
	MLBS	No	1	D: 08/08 T: 08/08	
	ORNL	No	1	D: 07/29 T: 07/29	
08	DELA	No	1	D: 07/24 T: 07/24	
	LENO	No	1	D: 07/19 T: 07/19	
	TALL	No	1	D: 07/14 T: 07/14	
09	DCFS	Yes	D: 1 T: Every 4 weeks	D: 7/24 T: 04/30 – 10/17	Tower Plots: Peak biomass sort for grazed plots same date as Dist Plot.
	NOGP	Yes	D: 1 T: Every 4 weeks	D: 07/19 T: 04/24 – 10/17	Tower Plots: Peak biomass sort for grazed plots same date as Dist Plots.
	WOOD	Yes	D: 1 T: Every 4 weeks	D: 07/29 T: 4/30 – 10/16	Tower Plots: Peak biomass sort for grazed plots same date as Dist Plots.

Domain Number	Site ID	Grazing Mgmt	Bouts per Growing Season*	Sampling Dates*† (MM/dd)	Additional Sampling Information
10	CPER	Yes	D: 1 T: Every 4 weeks	D: 7/29 T: 03/31 – 12/16	Tower Plots: Peak biomass sort for grazed plots same date as Dist Plots.
	RMNP	No	1	D: 06/29 T: 06/29	
	STER	No	1 bout per crop, per growing season	RD[13]	See RD[13]
11	CLBJ	No	2	D: 10/01 T b1: 06/28 T b2: 10/01	
	OAES	Yes	2	D: 10/16 T gr: 03/15 – 11/05 T b1: 06/13 T b2: 10/16	Grazing management may not affect all Tower Plots in given season; plots not grazed (no exclosures) get two sampling bouts (two biomass peaks); grazed plots (with exclosures) sampled every 4 weeks, and sorted to functional group at second biomass peak.
12	YELL	No	1	D: 07/09 T: 07/09	
13	MOAB	Yes	D: 1 T: Every 4 weeks	D: 08/12 T: 03/26 – 10/27	Tower Plots: Peak biomass sort for grazed plots same date as Dist Plots.
	NIWO	No	1	D: 08/08 T: 08/08	
14	JORN	No	1	D: 09/02 T: 09/02	Grazing not anticipated in Tower plots, but may occur. Domain Mgr communicates with site host to determine if Tower plots grazed.
	SRER	Yes	D: 1 T: 2	D: 09/12 T gr: see right T b1: 05/20 T b2: 09/12	Grazing intermittent in Tower plots; plots not grazed (no exclosures) get two sampling bouts (two biomass peaks); grazed plots (with exclosures) sampled every 4 weeks, and sorted to functional group at second biomass peak. Domain Mgr communicates with site host to determine when Tower plots are grazed, no dates provided here.
15	ONAQ	No	1	D: 06/19 T: 06/19	
16	ABBY	No	1	D: 07/23	

Domain Number	Site ID	Grazing Mgmt	Bouts per Growing Season*	Sampling Dates*† (MM/dd)	Additional Sampling Information
				T: 07/23	
	WREF	No	1	D: 07/29 T: 07/29	
17	SJER	Yes	D: 1 T: Every 4 weeks	D: 04/05 T: 09/27 – 06/04	Tower Plots: Peak biomass sort for grazed plots same date as Dist Plots.
	SOAP	No	1	D: 07/04 T: 07/04	
	TEAK	Yes	1	D: 07/24 T: 04/29 – 10/26	Tower Plot start date corresponds to green-up; if cows not present this early, requirement is for exclosures to be deployed in affected plots before cows arrive. Tower Plot peak biomass sort same date as Distributed Plot harvest.
18	BARR	No	1	D: 07/29 T: 07/29	
	TOOL	No	1	D: 07/24 T: 07/24	
19	BONA	No	1	D: 07/24 T: 07/24	
	DEJU	No	1	D: 07/29 T: 07/29	
	HEAL	No	1	D: 07/29 T: 07/29	
20	PUUM	No	TBD	TBD	Candidate site for continuous growth/decomp SOP.

* 'D' denotes 'Distributed Plots,' and 'T' indicates Tower Plots.

† A single date indicates the earliest desired start date for a given bout, and it is assumed that the sampling stop date is 14 days after the start date (see Section 4.2 for more details). A date range is provided for sampling start/stop in grazed Tower Plots.

APPENDIX E SITE-SPECIFIC MODIFICATIONS

TBD.

APPENDIX F CLIP-HARVESTING *TOXICODENDRON* SPECIES

F.1 Equipment and Materials

Protocol-specific equipment for mitigating exposure to toxic oils from *Toxicodendron* species. General equipment and PPE is listed in RD[14].

Table 15. Equipment and materials required for a team of two to minimize exposure to toxic oils from *Toxicodendron spp.* that should be clip-harvested.

