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## 🌐 USDA LTAR Cropland Common Experiment: Standardized primary metric protocols

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## Abstract

A component of the USDA ARS Long-Term Agroecosystem Research (LTAR) network is a Common Experiment standardized across all sites. In this overview protocol we describe the development of standardized protocols for the biophysical metrics collected in the Common Experiment. Throughout this collection, we refer to "metric" as the physical sample that can be quantified and used to inform the status of performance indicators within production, environment, economic, and society domains. We refer to "protocol" as the methods used to collect that metric so that all experimental sites are compatible. This set of protocols were developed for the Cropland Sites although some are also usable for Grazingland and Integrated Common Experiment Sites. This collection allows the LTAR network to ensure research is scalable and robust. All Cropland Common Experiment Sites within the network started following these protocols with the 2024 growing season.

## Attachments



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289KB

## Troubleshooting

## Context

- 1 The Common Experiment was envisioned for more than a decade, was formally introduced in 2018, and is now implemented at all LTAR sites (Robertson et al., 2008; Spiegel et al., 2018). It contrasts prevailing and alternative/aspirational production systems, with the latter including novel innovations hypothesized to advance sustainable intensification in locally appropriate ways. The Common Experiment as it is currently deployed is described by Tsegaye et al. (2024) and Liebig et al. (2024). Readers are encouraged to access these papers for a greater understanding of the LTAR network, Common Experiment, and challenges and opportunities associated with coordinated, cross-site research; together they provide valuable context for the procedural steps outlined below. Additionally, the Common Experiment at each LTAR site ("Site") is described in a series of papers included in the Journal of Environmental Quality Special Section: The USDA LTAR Common Experiment—Research to Support a Sustainable and Resilient Agriculture ([https://access.onlinelibrary.wiley.com/doi/toc/10.1002/\(ISSN\)1537-2537.USDA-LTAR-Common-Experiment](https://access.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1537-2537.USDA-LTAR-Common-Experiment)). The development of metrics and protocols briefly described in Liebig et al., 2024 are further detailed with a workflow provided here.

## Framework

- 2 The LTAR network is focused on working lands across the U.S. which includes croplands, grazing lands, and integrated crop/grazing land management. Researchers internal and external to USDA will advance science more rapidly when standardized metrics and protocols are utilized as much as possible. Standardization of metrics and protocols for field-based research has been documented as an essential component of multi-site research activities (Kladivko et al., 2014).

The metrics and protocols in this collection address research questions associated with agroecosystem efficiencies, sustainability, and tradeoffs (Kleinman et al., 2018). The metrics inform the status of performance indicators across four domains: production, economics, environment, and society (Figure 2 in Liebig et al., 2024; Spiegel et al., 2022). This collection includes protocols that provide measurements under the production and environmental domains. The process of determining metrics for economic and society domains are currently under development.

## Step 1. Identify indicators within production and environmental domains

- 3 The production and environmental domains provide the biophysical constraints for evaluating agroecosystems in the LTAR network (Spiegel et al., 2022). Within these two domains, several indicators exist and serve as the secondary conceptual framework (Table 1). There are six indicators (productivity, water quality, and so forth) which were

determined as the most critical when characterizing productivity and environment domains. The metrics and protocols that are described here are categorized by these six indicators.

Table 1. Disciplinary indicators under each domain.

A	B
<b>Productivity Domain</b>	<b>Environmental Domain</b>
Productivity (encompasses yield, biomass, quality)	Water quality
	Water quantity
	Soil
	Biodiversity and pest
	Greenhouse gas and air quality

## Step 2. Determine which metrics have the highest value

- Each potential metric was discussed and assigned as either primary, secondary, or tertiary (Table 2). A classification schema was necessary as resources are limited and Sites cannot collect every metric due to infrastructure, equipment, labor, financial, expertise, or other constraints.

Table 2. Classification schema for metrics. Primary metrics are those most important for all Common Experiment Sites to implement.

A	B
<b>Metric classification</b>	<b>Attributes</b>
Primary	Very high value. Inclusion of the metric is intended unless significant barriers exist or the metric is not applicable.
Secondary	High value. Inclusion of the metric is strongly encouraged but not essential for all Sites.
Tertiary	Moderate value. Inclusion of the metric is valuable if the Site has the necessary resources or it is particularly important in the region.

Metrics were assessed for their value to science now, expectations for the future, and practicality in carrying them out (Table 3). This approach ensured that any Site not able

to collect a particular metric immediately would be working towards collecting it. Sites vary in their readiness to collect some metrics while others are well-situated to do more. This collection outlines what is needed to best meet the goals of the Common Experiment.

Table 3. Criteria for selecting primary metrics in the LTAR Common Experiment.

