ESMC
Ecosystem Services Market Consortium

# Biodiversity Estimation for Agriculture Tool (BEAT) Description

## Version 1.2

**Ecosystem Services Market Consortium**
*Prepared with support by TetraTech*

March 2026

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## Acronyms and Abbreviations

| Acronyms/Abbreviations | Definition |
|---|---|
| BEAT | Biodiversity Estimation for Agriculture Tool |
| BMP | best management practice (also referred to as practice changes) |
| CDL | Cropland Data Layer |
| CRS | coordinate reference system |
| ESMC | Ecosystem Services Market Consortium |
| EVT | Existing Vegetation Type |
| GBIF | Global Biodiversity Information Facility |
| GHG | Greenhouse Gas |
| HUC | Hydrologic Unit Code |
| MRV | Measurement, Monitoring, Reporting, and Verification platform |
| NASS | National Agricultural Statistics Survey |
| NLCD | National Land Cover Dataset |
| NRCS | Natural Resource Conservation Service |
| PAD-US | Protected Areas Database of the United States |
| RAP | Rangeland Analysis Platform |
| UK DEFRA | United Kingdom Department for Environment, Food, and Rural Affairs |
| US | United States |
| USCB | United States Census Bureau |
| USDA | United States Department of Agriculture |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |

# 1. Executive Summary

This document provides a brief overview of ESMC's Biodiversity Estimation for Agriculture Tool (BEAT), which will serve as a new component of the EcoHarvest Measurement, Monitoring, Reporting, and Verification (MRV) platform. Inspired by the United Kingdom Department for Environment, Food, and Rural Affairs (UK DEFRA) Biodiversity Metric, the BEAT is designed to quantify biodiversity using five core terms: habitat quality, weighted functional presence, conservation priority, habitat size, and time response. Together, these terms capture ecological function, conservation context, and temporal dynamics, providing a structured framework for assessing biodiversity benefits associated with agricultural best management practices (BMPs). Descriptions of each term and a visual schematic is provided in **Section 2.2**, particularly **Table 1**. This first version (v1) of the BEAT will incorporate only estimated methods, which draw on publicly available datasets. It does not incorporate in-situ methods such as biodiversity and environmental measurements collected by a professional wildlife biologist or environmental scientist. Future versions may incorporate both such that the dual approach balances site-specific accuracy with scalability across ESMC's diverse geographic footprint (ESMC, 2025b).

This document summarizes important aspects of the BEAT including: (1) required inputs, (2) external datasets used, (3) outputs, and (4) other considerations covered in the technical documentation on GitHub. This document provides a high-level, non-technical summary of BEAT.

**Section 2.0** provides information on the motivation for the development of the BEAT. Input data requirements are described in **Sections 3.1-3.2**, external datasets are described in **Section 3.3**, and outputs are described in **Section 3.4**.

# 2. Background

## 2.1 Overall Goals of the Biodiversity Estimation for Agriculture Tool

ESMC is expanding its EcoHarvest MRV framework to include biodiversity outcomes alongside carbon and water quality credits. This work builds on ESMC's assessment of biodiversity quantification methods, which identified the United Kingdom Department for Environment, Food and Rural Affairs (UK DEFRA) Biodiversity Metric as the strongest candidate for adaptation to North American agricultural systems (ESMC, 2025a). In 2023, ESMC tested a modified version of this metric in Kansas with Pheasants Forever and Quail Forever. The resulting Kansas Biodiversity Estimation for Agriculture Tool (BEAT version 1.1) provided useful insight into how pollinator strips and other edge-of-field practices could be credited, but its

reliance on in-situ monitoring and narrow BMP scope highlighted the need for a more flexible and scalable framework that could be applied to multiple agricultural systems and BMP types.

To address this need, ESMC developed the BEAT (version 1.2 released March 2026 – this report), which will serve as a new component of the EcoHarvest MRV platform. The BEAT is designed to quantify biodiversity using five core terms: habitat quality, weighted functional presence, conservation priority, habitat size, and time response. Together, these terms capture ecological function, conservation context, and temporal dynamics, providing a structured framework for assessing biodiversity benefits associated with agricultural BMPs. The ESMC BEAT is among the first scientifically structured frameworks designed to quantify biodiversity outcomes within working agricultural systems at scale. Built on established public datasets and standardized estimation methods, it provides a rigorous and scalable approach across ESMC's diverse geographic footprint. The current release reflects this robust design, with future iterations potentially incorporating targeted in-situ field measurements, where strategically relevant, to complement and refine the existing methodology (ESMC, 2025b).