Item Description	Qty	Example Item	Purpose
Small paper bags, pre-weighed, labeled with bag weight	Variable	8# or lunch sack type	*Toxicodendron* biomass never handled directly again after it is placed in pre-weighed bag.
Labeled hand clippers, dedicated to *Toxicodendron* clipping	1	Same item type as indicated in equipment lists	Minimize spread of oils to other equipment.

F.2 Minimizing Exposure to Toxic Oil in the Field and Lab

General guidelines for preventing and mitigating exposure to toxic oils from *Toxicodendron* species can be found in RD[14].

The following are protocol-specific best-practice techniques for minimizing exposure to toxic oil during clip-harvest of Toxicodendron species.

1. Prior to field work:
   a. Count out bags for storing and drying ONLY Toxicodendron biomass. Don't mix Toxicodendron biomass with any other biomass.
   b. Pre-weigh (to nearest 0.01 g) and label each paper bag that will be used for storing and drying clip-harvested *Toxicodendron* biomass. Once the weight of each empty bag is included on the bag label, the biomass inside the bag will never have to be touched after it is initially placed in the bag.
2. To process *Toxicodendron* biomass in the laboratory:
   - Minimize potential spread of toxic oil by putting Toxicodendron biomass bags into the same drying oven every time.
   - When drying is complete, clean drying oven shelves used for drying *Toxicodendron* biomass bags with hot water and Tecnu. Wear appropriate PPE when cleaning.
   - Record weight of bag + dried biomass to nearest 0.01 g, and also record weight of individual empty bag (to 0.01 g) on data sheets. Dried *Toxicodendron* biomass should never leave the bag.

- Use a spreadsheet to calculate the mass of *Toxicodendron* by difference. The Herbaceous Biomass webUI will only accept one 'dryMass' value, so you must subtract out the weight of the bag prior to data entry.
- Use herbGroup = 'WST' for *Toxicodendron* biomass.

- After weighing, dispose of all *Toxicodendron* biomass bags.
  - *Toxicodendron* tissue will not be specimen mounted, or processed for Herbaceous Biogeochemistry (i.e., archived and sent for external chemical analysis).

