Fine-Root Ecology Database (FRED): A Global Collection of Root Trait Data with Coincident Site, Vegetation, Edaphic, and Climactic Data, Version 3

Document Revision Date: 1 February 2021

Summary:

To address the need for a centralized root trait database, we compiled the Fine-Root Ecology Database (FRED) from published and unpublished data sources. We have continued to add to the FRED database since the release of FRED 2.0 in 2018, and a new version of FRED is now available. FRED 3.0 has more than 150,000 observations of more than 330 root traits, with data collected from more than 1400 data sources. FRED 3.0 has 45% more root trait observations than FRED 2.0, particularly in the categories of root anatomy, morphology, and microbial associations. Ancillary data on associated site, vegetation, edaphic, and climatic conditions from across the globe have also increased concurrently with root trait observations.

FRED is focused on fine roots (traditionally defined as roots less than 2 mm in diameter), as coarse roots are studied using different methodology, often at very different scales, and have different traits and trait interpretations. However, FRED accepts data collected from roots of all sizes, and already contains several observations of coarse roots. Data collection will continue for the foreseeable future.

Related Publications:

More details about FRED and the motivation for undertaking this monumental data compilation effort can be found in the following publications:

Iversen CM, McCormack ML. 2021. Filling gaps in our understanding of belowground plant traits across the world: A Virtual Special Issue. *New Phytologist, in press.* [**FRED 3.0**]

McCormack ML, Powell AS, Iversen CM. 2018. Better plant data at the root of ecosystem models. *Eos* 99. https://doi.org/10.1029/2018EO104093. [**FRED 2.0**]

Iversen CM, McCormack ML, Powell AS, Blackwood CB, Freschet GT, Kattge J, Roumet C, Stover DB, Soudzilovskaia NA, Valverde-Barrantes OJ, van Bodegom PM, Violle C. 2017. Viewpoints: A global Fine-Root Ecology Database to address belowground challenges in plant ecology. *New Phytologist* 215: 15-26. https://doi.org/10.1111/nph.14459. [**FRED 1.0**]

Please also see the FRED website at: https://roots.ornl.gov for the most up-to-date information.

Data Products:

The newest version of FRED (Version 3) is now a 'real' database where data are efficiently stored and accessible through an interactive user interface. Observations can be filtered according to the scientific interests of the user. The user interface is accessed via https://roots.ornl.gov/public-release.

A description of the process for data filtering can be found in **Section 4** below.

Classic FRED

Note that a user can still download the entirety of FRED Version 3.0 as a single comma-separated (.CSV) file (**FRED3_Entire_Database_2021.CSV**, 112 MB). The associated documentation available is described below.

Filtered data products

If the user decides to filter the observations in FRED according to their search criteria, the user will receive a downloaded data file containing the observations that fit the selected filter criteria, as well as a companion file that contains data definitions and observation counts:

FRED3_Filtered_Database_YYYYMMDD-HHMMSS.CSV: One comma-separated (.CSV) file with the compiled root trait observations from published or contributed data sources that are encompassed by the selected filter criteria as well as associated ancillary data (where YYYYMMDD-HHMMSS is the date and time of download).

FRED3_Column_Definitions_ YYYYMMDD-HHMMSS.CSV: One comma-separated (.CSV) file with the definitions associated with every root trait or ancillary data type available in FRED 3.0, along with a count of the total number of observations for each in FRED 3.0 (where YYYYMMDD-HHMMSS is the date and time of download). Much of this information can also be found at the https://roots.ornl.gov/data-inventory and https://roots.ornl.gov/ancillary-data websites and in Table 4 below.

Additional Information

The following files are also available for download from links embedded within the user interface:

FRED3_Data_Sources_2021.pdf: One (.pdf) file with a list of the more than 1400 data sources cited in FRED 3.0. This information can also be found at https://roots.ornl.gov/data-sources.

FRED3_User_Guidance_Doc_2021.pdf: One (.pdf) file with guidelines and supplementary information regarding the content and usage of FRED 3.0. Current document. This document is also available at https://roots.ornl.gov/UserGuidance.

FRED3_Map_2021.jpg: One (.jpg) that contains a map and breakdown of observation numbers within each Köppen-Geiger designation in FRED 3.0 that we were able to associate with geographic coordinates. This map is also available at https://roots.ornl.gov/overview.

Data and Documentation Access:

FRED is freely available to the public with unrestricted access. The user interface for data filtering as well as download of companion files can be accessed via the portal at http://roots.ornl.gov/public-release. For inquiries and suggestions, contact Colleen Iversen at iversencm@ornl.gov or contact the FRED team through the contact form at http://roots.ornl.gov/contact. As erroneous or incomplete data are discovered and corrected, the necessary corrections are added to a list at http://roots.ornl.gov/updates.

Data Use and Referencing FRED

Users are requested to:

Reference the FRED 3.0 database with the following data citation and DOI in any resulting publications or data synthesis products:

> Iversen CM, McCormack ML, Baer JK, Powell AS, Chen W, Collins C, Fan Y, Fanin N, Freschet GT, Guo D, Hogan JA, Kou L, Laughlin DC, Lavely E, Liese R, Lin D, Meier IC, Montagnoli A, Roumet C, See CR, Soper F, Terzaghi M, Valverde-Barrantes OJ, Wang C, Wright SJ, Wurzburger N, Zadworny M. 2021. **Fine-Root Ecology Database (FRED): A Global Collection of Root Trait Data with Coincident Site, Vegetation, Edaphic, and Climatic Data, Version 3.** Oak Ridge National Laboratory, TES SFA, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A. Access on-line at: https://doi.org/10.25581/ornlsfa.014/1459186.
>
> Note: The author list for the data set includes FRED team members as well as people who contributed unpublished data to current or previous versions of FRED. Thank you to those scientists for advancing our understanding of belowground ecology with previously unpublished observations!

Ensure traceability of FRED data and reproducibility of your analyses.

Where possible and feasible, cite the original papers or data sources used in your analysis as they are listed in FRED 3.0 (this could be a separate table or list in your publication). Describe the criteria that you used to subset the FRED 3.0 data (e.g., different root categories, spatial or temporal limits, species, trait types, etc.) so that another user could repeat the process.

Send a citation or copy of your publication to FRED.

We would like to know that FRED 3.0 data are being used (and so would our sponsor at the U.S. Department of Energy), and other potential users may like to see how FRED 3.0 data have been applied. We list full citations for FRED-related publications at http://roots.ornl.gov/publications to help increase the visibility of your work.

Provide feedback to FRED

Are there any mistakes in the data or units? How can we improve the website, data filtering capabilities, etc.? Are there additional root trait data that should be added to FRED? Contact us at iversencm@ornl.gov or at https://roots.ornl.gov/contact.

Collaborate

Data users are encouraged to use the name and contact information of the data contributors included for each data source to pursue collaborations.

Version History:

FRED versions

The current version of FRED (FRED 3.0), supersedes FRED 2.0.

FRED 2.0 was available at https://roots.ornl.gov/public-release, from June 8, 2018 to February 1, 2021. After February 1, 2021 FRED 2.0 is available at https://roots.ornl.gov/previous-release.

Note that FRED 0.0 and 1.0 are only available from the authors of FRED upon request through the contact form at https://roots.ornl.gov/contact.

FRED and TRY

The first version, FRED 0.0 (Version 0), was integrated into the TRY Plant Trait Database and was released with TRY 4.0 (www.try-db.org).

FRED Version 2.3 was also integrated into the TRY Plant Trait Database and was released with TRY 5.0 (www.try-db.org).

FRED Version 3.0 will be integrated into the TRY Plant Trait Database and released with TRY 7.0 (*planned*, www.try-db.org).

FRED Version	Availability	Current Download Location
FRED 3.0	February 1, 2021 – present	http://roots.ornl.gov/public-release www.try-db.org (TRY 7.0, *planned*)
FRED 2.0	June 8, 2018 – February 1, 2021	http://roots.ornl.gov/previous-release www.try-db.org (TRY 5.0)
FRED 1.0	February 28, 2017 – June 8, 2018	http://roots.ornl.gov/contact
FRED 0.0	NA	http://roots.ornl.gov/contact www.try-db.org (TRY 4.0)

FRED Sponsor:

The Fine-Root Ecology Database is sponsored by the Office of Biological and Environmental Research within the U.S. Department of Energy's Office of Science.

Table of Contents:

1. Data Acquisition:

Version 3 of FRED has more than 150,000 observations of more than 330 root traits, with data collected from more than 1400 data sources. FRED is focused on fine roots (roots traditionally defined as less than 2 mm in diameter) but accepts data collected from roots of all sizes.

FRED Team Data Acquisition

Trait and Site Data

Data were acquired from the publicly available data sources presented in the companion file, **FRED3_Data_Sources_2021.pdf**. While we used numbers presented in tables or in article text whenever possible, many data were only available in graphic form. We extracted data from graphs using Grab It! Graph Digitizer, an application from Datatrend Software.

The quality of all observations were checked prior to the publication of FRED 3.0 as follows: For text-based observations, we examined all cells to ensure that their content relates to their specific categories. For numerical observations, we ordered each numerical value from least to greatest and plotted the values, checking apparent outliers against the data in their respective sources, and correcting or removing incorrect or impossible values. For statistical metrics (e.g. sample size, standard error, standard deviation), we checked to ensure that each accompanied a main value.

Derived Locations

Only ~70% of the observations in FRED 3.0 were reported with geo-referenced locations. To facilitate spatial analyses and visualization, we derived two additional location variables for the FRED database. ‘Latitude_Main’ and ‘Longitude_Main’ (column IDs F01185 and F01186, respectively) were derived to best describe the data collection location. Coordinate values were set, in order of priority, as (1) the single latitude/longitude point location reported in the original data source, (2) the average of the minimum and maximum latitudes and longitudes reported in the original data source, or (3) an estimated latitude and longitude based on the description of the sampling location reported in the original data source and using Google Earth to obtain an approximate location. This process increased the number of geo-referenced locations to 99% of the observations.

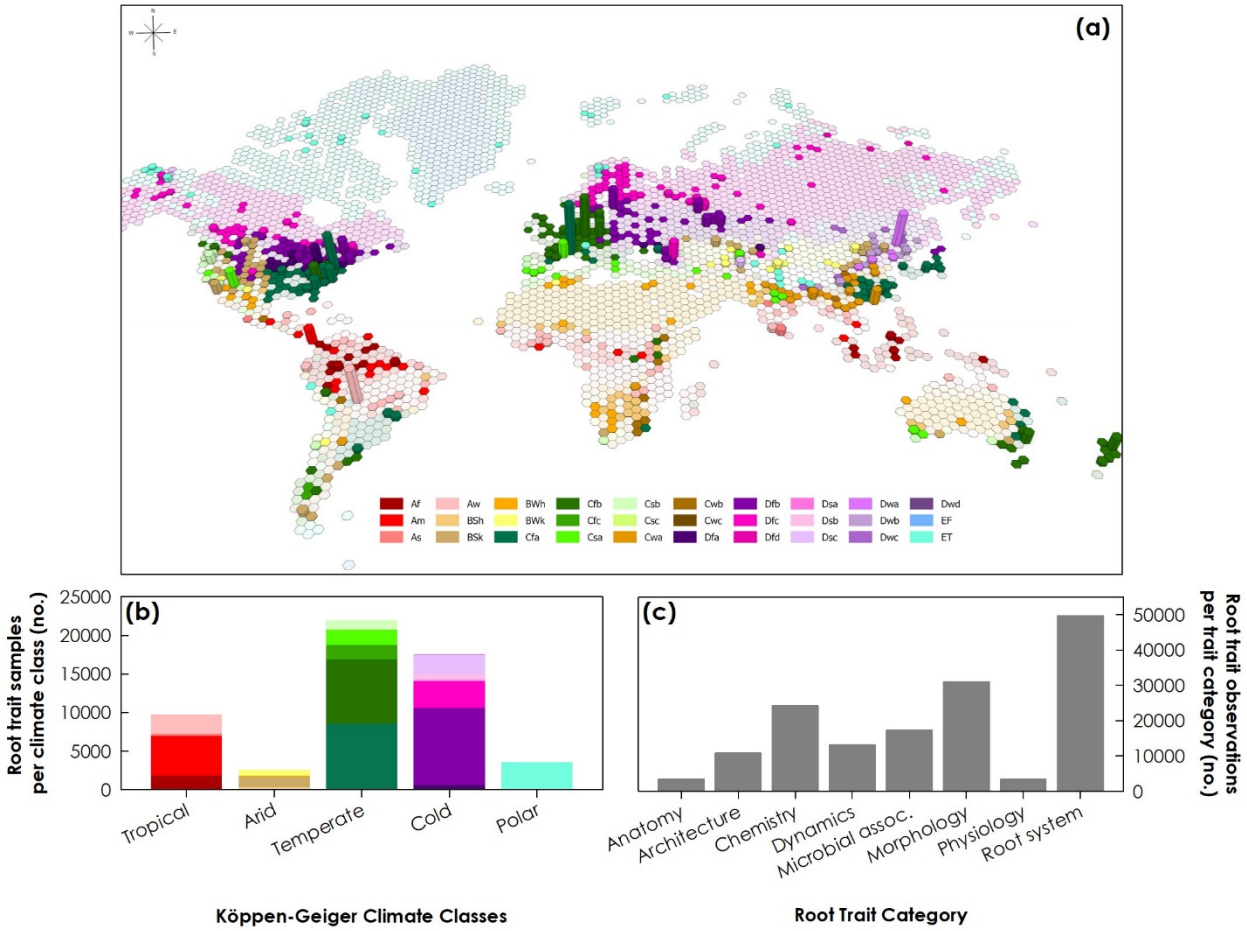


Fig. 1. FRED 3.0 observations are distributed unevenly across the globe (map from Iversen & McCormack 2021, *New Phytologist*, *in press*). For the purposes of this map, land cover within a Köppen-Geiger climate classification zone (Kottek et al., 2006, 10.1127/0941-2948/2006/0130) was aggregated into hex bins that are extruded in three-dimensional space based on the number of root trait samples collected in each bin. Map courtesy of Chris DeRolph. (b) The number of root trait samples collected from each Köppen-Geiger climate subclass (e.g., Kottek et al., 2006), summed within each climate class. (c) The distribution of observations in FRED 3.0 across broad categories of root traits; for more information about the trait categories, see https://roots.ornl.gov/data-inventory.

Do-It-Yourself FRED Data Entry

While we have had awesome (paid) student interns that search the literature and standardize the entry of data into the FRED framework, we also encourage scientists to enter their own data and meta-data into FRED, both because you know your data best, and because you may have access to individual replicates or samples that may not have been included in a main publication that is publicly available. We have written a series of guidelines to help facilitate this at http://roots.ornl.gov/DIY. Please upload contributed data at https://roots.ornl.gov/upload.

2. Data Use Guidelines:

FRED Data Use and Intellectual Property Rights – Guiding Principles

We actively encourage the broader scientific community to contribute published and unpublished data to FRED.

Here's the bottom line: When you submit published or unpublished data sources, all persons who contributed to the development of the data set (data contributors) agree that the data will be publicly available through the portal on the FRED website (http://roots.ornl.gov). Furthermore, all data contributors agree that there is no requirement on either the part of FRED or the persons downloading FRED for analyses (data users) that the data contributors be contacted regarding use of their data.

Data users are expected to follow professional scientific norms of citing and referencing inputs to their research. This does not preclude data users from contacting data contributors for purposes of collaboration.

Inclusion of Data into FRED

Data sources included in Version 3:

Data that have been harvested from peer-reviewed open literature are assumed to be in the public domain and have been included in FRED 3.0 without contacting the authors for permission. Authors may have been contacted if there was a question about their data. Similarly, data sets that are the result of previous data compilation activities and have been made available to the public through a data archive (e.g., ORNL DAAC) have also been included in FRED 3.0 without contacting the compilers or the original data contributors for permission. In both cases the data contributor and the complete reference of each data source have been included as meta-data in FRED 3.0 for all respective observations.