A	B
<b>Consideration</b>	<b>Specific questions asked</b>
Evidence-based	Has the metric shown to be robust and valuable in documenting change?
Sensitive to change	How much time is needed to see change in this metric? Is it responsive to the treatments employed or is there a different metric that is more appropriate?
Logistically feasible	Can this metric be collected at most Sites? If not, is there access to other facilities/laboratories to help?
Accurate and precise	Have the results from this metric shown to be repeatable and representative of the true response?
Broadly applicable	Is the metric applicable across plant types, regions, and climates?
Useful for models	Is the metric required as an input in several biophysical or climate models?
Useful for efficiencies	Is the metric necessary to calculate efficiencies such as water use efficiency, nitrogen use efficiency, etc.?
Reasonable cost	What costs exist for processing the sample and could this be prohibitive in collecting it? Are there adjustments to lessen the cost?
Interpretable and valued by multiple stakeholders	Is the metric valuable to stakeholders outside of LTAR such as other scientific communities, farmers, ranchers, policy and actionable science, and general citizens?
Scale	Is the metric relevant at the plot, field, or both scales?
Frequency	What is the preferred frequency of measurement? What would be the minimum frequency?
Reporting	What units are associated with the metric?
Additional considerations based on the discipline	Are there other metrics already established as standards that must be included?

Significant discussion among scientists occurred regarding language and how metrics were termed to ensure each would be properly understood. There were variations in terminology based on the region and the type of plant grown. For example, crop biomass

terminology varies based on the harvested product (e.g., grain, fruit, vegetable, forage), yet all of these represent the exportable product from the field that is economically valued. In this scenario, scientists determined that referring to biomass as either “staying” in the field or “leaving” the field would limit confusion and be most robust across different crop types. Biomass staying in the field represents the plant residue important for soil cover and nutrient cycling (input) while the biomass leaving the field represents the exportable fraction.

Metrics were defined at the finest resolution, each reflecting a unique entry in a spreadsheet. For example, a biomass sample submitted for nutrient analysis of nitrogen, phosphorus, potassium, sulfur, and carbon would have five associated metrics. Accordingly, each metric represents a standalone value in a data set.

### Step 3. Develop protocols for all primary metrics

- There are fewer protocols in this collection than metrics as metrics were grouped when appropriate. By grouping similar metrics, it reduced the number of written protocols and simplified implementation for field and lab personnel. An example of this is provided in Table 4 with a subset of productivity metrics shown in the first column. If the description, frequency, units, and general methodology (not shown in Table 4) were similar, one protocol was written. The process to distill written protocols required two actions of consolidation. Using aboveground biomass as an example, a first grouping was established for biomass staying or leaving the field. The in-field collection, processing, and analyses were similar whether biomass was retained or exported. The second grouping occurred when analytical methods were identical and carried out at the same time for multiple metrics such as the dry combustion method for carbon and nitrogen. Using this example, 12 metrics could be represented by three protocols.

Table 4. Example of a subset of productivity metrics and the consolidation process based on similarities.

A	B	C	D	E	F
Primary Metric	Short Description	Preferred Frequency	Minimum Frequency	Units	Protocol
Aboveground biomass staying in the field	All vegetative above-ground biomass, dry weight. Includes leaves, stem, and	Maximum vegetative biomass and maximum reproductive biomass	Once (1x) at Plant Maturity, Senescence, or Grazing Cycle	kg/ha dry biomass or g/m <sup>2</sup> dry biomass	USDA LTAR Common Experiment measurement: Aboveground biomass
Aboveground biomass leaving the field					

A	B	C	D	E	F
(Yield/Biomass )	non-grain components				
Aboveground biomass (staying): C concentration	Average g Carbon per kg aboveground dry matter	Maximum vegetative biomass and maximum reproductive biomass	Once (1x) at Plant Maturity, Senescence, or Grazing Cycle	g/kg dry biomass	USDA LTAR Common Experiment measurement: Concentration of carbon and nitrogen in aboveground biomass
Aboveground biomass (leaving): C concentration					
Aboveground biomass (staying): N concentration	Average g Nitrogen per kg aboveground dry matter				
Aboveground biomass (leaving): N concentration					
Aboveground biomass (staying): P concentration	Average g Phosphorus per kg aboveground dry matter	Maximum vegetative biomass and maximum reproductive biomass	Once (1x) at Plant Maturity, Senescence, or Grazing Cycle	g/kg dry biomass	USDA LTAR Common Experiment measurement: Concentration of phosphorus, potassium, and sulfur in aboveground biomass
Aboveground biomass (leaving): P concentration					
Aboveground biomass (staying): K concentration	Average g Potassium per kg aboveground dry matter				
Aboveground biomass (leaving): K concentration					
Aboveground biomass (staying): S concentration	Average g Sulfur per kg aboveground dry matter.				
Aboveground biomass (leaving): S concentration					

A protocol template was developed and utilized across all workgroups to help standardize content and format. The template prompted workgroups to document field methodology, sampling size, laboratory procedures, calculations, quality control

practices, required metadata, covariate metrics, and sample archiving. This template is attached to this protocol and also available as Template S1 in Liebig et al., 2024.