This report describes the structure, assumptions, and quantification methodologies underpinning the BEAT as of March 2026. It defines key terms, outlines required datasets and inputs and summarizes the core equations embedded within the Python-based implementation. As additional empirical data become available and methodological advancements occur, the BEAT may be further expanded to incorporate broader BMP coverage, additional organism groups, and evolving biodiversity accounting standards. This adaptive design ensures that biodiversity outcomes credited through the EcoHarvest MRV remain scientifically rigorous, transparent, and aligned with both producer realities and corporate sustainability goals (ESMC, 2025b).

## 2.2 Description of ESMC's BEAT

The ESMC BEAT is designed to quantify the biodiversity benefits of different BMPs using a set of core variables that can be universally applied. Each variable captures a distinct aspect of ecological function, conservation value, or temporal dynamics, allowing for a comprehensive and scalable measure of biodiversity outcomes (**Figure 1** and **Table 1**). The variables are defined as follows:

- **Habitat quality (q)**: an assessment of the ability of a site to support biodiversity along a continuum from one that does not support biodiversity to one that provides optimal support of biodiversity, which may vary by BMP
- **Weighted functional presence (o)**: a modeled measure of the presence of selected organism functional groups, weighted according to the ecological importance of their functional traits within the agricultural system

- **Conservation priority (c)**: an assessment of the proximity, degree of importance, and landscape position of a producer's edge-of-field or in-field BMP to protected lands as well as the connectivity between landscapes
- **Habitat size (s)**: a measure of the amount of land undergoing biodiversity enhancement
- **Time response (t)**: account for the time lag between BMP implementation and biodiversity outcomes as well as the potential benefit a BMP will have on biodiversity once it is implemented over a prolonged period of time

***Figure 1.*** *Schematic visualizing the 5 different terms included in the ESMC BEAT proposed in this report.*

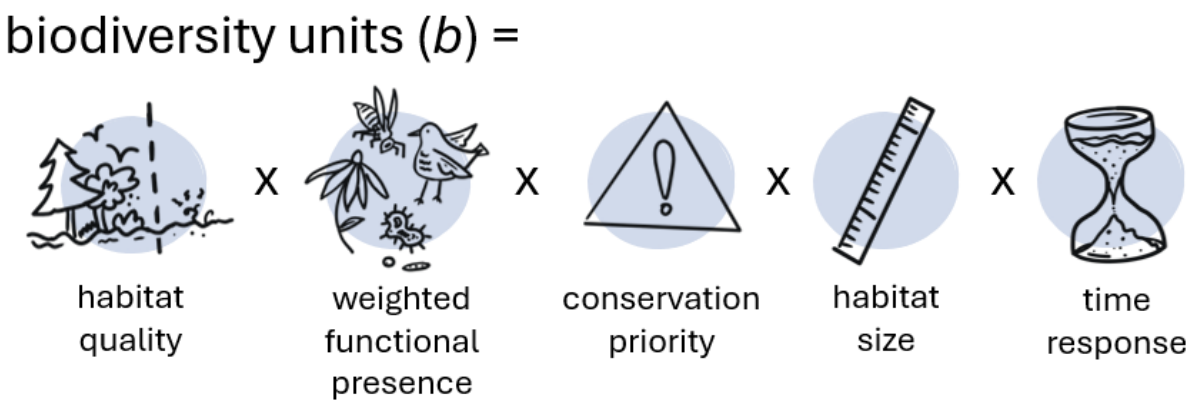


***Table 1****. Summary description of BEAT terms.*

| Proposed Term | Description | Varies by organism | Varies by BMP | Varies over time | Varies by method* |
|---|---|---|---|---|---|
| Habitat quality (q) | The goal of this term is to assess the ability of a site to support biodiversity along a continuum from one that does not support biodiversity to one that provides optimal support of biodiversity, which may vary by BMP. | No | Yes | Yes | Yes |
| Weighted functional presence (o) | A modeled measure of the presence of selected organism functional groups, weighted according to the ecological importance of their functional traits within the agricultural system. | Yes | Yes | Yes, except for soil organisms | Yes |
| Conservation priority (c) | The goal of this term is to assess the proximity and degree of importance of a producer's edge-of-field or in-field BMP to protected lands. | No | No | No, unless reference site priorities shift | No |
| Habitat size (s) | The goal of this term is to provide a measure of the amount of land undergoing biodiversity enhancement. | No | Yes | No, unless the producer adds/removes land | No |
| Time response (t) | The goal of this term is to account for the time lag between BMP implementation and biodiversity outcomes as well as the potential benefit a BMP will have on biodiversity once it is implemented over a prolonged period of time. | Yes | Yes | Yes | No |