Published data sources in future Versions:

As above, published data may be added to the database by FRED data managers as they become publicly available. To facilitate more efficient incorporation and full accuracy of data presentation, researchers are encouraged to become data contributors (https://roots.ornl.gov/contributors) and to submit their published data to FRED (https://roots.ornl.gov/upload). Upon submission of published data, all data contributors agree that the data will be publicly available through the FRED website (https://roots.ornl.gov/public-release) with no requirement that the data contributors be contacted upon the download or use of their data.

Unpublished data sources in future Versions:

We are only soliciting unpublished data that data contributors are willing to make freely available to the broader community with unrestricted access. These data may include, for example, more detail on published data (e.g., data from individual replicates rather than the published plot mean or untransformed data from aggregate statistical analysis), or data that have never been included in a publication. Upon submission of unpublished data, all data contributors agree that the data will be publicly available through the FRED website (https://roots.ornl.gov/public-release) with no requirement that the

data contributors be contacted upon the download or use of their data. Researchers who contribute unpublished data will become data contributors (https://roots.ornl.gov/contributors) and will also be listed as authors on the DOI for the release of the version of FRED that contains their data (e.g., Iversen *et al*., 2021 for FRED 3.0; see above).

We provide a searchable list of published and unpublished data sources that have been incorporated into FRED thus far at https://roots.ornl.gov/data-sources.

3. Privacy Statement:

FRED respects the privacy of all of our users, and we take seriously our responsibility to protect all personal information that we collect. To that end, we collect only what we need to ensure good customer service, to support systems operation, and to facilitate summary reporting of data downloads and general user characteristics and data usage. Ultimately, we want satisfied users, because today's users are tomorrow's data contributors to FRED.

When you request to download data from FRED, you are asked to:

- Confirm that you have read and agree to the Data Use Guidelines;
- Provide your Name and a valid Email Address;
- Provide basic location information (your Institution or Affiliation, City, and Country); and
- Describe your Data Usage Plan and a Primary Data Use.

The information you provide will be retained for the duration of the project and possibly longer within mandated archives of our research activities.

Your Email Address will be stored in our database, and:

- Your email address will only be used to notify you of important updates or problems (if any) with the data products you have downloaded;
- The domain name of your email address will be used in aggregate to summarize the number of data products downloaded, what types of users are downloading data, and their general locations. These summary statistics will not identify individual users;
- Individual email addresses will be identified in summary reports about FRED data downloads. These reports are only available to data system personnel and will not be made public.

Your Name and Location will be stored in our database, and:

- Your Name will only be available to data system personnel and will not be made public;
- Your Institution or Affiliation, City, Country and IP address will be used in aggregate to summarize the number of data products downloaded, what types of users are downloading data, and their general locations. These summary statistics will not identify individual users;

Your proposed Data Usage Plan and Primary Data Use information will be stored in our database, and:

- Your specific Data Usage Plan information will be used to assess the utility of FRED for multiple different types of projects, and to help steer future data collation. The details of your plan are only available to data system personnel and are not made public;
- Primary Data Use information will be used in aggregate to follow how users generally plan to use these data. These summary statistics will not identify individual users.

4. Tips for Using FRED 3.0:

FRED 3.0 has been encoded into database form (Microsoft Azure), and we have developed a user interface (programmed using Vue.js for the user interface and Node.js for the data interface) that allows users to filter the observations in FRED according to their scientific needs. In the sections below, we describe each filter and the recommended considerations for obtaining the FRED 3.0 observations that best match your scientific interests.

However, before we proceed with the description of the FRED 3.0 user interface, it would be helpful for you to understand how the data are organized in the FRED 3.0 database.

Background:

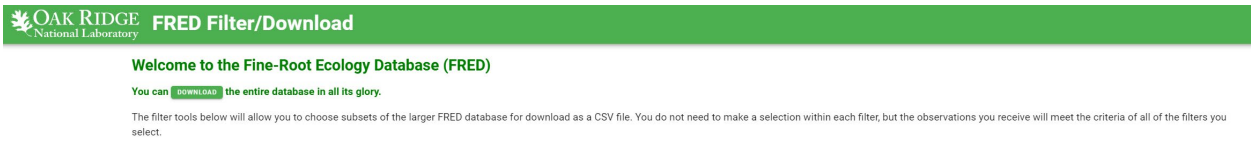
If you consider the original FRED flat file (CSV), each unique type of root trait or type of ancillary data are a separate column. There are 335 columns of root traits and 241 columns of ancillary data, as well as additional columns associated with the sample size (n) or error (SD, SE, etc.) for each root trait or ancillary data type where it is available.

Each observation is a new row, corresponding to a 'sample' or a 'plot' on which trait measurements were made. However, each row does not include observations in every column (i.e., FRED is a sparse matrix). As an example, a root ecologist may have collected roots from the soil by tracing them from an individual tree, and measured the specific root length, diameter, dry mass, and nutrient content of this 'sample'. Each of these observations would be in the same row, with the observations corresponding to the columns for SRL, D, etc., but columns for 'exudation' or 'aerenchyma' would be blank, with no observations for that row.

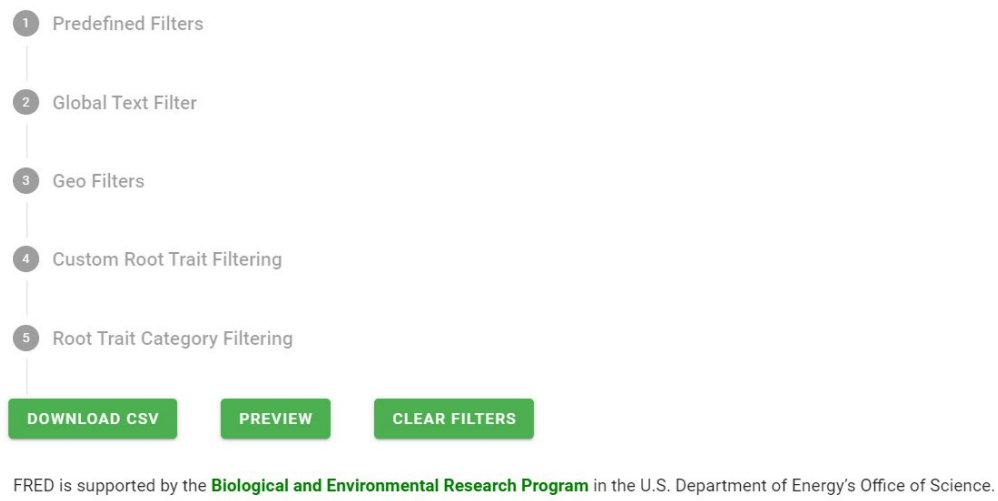
User Interface:

In a manner similar to this flat file setup, the FRED database user interface often uses the descriptor 'columns' in association with traits and ancillary data types, and 'rows' in association with observations. As you subset the observations in FRED, you will only receive the 'columns' or traits that you request where the database contains 'rows' or observations that correspond to your search criteria, along with all associated meta-data and ancillary data columns.

Request access the FRED database user interface at https://roots.ornl.gov/public-release. You'll be emailed a unique link to the user interface that expires after 24 hours.



Next, you'll see a series of filters that will help you to subset FRED 3.0 into the observations of scientific interest to you:



We now step through each data filter and describe things you might want to consider. Not all filters need to be selected.

1. **Predefined Filters**

   This filter offers you the opportunity to choose from one or several of the drop-down menus below for easy selection of major data groupings that we believe users are most likely to rely on. For example, are you interested in:

   – *Species-specific traits, or traits of plants growing in mixed communities?*

     This filter corresponds to Column ID F00027 (Notes_Single or multiple species) in the data dictionary. Selecting 'Single species' returns data that were collected for individual species, whereas 'multiple species' returns data that were collected for more than one species at a time; for instance, where researchers sampled a mixed plant community and did not identify and sort the roots before measuring them. Selecting 'single species' does not mean that all rows of data returned will describe the same species; it only means that there are no mixed-species data in any of the rows.

   – *What kind of root?*

     These filters correspond to the defining traits of the roots themselves.

     The first filter, *Belowground Part*, corresponds to Column ID F00055. It describes the morphological category in each row: BS (belowground stems), CR (coarse roots; roots >2 mm in diameter), FR (fine roots; roots 2 mm or below in diameter), R (rhizomes), TB (all underground parts, which may or may not include any number of the aforementioned types), TR (all roots, which may include coarse roots, fine roots, or both), unspecified (researchers did not specify which belowground parts they collected), or unspecified roots (researchers collected roots but did not specify which roots they collected). Categories with a plus sign only apply to rows with mixed types; for instance, selecting "CR + FR" will return all rows that describe coarse and fine roots, but will not return rows that describe only CR data or only FR data, nor will it return rows that describe CR and FR mixed with other types.

     The second filter, *Root order*, corresponds to column F00056. This is based on the centripetal (i.e. morphometric) root ordering scheme: roots of order 1 are the roots on the distal tip of the root system with no roots branching from them; order 2 roots are roots with at least one first-order root branching from them; order 3 roots are roots with second-order roots branching from them, and so on.

     The third filter, *Root functional class*, corresponds to column F00060. Absorptive roots are typically classified as fine roots of orders 1 through 3, and perform the functions associated with resource acquisition, while transport roots are typically classified as fine roots of orders 4 or higher, and perform the functions associated with resource transport (McCormack et al. 2015; *New Phytologist*).

The fourth filter, *Root vitality*, corresponds to column F00064. This filter describes roots that are living, dead, both, or unspecified. Choosing 'both' returns all rows of data that describe samples that contained both living and dead roots but does not return rows that describe samples containing only living roots or only dead roots.

- *What portion of the plant kingdom?*

  These filters select for accepted plant family, genus, and species names, corresponding to columns F01289, 1286, and 1287, respectively and verified against The Plant List (http://www.theplantlist.org/). While there are selection boxes within the filter, you can also type in the entry boxes to activate a drop-down predictive text menu that searches within any part of the plant name. To search by species, select the genus and the species epithet in separate filters rather than attempting to search the entire scientific name in the species box.

- *What kind of plant?*

  These filters relate to non-phylogenic categories of plants, and are based upon the categories and data available in the TRY plant trait database (https://www.try-db.org/).

  The first filter, *Growth form*, corresponds to column F01456 and includes different plant growth form types.

  The second filter, *Leaf habit*, corresponds to column F00042 and selects among plants that are evergreen or deciduous. Selecting 'deciduous/evergreen' in this filter returns rows for data where the leaf habit is mixed or convoluted and does not return data belonging singularly to the deciduous or evergreen categories.

  The third filter, *Photosynthetic pathway*, corresponds to column F00043 and selects among plants that use a C3, C4, or CAM photosynthesis pathway. The options including slashes return rows for data where photosynthetic pathway is mixed or convoluted, but does not return data belonging singularly to either included category; for instance 'C4/CAM' returns data for plants capable of using both C4 and CAM pathways, but does not return data for plants that only use C4 pathways or only use CAM pathways.

  The fourth filter, *Plant woodiness*, corresponds to column F00044 and selects whether plants are woody or not. The category "non-woody/woody" describes plants whose woodiness is mixed or convoluted and does not return data for rows defined in the other two categories.

- *Where did the roots grow?*

  These filters are for the growing conditions of the plant sampled and correspond to columns F01156 and F01158, respectively. In the *Growing conditions* filter, '*in situ*' selects data for plants which were grown or harvested under natural environments; 'pot' selects data for plants which were grown in artificial environments, such as pots, greenhouses, and growth chambers; and 'hydroponic' selects data for plants which were grown hydroponically. The *Indoor/outdoor* filter selects data for plants that were grown either indoors or outdoors.

2. Global Text Filter

Allows for keyword searches that return all related trait or taxonomic observations. For example, a search for 'nitrogen' would return all observations that include the word 'nitrogen' anywhere in the data and would also include any observations where 'nitrogen' is in the trait name or description. To find all of the root observations that have a specific trait, enter the unique column ID of the trait. For example, 'F00261' would find all observations that have a value for column F00261 (Root N content).

3. **Geo Filters**

   Filter on relative geographic location (within a given radius) or geographic area (bounded by minimum and maximum latitudes and longitudes).

   Enter values for latitude and longitude as either degrees, minutes, and seconds (e.g., 36° 0' 37.2852‘’ N, 84° 16' 10.7256" W) or decimal degrees (e.g., 36.010357, -84.269646).

4. **Custom Root Trait Filtering**

   Observations within each root trait can be down-selected to specific observations or ranges of observations. Filter observations across single or multiple root traits, either additively (‘AND’ operand) or separately (‘OR’ operand). Remove filters as needed. There is no limit to the number of filters.

   Filter types:

   - 'Has value' selects only rows containing an observation for the selected root trait.
   - 'Equals', 'Starts with', and 'Contains' are for filtering textual (non-numerical) data only.
   - 'Select list' builds a list of the unique values for the selected column using checkboxes in an additional drop-down menu.
   - 'Min', 'Max', and 'Between' are for filtering columns that have numeric values.

5. **Root Trait Category Filtering**

   Filter root traits by broad categories as in McCormack et al., 2017 (e.g., 'Morphology', 'Chemistry', 'Anatomy', see figure below). This section allows users to select all traits within a certain category, or multiple categories. For the traits included in each category, see https://roots.ornl.gov/data-inventory. Note: this filter limits the columns included in the result, though meta-data and ancillary data columns are always included.

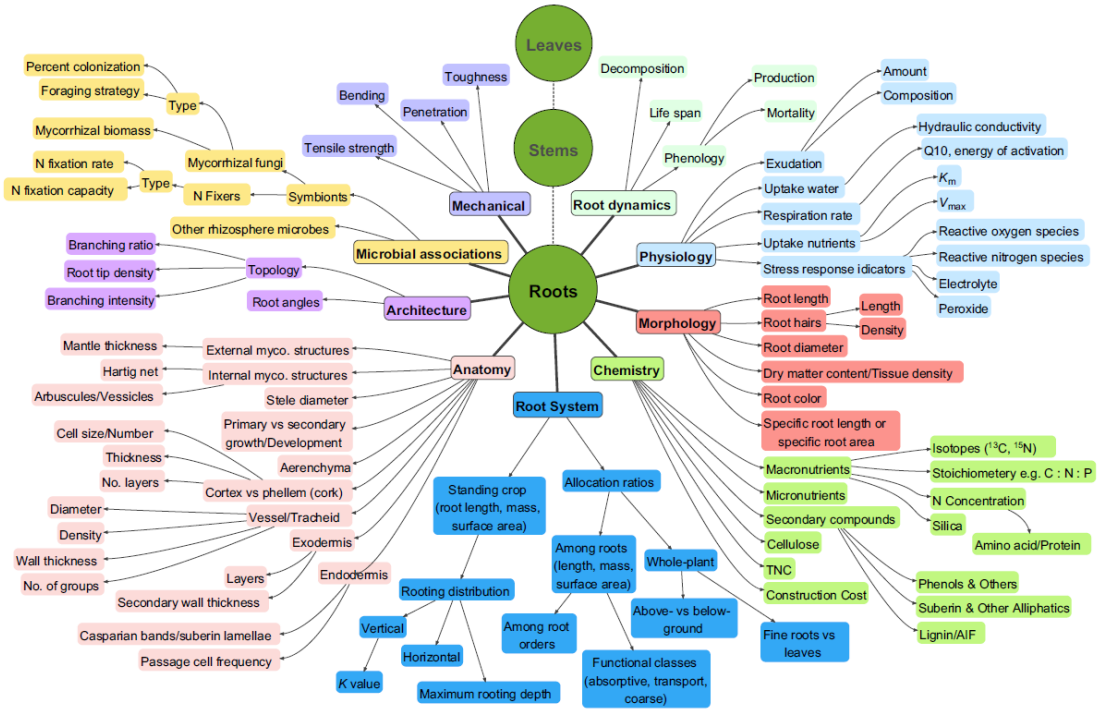


Fig. 2. Common traits relevant to the functioning of fine roots, aggregated by major trait categories (McCormack et al., 2017; https://doi.org/10.1111/nph.14459).

