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USDA LTAR Common Experiment measurement: Non-crop plant biodiversity

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Abstract

Non-crop plant diversity, implemented by producers to manage environmental quality or biodiversity-based ecosystem services within croplands, is important because it is strongly related to other biodiversity-based ecosystem services and ecosystem function. Diversity is often correlated with primary production and thus associated with numerous ecosystem services, including food, fuel, and fiber provisioning; water management and erosion control; nutrient cycling; carbon storage; and habitat for wildlife and pollinators. Moreover, plant diversity is an ecosystem characteristic amenable to manipulation and predictively responsive to climate change, thus providing a mechanism whereby ecosystem services may be sustainably managed now and into the changing future.

In the LTAR croplands common experiment, non-crop plant diversity is measured using a multi-scale plot known as a Whittaker plot. The presence and percent cover of species and ancillary data is observed in eight 1 m^2 subplots. The presence of species is observed in eight 10 m^2 subplots and four 100 m^2 subplots, which can be combined for a list of species at the 400 m^2 plot scale.

The multi-scale plot design is consistent with the methods of NEON (Barnett et al. 2019) and the Carolina Vegetation Project (Peet et al. 1998), similar to other multi-scale methods (Stohlgren 2007), and is based on Robert Whittaker's

approach to sampling vegetation. It is possible to modify the size of a Whittaker plot as necessary to fit within experimental constraints.

Because the effectiveness of floral strips or hedgerows may depend on landscape context, we also recommend assessing the proportional cover of arable crops as a proxy for landscape simplification (e.g., Tscharntke et al., 2005; Dainese et al., 2019). Calculate the proportional cover of arable crops in circular sectors of a 1 km radius around focal crops or a 750 m or 500 m radius (Albrecht et al. 2020).

To assess the impact of non-crop plant diversity on other aspects of biodiversity and ecosystem services, co-locate measurements of beneficial insects (e.g., butterflies and pollinators), soil health attributes, and soil microbial diversity with Whittaker plots.

Sample collection, processing, and analysis

12h

1 **Number of Whittaker plots:** We recommend a minimum of three plots per plant community at a given site, but plot number determination varies among sites based on the number of communities, available labor, and other constraints.

2 **Location of Whittaker plots:** A minimum sampling regime would occur at the field scale, in fields with eddy covariance towers, in one alternative and one prevailing treatment. Each field will include three Whittaker plots for a minimum total of six Whittaker plots. Around each eddy covariance tower, envision the eddy covariance footprint as a circle. Divide this circle into thirds and place a Whittaker plot within each third of the eddy covariance circle footprint. In a prevailing treatment field, these plots will probably be in a homogeneous crop. In an alternative treatment containing pasture, prairie strips, or hedgerows, again divide the eddy covariance tower footprint into thirds and ensure that one Whittaker plot occurs in the different plant communities present (e.g., homogeneous cropland and non-crop areas).

3 **Sampling frequency:** Sampling will occur during peak flowering periods when plant identification is easiest. These periods may occur once or twice annually (spring and autumn flowering times). For rotated crops, conduct sampling to capture different plant communities over time.

4 **Time required:** The initial set-up of each plot will take 3 to 4 hours and require a sighting compass to ensure the plot is square. With a minimum of two people, sampling should take 3 to 4 hours to perform per plot after the initial set-up.

Standard operating procedure for field sampling

5 **Plot Establishment.** Plant diversity sampling occurs in a square-shaped plot measuring 20 m on a side and containing four 100 m^2 subplots (Figure 1).

