NEON USER GUIDE TO LITTER CHEMICAL PROPERTIES (NEON.DP1.10031) AND LITTER STABLE ISOTOPES (NEON.DP1.10101)

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1 DESCRIPTION

1.1 Purpose

This document provides an overview of the data included in this NEON Level 1 data product, the quality controlled product generated from raw Level 0 data, and associated metadata. In the NEON data products framework, the raw data collected in the field - for example, the dry weights of litter functional groups from a single collection event, are considered the lowest level (Level 0). Raw data that have been quality checked via the steps detailed herein, as well as simple metrics that emerge from the raw data, are considered Level 1 data products.

The text herein provides a discussion of measurement theory and implementation, data product provenance, quality assurance and control methods used, and approximations and/or assumptions made during L1 data creation.

1.2 Scope

This document describes the steps needed to generate the following L1 data products: Litter chemical properties (NEON.DP1.10031), the carbon (C), nitrogen (N), and lignin concentrations in litterfall biomass, and Litter stable isotopes (NEON.DP1.10101), the C and N stable isotope values in litterfall biomass. This document also provides details relevant to the publication of the data products via the NEON data portal, with additional detail available in the files NEON Data Variables for Litter chemical properties (NEON.DP1.10031) (AD[06]) and NEON Data Variables for Litter stable isotopes (NEON.DP1.10101) (AD[07]), provided in the download package for this data product.

This document describes the process for ingesting and performing automated quality assurance and control procedures on C, N, and lignin concentration and stable isotope data measured in NEON litterfall samples. How the Level 0 data are processed is detailed in the files NEON Raw Data Validation for Carbon and nitrogen concentrations and stable isotopes in plants and soil (NEON.DP0.10103) (AD[04]) and NEON Raw Data Validation for Plant lignin concentrations (NEON.DP0.10031) (AD[05]), provided in the download package for this data product. Please note that raw data products (denoted by 'DP0') do not always have the same numbers (e.g., '10033') as the corresponding L1 data product.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Associated Documents

AD[01]	NEON.DOC.000001	NEON Observatory Design (NOD) Requirements
AD[02]	NEON.DOC.000913	TOS Science Design for Spatial Sampling
AD[03]	NEON.DOC.002652	NEON Level 1, Level 2 and Level 3 Data Products Catalog
AD[04]	NEON.DP0.10103.001 _dataValidation.csv	NEON Raw Data Validation for Carbon and nitrogen concentrations and stable isotopes in plants and soil (NEON.DP0.10103)
AD[05]	NEON.DP0.10031.001 _dataValidation.csv	NEON Raw Data Validation for Plant lignin concentrations (NEON.DP0.10031)
AD[06]	NEON.DP1.10031.001 _variables.csv	NEON Data Variables for Litter chemical properties (NEON.DP1.10031)
AD[07]	NEON.DP1.10101.001 _variables.csv	NEON Data Variables for Litter stable isotopes (NEON.DP1.10101)
AD[08]	NEON.DOC.001710	TOS Protocol and Procedure: Litterfall and Fine Woody Debris
AD[09]	NEON.DOC.000914	TOS Science Design for Plant Biomass, Productivity, and Leaf Area Index
AD[10]	NEON.DOC.000906	TOS Science Design for Terrestrial Biogeochemistry
AD[11]	NEON.DOC.000008	NEON Acronym List
AD[12]	NEON.DOC.000243	NEON Glossary of Terms
AD[13]	OS_Generic _Transi-tions.pdf	NEON Algorithm Theoretical Basis Document: OS Generic Transitions
AD[14]		NEON's Ingest Conversion Language (NICL) specifications

3 DATA PRODUCT DESCRIPTION

The Litter chemical properties (NEON.DP1.10031) and Litter stable isotopes (NEON.DP1.10101) data products provide data about litterfall samples collected using TOS Protocol and Procedure: Litterfall and Fine Woody Debris (AD[08]). Litterfall is defined as material dropped from the forest canopy with a butt end diameter < 2 cm and a length < 50 cm, collected in elevated 0.5 m^2 PVC traps. Fine woody debris is also collected using ground traps during execution of TOS Protocol and Procedure: Litterfall and Fine Woody Debris (AD[08]), but is not measured for chemistry or isotopes so will not be discussed further. Litterfall sampling and analyses implement the guidelines and requirements described in the TOS Science Design for Plant Biomass, Productivity, and Leaf Area Index (AD[09]) and TOS Science Design for Terrestrial Biogeochemistry (AD[10]). All chemical and isotopic data are reported at the spatial resolution of a plot. The temporal resolution is that of a single collection event.