APPENDIX G CLIPCELLNUMBER COORDINATES AND MAPS

G.1 Maps of clipCellNumber by subplotID

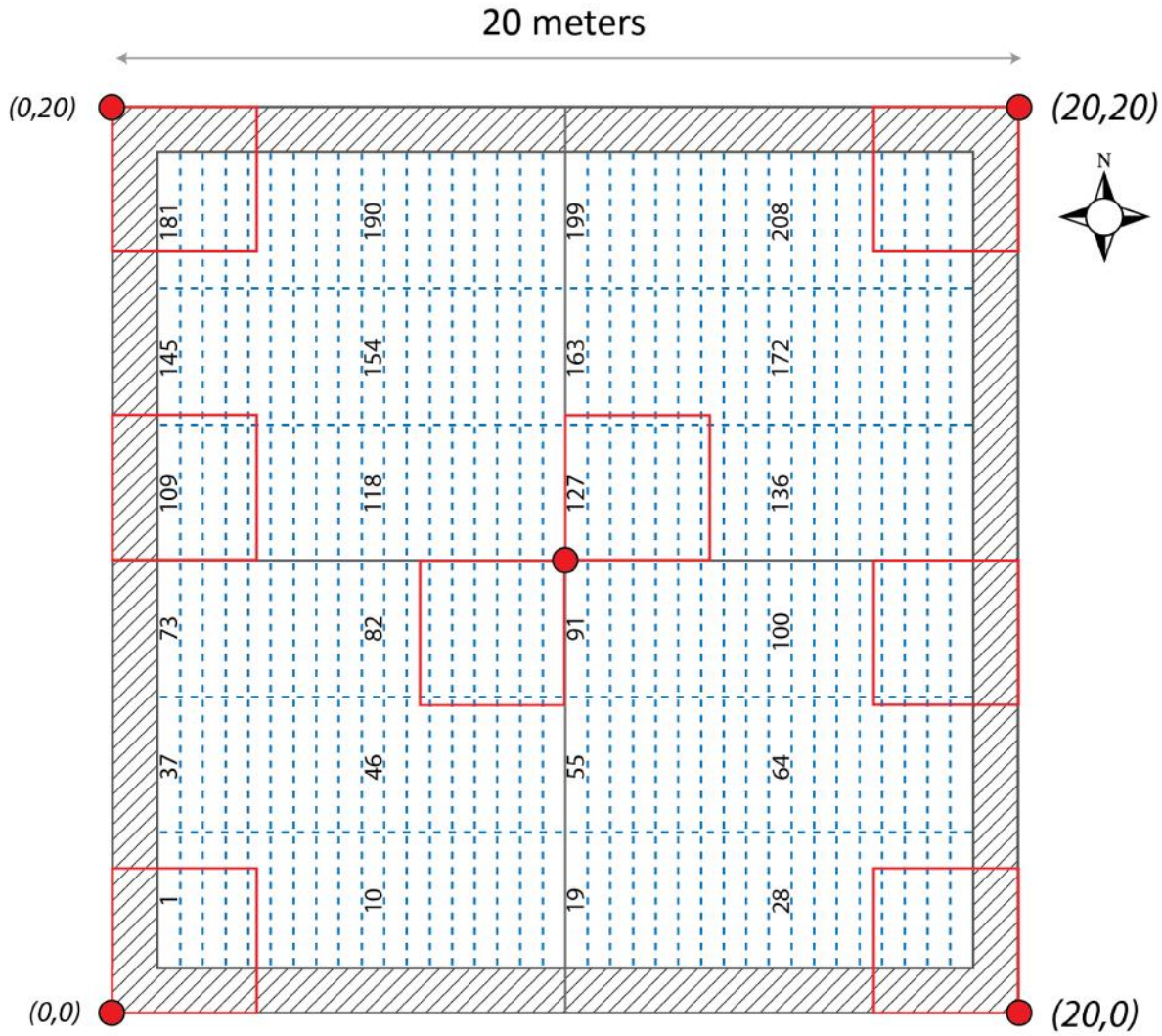

Figure 5. Map of clipCellNumbers in a 20m x 20m base plot (subplotID = 31 in provided Clip Lists). Red squares indicate nested subplots used for diversity sampling; clip cells that significantly overlap red squares are not used for clip sampling. However, clip cells with minimal overlap (e.g., 48-54, 68-72, 145-149) do support clip harvest sampling.