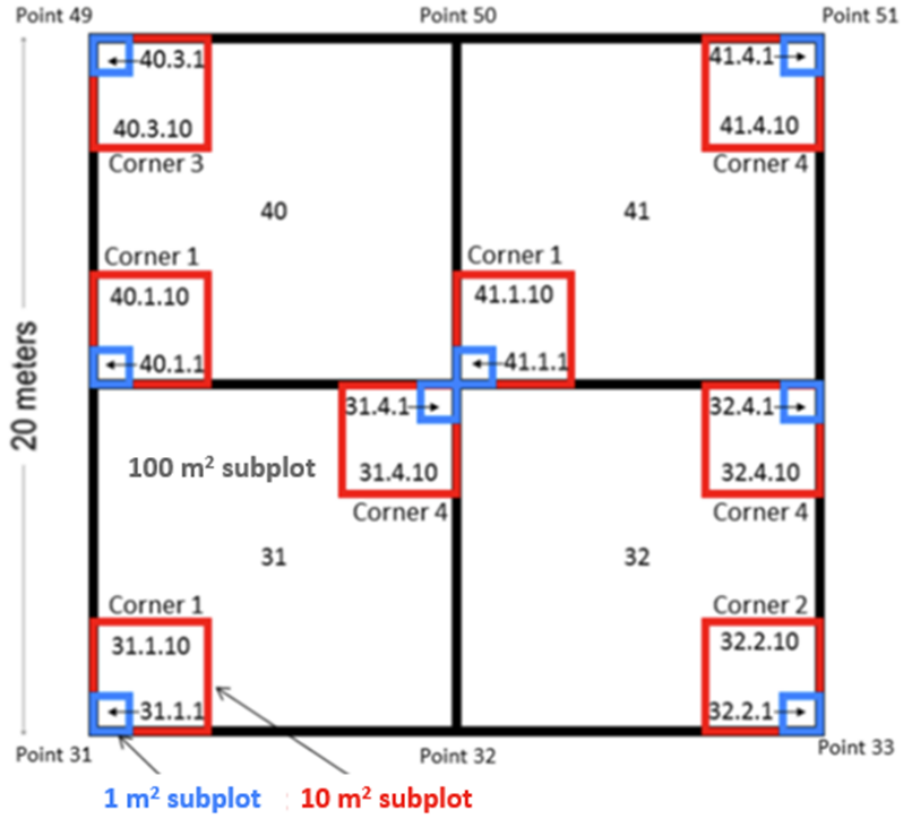

Figure 1. Example of a square multi-scale Whittaker plant diversity sampling plot used by NEON.

If the prairie strips or hedgerows are not large enough to accommodate a 20 m × 20 m plot, alter the plot dimensions to fit (e.g., 10 m × 40 m; size can be altered depending on the dimensions of strips/hedgerows in the field). Each subplot contains nested subplots: a 1 m^2 subplot is nested in a 10 m^2 subplot in each of two corners. For comparison of data across space and time, the dimensions of these plots and subplots should be consistent across plots and sites. This protocol assumes a center point and four corners will mark plots. The permanent markers define the corners of the plot and should maintain comparability over time. While delineating subplots, please avoid trampling plots—particularly the 1 m^2 subplots.

5.1 Delineate the sides of the 100 m^2 subplot, the 10 m^2 nested subplot (3.16 m from the nearest permanent marker at the plot corners or center) with flags or appropriate markers, and the 1 m^2 nested subplot.

5.2 The 1 m^2 nested subplot is delineated with a rigid frame anchored at the corner by a permanent plot marker. The square, multi-scale plot is for recording plant species composition and cover. This plot includes nested subplots at specific locations.

6 **General data collection.** The plot-based collection requires photography, observation of primarily abiotic elements—termed "variables"—in 1 m^2 nested subplots, and observations of vascular plant species at multiple spatial scales.

6.1 **Metadata.** Record the plotID, the primary botanist (measuredBy), additional staff (recordedBy), and the date (which should reflect the sampling completion day).

6.2 **1 m^2 nested subplots.** Photograph nested subplots, record variable cover estimates, and identify and record the cover and height of vascular plant species in the subplot.

a. Photograph the 1 m^2 nested subplot

While standing in the middle of the south edge outside the 1 m^2 nested subplot, take a plane-view picture of the nested 1 m^2 nested subplot such that the subplot frame fills the photograph. If standing at the south edge is impossible, move to the west, north, or east edge in that order. The photograph name should include the plot_ID, Module, subplot number, and date in the following format: CPER_001_PlantDiversity_31.1.1_20130812

b. Measure and record variables other than vascular plants

Estimate and record the combined cover of abiotic (nonliving) elements, non-vascular plant species, and overstory cover of species in each 1 m^2 nested subplot. Record each element to the nearest 1% (1% of a 1 m^2 plot is approximately the size of a fist). The cover of any one element should not exceed 100%, but the total cover of multiple elements may be greater than 100%. Observations should reflect those variables that cover the surface of the subplot (e.g., the moss growing on a rock but not that part of the rock under the moss or the litter on top of the soil but not the soil under the litter).

c. Measure and record vascular plant species data

1) Record the presence of vascular plant species by entering the Natural Resource Conservation Service (NRCS)/US Department of Agriculture (USDA) PLANTS database code in the taxonID field for each species. If entering data into a hand-held electric device, enter any part of the scientific name or NRCS code. If no species exist in the nested 1 m2 subplot, click "No plant cover present" on the electronic device or record the same in the taxonIDRemarks field of the first line of the datasheet. Enter species-specific comments in the taxonIDRemarks field.