** Method here refers to the estimated or in-situ approaches. Version 1 of the BEAT (this report) only focuses on the estimated method. Future versions will further refine the in-situ approach once more field data becomes available for ESMC program fields.*

## 2.3 Software Architecture

Overall, the BEAT has a structure similar to ESMC's Pollutant Load Estimation Tool (PLET) module, so it is compatible with both the EcoHarvest MRV and ESMC's procedure for generating water impacts. Specifically, the BEAT is written in Python using the Flask web application framework and relies on lookup tables and publicly available datasets housed within the module. Version 1 of the BEAT requires one input file; the user (i.e., producer) input geojson file provided through the EcoHarvest MRV. This file includes information about the fields of interest, associated geospatial data, and the practice changes being implemented on them. The BEAT takes this input file, runs some calculations internally, and returns a geojson output with all relevant biodiversity quantification attribute information appended to the original geojson input. The BEAT code and documentation are stored in an ESMC-hosted GitHub repository. The overall structure of the BEAT is described in **Figure 2** and in subsequent sections. The EcoHarvest MRV server is a containerized Python application (i.e., using the Flask-based application framework).

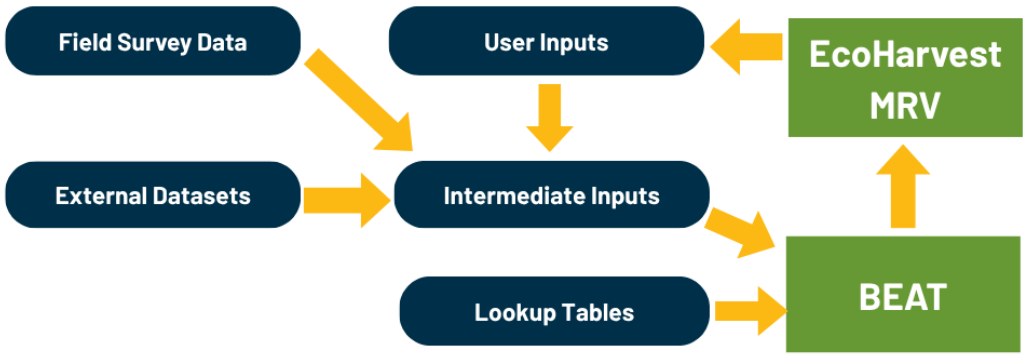


***Figure 2.*** *Schematic visualizing the overall information flow of ESMC's BEAT.*

# 3. BEAT Inputs and Outputs

## 3.1 Estimated and In-situ Methods

The BEAT will eventually support two methods for calculating biodiversity units: an estimated method and an in-situ method. This dual approach aims to balance accuracy with scalability. The estimated method will draw on publicly available datasets to automate and scale biodiversity assessments across larger agricultural regions with ESMC programming. The in-situ method will rely on direct field-based assessments, including habitat condition surveys

conducted by trained ecologists and field biologists over the course of the project duration. This method allows for detailed and site-specific biodiversity quantification, ensuring high accuracy and assessment of BMP effectiveness.

**It should be noted that the in-situ method is not incorporated in version 1 of the BEAT (this report**). However, as more ESMC program field data becomes available across the US for a variety of BMPs, future BEAT development efforts may look to build out this functionality. Specifically, in-situ measurements will help support the quantification and reporting of uncertainty associated with each term. As such, the ESMC BEAT represents a foundational framework that will evolve over time. Subsequent versions of the BEAT will be even more robust and aligned with ESMC's ecological and operational objectives. This iterative approach ensures the metric remains scientifically defensible, responsive to ESMC/producer/corporation needs, and compatible with both current and emerging Scope 3 greenhouse gas (GHG) and biodiversity accounting frameworks and guidance.