Measurements of litterfall carbon, nitrogen and lignin concentrations and C and N stable isotopes help to reveal drivers of variation in aboveground net primary productivity, stoichiometry, foliar resorption, and rates of decomposition at the plot, site, and continental scales. They also provide essential data for understanding change in ecosystem biogeochemical dynamics over time.

3.1 Spatial Sampling Design

Litterfall sampling is executed at each terrestrial NEON site that contains woody vegetation > 2 m tall. Sampling occurs only in base plots that fall in the tower airshed ('Tower plots', Figure 1). Distributed base plots are not sampled. In sites with forested airsheds, litterfall sampling takes place in 20 40 x 40 m plots. In sites with low-statured vegetation, litterfall sampling takes place in 4 40 x 40 m tower plots (to accommodate co-located soil sampling) plus 26 20 x 20 m plots, yielding 30 plots total. In some cases, available space, plot spacing requirements, and/or the tower airshed size restricts the number of plots that can be sampled for litterfall.

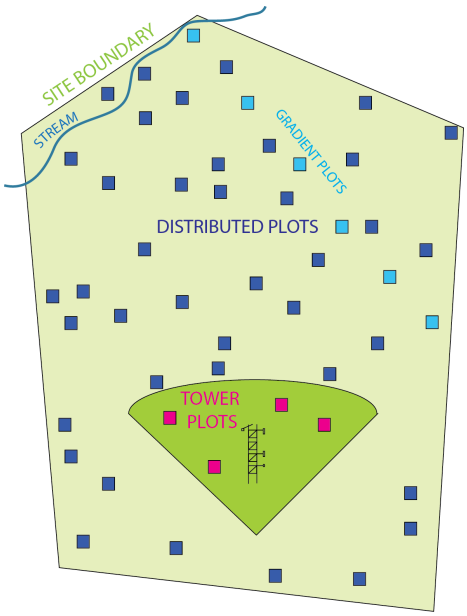

Figure 1: Representation of a NEON site with select Tower and Distributed plots shown

Trap placement within plots may be either targeted or randomized, depending on the vegetation. In sites with > 50% aerial cover of woody vegetation, placement of litter traps is random and utilizes the randomized list of clip cell locations used for herbaceous clip harvest and belowground biomass sampling. In sites with < 50% cover of woody vegetation, trap placement is targeted such that only clip cells beneath qualifying vegetation are considered for trap placement. One elevated litter trap is deployed for every 400 m^2 plot area, resulting in 1-2 traps per plot. However, sorted material is composited by plot prior to chemical and isotopic analysis if there is more than one trap. Elevated PVC litter trap design follows that used by the Smithsonian Tropical Research Institute Center for Tropical Forest Science (STRI/CTFS) (Muller-Landau and Wright 2010). Each is a 0.5 m^2 square with mesh 'basket' elevated ~80 cm above the ground and placed inside a clip cell.

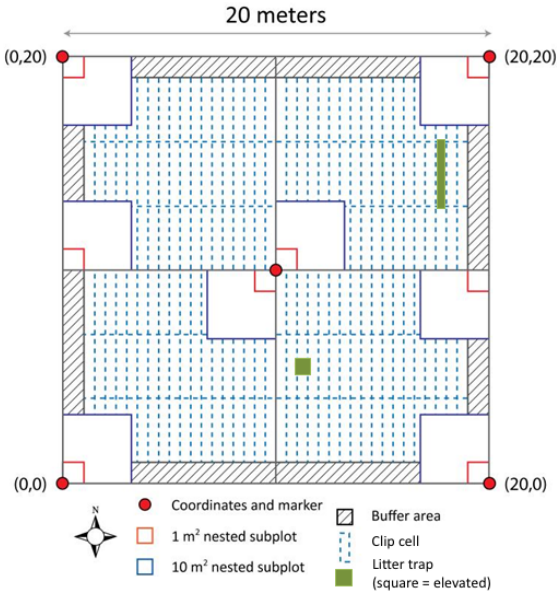

Figure 2: Arrangement of clip cells and traps within a 20 x 20 m plot. The square, elevated traps are used for litterfall collection

3.2 Temporal Sampling Design

Litterfall sampling schedules vary according to site vegetation type, with frequent sampling (1 x every 2 weeks) in deciduous sites during senescence but infrequent, year-round sampling (1 x every 1-2 months) at evergreen sites. However, only material from one of the peak senescence bouts (or, a fall bout for evergreen sites) is analyzed for chemistry and isotopes, and this occurs once every five years. Prior to analysis, material is sorted to 7 functional groups, then oven-dried at 65C and weighed. Only leaf and needle functional groups are analyzed, see TOS Protocol and Procedure: Litterfall and Fine Woody Debris (AD[08]) and TOS Science Design for Plant Biomass, Productivity, and Leaf Area Index (AD[09]) for more details.