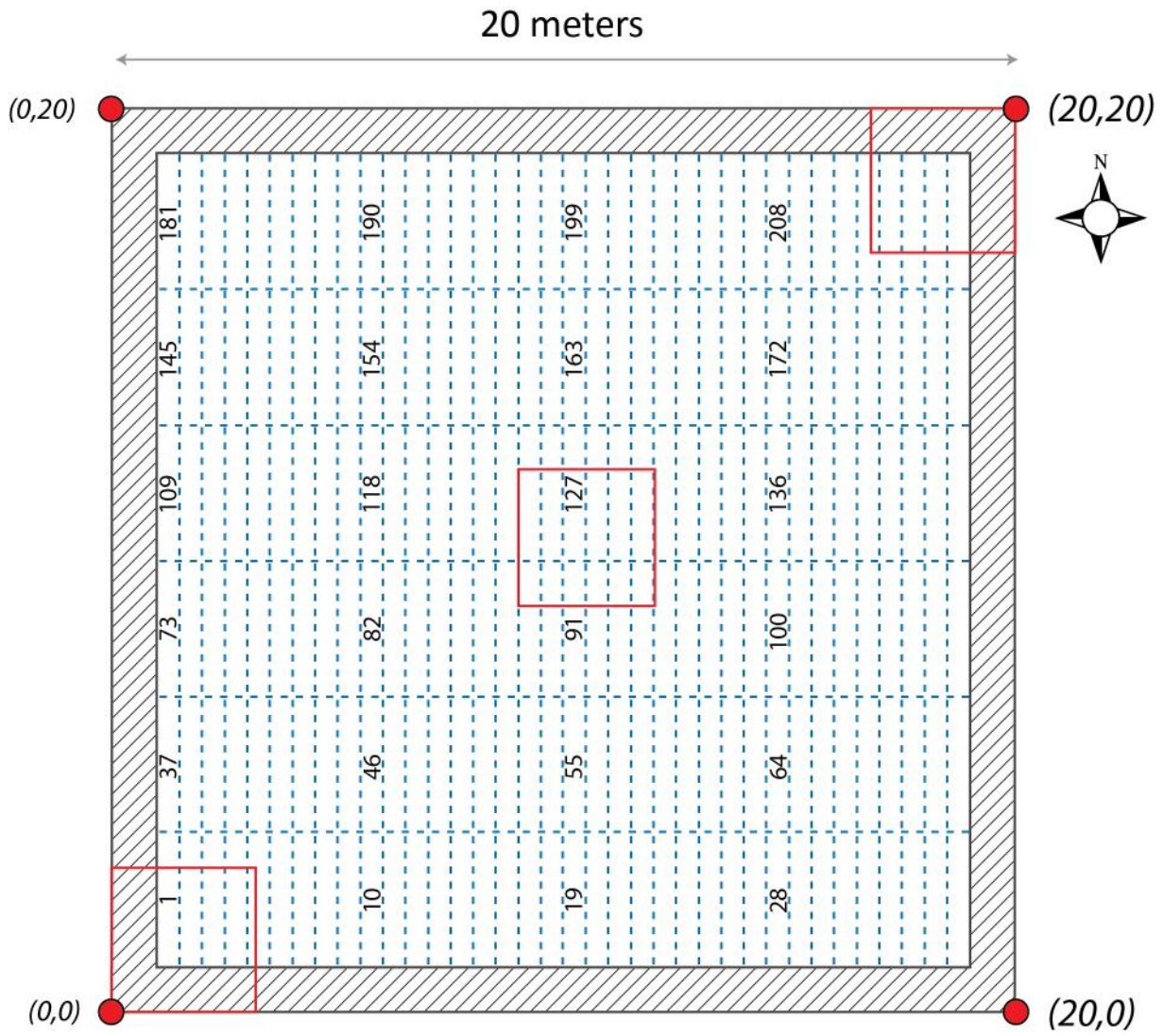

Figure 6. Map of clipCellNumbers for **subplotID = 21** in a 40m x 40m Tower base plot. Clip cells that overlap nested subplots indicated by red squares are not used for clip sampling.

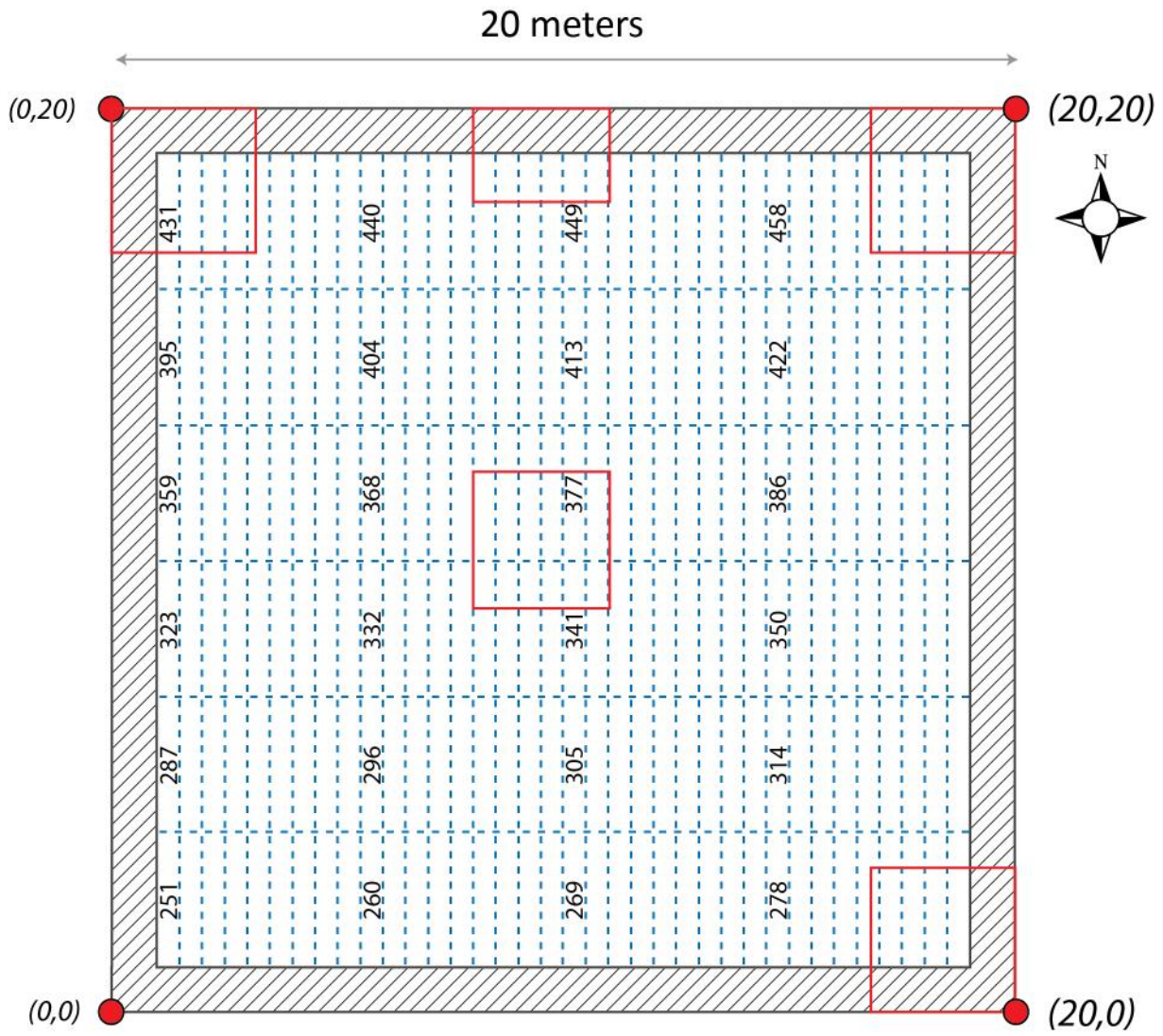

Figure 7. Map of clipCellNumbers for **subplotID = 23** in a 40m x 40m Tower base plot. Clip cells that overlap nested subplots indicated by red squares are not used for clip sampling.