## 3.2 Required Inputs (from the User)

As shown in **Figure 2**, user inputs come from the EcoHarvest MRV as users (i.e., producers) add fields and practice changes to this platform. Specific inputs of interest for the BEAT include the location and size of operations (i.e., cropland or pastureland fields) for both in-field and edge-of-field areas, and practice change information. Upon entering the previously mentioned inputs, data is stored in the EcoHarvest MRV database in a json and geojson format.

This is especially true for the provided BMP names, which are described in **Table 2**. At this time, biodiversity units can only be calculated for BMPs listed in **Table 2**; however, future versions of the BEAT may expand the number and types of BMPs offered.

***Table 2**. Description of best management practices (BMP, "bmp_name") values included in the BEAT.*

| Land use (i.e., user_lu) | "bmp_name" Value | BMP Full Name | Position | Description |
|---|---|---|---|---|
| cropland | cov_crop_1 | Cover crop 1 | In field | Represents a standard winter cover crop scenario with typical planting timing and average erosion and nutrient reduction benefits. Used as a conservative, location-agnostic representation of detected winter vegetation. |
| cropland | cov_crop_2 | Cover crop 2 | In field | Planting multiple (i.e., more than 1) species of non-cash crops during or between growing seasons to improve soil health, reduce erosion, and enhance nutrient cycling. |
| cropland | cons_till_1 | Conservation tillage 1 | In field | Conservation tillage, where 30-59% of crop residue is left on the field. Represents a moderate conservation tillage system with reduced soil disturbance and partial residue retention relative to conventional tillage. Used to represent all reduced-tillage fields without distinguishing residue levels. |

| Land use (i.e., user_lu) | "bmp_name" Value | BMP Full Name | Position | Description |
|---|---|---|---|---|
| cropland | cons_till_2 | Conservation tillage 2 | In field | Conservation tillage, where >= 60% of crop residue is left on the field. Represents the lowest-disturbance, highest-residue conservation tillage scenario in PLET module. Used to model no-till fields without introducing a separate BMP level. |
| cropland | nutrient_mgmt_1 | Nutrient management 1 | In field | The strategic application of fertilizers to optimize crop uptake and minimize nutrient losses to the environment. This instance specifically refers to determined fertilize rate management. Represents baseline nutrient management with manure treated as a nutrient source. Manure amendment is not credited as a standalone BMP; impacts are captured through standard nutrient management assumptions. May also represent optimized, but standard nutrient management without enhanced timing or stabilization. Used when nutrient efficiency is evaluated without advanced practices. |
| cropland | nutrient_mgmt_2 | Nutrient management 2 | In field | The strategic application of fertilizers to optimize crop uptake and minimize nutrient losses to the environment. This instance specifically refers to determined fertilize rate management plus additional nutrient management considerations. Represents enhanced nutrient management with improved timing and application strategy. Used as a single advanced nutrient management scenario. May also represent enhanced nutrient management incorporating stabilized or slow-release nitrogen products. Effectiveness is modeled through improved nutrient retention and reduced losses. |
| cropland | intercrop | Intercropping | In field | Growing two or more crop species in proximity to enhance biodiversity, suppress pests, and optimize resource use. |
| pastureland | rot_graze | Rotational grazing | In field | Managing livestock movement through pastures typically using fences. Animals are moved in a planned sequence to prevent overgrazing, promote forage regrowth, and improve soil quality. |
| cropland | pollinator_strip | Pollinator strip | Edge-of-field | Planting native flowering vegetation along field margins to provide habitat for pollinators. These may also be referred to in the scientific literature as prairie strips or wildflower strips. |
| cropland | riparian_buf | Riparian buffer | Edge-of-field | A strip of vegetation, which may include trees, grasses, and shrubs, planted along the edge of a waterway. Typically located in the transition zone between an agricultural field and a waterway. Promotes pollutant filtration, sediment transport reduction, provides habitat, and stabilizes the stream bank. These may also be referred to in scientific literature as vegetated buffers. |
| pastureland | riparian_buf | Riparian buffer | Edge-of-field | A strip of vegetation, which may include trees, grasses, and shrubs, planted along the edge of a waterway. Typically located in the transition zone between an agricultural field and a waterway. Promotes pollutant filtration, sediment transport reduction, provides habitat, and stabilizes the stream bank. These may also be referred to in scientific literature as vegetated buffers. |
| pastureland | pollinator_strip | Pollinator strip | Edge-of-field | Planting native flowering vegetation along field margins to provide habitat for pollinators. These may also be referred to in scientific literature as prairie strips or wildflower strips. |

## 3.3 External Datasets

The BEAT leverages a number of external, publicly available datasets, which are described in **Table 3**. By focusing on publicly available datasets, ESMC can minimize data development and management costs, benefit from existing data aggregation efforts, and enhance reproducible biodiversity quantification approaches (i.e., because datasets are open-source). The BEAT also requires numerous lookup tables that connect the numerical datasets with the biodiversity function and decisions, listed in **Table 4**.