What does success look like?

Once you have selected the appropriate filters according to your scientific interests, you can preview your data using the **'preview'** button at the bottom of the page. (Note: You can 'ctrl F' to search for words or column IDs of interest while in the 'preview' mode.)

If you are satisfied with your data preview, click '**download CSV**' to receive the following files.

FRED3_Filtered_Database_YYYYMMDD-HHMMSS.CSV

FRED3_Column_Definitions_ YYYYMMDD-HHMMSS.CSV

Note: Depending on whether your filter criteria have subset FRED into just a few observations or into many observations, the download process can take up to 5 minutes. Please be patient to receive your files! If you do not receive your files within a few minutes, please contact FRED at https://roots.ornl.gov/contact, as there may be a problem with the interface.

Click on the **'clear filters'** button to start again!

Again a reminder to please cite these data as:

Iversen CM, McCormack ML, Baer JK, Powell AS, Chen W, Collins C, Fan Y, Fanin N, Freschet GT, Guo D, Hogan JA, Kou L, Laughlin DC, Lavely E, Liese R, Lin D, Meier IC, Montagnoli A, Roumet C, See CR, Soper F, Terzaghi M, Valverde-Barrantes OJ, Wang C, Wright SJ, Wurzburger N, Zadworny M. 2021. **Fine-Root Ecology Database (FRED): A Global Collection of Root Trait Data with Coincident Site, Vegetation, Edaphic, and Climatic Data, Version 3.** Oak Ridge National Laboratory, TES SFA, U.S. Department of

Energy, Oak Ridge, Tennessee, U.S.A. Access on-line at:
https://doi.org/10.25581/ornlsfa.014/1459186.

5. Data File Description for FRED 3.0:

The full FRED3_Entire_Database_2021.CSV is a comma-separated value (.CSV) file of ~ 112 MB with over 150,000 observations of root traits from over 1,400 documented data sources. Associated statistical metric observations (Table 3) and ancillary data observations regarding associated site, vegetation, edaphic, and climatic conditions are more numerous. For example, ancillary data may repeat for all rows reported at the same geographic location. If you subset your data using the filtering tool above, your file will be a subset of these data but will be organized in a similar way, containing all the header rows, with columns (traits) and rows (observations) containing the observations that fit your search criteria.

Data File Organization

Classic FRED Header Rows:

The **FRED3_Entire_Database_2021.CSV** contains five header rows; Table 1 describes these in the order of their appearance:

Table 1. Header rows (i.e., the first 5 rows) are descriptive, and do not have unique row IDs; these rows come with each download of the full FRED database.

Header position	Header name	Example	Description
1st	Column names in FRED	Root N content	Name of root trait or ancillary data type selected by FRED curators.
2nd	Units	mg/g	Units of data in column.
3rd	Definition	Mass of nitrogen per root mass for sampled roots.	Definition of root trait or ancillary data type, as in the Data Dictionary of this document.
4th	Column ID	F00261 (F00001 to F01474)	Unique identifier for column. If column is moved, renamed, or otherwise changed in future versions, Column ID remains the same.
5th	Name in TRY	Root nitrogen content per dry mass	The name of root trait or ancillary data type in the TRY database (www.try-db.org) if applicable.

Filtered FRED Header Rows:

The **FRED3_Filtered_Database_YYYYMMDD-HHMMSS.CSV** contains ten header rows; Table 2 describes these in the order of their appearance:

Table 2. Header rows (i.e., the first 10 rows) are descriptive, and do not have unique row IDs; these rows come with each download of filtered data.

Header position	Header name	Example	Description
1st	Column ID	F00261 (F00001 to F01474)	Unique identifier for column. If column is moved, renamed, or otherwise changed in future versions, Column ID remains the same.
2nd	Column names in FRED	Root N content	Name of root trait or ancillary data type selected by FRED curators.
3rd	Definition	Mass of nitrogen per root mass for sampled roots.	Definition of root trait or ancillary data type, as in the Data Dictionary of this document.
4th	Name in TRY	Root nitrogen content per dry mass	The name of root trait or ancillary data type in the TRY database (www.try-db.org) if applicable.
5th	Units	mg/g	Units of data in column.
6th	Type		Type of data (Meta-Data, Root_Traits, Ancillary_Data)
7th	Category		Category of data (see https://roots.ornl.gov/data-inventory and https://roots.ornl.gov/ancillary-data for more on data categories).
8th	Date		Date of filtered data download; also includes information on filters selected or specific queries.
9th	Row count		Number of rows in filtered data.
10th	Column count		Number of rows with observations in a given column (essentially a count of observations for a given trait in filtered data).

Data Rows:

Observations associated with root traits, associated statistical metrics, and ancillary data can be found in rows 6 – 57195 for the full FRED 3.0 data set, with unique Row IDs (i.e., F00002 [Notes_Row ID]) ranging from 1 to 57520 for the full FRED 3.0 data set. If observations are filtered during the search process, users will receive only a subset of these data, but with each observation corresponding to the same unique Row ID as in the full FRED 3.0 database to ensure traceability. The data rows, as provided, are sorted in ascending order of their unique Row ID [Notes_Row ID].

No Data Values:

Fields with "No Data" are represented as blank cells. The data are not really missing; rather, no observations were available for that particular trait or ancillary data in the original data source.

The Following Generalizations and Abbreviations Have Been Used in FRED 3.0:

- 'Root mass' refers to root dry mass unless otherwise stated (e.g., 'root fresh mass').
- Each trait or ancillary data value is the mean of collected data unless otherwise stated.
- The word 'root' in a trait name or description refers to the part specified in the 'belowground part' column (Column ID F00055) and therefore may refer to coarse roots, fine roots, or the total root system, but also to belowground stem, rhizome, or other belowground non-root entities.

See Table 3 for Statistical Metrics used in FRED 3.0 and for column identification.

See Table 4 for Abbreviations used for units in FRED 3.0 and in the Data Dictionary.

Table 3. Statistical metrics and definitions associated with many traits or ancillary data types.

Statistical term	Definition
n	Sample size: number of observations for specified parameter
SE	Standard error of specified parameter; SD/(√n) for specified parameter
SD	Standard deviation of specified parameter
Median	Value below which 50% of observed data for specified parameter falls
Upper quartile	Value below which 75% of observed data for specified parameter falls
Lower quartile	Value below which 25% of observed data for specified parameter falls
95th percentile	Value below which 95% of observed data for specified parameter falls
5th percentile	Value below which 5% of observed data for specified parameter falls
95 percent confidence margin	Size of interval that has a 95% certainty of including the true mean.
Min	Minimum value observed for specified parameter
Max	Maximum value observed for specified parameter
Modal	Value for specified parameter that occurs most in the data set
Upper bound	If data are presented for pre-defined interval, the upper bound of that interval
Lower bound	If data are presented for a pre-defined interval, the lower bound of that interval

Use of Associated statistical metric notation for FRED 3.0 Column ID definition:

For example, the primary root trait column (e.g., Column ID=F00277) is the mean value by definition and the associated statistical metrics (Column IDs F00278 to F00285) define the values in their respective columns. Excerpt from the Data Dictionary:

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00277	Root P content	mg/g	n [F00278] SE [F00279] SD [F00280] Min [F00281] Max [F00282] Median [F00283] Upper quartile [F00284] Lower quartile [F00285]	Mass of phosphorous per root mass for sampled roots.

Table 4. Abbreviations used for units in FRED 3.0. Note that some items that are commonly presented as superscripts (e.g., cm^2) or subscripts (e.g., CO_2) will appear in FRED 3.0 without this special formatting (e.g. cm2 and CO2, respectively). Similarly, the abbreviation "u" is used for micro- instead of the commonly used "µ". This was done to avoid the use of special text characters in the database which may not be compatible with some software or analyses.

Abbreviation	Stands for
branch	Root branch
cm	Centimeters
cm^2	Square centimeters
cm^3	Cubic centimeters
cmolc	Centimoles of charge
d	Days
degrees_C	Degrees Celsius
FW	Fresh weight
g	Grams
g_C	Grams root carbon
h	Hours
ha	Hectares (square hectometers)
kg	Kilograms
km	Kilometers
L	Liters
m	Meters
m^2	Square meters
m^3	Cubic meters
mg	Milligrams
Mg	Megagrams (metric tons)
min	Minutes

Abbreviation	Stands for
ml	Milliliters
mm	Millimeters
mm^2	Square millimeters
µm	Micrometers†
µm^2	Square micrometers†
mmol	Millimoles
µmol	Micromoles†
mmolc	Millimoles of charge
mo	Months
MPa	Megapascals
mV	Millivolts
ng	Nanograms
nmol	Nanomoles
-cbar	Negative centibars
per_mil	Thousandths
pmol	Picomoles
s	Seconds
µg	Micrograms†
µm	Micrometers†
µmol	Micromoles†
yr	Years

6. References:

Iversen CM, McCormack ML. 2021. Filling gaps in our understanding of belowground plant traits across the world: A Virtual Special Issue. *New Phytologist, in press.* [**FRED 3.0**]

McCormack ML, Powell AS, Iversen CM. 2018. Better plant data at the root of ecosystem models. *Eos* 99. https://doi.org/10.1029/2018EO104093. [**FRED 2.0**]

Iversen CM, McCormack ML, Powell AS, Blackwood CB, Freschet GT, Kattge J, Roumet C, Stover DB, Soudzilovskaia NA, Valverde-Barrantes OJ, van Bodegom PM, Violle C. 2017. Viewpoints: A global Fine-Root Ecology Database to address belowground challenges in plant ecology. *New Phytologist* 215: 15-26. https://doi.org/10.1111/nph.14459. [**FRED 1.0**]

7. Data Sources for FRED 3.0:

Please download associated file, FRED3_Data_Sources_2021.pdf, for full citations of each original data source; data sources followed by "F1" were in FRED 1.0, sources followed by "F2" were added between the release of FRED 1.0 and FRED 2.0, and sources followed by "F3" are new to FRED 3.0. In FRED 3.0, columns F00003, F00004, and F00005 also have the abbreviated and full citations, respectively, as well as a digital object identifier (DOI) for each data source where applicable.

8. Data Access:

FRED 3.0 is freely available to the public with unrestricted access. The data and companion files are available for download via http://roots.ornl.gov/public-release.

Disclaimer of Liability

Data and documents available from the FRED website (http://roots.ornl.gov/) were prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, or any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Further, Oak Ridge National Laboratory is not responsible for the contents of any off-site pages referenced.

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9. Contact Us:

For queries and suggestions, contact Colleen Iversen at iversencm@ornl.gov or fill out the contact form at http://roots.ornl.gov/contact.

10. Acknowledgements:

We thank Chris DeRolph for his assistance with GIS mapping, Les Hook for his assistance with best data management practices, and a special thanks to Dave Connerth and Derek Brownlee for their assistance with the website https://roots.ornl.gov and the development of the searchable database and user interface. CMI, MLM, DC, JKB, and ASP were supported by the Office of Biological and Environmental Research in the United States Department of Energy's Office of Science. This document has been authored by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725 with the U.S. Department of Energy. The United States Government retains and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes. The Department of Energy will provide public access to these results of federally sponsored research in accordance with the DOE Public Access Plan (http://energy.gov/downloads/doe-public-access-plan).

11. Data Dictionary for FRED 3.0:

The Data Dictionary (Table 5) contains the identifiers and the descriptions for the 1191 columns in FRED 3.0.

Column ID is the unique and unchanging identifier for the root trait, associated statistical metric, ancillary data observation, or descriptive field listed in **Column name**. **Units / Format** and **Description** for the respective column follow.

Note that the complete **Description** is included in the FRED3_Entire_Database_2021.CSV and FRED3_Filtered_Database_YYYYMMDD-HHMMSS.CSV files. (Yes, this does make the 3rd Header row quite long.)

Similar root trait or ancillary data types may have the same prefix (e.g., 'Notes_', 'Data_', 'Plant taxonomy_', etc.). 'Notes_' refer to ancillary data that are often descriptive in nature. All root traits begin with 'Root' or have 'root' in the name of the trait. The data file could be sorted by the Column ID to group by prefix and would, in effect, sort the file by trait. The data rows, as provided, are sorted by [**Notes_Row ID**].

As mentioned above, the **Associated statistical metrics** define the value represented by the primary **Column ID**. F00098 is the first use of the statistical metric notation.

A note about some data values: we used Grab It!, a point-and-click application, to extract data from graphs and charts. Data derived from Grab It! are presented with up to 14 decimal places. However, this does not necessarily correspond to the number of significant figures in the source data; the additional decimal places should be treated with caution. Likewise, some data have been converted from their reported units or format and thereby contain extra decimal places. Such instances are noted in the column, "Notes_Miscellaneous notes" [F00079].

Table 5. Data dictionary for FRED 3.0. Root traits and ancillary data are presented in the order that they appear in downloads of the FRED database.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00001	Version_FRED version number			FRED version number in which data in row first appeared. Version 0 is not acknowledged in version 1 and subsequent versions.
F00002	Notes_Row ID			Number to designate specific row.
F00003	Abbreviated article citation			Abbreviated citation of contributing data source, e.g. "Doe et al 2015"
F00004	Data source_Citation			Long-form citation of contributing data source.
F00005	Data source_DOI			DOI (digital object identifier) of contributing data source.
F00006	Data set_Citation			If the data are from a previously compiled dataset other than FRED, long-form citation of contributing dataset.
F00007	Data set_DOI			If the data are from a dataset other than FRED, DOI (digital object identifier) of contributing dataset.
F00008	Notes_Site ID			Identifier used in data source to distinguish between multiple data collection sites.
F00009	Data_Raw or unpublished	"main article", "supplement",		Denotes data in row are raw data (including individual replicates corresponding with previously published means) or unpublished. "Main article" means raw data are from the primary published work, "supplement" means

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
		"contributed", or blank		data are from a published supplemental document to the article, and "contributed" means the author directly contributed the data to FRED.
F00010	Data_Duplicate data	"x" or blank		"x" denotes that FRED includes duplicates of data. This may be due to the presence of both unpublished and published data, with additional individual replicates corresponding with previously published means, or data provided in multiple sources.
F01291	Plant taxonomy_Accepted group_TPL			Group of plant according to The Plant List: *The Plant List* (2013). Version 1.1. Published on the internet; http://www.theplantlist.org/
F01290	Plant taxonomy_Accepted order_APW			Order of plant. For Angiosperms, this was determined using the Angiosperm Phylogeny Website (APW): Stevens, P. F. (2001 onwards). Angiosperm Phylogeny Website. Version 14, July 2017 [and more or less continuously updated since]. Online at http://www.mobot.org/MOBOT/research/APweb/. For other plant groups (Gymnosperms, Pteridophytes, and Bryophytes) this was determined first using APW, but in cases where there were discrepancies within APW, and to maintain consistency in suffix nomenclature (i.e. all orders ending in "iales"), additional sources were used including the USDA Plants Database (https://plants.usda.gov/) and the Missouri Botanical Garden (http://www.missouribotanicalgarden.org/plant-science/plant-science/research/plant-identification.aspx)
F01289	Plant taxonomy_Accepted family_TPL			Family of plant according to The Plant List: *The Plant List* (2013). Version 1.1. Published on the internet; http://www.theplantlist.org/
F01286	Plant taxonomy_Accepted genus_TPL			Genus of plant according to The Plant List: *The Plant List* (2013). Version 1.1. Published on the Internet; http://www.theplantlist.org/
F01287	Plant taxonomy_Accepted species_TPL			Species epithet of plant according to The Plant List: *The Plant List* (2013). Version 1.1. Published on the Internet; http://www.theplantlist.org/