3.3 Theory of Laboratory Measurements

Concentrations of carbon and nitrogen in plant material are commonly measured via combustion and elemental analysis (EA). If stable isotope ratios are also desired, as is the case with NEON root samples, isotope ratio mass spectrometry (IRMS) can be coupled to elemental analysis, yielding simultaneous concentration and stable isotope measurements.

Isotopes are measured as the abundance ratio of a heavy, rare isotope (H) to a light, more common isotope (L), normalized by those same ratios in a standard reference material.

$$\delta = [(R_{sample}/R_{standard} - 1)] \times 1000$$

where R = H/L. For all NEON stable isotopic data, $\delta^{15}N$ values are expressed on the atmospheric N_2 scale and $\delta^{13}C$ values are expressed on the Vienna Pee Dee Belemite scale.

Concentrations of lignin are determined using the acid detergent lignin method. This technique builds on the more common acid detergent fiber analysis, but includes a sulfuric acid digest plus ashing in order to separate lignin from cellulose. Lignin is thus defined operationally as the acid-insoluble residue. Concentration estimates of both lignin and cellulose are provided.

3.4 Laboratory Quality Assurance and Uncertainty

For the C and N data, primary reference materials are used to calibrate each EA-IRMS run and secondary reference materials are run as unknowns in order to gauge run acceptability. For the lignin data, no standards are used for calibration (since the technique is based purely on differences in mass) but a set of in-house standards with known lignin concentration are included in each run to gauge run acceptability. NEON collects and verifies calculated values for secondary reference materials and in-house standards for each run, but those data are not included in the download package to end users. However, long-term analytical precison and accuracy of the QA materials are reported, as these allow users to interpret and model the data in the context of its uncertainty range. Contracted external facilities upload a long-term summary file containing this information when they begin work for NEON, then again once per year or when their information changes (for example, a new instrument is aquired or a change is detected in analytical precision). NEON's Calibration/Validation department has regular procedures for auditing the quality assurance of external laboratories and their reports are available to data users.

Of the data tables contained in these two data products, ltr_litterStableIsotopes, ltr_litterCarbonNitrogen, and ltr_litterLignin will contain data for the individual NEON litterfall samples, while bgc_CNiso_externalSummary and lig_externalSummary (available in the expanded package) will contain the long-term precision and accuracy of the lab analyses involved in generating those data.

3.5 Variables Reported

All variables reported from the laboratory (L0 data) are listed in the files NEON Raw Data Validation for Carbon and nitrogen concentrations and stable isotopes in plants and soil (NEON.DP0.10103) (AD[04]) and NEON Raw Data Validation for Plant lignin concentrations (NEON.DP0.10031) (AD[05]). All variables reported in the published data (L1 data) are also provided separately in the files NEON Data Variables for Litter chemical properties (NEON.DP1.10031) (AD[06]) and NEON Data Variables for Litter stable isotopes (NEON.DP1.10101) (AD[07]).

Field names have been standardized with Darwin Core terms (http://rs.tdwg.org/dwc/; accessed 16 February 2014), the Global Biodiversity Information Facility vocabularies (http://rs.gbif.org/vocabulary/gbif/; accessed 16 February 2014), and the VegCore data dictionary (https://projects.nceas.ucsb.edu/nceas/projects/bien/wiki/VegCore; accessed 16 February 2014), where applicable. NEON TOS spatial data employs the World Geodetic System 1984 (WGS84) for its fundamental reference datum and Earth Gravitational Model 96 (EGM96) for its reference gravitational ellipsoid. Latitudes and longitudes are denoted in decimal notation to six decimal places, with longitudes indicated as negative west of the Greenwich meridian.

Some variables described in this document may be for NEON internal use only and will not appear in downloaded data.

3.6 Spatial Resolution and Extent

The finest resolution at which chemistry and isotope spatial data are reported is a plot.

plotID (ID of plot within site) → **siteID** (ID of NEON site) → **domainID** (ID of a NEON domain).

However, by joining litter chemistry and isotope data to the field metadata present in the Litterfall and Fine Woody Debris Sampling (NEON.DP1.10033) data tables and following the instructions contained in the User Guide for that product, more precise geolocations for the sampled traps can be calculated. Shapefiles of all NEON Terrestrial Observation System sampling locations can be found in the Document Library: http://data.neonscience.org/documents.