***Table 3.*** *Description of external datasets to be included in the BEAT.*

| Dataset Name | Description | Reference | Currently on ESMC Servers |
|---|---|---|---|
| Annual National Land Cover Dataset (NLCD) | Gridded (30-m resolution) dataset classifying land cover types across the contiguous United States. Updated annually by the USGS and widely used for ecological and land management applications. | USGS (2025) | No |
| Cropland Data Layer (CDL) | Gridded (30-m resolution) crop type data for the United States provided by the USDA National Agricultural Statistics Survey (NASS). Derived from satellite imagery. | USDA NASS (2025) | Yes |
| Eco-regions | Vectorized data developed by the United States Environmental Protection Agency to categorize unique habitats across the US based on a combination of environmental factors (geography, geology, soils, vegetation, climate, etc.). | USEPA (2013) | Yes |
| TIGER County Bounds | Vectorized administrative boundaries for all US counties, used for spatial referencing and regional analyses. | USCB (2023) | Yes |
| Global Biodiversity Information Facility (GBIF) Species Occurrence Data | Global repository of species occurrence and abundance data contributed by museums, research institutions, and citizen science programs. | GBIF (2025) | No |
| Protected Areas of the US Database (PAD-US) | National inventory of protected lands in the United States, including federal, state, and local conservation areas. Used to assess conservation priorities and landscape connectivity. | USGS (2024), GreenInfo Network (2026) | No |
| Global Microbial Mass (Carbon and Nitrogen) | Estimated global biomass carbon and nitrogen based on a comprehensive survey of publications from the 1970s to 2012. | Xu et al. (2014) | No |

***Table 4.*** *Description of lookup tables used in the BEAT. Created by both ESMC and Tetra Tech.*

| File Name | Description | Relevant Variable |
|---|---|---|
| birds_e_lookup.csv | List of unique GBIF bird species with their corresponding primary guild and “e” value assignment. | o |
| insects_e_lookup.csv | List of unique GBIF insect species with their corresponding primary guild and “e” value assignment. | o |
| plants_e_lookup.csv | List of unique GBIF plant species with their corresponding primary guild and “e” value assignment. | o |
| microbes_e_lookup.csv | List of unique microbial primary guilds and their assigned “e” values. | o |
| bmp_names_lookup.csv | List of input BMP names with their corresponding location value of in-field or edge-of-field. | s |

| File Name | Description | Relevant Variable |
|---|---|---|
| n_fixers_lookup.csv | List of BMP names, location values, and binary logic of whether nitrogen fixers are assumed to be present (0/1). | o |
| q_val_lookup.csv | Different NLCD and CDL class codes and their habitat quality (q) values for each BMP type. | q |
| q_val_add_lookup.csv | List of assumed added habitat quality for practice years based on the user land use, BMP name, and location. | q |
| time_res_lookup.csv | List of recovery rates, number of years required for certain species to reach 50% of the maximum time-response benefit, and overall speed for each land use, BMP name, and location. | t |
| w_val_lookup.csv | Lookup table of the w value for each target species for each land use, BMP name, and location. | o |
| width_lookup.csv | Binary value of whether a combination of land use, BMP name, and location requires a width component in the habitat size variable. | s |

## 3.4 Outputs

When running the BEAT, users are provided with a zip file with three outputs to the output location they have indicated in the flask_test.py script. The output geojson file appends all BEAT calculations to the original geojson input file that was provided to the BEAT. This appended information includes associated BEAT lookup table information, environmental metadata (e.g., county and ecoregion information), intermediate calculations, and final BEAT results (i.e., biodiversity units). Version 1 of the BEAT (this report) calculates estimated biodiversity units for all fields. For future versions of the BEAT, when in-situ data are available, these field collected data will be prioritized over estimated approaches. **Table 4** includes a description of each column to be included in BEAT output file. The output file is provided as a geojson file as well as a CSV file.