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01344	Plant taxonomy_Accepted subspecies_TPL			Variety, cultivar, or subspecies of plant according to The Plant List: The Plant List (2013). Version 1.1. Published on the Internet; http://www.theplantlist.org/
F00017	Plant taxonomy_Family_In original source			Family of plant, according to data source.
F00018	Plant taxonomy_Genus_In original source			Genus of plant, according to data source.
F00019	Plant taxonomy_Species_In original source			Species epithet of plant, according to data source.
F00020	Plant taxonomy_Subspecies_In original source			Variety, cultivar, or subspecies of plant, according to data source.
F01413	Plant taxonomy_Species name unresolved			"Unresolved" means species name is listed as unresolved in The Plant List. "Absent" means species name is not listed in the Plant List at all.
F00027	Notes_Single or multiple species	"x" or blank		"x" in this column denotes the data in the row are community-level (i.e., if root samples were taken from a mixed community of species). Blank indicates the data are attributable to a single species.
F00032	Plant growth form_TRY	"fern", "graminoid", "herb", "herb/shrub", "herb/shrub/tree", "lichen", "moss", "shrub", "shrub/tree", "tree", "climber"		Growth form of plant, according to the categorical traits data package from the TRY database: Kattge, J., Bönisch, G., Günther, A., Wright, I., Zanne, A., Wirth, C., Reich, P.B. and the TRY Consortium (2012) TRY - Categorical Traits Dataset. Data from: TRY - a global database of plant traits. TRY File Archive https://www.try-db.org/TryWeb/Data.php#3. If growth form data are not available in TRY categorical traits database, the database from Engemann et al 2016 was used instead when applicable: Engemann K, Sandel B, Boyle BL, Enquist BJ, Jørgensen PM, Kattge J, McGill BJ, Morueta-Holme N, Peet RK, Spencer NJ, Violle C, Wiser SK, Svenning J-C. 2016. A plant growth form dataset for the New World. *Ecology.* DOI: 10.1002/ecy.1569.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
				"Climber" is used for species designated in the "climber" column of the TRY categorical traits package or designated as "vine" in the Engelmann database, and includes vines and lianas.
F01456	Plant growth form_Taseski	"freestanding", "climber", "parasite", "epiphyte", "hemi-epiphyte", "holo-mycoheterotroph", "aquatic"		Growth form of plant, according to Taseski database. Listed as freestanding, climber, parasite, epiphyte, hemi-epiphyte, holo-mycoheterotroph, or aquatic. Taseski GM, Beloe CJ, Gallagher RV, Chan JY, Dalrymple RL, Cornwell WK. 2019. A global growth-form database for 143,616 vascular plant species. Ecology 100(3):e02614. DOI: 10.1002/ecy.2614.
F00042	Plant leaf habit_TRY	"deciduous", "deciduous / evergreen", "evergreen"		Whether plant is deciduous or evergreen. Data are from the categorical traits data package from the TRY database: Kattge, J., Bönisch, G., Günther, A., Wright, I., Zanne, A., Wirth, C., Reich, P.B. and the TRY Consortium (2012) TRY - Categorical Traits Dataset. Data from: TRY - a global database of plant traits. TRY File Archive https://www.try-db.org/TryWeb/Data.php#3
F00041	Plant leaf type_TRY	"broadleaved", "needleleaved", "scale-shaped", "microphylle", "scale-shaped / needleleaved", "without leaves", "pinnate"		Plant leaf type, according to the categorical traits data package from the TRY database: Kattge, J., Bönisch, G., Günther, A., Wright, I., Zanne, A., Wirth, C., Reich, P.B. and the TRY Consortium (2012) TRY - Categorical Traits Dataset. Data from: TRY - a global database of plant traits. TRY File Archive https://www.try-db.org/TryWeb/Data.php#3
F00044	Plant woodiness_TRY	"woody", "woody / non-woody", "non-woody"		Whether plant is woody or non-woody, according to the categorical traits data package from the TRY database: Kattge, J., Bönisch, G., Günther, A., Wright, I., Zanne, A., Wirth, C., Reich, P.B. and the TRY Consortium (2012) TRY - Categorical Traits Dataset. Data from: TRY - a global database of plant traits. TRY File Archive https://www.try-db.org/TryWeb/Data.php#3

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00043	Plant photosynthetic pathway_TRY	"C3", "C4","CAM"		Photosynthesis strategy of plant, according to the categorical traits data package from the TRY database: Kattge, J., Bönisch, G., Günther, A., Wright, I., Zanne, A., Wirth, C., Reich, P.B. and the TRY Consortium (2012) TRY - Categorical Traits Dataset. Data from: TRY - a global database of plant traits. TRY File Archive https://www.try-db.org/TryWeb/Data.php#3. In cases where a species was categorized as having multiple pathways, a single pathway was assigned according to the primary data source, the USDA Plants database (https://plants.usda.gov/), or following a search of primary literature. In these cases, this is indicated in Notes_Miscellaneous notes [F00079].
F00055	Belowground Part	"CR", "FR", "R", "BS", "TR", "TB", "unspecified", "unspecified roots"		Plant parts included in row data. CR = coarse roots (roots with diameter greater than 2 mm), FR = fine roots (roots with diameter less than 2 mm), R = rhizomes, BS = belowground stems, TR = total root system, and TB = total belowground system. "TR" is used when all plant roots are considered but the source does not specify whether or not coarse roots are present. "TB" is used when all belowground plant mass is considered but the source does not name all the plant parts comprised therein. Note that the FR category may contain roots measured from all roots from 0 to 2 mm in diameter, or may contain more restricted measures, e.g. 0 to 1 mm. The specific ranges of diameters included or allowed for a given sample are reported as the upper and lower bounds for root diameter classes in F00949 and F00950, respectively.
F00056	Root order			Root branching order, with 1 being either the distal (centripetal, i.e. morphometric scheme) or basal root (centrifugal, i.e. developmental scheme) depending on the classification scheme. Refer to F00059 (Root order classification scheme) for further information regarding the classification of root order.
F00057	Min_Root order			For an interval covering a range of root orders, the lowest order in the interval. If this value is unaccompanied by a maximum value in Max_Root order [F00058], all roots in the

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
				order above the order specified here are considered.
F00058	Max_Root order			For an interval covering a range of root orders, the highest order in the interval.
F00059	Notes_Root order classification scheme	"centrifugal", "centripetal"		Whether order scheme was centrifugal or centripetal. A centrifugal scheme counts the basal root as first order, with the distal root tip counted as the highest order (coarsest to finest). This is also known as the developmental approach. A centripetal scheme counts the distal tip as the first order, with the basal root counted as the highest order (finest to coarsest). This is also known as the morphometric approach.
F00060	Root functional class	"absorptive", "transport"		Whether roots are absorptive (orders 1-3 or designated by author's assessment) or transport (order >3 or designated by author's assessment).
F00949	Root diameter class_Lower bound	mm		For diameter-based categories, the minimum diameter defining the category.
F00950	Root diameter class_Upper bound	mm		For diameter-based categories, the maximum diameter defining the category.
F00061	Root age	d		Age of a sampled root as determined by time since root appearance.
F00062	Root age_Lower bound	d		Minimum age of roots for which data in row are measured.
F00063	Root age_Upper bound	d		Maximum age of roots for which data in row are measured.
F00064	Root vitality_Roots living or dead	"living", "dead", "both"		Whether roots are considered to be alive or dead at time of sampling.
F00065	Notes_Method of determining dead roots			Basis for how the authors determined whether roots were living or dead.
F00066	Root heterorhizy_Fibrous or pioneering	"fibrous", "pioneer"		Whether observed roots are fibrous or pioneer (framework) roots.
F00067	Soil depth_Sampling depth	cm		The depth at which the measurement is taken.
F00068	Soil depth_Upper sampling depth	cm		The minimum (shallower) depth at which the measurement is taken if soil depth is presented

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
				as a categorical interval. A negative number means the authors consider the interval to begin above the soil layer (typically a litter layer or organic layer).
F00069	Soil depth_Lower sampling depth	cm		The maximum (deeper) depth at which the measurement is taken if soil depth is presented as a categorical interval.
F00072	Soil block_Length	cm		Length of soil blocks if collected.
F00073	Soil block_Width	cm		Width of soil blocks if collected.
F00074	Soil block_Height	cm		Height/depth of soil blocks if collected.
F00075	Soil block_Volume	cm^3		Volume of soil blocks if collected.
F00097	Root aerenchyma porosity fraction	percent	n [F00098]	Percent porosity of root aerenchyma.
F01374	Root porosity fraction	Percent	Median [F01374] Minimum [F01375] Maximum [F01376] Upper quartile [F01377] Lower quartile [F01378]	Percent total porosity of root.
F00100	Root aerenchyma fraction of cross section	percent	n [F00101] SE [F00102]	Percentage of root cross-sectional area that consists of aerenchyma.
F00103	Root aerenchyma presence	"yes" or "no"		Whether aerenchyma are present in root.
F00104	Root cortex thickness	µm	n [F00105] SE [F00106] SD [F00107]	Thickness of root cortex.
F00108	Root exodermal wall thickness	µm		Thickness of exodermal wall from root scans.
F00109	Root passage cell number in exodermis	number		Number of passage cells in exodermis.
F00110	Root passage cell number per root circumference	number/mm		Number of passage cells per mm root circumference.
F00111	Mycorrhiza_Root length fraction that contains arbuscules	percent	SE [F00112]	Percentage of root length that contains arbuscules, determined using a random intercept method.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00113	Mycorrhiza_Root length fraction that contains vesicles	percent	SE [F00114]	Percentage of root length that contains fungal vesicles, determined using a random intercept method.
F00157	Root phellem	number		Number of phellem layers on root.
F00122	Root stele cross-sectional fraction	percent	n [F00123] SE [F00124]	Percentage of root cross-sectional area that is occupied by the stele.
F00118	Root stele diameter	µm	n [F00119] SE [F00120] SD [F00121]	Diameter of root stele.
F00115	Root stele diameter/root diameter ratio	ratio	n [F00116] SE [F00117]	Stele diameter divided by root diameter.
F00125	Root stele/root cortex ratio	ratio	n [F00126]	Proportion of root cross sectional area occupied by the stele divided by proportion of root cross sectional area occupied by the cortex.
F00134	Root conduit number per root stele area	number/m m^2	n [F00135] SE [F00136]	Number of conduits per stele cross-sectional area.
F00142	Root conduit diameter	µm	n [F00143] SE [F00144]	$D_h = \left[\left(\frac{1}{n}\right)\sum_{i=1}^{n} d^4\right]^{1/4}$ where d is conduit lumen diameter and n is conduit number.
F00154	Root conduit wall thickness	µm	n [F00155] SE [F00156]	Thickness of conduit wall from root scans.
F00150	Root metaxylem cell wall thickness	µm	SE [F00151]	Thickness of the cell wall in the root metaxylem.
F00128	Root metaxylem cell wall thickness/vessel diameter ratio	percent	SE [F00129]	Percentage of metaxylem vessel diameter that consists of cell wall thickness.
F00140	Root metaxylem vessel diameter	µm	SE [F00141]	Vessel diameter of root metaxylem.
F00132	Root number of tracheary elements	number	SE [F00133]	Number of tracheary elements present in root, with secondary cell-wall thickening counted per xylem pole.
F01313	Root number of vessels	number	n [F01314] SE [F01327]	Number of vessels per root cross-section.
F00152	Root protoxylem cell wall thickness	µm	SE [F00153]	Thickness of the cell wall in the root protoxylem.
F00130	Root protoxylem cell wall thickness per protoxylem diameter	percent	SE [F00131]	Percentage of protoxylem vessel diameter that consists of cell wall thickness.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00148	Root protoxylem diameter	µm	SE [F00149]	Vessel diameter of root protoxylem.
F01324	Root stele cross-sectional area	μm^2	n [F01447] SE [F01235]	Cross-sectional area of root stele.
F01319	Root vessel cross-sectional area	μm^2	n [F001320] SE [F01326]	Cross-sectional area per root vessel.
F00145	Root vessel diameter	µm	n [F00146] SE [F00147]	Diameter of root vessels.
F01321	Root vessel number per root cross-sectional area	number/mm^2	n [F01322] SE [F01455]	Number of vessels in root per root cross-sectional area.
F01311	Root xylem cross-sectional area	μm^2	n [F01312] SE [F01448]	Cross-sectional area of root xylem.
F01315	Root xylem cross-sectional fraction	percent	n [F01316] SE [F01449]	Percentage of root cross-sectional area occupied by xylem.
F00137	Root xylem vessel number per root stele area	number/mm^2	n [F00138] SE [F00139]	Number of xylem vessels per root stele cross-sectional area.
F00187	Root branching architecture_Root length per higher order root length	ratio		Root length for a given order divided by the length of the roots in the higher order.
F00179	Root branching intensity (branching ratio)_Number of roots per higher order root	ratio	n [F00180] SE [F00181]	Number of roots in a given order divided by the number of roots in the higher order.
F00182	Root branching intensity_root tips per higher order root length	number/cm	n [F01415] SE [F00184] Min [F00185] Max [F00186] Median [F01371] Upper quartile [F01372] Lower quartile [F01373]	Number of lower-order roots per centimeter length of higher-order root.
F01339	Root branching intensity_root tips per total root length	number/cm	n [F01340] SE [F01341] Min [F01342] Max [F01343]	Number of lower-order roots per total root length in category.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00219	Root tips per ground area	number/m^2	n [F00220] SE [F00221]	Total number of root tips per square meter of ground area (sampled from a given depth increment).
F00216	Root tips per minirhizotron frame	number/frame	SE [F00218]	Number of root tips observed per minirhizotron frame.
F00222	Root tips per plant	number/plant	n [F00223]	Total number of root tips for an entire plant.
F00176	Root tips per root branch	number/branch	n [F00177] SE [F00178]	Number of root tips and root endings per root branch.
F00224	Root tips per soil volume	number/L	SE [F00225]	Number of root tips per liter of soil.
F00192	Specific root tip abundance (SRTA)	number/mg	n [F00193] SE [F00194] SD [F00195]	Number of root tips per milligram of root mass.
F00210	Root dichotomous branching index		n [F00211] SE [F00212]	Determined by formula $[P_e - \min(P_e)] / [\max(P_e) - \min(P_e)]$. DBI of 1 indicates a completely herringbone topology, while DBI of 0 indicates a completely dichotomous topology.
F00213	Root external path length (Pe)	number	n [F00214] SE [F00215]	Sum of the number of links in all paths from each external link (root segment between two nodes) to the base link (the link from which all other links descend). (Definition from Beidler et al. 2015, DOI: 10.1111/nph.13123).
F01414	Root forks per root length	number/cm	n [F01463]	Number of root forks per cm of root length.
F00207	Specific root fork density (SRFD)	number/g	n [F00208] SE [F00209]	Number of root bifurcations per gram of root mass.
F00199	Root fractal dimension			Fractal dimension of scanned roots.
F00170	Root link branching angle	degrees	n [F00171] SE [F00172]	Mean angle between a link (segments of roots between two nodes or a node and a tip) and the extension of the link before it.
F00203	Root link length	cm	n [F00204] SE [F00205] SD [F00206]	Length of root links (segments of roots between two nodes or a node and a tip).
F00173	Root links per root branch	number/branch	n [F00174] SE [F00175]	Number of links (segments of roots between two nodes or a node and a tip) per root branch.
F00226	Root topological index (TI)			Slope of the linear regression of log10(Pe) against log10μ, in which Pe is external path