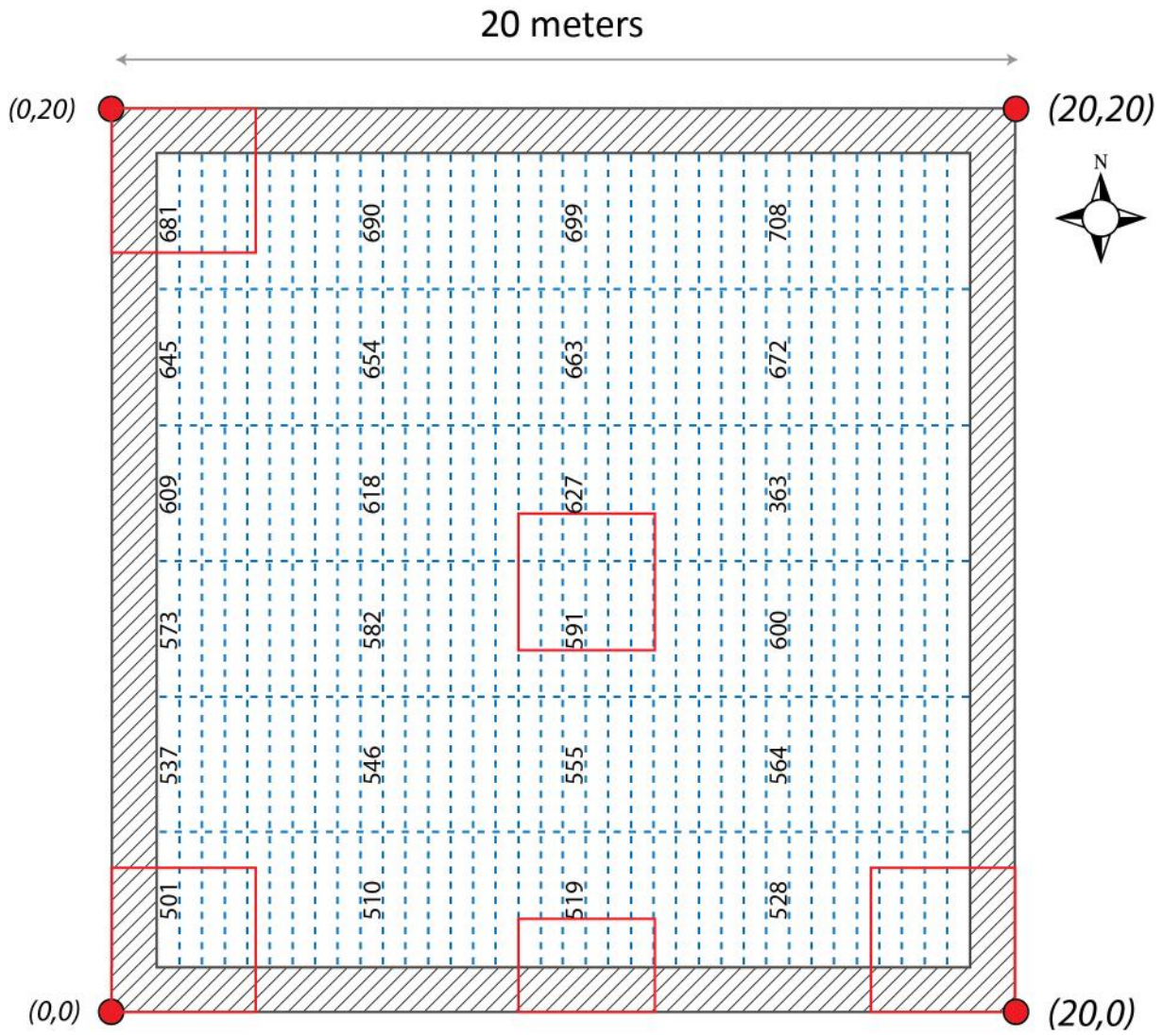

Figure 8. Map of clipCellNumbers for **subplotID = 39** in a 40m x 40m Tower base plot. Clip cells that overlap nested subplots indicated by red squares are not used for clip sampling.