Although secondary and tertiary metrics were identified by the disciplinary workgroups, protocols have yet to be developed for them. As the existing protocols are implemented for primary metrics, scientists will assess their suitability and refine as needed as well as publish new protocols. Protocols will be included in this collection as they are published. All protocols have standardized keywords; they are readily found at <https://www.protocols.io> using keywords "LTAR Common Experiment" in the search function.

## Step 4. Review protocols

- Each protocol followed a similar review process as shown in Figure 1. Once the protocol was written initially it moved through seven steps of review and editing before publication.

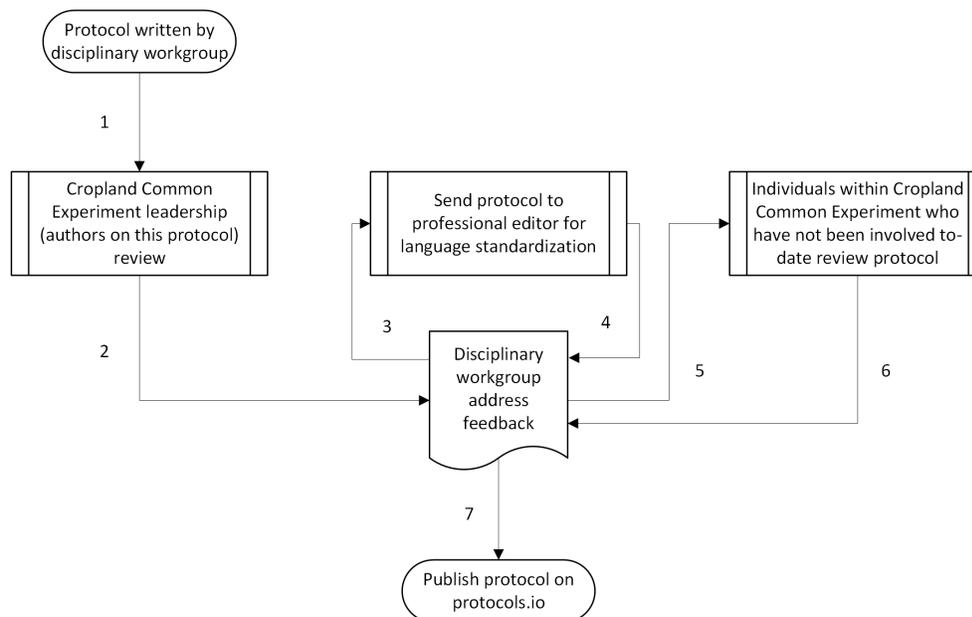


Figure 1. Workflow utilized by the Cropland Common Experiment in writing, reviewing, editing, and publishing the protocols in this collection.

## Step 5. Implement protocols across the LTAR network

- Sites are working to integrate these protocols into their research workflows. Metrics may have been collected in the past following a very similar methodology as outlined in these protocols; this allows historical data to be confidently aligned with current data.

However, other metrics may have been collected following a different methodology not necessarily compatible with these protocols. Some Sites are also determining whether to continue using both old and new methodologies to ensure historical data are not orphaned. Given the long history of many LTAR sites, changes in methodology over time due to technological and scientific advancements are expected. Thus, the task of reconciling different methodologies and determining how to connect historical data with current data is ongoing.

## Step 6. Enter metric data into LTAR data infrastructure

- 8 The standardized metrics and protocols serve as the foundational structure for data entry processes used in the LTAR Common Experiment. These standards align with the network's goal to enhance data consistency, data sharing, and research outcomes across Sites.

The entry templates will be shared in a future version of this collection as they are currently under development. The data entry templates will be in a row-column format with metric codes and units documented for those users wanting to implement the protocols in an exact fashion as the LTAR Common Experiment.

## Protocol references

*Journal of Environmental Quality* Special Section: The USDA LTAR Common Experiment—Research to Support a Sustainable and Resilient Agriculture ([https://access.onlinelibrary.wiley.com/doi/toc/10.1002/\(ISSN\)1537-2537.USDA-LTAR-Common-Experiment](https://access.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1537-2537.USDA-LTAR-Common-Experiment)).

Two papers from the Special Section that are highlighted specifically in this protocol:

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