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
				length and μ represents magnitude (number of root tips in the system). A greater TI indicates a more "herringbone" branching system.
F00253	Root C content	mg/g	n [F00254] SE [F00255] SD [F00256]	Mass of carbon per root mass for sampled roots.
F00249	Root Ca content	mg/g	n [F00250] SE [F00251] SD [F00252]	Mass of calcium per root mass for sampled roots.
F01299	Root Ca content per root fresh mass	mg/g_FW		Mass of calcium per root fresh weight for sampled roots.
F00289	Root K content	mg/g	n [F00290] SE [F00291] SD [F00292]	Mass of potassium per root mass for sampled roots.
F01302	Root K content per root fresh mass	mg/g_FW		Mass of root potassium per fresh mass for sampled roots.
F00257	Root Mg content	mg/g	n [F00258] SE [F00259] SD [F00260]	Mass of magnesium per root mass for sampled roots.
F01300	Root Mg content per root fresh mass	mg/g_FW		Mass of magnesium per root fresh weight for sampled roots.
F00273	Root 15N content	per_mil		Concentration of nitrogen stable isotope in sampled roots, determined with a mass spectrometer.
F00261	Root N content	mg/g	n [F00262] SE [F00263] SD [F00264] Min [F00265] Max [F00266] Median [F00267] Upper quartile [F00268] Lower quartile [F00269]	Mass of nitrogen per root mass for sampled roots.
F00270	Root N content per root length	mg/m	n [F00271] SE [F00272]	Root nitrogen mass per meter of root length.
F00276	Root N_Molar organic N content	mmol/g		Millimoles of organic nitrogen in root per gram of root mass.
F00277	Root P content	mg/g	n [F00278] SE [F00279]	Mass of phosphorous per root mass for sampled roots.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
			SD [F00280] Min [F00281] Max [F00282] Median [F00283] Upper quartile [F00284] Lower quartile [F00285]	
F01301	Root P content per root fresh mass	mg/g_FW		Mass of root phosphorus per fresh mass for sampled roots.
F00293	Root S content	mg/g	n [F00294] SE [F00295]	Mass of sulfur per root mass for sampled roots.
F01303	Root S content per root fresh mass	mg/g_FW		Mass of root sulfur per fresh mass for sampled roots.
F00296	Root Al content	mg/g	n [F01338] SE [F00297]	Mass of aluminum per root mass for sampled roots.
F01304	Root Al content per root fresh mass	mg/g_FW		Mass of root aluminum per fresh mass for sampled roots.
F00298	Root As content	mg/kg	n [F00299] SE [F00300]	Mass of arsenic per root mass for sampled roots.
F00301	Root B content	mg/kg	n [F00302] SE [F00303] SD [F00304]	Mass of boron per root mass for sampled roots.
F00305	Root Cd content	mg/kg	n [F00306] SE [F00307]	Mass of cadmium per root mass for sampled roots.
F00308	Root Cl- ion content	mg/g	SE [F00310]	Mass of Cl^- ions per root mass for sampled roots, determined with flame photometer.
F00311	Root Cr content	mg/kg	n [F00312] SE [F00313]	Mass of chromium per root mass for sampled roots.
F00314	Root Cu content	mg/kg	n [F00315] SE [F00316] SD [F00317]	Mass of copper per root mass for sampled roots.
F00318	Root Fe content	mg/g		Mass of iron per root mass for sampled roots.
F00322	Root Mn content	mg/g	n [F00323] SE [F00324] SD [F00325]	Mass of manganese per root mass for sampled roots.
F01305	Root Mn content per root fresh mass	mg/g_FW		Mass of root manganese per fresh mass for sampled roots.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00334	Root Na content	mg/g	SE [F01388]	Mass of sodium per root mass for sampled roots.
F00331	Root Na+ content	mg/g	SE [F00333]	Mass of Na^+ ions per root mass, determined by silver ion titration.
F00326	Root Ni content	mg/kg	n [F00327] SE [F00328]	Mass of nickel per root mass for sampled roots.
F00319	Root Pb content	mg/kg	n [F00320] SE [F00321]	Mass of lead per root mass for sampled roots.
F00329	Root Si content	mg/g	SE [F00330]	Mass of silicon per root mass for sampled roots.
F00335	Root Zn content	mg/kg	n [F00336] SE [F00337]	Mass of zinc per root mass for sampled roots.
F00246	Root construction cost	g/g	n [F00247] SE [F00248]	Grams of glucose equivalent per gram of root dry weight.
F00245	Root cellulose and hemicellulose content per root mass	percent		Sum of concentrations of cellulose and all hemicelluloses in root.
F00237	Root cellulose content	percent	n [F00238] SE [F00239]	Concentration of cellulose in root.
F00240	Root cellulose content per root C content	percent		Percentage of root carbon that is cellulose.
F00242	Root hemicellulose content per root C content	percent_C		Percentage of root carbon that is hemicellulose.
F00243	Root hemicellulose content per root mass	percent	n [F01389] SE [F00244]	Percentage of root mass that is hemicellulose.
F00380	Root 12 phenol content per root C content	mg/g_C	SE [F00381]	Total concentration of twelve monophenols extracted from root per root C content.
F00342	Root acid hydrolyzable compounds content	mg/g	n [F00343] SD [F00344] SE [F00345]	Concentration of acid soluble compounds in root.
F00431	Root alkyl C content per root C content	mg/g_C	n [F00432] SE [F00433]	Fraction of root carbon that is in alkyl groups.
F00346	Root arabinans content	percent		Concentration of arabinans in root.
F00437	Root aromatic C content per root C content	mg/g_C	n [F00438] SE [F00439]	Fraction of root carbon that is in aromatic groups.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00340	Root ash C content per root C content	Percent_C		Percentage of root carbon that is ash.
F00347	Root ash content	percent		Concentration of ash in root.
F00348	Root bound phenol content per root C content	mg/g_C	SE [F00349]	Concentration of phenolic compounds that are bound to cell walls through ester/ether linkages per root carbon content.
F00350	Root cinnamyl phenol content per root C content	mg/g_C	SE [F00351]	Concentration of cinnamyl phenols in root per root carbon content.
F01330	Root condensed tannins	mg/g	n [F01331] SE [F01332]	Concentration of condensed tannins in root.
F00352	Root ethanol soluble fraction	percent		Percentage of root tissue that is soluble in ethanol.
F00353	Root free phenol content per root C content	ug/g_C	SE [F00354]	Concentration of phenolic compounds that are nonassociated forms in cell vacuoles per root carbon content.
F00355	Root galactans fraction	percent		Concentration of galactans in root.
F00358	Root lignin content	percent	n [F00359] SE [F00360]	Concentration of lignin in root.
F00361	Root lignin content per root C content	percent_C		Percentage of root carbon that exists as lignin.
F00356	Root lignin phenol content per root C content	mg/g_C	SE [F00357]	Total concentration of monophenols that constitute lignin in root per root carbon content.
F00338	Root lignin phenol vegetation index (LPVI)		SE [F00339]	[S%(S% + 1)/(V% + 1) + 1] * [C%(C% + 1)/(V% + 1) + 1], where V%, S%, and C% are the respective percentages of vanillyl phenol, syringyl phenol, and cinnamyl phenol in root lignin. Indicator for taxonomic source identification.
F00362	Root lipid content	percent	n [F01391] SE [F01387]	Concentration of lipids in root.
F00364	Root mannans content	percent		Concentration of mannans in root.
F00365	Root neutral detergent soluble fraction	percent		Percentage of root mass that is soluble in neutral detergent.
F00366	Root non-acid hydrolyzable compounds content	mg/g	n [F00367] SD [F00368] SE [F00369]	Concentration of compounds in root that are not acid soluble. Also known as Root acid insoluble fraction (AIF).

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00374	Root nonpolar compounds content	mg/g	n [F00375] SD [F00376] SE [F00377]	Concentration of nonpolar compounds in root.
F00434	Root O-alkyl C content per root C content	mg/g_C	n [F00435] SE [F00436]	Fraction of root carbon that is in O-alkyl groups.
F00378	Root *p*-hydroxy phenol content per root C content	mg/g_C	SE [F00379]	Concentration of *p*-hydroxybenzoic acid, *p*-hydroxyacetophenon, and *p*-hydroxybenzaldehyde phenols in root per root C content.
F00382	Root phenols content	mg/g	n [F01239] SE [F00383]	Concentration of phenols per unit root dry mass.
F01328	Root phenols_chlorogenic acid molarity per root mass	µM chlorogenic acid/g		Micromoles of chlorogenic acid yielded per root mass from ethanol boiling extraction and Folin-Ciocalteu's phenol reagent. See page 1221 of Zadworny et al. 2017, DOI: 10.1111/gcb.13514, for further information.
F00384	Root polar compounds content	mg/g	n [F00385] SD [F00386] SE [F00387]	Concentration of polar compounds in root.
F00388	Root polyphenol content	percent	n [F00389] SE [F00390]	Concentration of polyphenols in root.
F00391	Root rhamnan content	percent		Concentration of rhamnans in root.
F01329	Root starch fraction	percent		Percentage of root mass consisting of starches.
F00392	Root structural C content per root C content	percent		Percentage of root carbon that is structural.
F00393	Root syringyl phenol content per root C content	mg/g_C	SE [F00394]	Concentration of syringyl phenols in root per root carbon.
F00395	Root vanillyl phenol content per root C content	mg/g_C	SE [F00396]	Concentration of vanillyl phenols in root.
F00397	Root water or ethanol soluble compounds fraction	percent	SE [F00398]	Percentage of root tissue that is soluble in water or ethanol.
F00399	Root water soluble compounds fraction	percent	SE [F00400]	Percentage of root tissue that is soluble in water.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00401	Root water soluble compounds per root mass	percent		Percentage of root tissue that consist of water-soluble sugars, as determined by a phenol–sulfuric acid assay.
F01281	Root water soluble phenol compounds per root mass	percent	n [F01450] SE [F01451]	Percentage of root tissue that consists of water-soluble phenols.
F00402	Root xylan content	percent		Concentration of xylans in root.
F00407	Root 3,5-dihydroxybenzoic acid groups/vanillyl phenols ratio	percent	SE [F00408]	Percent of 3,5-dihydroxybenzoic acid to vanillyl phenols in root. Indicative of degradation status.
F00403	Root acid/aldehyde ratio for syringyl phenols	ratio	SE [F00404]	Ratio of acid to aldehyde in root syringyl phenols. Indicative of diagenetic state of lignin.
F00405	Root acid/aldehyde ratio for vanillyl phenols	ratio	SE [F00406]	Ratio of acid to aldehyde in root vanillyl phenols. Indicative of diagenetic state of lignin.
F00413	Root C/N ratio	ratio	n [F00414] SE [F00415] SD [F00416]	Ratio of carbon to nitrogen in root by mass.
F00417	Root cinnamyl phenol/vanillyl phenol ratio	ratio	SE [F00418]	Ratio of cinnamyl phenol to vanillyl phenol in root. Index for woody or nonwoody source.
F00419	Root lignin/N ratio	ratio	n [F01390] SE [F00420]	Ratio of lignin concentration to N concentration in root.
F00409	Root NAH/root N ratio	ratio	n [F00410] SE [F00411] SD [F00412]	Ratio of non-acid hydrolysable compounds to nitrogen in root tissue.
F00421	Root organic N/root total N ratio	ratio		Root organic N concentration divided by total root N concentration.
F00422	Root polyphenol/root N ratio	ratio		Ratio of root polyphenol concentration to root N concentration.
F00423	Root syringyl/vanillyl phenol ratio	ratio	SE [F00424]	Ratio of syringyl phenol to vanillyl phenol in root. Index for taxonomic level (angiosperm or gymnosperm) of plant from which phenol was derived.
F00425	Root vanillyl phenol/lignin phenol ratio	ratio	SE [F00426]	Ratio of vanillyl phenol to lignin phenol in root. Indicative of lignin quality.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00427	Root non-structural C content per root C content	percent_C		Percentage of root carbon that is non-structural
F00428	Root total non-structural carbohydrate content (TNC)	mg/g	n [F00429] SE [F00430]	Glucose equivalents per dry weight of roots, determined colorimetrically.
F00461	Root decomposition_Annual k constant	yr^{-1}	SE [F00462]	The *k* constant for the root in the exponential decay function $M_t = M_0 e^{-kt}$, where M_t is the mass of litter after time *t*, and M_0 is the initial mass of litter.
F00466	Root decomposition_Annual N immobilized in decomposing roots	mg/g/yr	n [F00467] SE [F0468]	Amount of nitrogen immobilized over the course of a year in decomposing roots.
F00465	Root decomposition_Annual necromass decomposition rate per ground area	$g/m^2/yr$		Amount of root necromass that decomposes over the course of a year.
F00457	Root decomposition_Estimated cumulative monthly mass loss	$kg/m^2/mo$		Difference between cumulative growth rate and fine root biomass.
F01364	Root decomposition_Fraction C remaining	percent	SE [F01365]	For decomposition experiment, percentage of original root carbon remaining.
F00458	Root decomposition_Fraction mass remaining	percent	n [F00459] SE [F00460]	For decomposition experiment, percentage of original root mass remaining.
F00591	Root decomposition_Fraction N remaining	percent	n [F00592] SE [F00593]	For decomposition experiment, percentage of original root nitrogen remaining.
F00463	Root decomposition_Monthly k constant	mo^{-1}		*K* constant (decomposition constant, see F00461) for a single month.
F00464	Root decomposition_Monthly necromass decomposition rate per ground area	$g/m^2/mo$		Amount of root necromass that decomposes over the course of a month.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00077	Root decomposition duration_d	d		Number of days roots had been decomposing at time of collection.
F01285	Root decomposition duration_mo	mo		Number of months roots had been decomposing at time of collection.
F00085	Notes_Root decomposition_Litter bag mesh size	mm		Size of mesh used for litterbags or in-growth cores.
F00476	Root age survivorship fraction	percent	SE [F00477] 95% confidence margin [F007478]	Percentage of roots that live to the age presented in the "root age" column.
F00469	Root mean lifespan_d	d	n [F00471] 5th percentile [F00472] 95TH percentile [F00473] SE [F00474]	Mean lifespan of roots observed, expressed in days.
F01295	Root mean lifespan_Main_d	d		Mean lifespan in days. This column combines data from both "Root mean lifespan_d" (F00470) and "Root mean lifespan_yr" (F01292) columns. If source originally presents lifespan in years or months, lifespan is converted to days for this value.
F01292	Root mean lifespan_yr	yr		Mean lifespan of roots observed, expressed in years.
F00470	Root median lifespan_d	d	SE [F00475]	Median lifespan of roots observed, expressed in days.
F01296	Root median lifespan_Main_d	d		Median lifespan in days. This column combines data from both "Root median lifespan_d" (F00470) and "Root median lifespan_yr" (F01293) columns. If source originally presents lifespan in years or months, lifespan is converted to days for this value.
F01293	Root median lifespan_yr	yr		Median lifespan of roots observed, expressed in years.
F00483	Root survivorship_Fraction of root tips surviving after one year	percent roots/yr	n [F00484]	Percentage of root tips that survive after one year.
F00480	Root survivorship_Fraction	percent	n [F00481] SE [F00482]	Percentage of roots which survive for the time interval represented in the row (i.e., the time