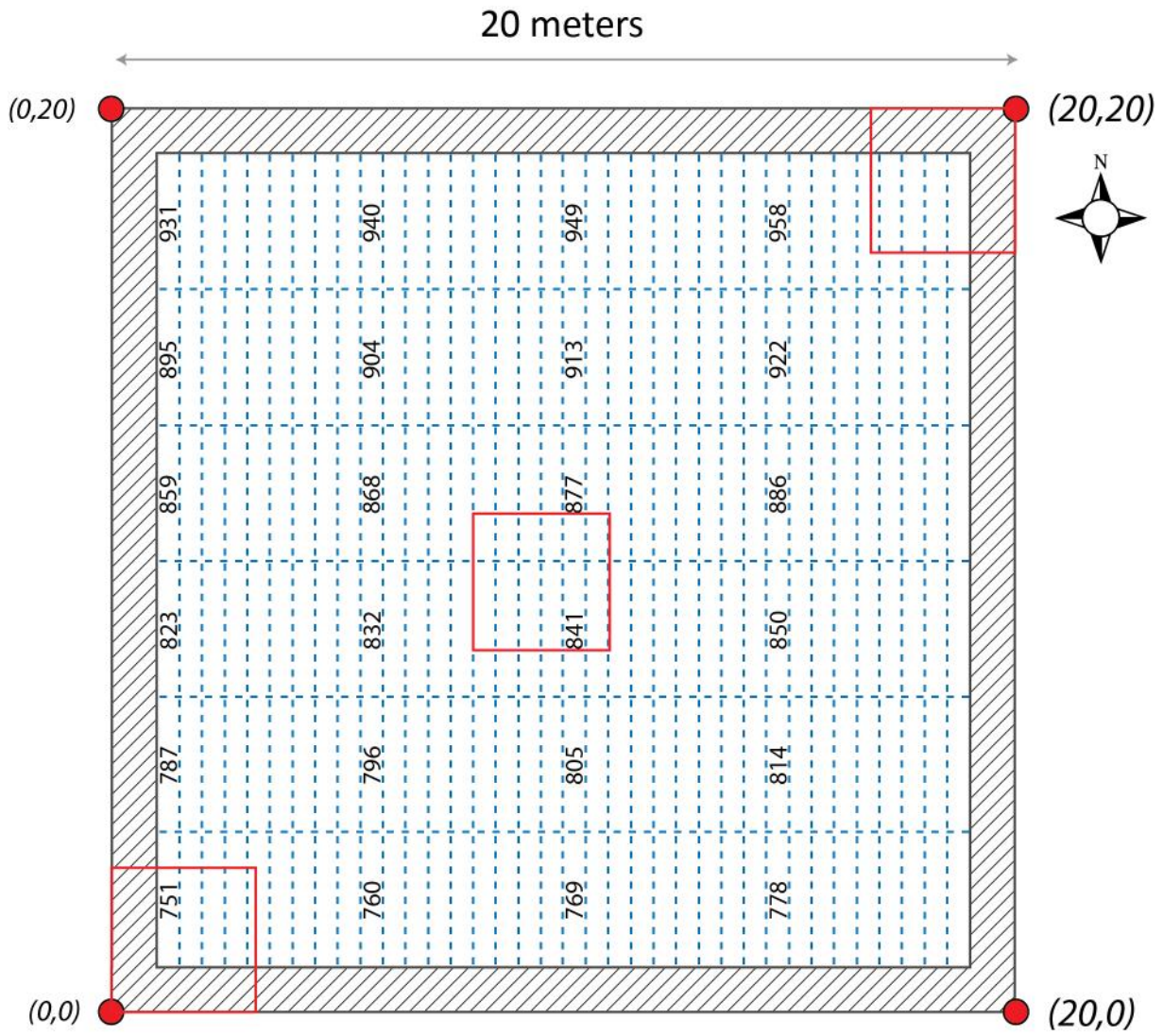

Figure 9. Map of clipCellNumbers for **subplotID = 41** in a 40m x 40m Tower base plot. Clip cells that overlap nested subplots indicated by red squares are not used for clip sampling.

G.2 Coordinates for clipCellNumbers by subplotID

Table 16. List of clipCellNumbers by subplotID and associated easting and northing coordinates. Coordinates correspond to the SW corner of a 0.1m x 2m clip strip, and indicate the distance in meters relative to the SW corner of the plot (subplotID = 31) or subplot (subplotID = 21, 23, 39, 41).

clipCellNumber subplotID = 31	clipCellNumber subplotID = 21	clipCellNumber subplotID = 23	clipCellNumber subplotID = 39	clipCellNumber subplotID = 41	easting offset	northing offset
1	1	251	501	751	1.2	1.5
2	2	252	502	752	1.7	1.5
3	3	253	503	753	2.2	1.5
4	4	254	504	754	2.7	1.5
5	5	255	505	755	3.2	1.5
6	6	256	506	756	3.7	1.5
7	7	257	507	757	4.2	1.5
8	8	258	508	758	4.7	1.5
9	9	259	509	759	5.2	1.5
10	10	260	510	760	5.7	1.5
11	11	261	511	761	6.2	1.5
12	12	262	512	762	6.7	1.5
13	13	263	513	763	7.2	1.5
14	14	264	514	764	7.7	1.5
15	15	265	515	765	8.2	1.5
16	16	266	516	766	8.7	1.5
17	17	267	517	767	9.2	1.5
18	18	268	518	768	9.7	1.5
19	19	269	519	769	10.2	1.5
20	20	270	520	770	10.7	1.5
21	21	271	521	771	11.2	1.5
22	22	272	522	772	11.7	1.5
23	23	273	523	773	12.2	1.5
24	24	274	524	774	12.7	1.5
25	25	275	525	775	13.2	1.5
26	26	276	526	776	13.7	1.5
27	27	277	527	777	14.2	1.5
28	28	278	528	778	14.7	1.5
29	29	279	529	779	15.2	1.5
30	30	280	530	780	15.7	1.5
31	31	281	531	781	16.2	1.5
32	32	282	532	782	16.7	1.5
33	33	283	533	783	17.2	1.5
34	34	284	534	784	17.7	1.5
35	35	285	535	785	18.2	1.5
36	36	286	536	786	18.7	1.5
37	37	287	537	787	1.2	4.5