***Table 5.*** *Description of columns to be included in the BEAT output (biodiv_result.csv)*

| Do d | Description | Units |
|---|---|---|
| id | Unique field identifier (i.e., “14f279d3a-fds-542-9a9kc-144e35741f64l”) | - |
| user_lu | User-defined land use for the field | - |
| geometry | Field or edge-of-field geometry (spatial data object), which must have a coordinate reference system (crs) geospatial ESPG code equal to 4326. | - |
| esmc_program | ESMC program name | - |
| base_year | Baseline year (e.g., 2023) | year |
| eval_year | Evaluation year (e.g., 2024 on) | year |
| area_ac | Area of BMP | ac |
| width_m | Estimated BMP width | m |
| fips | Federal Information Processing Standards code for the county where the BMP is located | - |
| state | Full name of the state (e.g, Illinois) | - |
| state_abbrev | State abbreviation (e.g., IL) | - |
| county | County name (e.g., McLean) | - |

| Do d | Description | Units |
|---|---|---|
| eco_lev3_code | Level III Ecoregion code | - |
| eco_lev3_name | Level III Ecoregion name | - |
| eco_lev2_name | Level II Ecoregion name | - |
| eco_lev1_name | Level I Ecoregion name | - |
| near_padus_id | Nearest PAD-US ID to farm location | - |
| near_padus_dist_m | Distance from nearest PAD-US site to farm location | m |
| near_padus_gap | GAP status indicating conservation management of the nearest PAD-US site | - |
| near_padus_wincheck | Logical check whether the field centroid is within a PAD-US polygon (if true, then near_padus_dist_m should = 0) | - |
| bmp_position | BMP location (in-field or edge-of-field) | - |
| plants_w_value | Corresponding “w” plant value for that BMP and type and location | - |
| insects_w_value | Corresponding “w” insects value for that BMP and type and location | - |
| birds_w_value | Corresponding “w” birds value for that BMP and type and location | - |
| soil_microbes_w_value | Corresponding “w” microbes value for that BMP and type and location | - |
| width_logic | Binary notation if width is relevant to the s term calculation (size) | - |
| plants_rr_value | Plant recovery-rate parameter | - |
| insects_rr_value | Insect recovery-rate parameter | - |
| birds_rr_value | Bird recovery-rate parameter | - |
| soil_microbes_rr_value | Soil microbe recovery-rate parameter | - |
| plants_y50_value | Number of years required for plants to reach 50% of the maximum time-response benefit | years |
| insects_y50_value | Number of years required for insects to reach 50% of the maximum time-response benefit | years |
| birds_y50_value | Number of years required for birds to reach 50% of maximum time-response benefit | years |
| soil_microbes_y50_value | Number of years required for soil microbes to reach 50% of the maximum time-response benefit | years |
| plants_rec_speed | Recovery rate parameter for plant time-response curves | - |
| insects_rec_speed | Recovery rate parameter for insect time-response curves | - |
| birds_rec_speed | Recovery rate parameter for bird time-response curves | - |
| soil_microbes_rec_speed | Recovery rate parameter for soil microbe time-response curves | - |
| n_fixers_logic | Logical value noting whether the associated BMP will be given credit for nitrogen fixers in the o term | - |
| q_value_add | Amount to be added to the q value term for a particular baseline BMP q value under practice change conditions | - |
| nlcd_b_q_mean | Mean baseline habitat quality score derived from NLCD land cover | - |
| nlcd_p_q_mean | Mean practice-change habitat quality score derived from NLCD land cover | - |
| cdl_b_q_mean | Mean baseline habitat quality score derived from CDL land cover | - |