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
	roots surviving for exposition period			period between the dates in the "[date] beginning collection" and "[date] ending collection" columns).
F00479	Root survivorship_Fraction roots surviving for growing season	percent		Percentage of roots which survive over the course of a growing season.
F00518	Root growth_Annual C production per ground area	Mg_C/ha/yr	n [F00519] SE [F00520]	Amount of root carbon produced in one year.
F00546	Root growth_Annual length production per ground area	$m/m^2/yr$	n [F00547] SE [F00548] 5^{th} percentile [F00549] 95^{th} percentile [F00550]	Annual increase in total root length per unit ground area.
F00553	Root growth_Annual length production per minirhizotron surface area	$mm/cm^2/yr$	SE [F00554]	New root length observed per square centimeter of minirhizotron surface per year.
F00521	Root growth_Annual mass production per ground area	$g/m^2/yr$	n [F00522] SE [F00523] 5^{th} percentile [F00524] 95^{th} percentile [F00525]	Amount of root mass produced in one year.
F00510	Root growth_Annual net new length production per ground area	$m/m^2/yr$	n [F00511]	Live root length density appearance minus live root length density disappearance, adjusted to an annual value by subtracting net new length growth from the value for the previous sampling date, dividing by the number of days between sampling dates, and multiplying the result by the number of days in the year.
F00571	Root growth_Annual surface area production per ground area	$m^2/m^2/yr$	5^{th} percentile [F00572] 95^{th} percentile [F00573] SE [F01358]	Root surface area produced per square meter of ground area per year.
F00559	Root growth_Bimonthly number of roots born per ingrowth screen area	$number/cm^2/2mo$	SE [F00560]	Inferred number of roots born per square centimeter of in-growth screen per two months.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00543	Root growth_Cumulative length production per ground area	m/m^2	n [F00544] SE [F00545]	Cumulative root length density appearance per unit ground area.
F00527	Root growth_Cumulative mass production per ground area	Mg/ha	SE [F00528]	Total root mass produced since the beginning of the study.
F00526	Root growth_Cumulative monthly mass ingrowth per screen area	$kg/m^2/mo$		Cumulative rate of root growth into in-growth mesh, in kg per mesh cross-sectional area per month.
F00507	Root growth_Cumulative net length production per ground area	m/m^2	n [F00508] SE [F00509]	Difference between cumulative live root appearance and cumulative live root disappearance.
F00538	Root growth_Daily elongation rate	mm/d	SE [F00539]	Rate at which elongation occurs for the roots where it does occur.
F00568	Root growth_Daily length production per coarse root length	cm/d/cm		Total fine root length production per day per length of woody root.
F00551	Root growth_Daily length production per minirhizotron surface area	$mm/cm^2/d$	SE [F00552]	New root length observed per square centimeter of minirhizotron surface per day.
F00569	Root growth_Daily mass production per coarse root length	mg/d/cm		Total fine root mass produced per day per length of woody root.
F00529	Root growth_Daily mass production per ground area	$g/m^2/d$	n [F01420] SE [F01421] SD [F01422]	Amount of root mass produced in one day.
F00537	Root growth_Elongation fraction	percent		Percentage of roots that have elongated since the previous measurement.
F00513	Root growth_Fraction peak production	unitless	SE [F00514]	The root production rate observed at a specific point divided by the maximum root production rate observed during the entire observation period.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00286	Root growth_Length produced per P content	m/mg	n [F00287] SE [F00288]	Root length produced per unit mass of root phosphorus.
F00556	Root growth_Length production per ground area and exposition period	km/m^2	n [F00557] SE [F00558]	Increase in root length per square meter of ground area during the observation period specified in the "[year/month/day] beginning data collection" and "[year/month/day] ending data collection" columns.
F00540	Root growth_Length production per minirhizotron frame	mm/frame	SE [F00542]	Root length produced per minirhizotron frame.
F00566	Root growth_Length recovery from pruning	cm	SE [F00567]	Root length recovery from pruning.
F00534	Root growth_Mass production per ground area and exposition period	Mg/ha	n [F00535] SE [F00536]	Root biomass produced for the time interval specified in "main exposition period" and "production duration" or "in growth duration" (columns F01294 and F0076,F01283,F01284, or F01280).
F01276	Root growth_Mass production per plant per growing season	g/plant/growing season		Increase in biomass per plant (by dry weight) over the course of one growing season.
F00531	Root growth_Monthly mass ingrowth per screen area	$kg/m^2/mo$		Monthly rate of root growth into in-growth mesh, in kg per mesh cross sectional area per month.
F00532	Root growth_Monthly mass production per ground area	$g/m^2/mo$		Amount of root mass produced in one month.
F00533	Root growth_Monthly mass production per soil volume	$mg/cm^3/mo$	n [F01437] SE [F01438]	Root mass produced per cubic centimeter of soil each month.
F00903	Root growth_Number of roots per area of ingrowth screen	number/cm^2	SE [F00905]	Number of roots per square cm of in-growth screen.
F00561	Root growth_Predicted amplitude of monthly net root production	Log10 (Number of roots/$0.2m^2$)		Log of predicted amplitude of monthly net root production if it occurs (i.e. if mRIQ>0), based on negative binomial distribution. See Mao et al. 2013 (DOI: 10.1007/s11104-012-1324-2)for further details.
F00562	Median_Root growth_Probability monthly net root	unitless	Upper quartile [F00563]	Probability that monthly net root production is greater than 0 roots per 0.2 m^{-2}, based on modelling by logistic regression. See Mao et

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
	production greater than 0		Lower quartile [F00564] 95% confidence interval [F00565]	al. 2013 (DOI: 10.1007/s11104-012-1324-2) for further details.
F00574	Root growth_Surface area production per ground area and exposition period	m^2/m^2	n [F00575] SE [F00576]	Increase in root surface area per square meter of ground area during the observation period specified in the "Exposition period_Main" column" [F01294]
F00570	Root pruning recovery	Percent		Percentage pruned woody roots that recovered by proliferating fine roots.
F00515	Root relative growth rate (RGR)_Root length	m/m/d	SE [F00517] Median [F01366] Maximum [F01367] Upper quartile [F01368] Lower quartile [F01369] Minimum [F01370]	[ln (each growth response at 30, 60 and 90 days of the treatments) - ln (each growth response at 0, 30 and 60 days of the treatments, respectively)]/30 days; see Imada et al. 2008 (DOI: 10.1111/j.1365-2435.2008.01454.x) for more details.
F00500	Root mortality_Annual root length mortality per ground area	$m/m^2/yr$	n [F00501] SE [F00502]	Annual mortality of root length density.
F00498	Root mortality_Annual root length mortality per minirhizotron surface area	$mm/cm^2/yr$	SE [F00499]	Observed length of roots which dies per minirhizotron surface per year.
F00490	Root mortality_Annual root mass mortality per ground area	$g/m^2/yr$	n [F00491] SE [F00492]	Amount of root biomass that dies in one year per square meter of ground area.
F00487	Root mortality_Cumulative root length disappearance per ground area	m/m^2	n [F00488] SE [F00489]	Cumulative root length density disappearance observed per ground area.
F00493	Root mortality_Cumulative root length mortality per minirhizotron frame	mm/frame	SE [F00495]	Root length mortality observed per minirhizotron frame since the beginning of observation.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00496	Root mortality_Daily root length mortality per minirhizotron surface area	$mm/cm^2/d$	SE [F00497]	Observed length of roots which dies per minirhizotron surface per day.
F00505	Root mortality_Fraction initial intersections with ingrowth screen lost	percent	SE [F00506]	For in-growth screen, percentage of root-screen contacts lost after installation.
F00485	Root mortality_Monthly mass disappearance per soil volume	$mg/cm^3/mo$		Mass of root biomass that disappears per cubic centimeter of soil per month. Calculated based on loss of mass.
F00486	Root mortality_Monthly necromass increase per soil volume	$mg/cm^3/mo$		Amount of root biomass that dies per cubic centimeter of soil per month. Calculated based on change in necromass.
F00503	Root mortality_Monthly number of roots lost per ingrowth screen area	$number/cm^2/2mo$	SE [F00504]	Inferred number of roots to die per square centimeter of in-growth screen per two months.
F00577	Root mortality_Root N loss per annual plant N uptake	percent		Nitrogen lost through fine root mortality as a percentage of annual whole-plant nitrogen uptake.
F00578	Root mortality_Root N loss per plant N content per ground area	percent	SE [F01432]	Nitrogen lost through fine root mortality as a percentage of whole-plant N storage (root nitrogen per ground area).
F00579	Root turnover_Annual biomass turnover per ground area	$g/m^2/yr$	n [F00580] SE [F00581]	Root mass multiplied by turnover rate.
F00589	Root turnover_Estimated rate per growing season	$season^{-1}$		Number of days in growing season divided by median lifespan of roots.
F00585	Root turnover_Mass per dry season	$season^{-1}$	SE [F00586]	Turnover during dry season as defined in original data source.
F00587	Root turnover_Mass per wet season	$season^{-1}$	SE [F00588]	Turnover during wet season as defined in original data source.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00582	Root turnover_Annual root system replacement	yr^{-1}	n [F00583] SE [F00584] SD [F01423] Median [F01359] Max [F01360] Upper quartile [F01361] Lower quartile [F01362] Min [F01363]	Turnover as the inverse of belowground net primary productivity.
F00609	Mycorrhiza_Fraction contact exploration mycorrhizae	percent	SE [F00610]	Percentage of mycorrhizal tips that are of the contact exploration type.
F00611	Mycorrhiza_Fraction long-distance exploration mycorrhizae	percent	SE [F00612]	Percentage of mycorrhizal tips that are of the long-distance exploration type.
F00613	Mycorrhiza_Fraction medium-distance exploration mycorrhizae	percent		Percentage of mycorrhizal tips that are of the medium-distance exploration type.
F00617	Mycorrhiza_Fraction mycorrhizal root tips that are living	percent		Percentage of mycorrhizal tips that are living.
F00638	Mycorrhiza_Fraction of root length	percent	n [F00639] SE [F00640] SD [F01306]	Percentage of root length colonized by mycorrhizal fungi, identified by the presence of mycorrhizal hyphae, arbuscules, or vesicles. This column contains information from both AM and EM colonization reported in columns F00622 and F00626, and additional data when mycorrhizal type was unspecified or both colonization types were present.
F00622	Mycorrhiza_Fraction root length colonized by AM mycorrhizae	percent	n [F00623] SE [F00624] SD [F00625] Median [F01441] Upper quartile [F01442] Lower quartile [F01443]	Percentage of root length which shows colonization by arbuscular mycorrhizal fungi. These data may also be contained in column F00638.
F00626	Mycorrhiza_Fraction root length colonized by EM mycorrhizae	percent	SE [F00628]	Percentage of root length which shows colonization by ectomycorrhizal fungi. These data may also be contained in column F00638.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00619	Mycorrhiza_Fraction root tips colonized by mycorrhizae	percent	n [F00620] SE [F00621]	Percentage of root tips that are colonized by mycorrhizal fungi.
F00615	Mycorrhiza_Fraction short-distance exploration mycorrhizae	percent	SE [F00616]	Percentage of mycorrhizal tips that are of the short-distance exploration type.
F00606	Mycorrhiza_Length of AM hyphae per soil mass	mm/g		Millimeters of arbuscular mycorrhizal hyphae per gram of soil, determined by dispersing soils in sodium metaphosphate solution, passing through a series of sieves, collecting hyphae on filters, and examining hyphae through a microscope.
F00641	Mycorrhiza_Number of AM spores per soil mass	spores/g	n [F00642] SE [F00643] SD [F00644]	Number of arbuscular mycorrhizae spores per gram of soil, determined by isolating the spores using the wet-sieving technique and counting them under a microscope.
F00635	Mycorrhiza_Number of root tips per root length colonized by mycorrhizae	number/cm	n [F00636] SE [F00637]	Number of tips per cm of root on root branch that contains mycorrhizal fungi.
F00607	Mycorrhiza_PLFA proxy for EM mass per ground area	g/m^2	SE [F00608]	Grams of external ectomycorrhizal mycelium biomass in soil per square meter of ground area for a given sampling depth, estimated based on PLFA with a conversion factor of 2 nmol 18:2ω6.9 per milligram of fungal biomass.
F01333	Mycorrhiza_PLFA proxy for mycorrhizal hyphal C per soil mass	mg/kg	SE [F01334]	Milligrams of mycorrhizal hyphal carbon per kilogram of soil mass, estimated from PLFA biomarkers as specified in: Chen, W. et al. 2016. DOI: 10.1073/pnas.1601006113.
F00645	Mycorrhiza_Type_In original source	“AbtM”, “AM”, “DS”, “EeM”, “EM”, “ErM”, “mycorrhizal”, “OrM”, “NM”		Type of mycorrhizae formed. "AbtM" = arbutoid mycorrhizae; “AM” = arbuscular mycorrhizae; “DS” = dark septate endophyte mycorrhizae; “EeM” = ectendomycorrhizae; “EM” = ectomycorrhizae; “ErM” = ericoid mycorrhizae”;, "OrM" = orchid mycorrhizae; “mycorrhizal” means mycorrhizae are present but type is unknown; “NM” = non-mycorrhizal.
F00631	Mycorrhiza_Visual estimate of root colonization intensity	percent	n [F00632] SE [F00633] Min [F01435]	Intensity of mycorrhizal colonization based on five categories of mycorrhizal intensity,

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
			Max[F01436]	estimated visually and averaged across samples examined.
F00649	Root nodules_Nodule mass on dead roots per ground area	g/m^2	SE [F00651]	Total dry weight of all root nodules collected from dead roots in soil cores.
F00646	Root nodules_Nodule mass on living roots per ground area	g/m^2	SE [F00648]	Total dry weight of all root nodules collected from living roots in soil cores.
F01288	Mycoheterotrophy	"x" or blank		"x" denotes the presence of mycoheterotrophy. Blank indicates the data are not related to mycoheterotrophy or that mycoheterotrophy data were not available.
F00659	Root microbes_Bacterial biomass C content per root mass	mg/g		Concentration of bacterial carbon in root material, estimated based on calculated average conversion factor of muramic acid to fungal carbon.
F00658	Root microbes_Fungal biomass C content per root mass	mg/g		Concentration of fungal carbon in root material, estimated based on calculated average conversion factor of glucosamine to fungal carbon.
F00660	Root microbes_Fungal C/bacterial C ratio	ratio		Ratio of root fungal carbon to root bacterial carbon.
F00656	Root microbes_Microbial biomass C content per root mass	mg/g		Carbon from microbial biomass in roots, calculated from root ergosterol and the ergosterol/microbial biomass carbon ratio of the rhizosphere soil.
F00657	Root microbes_Microbial biomass N content per root mass	mg/g		Nitrogen from microbial biomass in roots, calculated from root ergosterol and microbial biomass C/N ratio of the rhizosphere soil.
F00652	Root microbes_Root glucosamine content per root mass	mg/g		Concentration of glucosamine measured in root material.
F00629	Root microbes_Root length hyphal fraction	percent	SE [F00630]	Percentage of root length that contains fungal hyphae, determined using a random intercept method.
F00653	Root muramic acid content	mg/kg		Concentration of muramic acid measured in root material.
F01317	Root cross-sectional area	μm^2	n [F01318] SE [F01323]	Cross-sectional area of root.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00679	Root diameter	mm	n [F00680] SE [F00681] SD [F00682] Min [F00683] Max [F00684] Median [F00685] Upper quartile [F00686] Lower quartile [F00687] Modal [F00688]	Diameter of roots observed.
F00689	Root dry matter content (RDMC)	ratio	n [F01310] SE [F00690]	Root dry mass divided by root fresh mass.
F00691	Root color_White or brown	"White", "Brown"		Whether observed roots are considered to be white or brown.
F00733	Root hair density	number/mm^2	n [F00734] SE [F00735]	Number of root hairs per root surface area.
F00736	Root hair diameter	µm	n [F00737] SE [F00738]	Diameter of root hairs.
F00692	Root hair incidence	percent	n [F00693] SE [F00694] SD [F00695]	Percentage of fine roots that contain root hairs, by the gridline method.
F00696	Root hair length	um	n [F00697] SE [F00698] SD [F00699]	Length of root hairs.
F00700	Root hair volume per root mass	cm^3/g	n [F00701] SE [F00702]	Volume of root hairs per gram of root mass, estimated using specific root length.
F00703	Root length from base to tip	cm	n [F00704] SE [F00705] SD [F00706] 95th percent confidence interval min [F00707] 95th percent confidence interval max [F00708]	Distance from root base to tip.
F00709	Root tissue density (RTD)	g/cm^3	n [F00710] SE [F00711] SD [F00712] Min [F00713] Max [F00714] Median [F00715]	Weight of roots sampled divided by volume of roots.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
			Upper quartile [F00716] Lower quartile [F0717]	
F00718	Specific root area (SRA)	cm^2/g	n [F00719] SE [F00720] SD [F00721] Median [F00722] Lower quartile [F00723] Min [F00724] Max [F00725] Upper quarile [F00726]	Root surface area divided by root mass.
F00727	Specific root length (SRL)	m/g	n [F00728] SE [F00729] SD [F00730] Min [F00731] Median [F01345] Upper quartile [F01346] Lower quartile [F01347] Max [F00732]	Length of roots divided by root mass.
F00743	Root acid phosphatase activity per root mass	umol_pNP/g/h	n [F00744] SE [F00745] Max [F00746] Upper quartile [F00747] Median [F00748] Lower quartile [F00749] Min [F00750]	Acid phosphatase activity per unit root mass.
F00754	Root exudation_C exudation rate per root mass	µg_C/g_fine root/h	n [F00755] SE [F00756]	Carbon exudation rate by mass of fine roots.
F01416	Root exudation_C exudation rate per root length	ug_C/cm/h	SE [F01417]	Carbon exudation rate by length of fine roots.
F01418	Root exudation_C exudation rate per plant	g_C/m2/d	SE [F01419]	Total carbon exudation rate by fine roots per individual plant.
F00751	Root exudation_Fraction estimated root mass	percent	n [F00752] SE [F00753]	Collected exudates scaled as proportion of estimated biomass accumulation.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01404	Root exudation_molar C exudation rate per root area	µmol_C/m^2 /h		Root carbon exudation rate in terms of micromoles of Carbon exuded per root area.
F00760	Root phosphatase activity per root length	µg/m/h	n [F00761] SE [F00762]	Phosphatase activity of roots, based on release of *p*-nitrophenol from a solution of *p*-nitrophenyl phosphate per meter of root length per hour.
F01430	Root exudation_Concentration in soil	µg/kg	SE [F01431]	Concentration of root exudates in the soil, estimated using 13C labelling.
F00757	Root phosphatase activity per root mass	umol_p-NP/g/min	n [F00758] SE [F00759]	Hydrolysis of p-nitrophenyl phosphatase to p-nitrophenol after incubation at 37°C for 1 hour.
F00780	Plant N uptake rate_Annual N uptake per ground area	kg/ha/yr	n [F00781] SE [F00782]	Total amount of nitrogen taken up by plants per hectare over the course of a year.
F01396	Plant N uptake_Daily uptake of molar 15N-Glycine per shoot dry mass	µmol/g/d	SE [F01397]	Uptake of 15N-Glycine tracer over the course of 24 hours per shoot dry mass, estimated with the equation F = [T(AS-AB)]/AF, where T is the plant N concentration AS is the atom percent excess 15N in the sample, AB is the atom percent excess 15N in the natural sample, and AF is the atom percent excess 15N in the tracer.
F01392	Plant N uptake_Daily uptake of molar 15NH4+ per shoot dry mass	µmol/g/d	SE [F01393]	Uptake of 15N-NH4+ tracer over the course of 24 hours per shoot dry mass, estimated with the equation F = [T(AS-AB)]/AF, where T is the plant N concentration AS is the atom percent excess 15N in the sample, AB is the atom percent excess 15N in the natural sample, and AF is the atom percent excess 15N in the tracer.
F01394	Plant N uptake_Daily uptake of molar 15NO3- per shoot dry mass	µmol/g/d	SE [F01395]	Uptake of 15N-NO3- tracer over the course of 24 hours per shoot dry mass, estimated with the equation F = [T(AS-AB)]/AF, where T is the plant N concentration AS is the atom percent excess 15N in the sample, AB is the atom percent excess 15N in the natural sample, and AF is the atom percent excess 15N in the tracer.
F01398	Plant N uptake_Daily uptake of molar total 15N per shoot dry mass	µmol/g/d	SE [F01399]	Combined uptake of 15N-NH4+, 15N-NO3-, and 15N-Glycine tracers over the course of 24 hours per shoot dry mass, estimated with the equation F = [T(AS-AB)]/AF, where T is the