3.7 Temporal Resolution and Extent

The finest resolution at which temporal data are reported is the range between **setDate** and **collectDate**; the date used in querying files is the **collectDate**. The NEON Data Portal currently provides data in monthly files for query and download efficiency. Code to stack files across months is available here: https://github.com/NEONScience/NEON-utilities.

3.8 Associated Data Streams

In order to make full utility of the data contained in Litter chemical properties (NEON.DP1.10031) and Litter stable isotopes (NEON.DP1.10101), users will most likely wish to download the field and internal laboratory metadata, including biomass, for the parent litterfall samples. These can be found in the Litterfall and Fine Woody Debris Sampling (NEON.DP1.10033) data product, where **cnSampleID** and **ligninSampleID** in the ltr_chemistrySubsampling table can be used to join on the same field names in the chemistry and isotope data tables.

3.9 Product Instances

Once every five years, one litterfall sampling bout is analyzed for chemistry and isotopes per site. For each site, 20 to 30 plots are sampled, and one or two functional groups are analyzed per plot. Thus, we expect between 180-540 data records per year Observatory-wide for litterfall chemistry and isotope data.

3.10 Data Relationships

Each record in the ltr_chemistrySubsampling table in Litterfall and Fine Woody Debris Sampling (NEON.DP1.10033) may appear from zero to two times in the ltr_litterStableIsotopes, ltr_litterCarbonNitrogen, and ltr_litterLignin tables, with unique identifiers recorded in the **cnSampleID** and **ligninSampleID** fields. Most **cnSampleID**s and **ligninSampleID**s will appear once, but some may appear twice if analytical replicates were conducted by the laboratory. Duplicates and/or missing data may exist where protocol and/or data entry abberations have occurred; *users should check data carefully for anomalies before joining tables*.

Below is a summary of the tables and data relationships expected for each product.

Litter stable isotopes (NEON.DP1.10101)

ltr_litterStableIsotopes.csv - > One record expected per **cnSampleID** x **analyticalRepNumber** combination

bgc_CNiso_externalSummary.csv - > One record expected per **laboratoryName** x **analyte** x **sampleType** x **labSpecificStartDate** combination. Can use corresponding variables in isotope and chemistry tables to associate sample data with relevant uncertainty values.

Litter chemical properties (NEON.DP1.10031)

ltr_litterCarbonNitrogen.csv - > One record expected per **cnSampleID** x **analyticalRepNumber** combination

ltr_litterLignin.csv - > One record expected per **ligninSampleID** x **analyticalRepNumber** combination

bgc_CNiso_externalSummary.csv - > One record expected per **laboratoryName** x **analyte** x **sampleType** x **labSpecificStartDate** combination. Can use corresponding variables in isotope and chemistry tables to associate sample data with relevant uncertainty values.

lig_externalSummary.csv <- One record expected per **laboratoryName** x **analyte** x **sampleType** x **labSpecificStartDate** combination. Can use corresponding variables in isotope and chemistry tables to associate sample data with relevant uncertainty values.

3.11 Special Considerations

4 DATA ENTRY CONSTRAINT AND VALIDATION

Many quality control measures are implemented at the point of data entry within a mobile data entry application or web user interface (UI). For example, data formats are constrained and data values controlled through the provision of list-of-value options, which reduce the number of processing steps necessary to prepare the raw data for publication. An additional set of constraints are implemented during the process of ingest into the NEON database. The product-specific data constraint and validation requirements built into data entry and database ingest are described in the documents NEON Raw Data Validation for Carbon and nitrogen concentrations and stable isotopes in plants and soil (NEON.DP0.10103) and NEON Raw Data Validation for Plant lignin concentrations (NEON.DP0.10031), provided with every download of this data product. Data entry constraints are described in Nicl syntax in the validation file provided with every data download, and the Nicl language is described in NEON's Ingest Conversion Language (NICL) specifications (AD[14]).

5 DATA PROCESSING STEPS

Following data entry into a mobile application or web user interface, the steps used to process the data through to publication on the NEON Data Portal are detailed in the NEON Algorithm Theoretical Basis Document: OS Generic Transitions (AD[13]).

6 REFERENCES

Muller-Landau, H. C., and S. J. Wright. 2010. Litterfall Monitoring Protocol. The Center for Tropical Forest Science Global Forest Carbon Research Initiative (http://www.forestgeo.si.edu/).