| Do d | Description | Units |
|---|---|---|
| cdl_p_q_mean | Mean practice-change habitat quality score derived from CDL land cover | - |
| birds_guilds_field_b | Number of bird functional guilds present under baseline field conditions | count |
| birds_guilds_field_p | Number of bird functional guilds present under practice change field conditions | count |
| insects_guilds_field_b | Number of insect functional guilds present under baseline field conditions | count |
| insects_guilds_field_p | Number of insect functional guilds present under practice change field conditions | count |
| plants_guilds_field_b | Number of plant functional guilds present under baseline field conditions | count |
| plants_guilds_field_p | Number of plant functional guilds present under practice change field conditions | count |
| birds_guilds_padus_b | Number of bird functional guilds present in PAD-US reference area under baseline conditions | count |
| birds_guilds_padus_p | Number of bird functional guilds present in PAD-US reference area under practice change conditions | count |
| insects_guilds_padus_b | Number of insect functional guilds present in PADUS reference area under baseline conditions | count |
| insects_guilds_padus_p | Number of insect functional guilds present in PADUS reference area under practice change conditions | count |
| plants_guilds_padus_b | Number of plant functional guilds present in PADUS reference area under baseline conditions | count |
| plants_guilds_padus_p | Number of plant functional guilds present in PADUS reference area under practice change conditions | count |
| birds_b_r | Baseline bird functional role ratio used in weighted functional presence | - |
| birds_p_r | Practice change bird functional role ratio used in weighted functional presence | - |
| insects_b_r | Baseline insect functional role ratio used in weighted functional presence | - |
| insects_p_r | Practice change insect functional role ratio used in weighted functional presence | - |
| plants_b_r | Baseline plant functional role ratio used in weighted functional presence | - |
| plants_p_r | Practice change plant functional role ratio used in weighted functional presence | - |
| birds_guilds_count | Total number of bird functional guilds supported | count |
| birds_b_ej | Baseline functional role support term for birds | - |
| birds_p_ej | Practice change functional role support term for birds | - |
| insects_guilds_count | Total number of insect functional guilds supported. | count |
| insects_b_ej | Baseline functional role support term for insects | - |
| insects_p_ej | Practice change functional role support term for insects | -- |
| plants_guilds_count | Total number of plant functional guilds supported. | count |
| plants_b_ej | Baseline functional role support term for plants | - |
| plants_p_ej | Practice change functional role support term for plants | - |
| SMC30cm_mean | Mean soil microbial biomass as carbon in the field | mg/kg |
| SMN30cm_mean | Mean soil microbial biomass as nitrogen in the field | mg/kg |

| Do d | Description | Units |
|---|---|---|
| SMC30cm_mean_padus | Mean soil microbial biomass as carbon in the nearest PAD-US site | mg/kg |
| SMN30cm_mean_padus | Mean soil microbial biomass as nitrogen in the nearest PAD-US site | mg/kg |
| microbes_mean_field | Average of carbon and nitrogen biomass in the field | mg/kg |
| microbes_mean_padus | Average of carbon and nitrogen biomass in the nearest PADUS site | mg/kg |
| microbes_default | Soil microbe functional group default score | - |
| microbes_r_e | Soil microbe functional role ratio (r) and e terms based on and the default functional group score biomass in the field to biomass in the nearest PAD-US site | - |
| birds_b_o | Baseline weighted functional presence term for birds | - |
| insects_b_o | Baseline weighted functional presence term for insects | - |
| plants_b_o | Baseline weighted functional presence term for plants | - |
| soil_microbes_b_o | Baseline weighted functional presence term for soil microbes | - |
| birds_p_o | Practice-change weighted functional presence term for birds | - |
| insects_p_o | Practice-change weighted functional presence term for insects | - |
| plants_p_o | Practice-change weighted functional presence term for plants | - |
| soil_microbes_p_o | Practice-change weighted functional presence term for soil microbes | - |
| o_b_value | Total baseline weighted functional presence term (summed across organism groups) | - |
| o_p_value | Total practice-change weighted functional presence term (summed across organism groups) | - |
| c_value | Conservation priority term value based on proximity to protected lands | - |
| s_value | Habitat size term value based on BMP area and width logic | - |
| t_b_value | Baseline time response term value | - |
| t_p_value | Practice-change time response term value | - |
| bu_b | Baseline biodiversity units for the BMP | - |
| bu_p | Practice-change biodiversity units for the BMP | - |
| tot_area_ac | Total area of all BMPs applied to the field | ac |
| area_frac | Fractional area weight of the BMP relative to total BMP area on the field | - |
| bu_b_wtd | Area-weighted baseline biodiversity units | - |
| bu_p_wtd | Area-weighted practice-change biodiversity units | - |
| bu_diff | Difference between area-weighted practice-change and area-weighted baseline biodiversity units | - |
| bu_b_all_bmps | Total baseline biodiversity units weight summed across all BMPs on the field | - |
| bu_p_all_bmps | Total practice-change biodiversity units weight summed across all BMPs on the field | - |