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
				plant N concentration AS is the atom percent excess 15N in the sample, AB is the atom percent excess 15N in the natural sample, and AF is the atom percent excess 15N in the tracer.
F00766	Root K uptake_Fraction K uptake capacity per soil depth interval	percent		Estimated potassium uptake capacity of roots at the depth interval specified in Soil depth_Upper sampling depth (F00068) and Soil depth_Lower sampling depth (F00069) relative to the plant's total uptake capacity.
F00770	Root N uptake_Cumulative N uptake	g/m^2	n [F00771] SE [F00772]	Total root nitrogen uptake since the first observation per meter square of ground area.
F00773	Root N uptake_Hourly uptake of 15NH4+ per root fresh mass	ng/mg FW/h	SD [F00774]	Hourly uptake of nitrogen by roots per root fresh mass, as determined by a root bioassay using 15NH4+. Reported in terms of nanograms of NH4+.
F01457	Root N uptake_Hourly uptake of NH4+ per root mass	mg/g/h	SE [F01458]	Hourly maximum uptake capacity of NH4+ per root mass, determined by colorometric methods.
F00775	Root N uptake_Hourly uptake of molar NH4+ per root fresh mass	nmol/g_FW/h	SD [F00776]	Hourly uptake of nitrogen by roots per root fresh mass, as determined by a root bioassay using $^{15}NH_4^+$. Reported in terms of nmol of NH_4^+.
F00777	Root N uptake_Hourly uptake per unit root mass	µg/g/h	n [F00778] SE [F00779]	Amount of nitrogen taken up per unit root mass per hour.
F01405	Root N uptake_Molar inorganic N uptake per root area	$\mu mol/m^2/h$		Hourly uptake of inorganic nitrogen in terms of micromoles of nitrogen per root area.
F01406	Root N uptake_Molar NH4+ uptake per root area	$\mu mol/m^2/h$		Hourly uptake of nitrogen by roots per root surface area, as determined by a root bioassay using $^{15}NH_4^+$. Reported in terms of µmol of NH_4^+.
F01407	Root N uptake_Molar NO3- uptake per root area	$\mu mol/m^2/h$		Hourly uptake of nitrogen by roots per root surface area, as determined by a root bioassay using $^{15}NO_3^-$. Reported in terms of µmol of NO_3^-.
F01459	Root N uptake_Hourly NO3- uptake per root mass	mg/g/h	SE [F01460]	Hourly maximum uptake capacity of NO3- per root mass, determined by colorometric methods.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01408	Root N uptake_Molar organic N uptake per root area	µmol/m^2/h		Hourly uptake of organic nitrogen in terms of micromoles of nitrogen per root area.
F00769	Root N_Annual turnover per ground area	g/m^2/yr		Annual root nitrogen turnover per meter square of ground area.
F00763	Root P uptake_Fraction maximum P uptake rate	fraction	n [F00764] SE [F00765]	Fraction of maximum phosphorus uptake rate achieved by age group specified in F00062 and F00063.
F00784	Root P uptake_Hourly uptake of H2PO4-	ng/mg/h	SD [F00785]	Hourly uptake of H_2PO_4, as determined by a root bioassay.
F00786	Root P uptake_Rate per root mass	pmol/g/s	SE [F00787]	Rate of phosphorus uptake per gram of root per second.
F00788	Root P uptake_Rate per root surface area per second	pmol/cm^2/s	SE [F00789]	Phosphorus uptake per unit root area, determined with tissue cassettes.
F00791	Root preferred N form			Form or forms of nitrogen preferentially taken up by roots. NH4-N is NH_4, NO3-N is NO_3, and ON is organic nitrogen. If multiple forms are preferred, their relative preference to each other is shown with >=,<=, or = symbols.
F00796	Root Rb uptake_Hourly Rb uptake per root mass	ng/mg/h	SD [F00798]	Hourly uptake rate of rubidium by roots, as determined by a root bioassay using $^{86}Rb^+$, reported in terms of nanograms taken up per fresh weight of roots per hour.
F00792	Root Rb uptake_Hourly uptake of molar Rb+ per root fresh mass	nmol/g_FW/h	SE [F00794] SD [F00795]	Hourly uptake rate of rubidium by roots per root fresh mass, as determined by a root bioassay using $^{86}Rb^+$, reported in nmol taken up per fresh weight of roots per hour.
F01425	Root Rb uptake_Daily uptake of molar Rb+ per root length	nmol/m/d	SE [F01426]	Daily uptake rate of rubidium by roots, reported in terms of nanograms taken up per meter of root length.
F01427	Root Li uptake_Daily uptake of molar Li per root length	nmol/m/d	SE [F01428]	Daily uptake rate of lithium by roots, reported in terms of micrograms taken up per meter of root length.
F00802	Root respiration rate per root dry mass_CO2 release	nmol_CO_2/g/s	n [F00803] SE [F00804] SD [F01424]	Root respiration rate of CO_2 per g root dry mass per second.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00799	Root respiration rate per root dry mass_O2 uptake	nmol_O_2/g/s	n [F00800] SE [F00801]	Root respiration rate of O_2 per root dry mass, as measured in a respiration chamber.
F00807	Root respiration rate per root length_CO2 release	nmol_CO_2/m/s	n [F00808] SE [F00809]	Root respiration rate of CO_2 per meter of root length, as measured in a respiration chamber.
F00805	Root respiration rate per root mass_C release	µg_C/g/s	n [F00806]	Root respiration rate, converted from terms of nmol O_2 g^{-1} s^{-1},converted to ug C g^{-1} s^{-1}using a respiratory quotient of 1.25. See Matamala & Schlesinger 2000 (DOI: 10.1046/j.1365-2486.2000.00374.x) for further details.
F00819	Root water uptake per root length	ml/cm/d		Daily water uptake in milliliters, per centimeter of root length.
F00815	Root water uptake per root surface area	$cm^3/cm^2/s$	n [F00816] SD [F00817] SE [F00818]	Water absorption rate per surface area of root.
F00822	Root water uptake_Hourly uptake rate per soil volume	$cm^3/cm^3/h$		Rate of water uptake by roots, divided by the volume of soil from which roots take up water.
F00812	Root water uptake_Hydraulic conductivity (Lp)	$cm^3/cm/s/(MPa \times 10^6)$	SE [F00813]	Hydraulic conductivity of roots.
F00841	Aboveground/belowground net primary production ratio	ratio	SE [F00842]	Annual aboveground net primary production (NPP) divided by belowground NPP.
F00838	Belowground/aboveground mass ratio	ratio	n [F00839] SE [F00840]	Ratio of belowground biomass (g m^{-2}) to aboveground biomass (g m^{-2}).
F00844	Fine root C/leaf C ratio	ratio		Ratio of fine root carbon to leaf carbon.
F00843	Fine root mass/leaf mass ratio	ratio		Ratio of fine-root mass to leaf mass.
F00846	Root mass fraction (RMF)	ratio	n [F00847] SE [F00848] Min [F00849] Max [F00850] Median [F01384] Upper quartile [F01385] Lower quartile [F01386]	Root biomass divided by total plant biomass.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00851	Root/shoot ratio	ratio	n [F00852] SE [F00853] Min [F01379] Max [F01380] Median [F01381] Upper quartile [F01382] Lower quartile [F01383]	Ratio of root tissue mass to shoot mass, where rhizomes are counted as shoot mass.
F00854	Coarse root/fine root mass ratio	ratio		Ratio of coarse root biomass to fine root biomass.
F00864	Root length_Diameter class fraction	percent	n [F00865] SE [F00866]	Percentage of root length composed of a specific root diameter class.
F00867	Root length_Root order class fraction	percent	n [F00868] SE [F00869]	Percentage of root length composed of a specific root order.
F00855	Root mass_Diameter class fraction	percent	SE [F00857] Median [F01348] Upper quartile [F01349] Lower quartile [F01350] Min [F01351] Max [F01352]	Percentage of root biomass contributed by a particular diameter class.
F00858	Root mass_Root order class fraction	percent	n [F00859] SE [F00860]	Percentage of root biomass contributed by a particular root order.
F00884	Root mass_Species fraction	percent		Percentage of total root mass composed of a particular species in a community.
F00870	Root necromass/biomass ratio	ratio	SE [F00871]	Dead root mass divided by live root mass.
F00872	Root surface area fraction per root order class	percent	SE [F00874]	Percentage of total root surface area that a specific root order comprises.
F00953	Root tip fraction per root diameter class	percent		Proportion of total number of root tips comprised by a particular diameter class.
F00875	Taproot mass fraction	percent	n [F00876] SE [F00877]	Percentage of root mass that consists of the taproot.
F00954	Rooting depth	cm	SE [F00955] Min [F01409]	Depth which includes all observed roots.
F00959	Rooting depth_Extrapolated	m		Depth which includes 50% of total roots in profile, extrapolated from logistic dose-

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
	50 percent rooting depth			response model described in Schenk & Jackson 2003, DOI: 10.3334/ORNLDAAC/659
F00960	Rooting depth_Extrapolated 95 percent rooting depth	m		Depth which includes 95% of total roots in profile, extrapolated from logistic dose-response model described in Schenk & Jackson 2003, 10.3334/ORNLDAAC/659
F00957	Rooting depth_Interpolated 50 percent rooting depth	m		Depth which includes 50% of all observed roots in profile, calculated by fitting logistic dose-response curve to cumulative root profile and interpolating to maximum sampling depth, using the equation $D_{S50} = D_{50} * (\frac{R_{max}}{0.5R_{S\,max}} - 1)^{\frac{1}{c}}$ where R_{max} is the estimated total amount of roots, R_{Smax} is the total amount of roots in sampled profile, and C is a dimensionless shape parameter.
F00958	Rooting depth_Interpolated 95 percent rooting depth	m		Depth which includes 95% of roots in profile, calculated by fitting logistic dose-response curve to cumulative root profile and interpolating to maximum sampling depth, using the equation $D_{S95} = D_{50} * (\frac{R_{max}}{0.95R_{S\,max}} - 1)^{\frac{1}{c}}$.
F00963	Rooting depth_Fraction roots in soil depth increment	percent	SD [F00964]	Proportion of observed roots (quantified by column F00961, "Notes_Rooting depth measurement") contained in depth interval.
F00956	Rooting depth_Active	cm		Depth where most of the root activity of interest occurs.
F00961	Notes_Rooting depth measurement	"length", "mass", "number", "surface", "unknown"		Measurement used to determine 50% and 95% rooting depth (e.g., mass, number, length).
F00962	Notes_Sampled to maximum rooting depth (yes, no)	Yes or No		Whether sampling depth exceeds maximum rooting depth.
F00885	Belowground biomass per ground area	g/m^2	n [F00886] SE [F00887] SD [F00888] Median [F00889] Upper quartile [F00890]	Root mass per square meter for the specified depth increment.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
			Lower quartile [F00891] Min [F00892] Max [F00893] 5th percentile [F00894] 95th percentile [F00895]	
F00898	Belowground biomass per plant	g/plant	n [F00899] SE [F00900] Min [F00901] Max [F00902]	Total root mass for the entire plant.
F00896	Belowground biomass per soil volume	kg/m^3	n [F00897] SE [F01429]	Kilograms of root mass per cubic meter of soil.
F00917	Belowground necromass per ground area	g/m^2	n [F00918] SE [F00919] SD [F00920]	Dead root mass per square meter for the specified depth increment.
F00909	Root C content per ground area	kg/ha	n [F00910] SE [F00911] SD [F00912]	Total mass of root carbon per ground area.
F00913	Max_Root annual C content per ground area	Mg/ha	SE [F00914]	Maximum value of root carbon stock measured per year, in mass of carbon per ground area for the specified depth increment.
F00915	Min_Root annual C content per ground area	Mg/ha	SE [F00916]	Minimum value of root carbon stock per year, in mass of carbon per ground area.
F00906	Root C content per soil mass	mg/g	SE [F00908]	Mass of root carbon per gram of soil.
F00196	Root intact branch length	cm	n [F00197] SE [F00198]	Total root length contained within an intact root branch.
F00934	Root length density (RLD)_Root length per ground area	m/m^2	n [F00935] SE [F00936] SD [F00937]	Root length divided by soil core cross-sectional area.
F00938	Root length density (RLD)_Root length per soil volume	cm/cm^3	n [F00939] SE [F00940] SD [F00941] Median [F01353] Min [F01354] Max [F01355] Upper quartile [F01356] Lower quartile [F01357]	Root length divided by the sampled soil volume.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00930	Root length per minirhizotron frame	mm/frame	SE [F00932]	Total root length observed per minirhizotron frame.
F00944	Root length per minirhizotron surface area	m/m^2	SE [F00945]	Meters of root length visible per square meter of minirhizotron surface.
F00942	Root length per plant	m/plant	n [F00943]	Total length of all roots for an entire plant.
F00927	Root length ratio (RLR)	m/g	n [F00928] SE [F00929]	Root length per gram of plant mass.
F00933	Root length_Species fraction	percent		Percentage of total root length belonging to an individual species.
F00921	Root N content per ground area	kg/ha	n [F00922] SE [F00923]	Total mass of root nitrogen per ground area for the specified depth increment.
F00924	Root N mass per soil mass	mg/g	SE [F00926]	Mass of root nitrogen per gram of soil.
F00878	Root surface area per ground area	m^2/m^2	n [F00879] SE [F00880]	Total surface area of roots per square meter of ground area.
F00946	Root volume per ground area	cm^3/m^2	n [F00947] SE [F00948]	Total volume of roots per square meter of ground area for the specified depth increment.
F00661	Soil microbes_Fungal/bacterial rRNA copy number ratio	ratio	n [F00662] SE [F00663]	Ratio of fungal rRNA gene copy number to bacterial rRNA gene copy number ratio from DNA extraction and PCR runs from soil.
F00664	Soil microbes_Ergosterol content	mg/kg	SE [F00666]	Mass of ergosterol per gram of soil or growth medium.
F00667	Soil microbes_PLFA proxy for fungal mass per soil mass	nmol/g	SE [F00668]	Amount of phospholipid fatty acid 18.2ω6.9 lost during soil incubation, used as an indicator of fungal biomass in the soil.
F01335	Soil microbes_PLFA 18: 2w6.9 mass per soil mass_indicator for soil fungus	µg/g		Concentration by mass of phospholipid-derived fatty acid 18:2ω6.9 in soil, used as an indicator for soil fungal content.
F01336	Soil microbes_PLFA 18: 2w6.9 molar concentration per soil mass_indicator for soil fungus	nmol/g		Nanomoles of phospholipid-derived fatty acid 18:2ω6.9 in soil per soil mass, used as an indicator for soil fungal content. This value can be multiplied by 2 to serve as a proxy for soil fungal mass in milligrams.
F01337	Soil microbes_PLFA molar concentration per soil	nmol/g		Nanomoles in soil of a phospholipid-derived fatty acid used as an indicator for soil microbes (i15:0, a15:0, i16:0, 16:1ω9,