If an exact determination is impossible, take the following measures:

- Describe uncertainty about the genus or species with the appropriate identification qualifiers and/or detailed notes.

- Group or “lump” taxonomically similar species by entering the accepted NRCS genus code followed by sp/spp (depending on the number of species in each plot) or by entering possible species in the taxonIDRemarks field.
- If a species is not identifiable in the field and the individual does not have parts needed for identification, enter the lowest taxonomic rank that can be determined (e.g., genus or species) followed by the sp. suffix.
- If a species is not identifiable in the field, enter the lowest rank taxon code (e.g., genus), a name to track the species in morphospeciesID, and any comments in the morphospeciesIDRemarks.

2) Estimate the combined cover of all individuals of each species in the nested subplot.

- Only estimate the cover of plants, or portions of plants, with stems that at least partially originate inside the subplot frame.
- Estimate cover to the nearest 1%.
- Enter 0.5 for estimates of cover < 1%.
- Enter the basal area for cover of trees taller than 3 m.
- Plant species will often spatially overlap. Record cover as the total aerial coverage for each species; estimates should not exceed 100% for a single species, but total subplot cover may be greater than 100%.

Make cover estimates more repeatable across observers, plots, and sites with calibration.

• Familiarize yourself with what particular cover estimates (e.g., 1%, 10%, 15%, etc.) look like and use them as reference sizes. For example, if you know that 1% cover is approximately the same size as your fist, use your fist as a reference.

• Each 1 m^2 nested subplot frame is calibrated in 10 cm sections to facilitate cover estimates (Fig. 2).

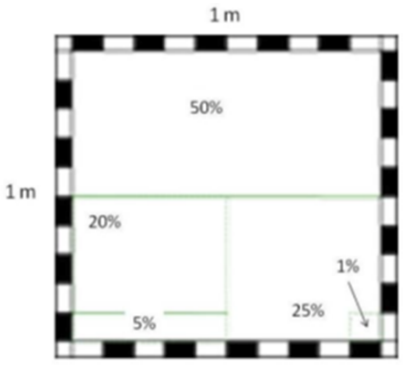

Figure 2. The 1 m^2 subplots are calibrated with black and white marks to make estimates of plant species cover more accurate and repeatable.

• Visually group species together into a percent cover.

• Fine-tune estimates by subtracting out any spaces or gaps.

Delineating a precise plot

7 These plots are permanent. We mark the corners and center with permanent ground anchors. These anchors can be relocated with metal detectors if necessary.
https://www.homedepot.com/b/Hardware-Tie-Down-Straps-Tie-Down-Hardware-Accessories/Ground-Anchor/N-5yc1vZ2fkomlxZ1z1bt09

The insertion depth may need alteration to accommodate sites with tillage.