***Table 6.*** *Description of files included in the BEAT zipped folder output (.zip).*

| Number | File Name | Description |
|---|---|---|
| 1 | biodiv_log.txt | Log file providing a summary of the BEAT run. This document includes notes on various checks that are completed during a BEAT run as well as error message, if any issues arise. This is an important file for debugging issues with the BEAT. |
| 2 | biodiv_result.geojson | BEAT result file as a geojson (see **Table 4** for a description of columns) |
| 3 | bioiv_result.csv | BEAT result file as a csv (see **Table 4** for a description of columns). **Note: This output file does not have a 'geometry' column.** |
| 4 | biodiv_summary_result.csv | BEAT results summarized by field id. Values are summarized using an area-weighted average when fields have more than one BMP. |

***Table 7.*** *Description of columns to be included in the BEAT output (biodiv_summary_result.csv)*

| Output Column | Description | Units | Data Type Format |
|---|---|---|---|
| id | Unique field identifier (i.e., "14f279d3a-fds-542-9a9kc-144e35741f64l") | - | string |
| user_lu | User-defined land use for the field | - | string (possible values: "cropland" or "pastureland") |
| esmc_program | ESMC program name | - | string |
| base_year | Baseline year (e.g., 2023) | year | integer |
| eval_year | Practice change year (e.g., 2024) | year | integer |
| state_abbrev | State abbreviation (e.g., IL) | - | string |
| bu_b_all_bmps | Total baseline biodiversity units weight summed across all BMPs on the field | - | float |
| bu_p_all_bmps | Total practice-change biodiversity units weight summed across all BMPs on the field | - | float |
| bu_b_all_bmps | Total baseline biodiversity units weight summed across all BMPs on the field | - | float |

# 4. References Cited


Ecosystem Services Market Consortium (ESMC). (2025a). *Biodiversity Pilot Project Case Study Report*. Prepared in collaboration with Tetra Tech. 15 p.

Ecosystem Services Market Consortium (ESMC). (2025b). *Biodiversity Module Refinement Report - DRAFT*. Prepared in collaboration with Tetra Tech. 28 p.

Global Biodiversity Information Facility (GBIF). (2025). Species Search. https://www.gbif.org/species/search. Accessed 25 September 2025.

GreenInfo Network. (2026). *Protectedlands.net – How to Use PAD-US*. https://www.protectedlands.net/uses-of-pad-us/. Accessed 15 January 2026.

Janssen, P. (2025). The "guild" concept in riparian ecology: Use, limitations and prospects for improving the reproducibility and transferability of results. *Ecological Indicators*, 171:113152.

Multi-Resolution Land Characteristics (MRLC). (2024). *National Land Cover Dataset (NLCD), CONUS All Years*. Available online: https://www.mrlc.gov/data/nlcd-land-cover-conus-all-years.

Schipper, A. M., Hilbers, J. P., Meijer, J. R., Antão, L. H., Benítez-López, A., et al. (2019). Projecting terrestrial biodiversity intactness with GLOBIO 4. Global Change Biology, 26, 760–771. https://doi.org/10.1111/gcb.14848

United States Department of Agriculture National Agriculture and Statistics Survey (USDA NASS). (2025). *Cropland Data Layer – National Download*. https://www.nass.usda.gov/Research_and_Science/Cropland/Release/index.php. Accessed: 23 May 2024.

United States Census Bureau (USCB). (2023). TIGER State Line Boundaries. https://www.census.gov/cgi-bin/geo/shapefiles/index.php. Accessed 3 July 2024.

United States Environmental Protection Agency (USEPA). (2013). Level III and IV Ecoregions of the Conterminous United States. https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states. Accessed 3 July 2024.

United States Geological Survey (USGS). (2025). *Annual Land Cover Database*. https://www.usgs.gov/centers/eros/science/annual-national-land-cover-database. Accessed 10 July 2025.

United States Geological Survey (USGS). (2024). *Protected Areas Database of the United States (PAD-US) v4*. https://www.sciencebase.gov/catalog/item/65294599d34e44db0e2ed7cf. Accessed 20 July 2025.

Xu, X., Thornton, P. E., & Potapov, V. (2014). *A Compilation of Global Soil Microbial Biomass Carbon, Nitrogen, and Phosphorus Data (Version 1)*. ORNL Distributed Active Archive Center. https://doi.org/10.3334/ORNLDAAC/1264. Accessed 6 February 2026.