clipCellNumber subplotID = 31	clipCellNumber subplotID = 21	clipCellNumber subplotID = 23	clipCellNumber subplotID = 39	clipCellNumber subplotID = 41	easting offset	northing offset
38	38	288	538	788	1.7	4.5
39	39	289	539	789	2.2	4.5
40	40	290	540	790	2.7	4.5
41	41	291	541	791	3.2	4.5
42	42	292	542	792	3.7	4.5
43	43	293	543	793	4.2	4.5
44	44	294	544	794	4.7	4.5
45	45	295	545	795	5.2	4.5
46	46	296	546	796	5.7	4.5
47	47	297	547	797	6.2	4.5
48	48	298	548	798	6.7	4.5
49	49	299	549	799	7.2	4.5
50	50	300	550	800	7.7	4.5
51	51	301	551	801	8.2	4.5
52	52	302	552	802	8.7	4.5
53	53	303	553	803	9.2	4.5
54	54	304	554	804	9.7	4.5
55	55	305	555	805	10.2	4.5
56	56	306	556	806	10.7	4.5
57	57	307	557	807	11.2	4.5
58	58	308	558	808	11.7	4.5
59	59	309	559	809	12.2	4.5
60	60	310	560	810	12.7	4.5
61	61	311	561	811	13.2	4.5
62	62	312	562	812	13.7	4.5
63	63	313	563	813	14.2	4.5
64	64	314	564	814	14.7	4.5
65	65	315	565	815	15.2	4.5
66	66	316	566	816	15.7	4.5
67	67	317	567	817	16.2	4.5
68	68	318	568	818	16.7	4.5
69	69	319	569	819	17.2	4.5
70	70	320	570	820	17.7	4.5
71	71	321	571	821	18.2	4.5
72	72	322	572	822	18.7	4.5
73	73	323	573	823	1.2	7.5
74	74	324	574	824	1.7	7.5
75	75	325	575	825	2.2	7.5
76	76	326	576	826	2.7	7.5
77	77	327	577	827	3.2	7.5
78	78	328	578	828	3.7	7.5
79	79	329	579	829	4.2	7.5

clipCellNumber subplotID = 31	clipCellNumber subplotID = 21	clipCellNumber subplotID = 23	clipCellNumber subplotID = 39	clipCellNumber subplotID = 41	easting offset	northing offset
80	80	330	580	830	4.7	7.5
81	81	331	581	831	5.2	7.5
82	82	332	582	832	5.7	7.5
83	83	333	583	833	6.2	7.5
84	84	334	584	834	6.7	7.5
85	85	335	585	835	7.2	7.5
86	86	336	586	836	7.7	7.5
87	87	337	587	837	8.2	7.5
88	88	338	588	838	8.7	7.5
89	89	339	589	839	9.2	7.5
90	90	340	590	840	9.7	7.5
91	91	341	591	841	10.2	7.5
92	92	342	592	842	10.7	7.5
93	93	343	593	843	11.2	7.5
94	94	344	594	844	11.7	7.5
95	95	345	595	845	12.2	7.5
96	96	346	596	846	12.7	7.5
97	97	347	597	847	13.2	7.5
98	98	348	598	848	13.7	7.5
99	99	349	599	849	14.2	7.5
100	100	350	600	850	14.7	7.5
101	101	351	601	851	15.2	7.5
102	102	352	602	852	15.7	7.5
103	103	353	603	853	16.2	7.5
104	104	354	604	854	16.7	7.5
105	105	355	605	855	17.2	7.5
106	106	356	606	856	17.7	7.5
107	107	357	607	857	18.2	7.5
108	108	358	608	858	18.7	7.5
109	109	359	609	859	1.2	10.5
110	110	360	610	860	1.7	10.5
111	111	361	611	861	2.2	10.5
112	112	362	612	862	2.7	10.5
113	113	363	613	863	3.2	10.5
114	114	364	614	864	3.7	10.5
115	115	365	615	865	4.2	10.5
116	116	366	616	866	4.7	10.5
117	117	367	617	867	5.2	10.5
118	118	368	618	868	5.7	10.5
119	119	369	619	869	6.2	10.5
120	120	370	620	870	6.7	10.5
121	121	371	621	871	7.2	10.5