8 Delineate the perimeters of the plot and subplots by tape measures and subplot frames as follows (Figure 3):

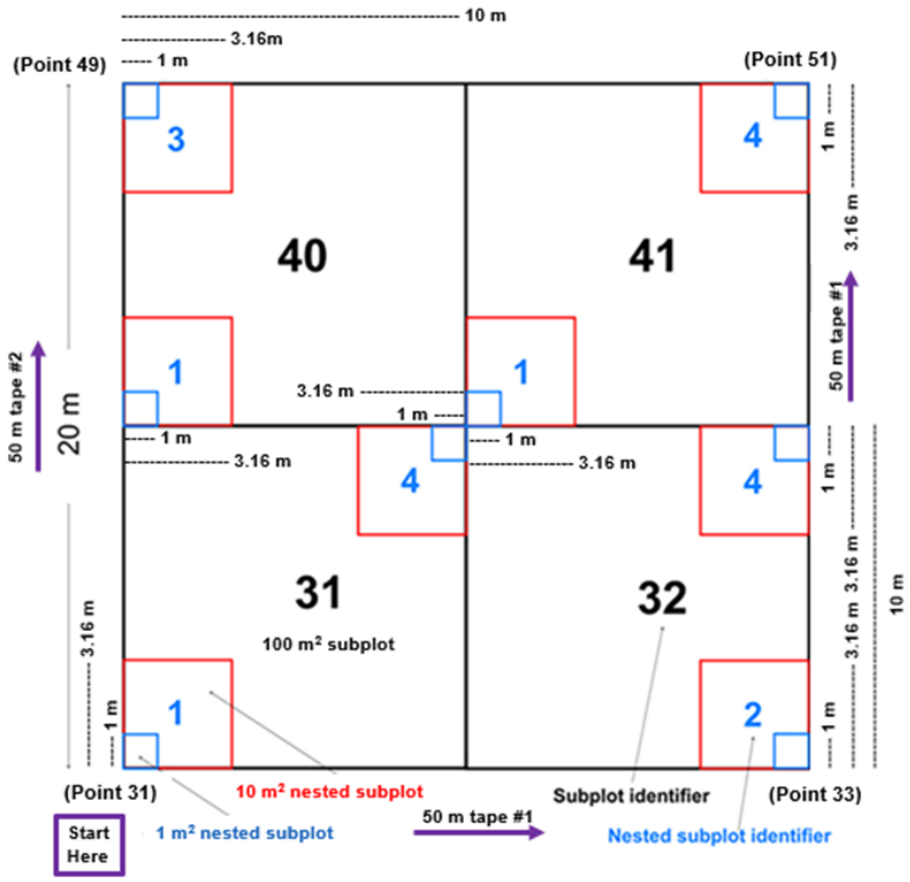

Figure 3. The plot will have permanent markers and require temporary flags placed each time it is measured.

8.1 Record the date and plot number.

Begin in the southwest corner of the plot (point 31). At most sites, this permanent marker will have labels with plot information.

Anchor 50 m of tape and extend it toward the southeast corner (point 33).

8.2 Walk on the south side of the tape to avoid trampling plants inside the 20 × 20 m plot.

8.3 While pulling the tape, insert pin flags into the ground touching the outside edge of the tape at 1 m, 3.16 m, 10 m, 16.84 m, and 19 m.

- Anchor the tape at 20 m at the southeast corner of the plot (point 33) and pull it toward the marker at the northeast corner (point 51) of the plot.

8.4 Walk on the east side of the tape to avoid trampling plants inside the 20 × 20 m plot.

8.5 While pulling the tape, insert pin flags into the ground touching the outside edge of the tape at 21 m, 23.16 m, 30 m, 36.84 m, and 39 m.

- Return to the southwest corner (point 31) of the plot.
- Anchor a second 50 m of tape and extend it toward the northwest corner (point 49).

8.6 Walk on the west side of the tape to avoid trampling plants inside the 20 × 20 m plot.

8.7 While pulling the tape, insert pin flags into the ground touching the outside edge of the tape at 1 m, 3.16 m, 10 m, 16.84 m, and 19 m.

- Anchor the tape at 20 m at the northwest corner (point 49) of the plot and pull it toward the marker at the northeast corner (point 51) of the plot.

8.8 Walk on the north side of the tape to avoid trampling plants inside the 20 × 20 m plot.

8.9 While pulling the tape, insert pin flags into the ground touching the outside edge of the tape at 21 m, 23.16 m, 30 m, 36.84 m, and 39 m.

- Anchor a third piece of tape at the center of the plot (point 41) and extend it south toward the flag at 10 m.

8.10 Insert pin flags into the ground at 1 m and 3.16 m.

- Return to the center and extend the tape east toward the flag at 30 m.

8.11 Insert pin flags into the ground at 1 m and 3.16 m.

- Return to the center and extend the tape north toward the flag at 30 m.

8.12 Insert pin flags into the ground at 1 m and 3.16 m.

- Return to the center and extend the tape west toward the flag at 10 m. Leave the tape in this place to facilitate sampling subplot x.

8.13 Insert pin flags into the ground at 1 m and 3.16 m.

Concurrently sampled covariate metrics

9 Because the effectiveness of floral strips or hedgerows may depend on landscape context, we also recommend assessing the proportional cover of arable crops as a proxy for landscape simplification (e.g., Tscharntke et al., 2005; Dainese et al., 2019). Calculate proportional cover of arable crops in circular sectors of a 1 km radius around focal crops or a 750 m or 500 m radius (Albrecht et al. 2020).

10 Co-locating measurements of productivity, soil health, or other organisms with these Whittaker plots may help enable analyses of relationships between plant diversity and other ecosystem services.