clipCellNumber subplotID = 31	clipCellNumber subplotID = 21	clipCellNumber subplotID = 23	clipCellNumber subplotID = 39	clipCellNumber subplotID = 41	easting offset	northing offset
122	122	372	622	872	7.7	10.5
123	123	373	623	873	8.2	10.5
124	124	374	624	874	8.7	10.5
125	125	375	625	875	9.2	10.5
126	126	376	626	876	9.7	10.5
127	127	377	627	877	10.2	10.5
128	128	378	628	878	10.7	10.5
129	129	379	629	879	11.2	10.5
130	130	380	630	880	11.7	10.5
131	131	381	631	881	12.2	10.5
132	132	382	632	882	12.7	10.5
133	133	383	633	883	13.2	10.5
134	134	384	634	884	13.7	10.5
135	135	385	635	885	14.2	10.5
136	136	386	636	886	14.7	10.5
137	137	387	637	887	15.2	10.5
138	138	388	638	888	15.7	10.5
139	139	389	639	889	16.2	10.5
140	140	390	640	890	16.7	10.5
141	141	391	641	891	17.2	10.5
142	142	392	642	892	17.7	10.5
143	143	393	643	893	18.2	10.5
144	144	394	644	894	18.7	10.5
145	145	395	645	895	1.2	13.5
146	146	396	646	896	1.7	13.5
147	147	397	647	897	2.2	13.5
148	148	398	648	898	2.7	13.5
149	149	399	649	899	3.2	13.5
150	150	400	650	900	3.7	13.5
151	151	401	651	901	4.2	13.5
152	152	402	652	902	4.7	13.5
153	153	403	653	903	5.2	13.5
154	154	404	654	904	5.7	13.5
155	155	405	655	905	6.2	13.5
156	156	406	656	906	6.7	13.5
157	157	407	657	907	7.2	13.5
158	158	408	658	908	7.7	13.5
159	159	409	659	909	8.2	13.5
160	160	410	660	910	8.7	13.5
161	161	411	661	911	9.2	13.5
162	162	412	662	912	9.7	13.5
163	163	413	663	913	10.2	13.5

clipCellNumber subplotID = 31	clipCellNumber subplotID = 21	clipCellNumber subplotID = 23	clipCellNumber subplotID = 39	clipCellNumber subplotID = 41	easting offset	northing offset
164	164	414	664	914	10.7	13.5
165	165	415	665	915	11.2	13.5
166	166	416	666	916	11.7	13.5
167	167	417	667	917	12.2	13.5
168	168	418	668	918	12.7	13.5
169	169	419	669	919	13.2	13.5
170	170	420	670	920	13.7	13.5
171	171	421	671	921	14.2	13.5
172	172	422	672	922	14.7	13.5
173	173	423	673	923	15.2	13.5
174	174	424	674	924	15.7	13.5
175	175	425	675	925	16.2	13.5
176	176	426	676	926	16.7	13.5
177	177	427	677	927	17.2	13.5
178	178	428	678	928	17.7	13.5
179	179	429	679	929	18.2	13.5
180	180	430	680	930	18.7	13.5
181	181	431	681	931	1.2	16.5
182	182	432	682	932	1.7	16.5
183	183	433	683	933	2.2	16.5
184	184	434	684	934	2.7	16.5
185	185	435	685	935	3.2	16.5
186	186	436	686	936	3.7	16.5
187	187	437	687	937	4.2	16.5
188	188	438	688	938	4.7	16.5
189	189	439	689	939	5.2	16.5
190	190	440	690	940	5.7	16.5
191	191	441	691	941	6.2	16.5
192	192	442	692	942	6.7	16.5
193	193	443	693	943	7.2	16.5
194	194	444	694	944	7.7	16.5
195	195	445	695	945	8.2	16.5
196	196	446	696	946	8.7	16.5
197	197	447	697	947	9.2	16.5
198	198	448	698	948	9.7	16.5
199	199	449	699	949	10.2	16.5
200	200	450	700	950	10.7	16.5
201	201	451	701	951	11.2	16.5
202	202	452	702	952	11.7	16.5
203	203	453	703	953	12.2	16.5
204	204	454	704	954	12.7	16.5
205	205	455	705	955	13.2	16.5

clipCellNumber subplotID = 31	clipCellNumber subplotID = 21	clipCellNumber subplotID = 23	clipCellNumber subplotID = 39	clipCellNumber subplotID = 41	easting offset	northing offset
206	206	456	706	956	13.7	16.5
207	207	457	707	957	14.2	16.5
208	208	458	708	958	14.7	16.5
209	209	459	709	959	15.2	16.5
210	210	460	710	960	15.7	16.5
211	211	461	711	961	16.2	16.5
212	212	462	712	962	16.7	16.5
213	213	463	713	963	17.2	16.5
214	214	464	714	964	17.7	16.5
215	215	465	715	965	18.2	16.5
216	216	466	716	966	18.7	16.5