Quality assurance and quality control

11 We recommend using a hand-held electric device (smartphone or tablet) with the ArcGIS Survey123 application installed to collect plant diversity data at each plot. Participating sites will be given access to a specific survey—the LTAR Modified Whittaker survey—to collect these data, which can viewed on a browser. On mobile devices, this survey will be downloadable through the ArcGIS Survey123 app.

> **Note**
>
> To access this survey, you must a) have a USDA ArcGIS Enterprise account and b) be added to the LTAR Modified Whittaker survey group. Contact **datamanager@archbold-station.org** for assistance on methods to obtain access as a USDA or non-USDA user.

12 Before joining the Survey123 group, we will inquire about site-specific information to populate your survey, i.e., plot names, a species list, and additional metrics collected in the field.

13 We created this survey to standardize data collection across sites. Each participating site will follow the same species nomenclature. Variable names and data structures will be identical across sites. Because loading the survey can take time when the species list is long, each site will use a “restricted” species list tallied to their flora. The recorder should add species absent

from this list using the species comment section and later contact the data manager in charge of the project to update the site-specific flora with additional species.

14 Using Survey123 is a good way to minimize mistakes during data collection but does not entirely prevent them. Data collected in the field are automatically saved and uploaded in a spreadsheet, thus avoiding the data entry step and the mistakes that can occur when entering data from a field datasheet into a spreadsheet. However, this feature also means no datasheet is available to double-check the entered data, making mistakes in data entered in the field more difficult to correct.

15 We recommend performing the following checks and quality control steps.

15.1 **Before the survey:**

- Download the LTAR Modified Whittaker survey on the ArcGIS Survey123 app on your device. Because of the large species lists, this download is sizeable, and we recommend doing it over wifi before going to the field.

15.2 **During the survey:**

- Double-check that you have correctly filled out the field name, plot/subplot ID, and recorder name before adding species records. This step is important because such mistakes are uncorrectable. Give the same attention when entering percent cover information for the 1 m^2 plot.
- When recording species, use the photo button in the survey to photograph any species of unsure identification.
- Similarly, use the comment field in the survey to note any discrepancies. Note that the comments will be linked to individual records.

15.3 **After the survey:**

- Log in to survey123.arcgis.com at the end of a field day to view all your records online. Ensure that all plots/subplots sampled are present in the online spreadsheet.
- Check that none of the percent cover data for individual species are above 100 and if so, determine if this is due to a trailing “0”.
- At the end of a field season, if you encountered new species that were not a part of your original species list, pass on this information to your data manager to update the survey.

Calculations

16 Participating sites may decide to do their own calculations of species richness at each spatial scale. However, note the creation of an R markdown script to process the vegetation survey data. This code calculates species richness at each spatial scale across the nested plots. It

also prevents species entered multiple times across the nested plots from being counted multiple times.

Note

The code is available upon request. Please send your request to **datamanager@archbold-station.org**.

Archiving

17 Participating sites should archive their data into a single master file (LTAR will set the standard template) including the raw vegetation data (accumulated over the years) and associated metadata. Metadata should include information on plot locations (GPS coordinates) and associated treatments. Treatments can include pasture management type, vegetation types, stocking rates, crop type, and crop management. More treatment categories can be added as needed.

Recommendations for data collection

18 Table 1. Summary of recommendations for measurement of non-crop plant diversity.

	A	B	C	D
	Attribute	**Preferred**	**Minimum**	**Comments**
	Spatial scale	Field, one prevailing, and one alternative	Field, one prevailing, and one alternative	This plot setup incorporates spatial scale. It will assess plant diversity at 1 m2, 10 m2, 100 m2, and 400 m2 and will generate a species area curve as well as various plant diversity metrics
	Frequency	Sampling will occur during peak flowering periods when plant identification is easiest. These times may be once or twice annually (spring and autumn flowering periods)	Annually during peak flowering periods	If crop rotations occur, sampling frequency will need to be adjusted to capture the changes in plant communities over time

	A	B	C	D
	Proportional cover of arable crops as a proxy for landscape simplification (e.g., Tscharntke et al., 2005; Dainese et al., 2019).	Calculate proportional cover of arable crops in circular sectors of a 1 km radius around focal crops or a 750 m or 500 m radius (Albrecht et al. 2020).		Proportional cover of arable crops only once every five years
	Colocate measurements of soil, nutrient cycling, ANPP, or other organisms with Whittaker plots if possible	Field, one prevailing, and one alternative	Field, one prevailing, and one alternative	Other covariates could be various measurements of ecosystem functions (productivity, pollination, pest control, soil health, etc.)

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