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
	mass_indicator for soil microbes			16:1ω7c, 10Me16:0, cy17:0, i17:0, a17:0, 18:1ω7, or cy19:0) per gram of soil.
F00980	Soil pH_water		n [F01464] SE [F00981]	Mean pH of soil at data collection location, measured in water.
F01402	Notes_Soil pH_Water			Notes pertaining to data in column F00980 (Soil pH_water). "Method unspecified" means that the data in column F00980 are not confirmed in the source to have been measured in water. "Direct measure of liquid media" means that the plants grew in a liquid medium, such as Hoagland's solution, which could be measured directly without dilution.
F01400	Soil pH_Salt			Mean pH of soil at data collection location, measured in a salt solution.
F01403	Notes_Soil pH_Salt			The type of salt used to measure the data in "Soil pH_Salt" [F01400].
F01461	Root pH_Water		SE [F01462]	pH of root powder, measured in water.
F00983	Notes_Soil type			Name of soil in sampling area, as described in original data source.
F00984	Soil horizon			Soil horizon from which sample is taken.
F00985	Soil depth	cm		Depth of soil profile.
F00982	Soil texture			Textural class of soil in sampling area.
F00986	Soil texture_Fraction sand	percent		Mean percentage of sand (particles 0.05-2 mm) in the sampled soil.
F00987	Soil texture_Fraction silt	percent		Mean percentage of silt (particles 0.002-0.05 mm) in the sampled soil.
F00988	Soil texture_Fraction clay	percent		Mean percentage of clay (particles less than 0.002 mm) in the sampled soil.
F00989	Soil organic matter content	percent	n [F01465] SE [F00990]	Percentage of organic matter in the sampled soil.
F00991	Soil bulk density	g/cm^3	SE [F00992]	M/V where M is the mass of the soil sample under field conditions and V is the volume of the soil sample.
F00993	Soil bulk density_Isolated aggregates	g/cm^3	SE [F00994]	Bulk density of isolated soil aggregates (clods).
F00998	Soil organic C content	mg/g		Amount of organic carbon per mass of soil.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00999	Soil N content	mg/g	n [F01466] SE [F01000] SD [F01001]	Nitrogen concentration in soil as determined by soil test.
F01002	Soil N_Mineral N content	mg/kg		Mineral nitrogen concentration in soil.
F01003	Soil N_NH4 content	mg/kg	SE [F01004] Min [F01005] Max [F01006]	Concentration of NH_4^+ in soil, extracted by solution or method named in "Notes_Soil NH4 extraction method" column [F00080].
F01007-F01008	Soil N_NO3 content	mg/kg	Min [F1007] Max [F1008]	Concentration of NO_3^- in soil, extracted by solution or method named in "Notes_Soil NO3 extraction method" column [F00081].
F00080	Notes_Soil NH4 extraction method			Extractive solution or method used to extract soil NH_4.
F00081	Notes_Soil NO3 extraction method			Extractive solution or method used to extract soil NO_3.
F00082	Notes_Soil PO4 extraction method			Extractive solution or method used to extract soil PO_4.
F00083	Notes_Soil P extraction method			Extractive solution or method used to extract soil P.
F00084	Notes_Soil K extraction method			Extractive solution or method used to extract soil K.
F01012	Soil nonpolar extractable content	percent		Percentage of soil that consists of fats, oils, and waxes.
F01013	Soil water soluble sugar fraction	percent		Percentage of soil that consists of water-soluble sugars, as determined by a phenol-sulfuric acid assay.
F01014	Soil water soluble phenol fraction	percent		Percentage of soil that consists of water-soluble phenols.
F01017	Soil N_Hydrolytic content	mg/kg		Concentration of hydrolytic nitrogen in soil.
F01018	Soil P content	mg/g	n [F01467] SE [F01019] SD [F01020]	Concentration of phosphorus in the soil.
F01021	Soil P_Resin-extractable P	mg/kg		Resin-extractable soil phosphorus per kg of soil.
F01023	Soil Fe content	mg/kg		Concentration of iron in soil.
F01024	Soil Mg content	mg/kg		Concentration of magnesium in soil.
F01025	Soil Ca content	mg/kg		Concentration of calcium in soil.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01026	Soil P_Inorganic P content_HCl extraction	mg/kg		Concentration of soil inorganic P extractable by diluted HCl. See Ushio et al. 2015 (DOI: 10.1111/1365-2435.12424) for further information.
F01027	Soil P_Inorganic P content_NaHCO3 extraction	mg/kg		Concentration of soil inorganic P extractable by $NaHCO_3$.
F01028	Soil P_Al and Fe bound inorganic P content	mg/kg		Concentration of soil inorganic P loosely bound to aluminum and iron. See Ushio et al. 2015 (DOI: 10.1111/1365-2435.12424) for further information.
F01029	Soil P_Occluded inorganic P content	mg/kg		Concentration of occluded inorganic phosphorus in soil.
F01030	Soil P_Organic P content_NaHCO3 extraction	mg/kg		Concentration of soil organic P extractable by $NaHCO_3$.
F01031	Soil P_Organic P content_NaOH extraction	mg/kg		Concentration of organic phosphorus extractable by NaOH. See Ushio et al. 2015 (DOI: 10.1111/1365-2435.12424) for further information.
F01032	Soil P_Organic P content_HCl extraction	mg/kg		Concentration of soil organic phosphorus extractable by concentrated hot HCl. See Ushio et al. 2015 (DOI: 10.1111/1365-2435.12424) for further information.
F01033	Soil P_Total extractable content	mg/kg		Total concentration of soil phosphorus yielded by the extraction method named in "Notes_Soil P extraction method" column [F00083].
F01034	Notes_Soil solution P concentration for P uptake	µmol		Molar concentration of phosphorus in solution used for determining phosphorus uptake.
F01035	Soil K_Extractable K content	mg/kg	SE [F01036]	Concentration of potassium in soil extractable by method named in "Notes_Soil K extraction method" column [F00084].
F01037	Soil K content	mg/g	n [F01471] SE [F01472] SD [F01038]	Potassium concentration of soil as determined by soil test.
F01039	Soil Zn content	mg/g		Concentration of zinc in soil.
F01040	Soil Ca2+ content	mg/kg		Concentration of calcium 2+ ion in soil.
F01041	Soil Mg2+ content	mg/kg		Concentration of magnesium 2+ ion in soil.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01046	Soil N content per ground area	Mg/ha	n [F01047] SE [F01048]	Megagrams of nitrogen in soil per hectare.
F01049	Soil P content per ground area	Mg/ha	n [F01050] SE [F01051]	Megagrams of phosphorus in soil per hectare.
F01052	Soil Ca_Exchangeable charge	$mmol_c/kg$		Millimoles of charge of exchangeable calcium per kilogram of soil.
F01068	Soil Ca_Exchangeable Ca^{2+} mass	mg/kg	n [F01470] SE [F01069]	Concentration of exchangeable Ca2+ ions in soil.
F01053	Soil Mg_Exchangeable charge	$mmol_c/kg$		Millimoles of charge of exchangeable magnesium per kilogram of soil.
F01054	Soil K_Exchangeable charge	$mmol_c/kg$		Millimoles of charge of exchangeable potassium per kilogram of soil.
F01055	Soil Fe_Exchangeable charge	$mmol_c/kg$		Millimoles of charge of exchangeable iron per kilogram of soil.
F01056	Soil Mn_Exchangeable charge	$mmol_c/kg$		Millimoles of charge of exchangeable manganese per kilogram of soil.
F01057	Soil Na_Exchangeable charge	$mmol_c/kg$		Millimoles of charge of exchangeable sodium per kilogram of soil.
F01059	Soil cation exchange capacity (CEC)	$cmol_c/kg$		Exchangeable cations that can be absorbed by soil.
F01060	Soil effective cation exchange capacity (ECEC)	$cmol_c/kg$		The total basic and acidic cations in the soil, extracted with an unbuffered salt.
F01068	Soil Ca_Exchangeable Ca^{2+} mass	mg/kg	SE [F01069]	Concentration of exchangeable Ca^{2+} ions in soil.
F01070	Soil K_Exchangeable K+ mass	mg/kg	SE [F01071]	Concentration of exchangeable K^{+} ions in soil.
F01072	Soil Mg_Exchangeable Mg^{2+} mass	mg/kg	n [F01473] SE [F01073]	Concentration of exchangeable Mg^{2+} ions in soil.
F01074	Soil Na_Exchangeable Na+ mass	mg/kg	n [F01474] SE [F01075]	Concentration of exchangeable Na^{+} ions in soil.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01076	Soil N_Exchangeable NH4+ mass	mg/kg	SE [F01077]	Concentration of exchangeable NH_4^+ ions in soil.
F01078	Soil N_Exchangeable NO3- mass	mg/kg	SE [F01079]	Concentration of exchangeable NO_3^- ions in soil.
F01080	Soil P_Exchangeable PO43- mass	mg/kg	SE [F01081]	Concentration of exchangeable PO_4^{3-} ions in soil.
F01082	Soil N_Annual available N per ground area	kg/ha/yr		Annual amount of N available in soil per hectare.
F01083	Soil N_Available N content	mg/kg		Concentration of plant-available nitrogen in soil.
F01084	Soil P_Available P content	mg/kg	n [F01468] SE [F01469]	Concentration of plant-available phosphorus in soil.
F01086	Soil P_Available P per ground area	kg/ha		Kilograms of plant-available phosphorus per hectare soil.
F01087	Soil redox potential	mV		Redox potential of soil.
F01098	Soil temperature	degrees_C		Mean temperature of soil at data collection site.
F01136	Soil water_Gravimetric water content	percent	n [F01433] SE [F01434]	Percentage of bulk soil mass that consists of water under field conditions.
F01099	Soil water_Volumetric content	percent	n [F01100] SE [F01101]	Percentage of bulk soil volume that consists of water under field conditions.
F01102	Soil water_Potential (SWP)	bars		Soil water potential, measured with a tensiometer and/or psychrometer.
F01103	Soil water_Matric potential	-cbars		Matric potential of soil.
F01104	Soil water_Available soil water at field capacity	cm		Plant-available water in soil at field capacity.
F01105	Soil water_Storage capacity	mm/120cm		Water storage capacity of soil in mm per 120 cm depth. Based on amount of water retained in the soil at matric potentials > -1.5 MPa and < -300 hPa.
F01107	Soil aggregate stability in sodium oxalate fraction	percent fine particles in aggregate		Aggregate stability in sodium oxalate in percent fine particles in aggregate, determined by method described in: Strickland TC et al.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
				1988. *Soil Sci. Soc. Am. J.* 52: 829-833. DOI: 10.2136/sssaj1988.03615995005200030041x
F01106	Soil aggregate stability in water fraction	percent fine particles in aggregate		Aggregate stability in water in percent fine particles in aggregate, determined by method described in: Strickland TC et al. 1988. *Soil Sci. Soc. Am. J.* 52: 829-833.
F01016	Soil acid insoluble (lignin) fraction	percent		Percentage of soil that consists of acid-insoluble lignin.
F01015	Soil acid soluble cellulose and hemicellulose fraction	percent		Percentage of soil that consists of acid-soluble cellulose and hemicellulose.
F01022	Soil Al content	mg/kg		Concentration of aluminum in soil.
F01066	Soil Al_Exchangeable Al3+ mass	mg/kg	SE [F01067]	Concentration of exchangeable Al_3^+ ions in soil.
F01058	Soil Al_Exchangeable charge	$mmol_c/kg$		Millimoles of charge of exchangeable aluminum per kilogram of soil.
F01061	Soil Al_saturation	percent		Proportion of soil adsorption complex saturated with Al cations.
F01042	Soil Al/Ca ratio	ratio		Ratio of aluminum to calcium in soil.
F01062	Soil base cation saturation	percent	n [F01063] SE [F01064]	Proportion of soil adsorption complex saturated with exchangeable cations.
F01065	Soil base cation saturation_ECEC	percent		Base cation saturation calculated based on effective cation exchange capacity (CEC).
F00995	Soil C content	mg/g	n [F00996] SE [F00997]	Carbon content of soil as determined by soil test or elemental analyzer.
F01043	Soil C content per ground area	Mg/ha	n [F01044] SE [F01045]	Megagrams of carbon in soil per hectare.
F01009	Soil C/N ratio	ratio	n [F01010] SE [F01011]	Carbon-to-nitrogen ratio of soil.
F01108	Soil microbes_Microbial biomass C content in soil	mg/kg		Mass of carbon from microbial biomass per gram of soil, measured by fumigation extraction.
F01109	Soil microbes_Microbial biomass N content in soil	mg/kg		Mass of nitrogen from microbial biomass per gram of soil, measured by fumigation extraction.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01110	Soil microbes_Microbial biomass C/N ratio	ratio		Ratio of carbon to nitrogen in microbial biomass measured by fumigation extraction.
F01111	Soil microbes_Microbial biomass C content_Initial	mg/kg		Microbial biomass carbon concentration, measured by fumigation extraction, prior to the sowing of the studied plant.
F01112	Soil microbes_Microbial biomass N content_Initial	mg/kg		Microbial biomass nitrogen concentration, measured by fumigation extraction, prior to the sowing of the studied plant.
F01113	Soil microbes_Microbial biomass C/N ratio_Initial	ratio		Microbial biomass carbon-to-nitrogen ratio, measured by fumigation extraction, prior to the sowing of the studied plant.
F01114	Soil egosterol content	mg/kg	n [F01115]	Concentration of ergosterol in soil, measured with HPLC (high-performance liquid chromatography).
F01117	Soil ergosterol C/microbial biomass C ratio	percent		Proportion of soil ergosterol carbon to soil microbial biomass carbon, expressed as a percentage.
F01118	Soil egosterol content_Initial	mg/kg		Ergosterol concentration of soil prior to the sowing of the studied plant.
F01119	Soil ergosterol C/microbial biomass C ratio_Initial soil	percent		Ratio of ergosterol to microbial biomass C in soil prior to the sowing of the studied plant.
F01453	Rhizosphere soil_specific rhizosheath mass by FW	g/g	SE [F01454]	Mass of soil left on root after all bulk soil is shaken off, divided by root fresh mass.
F01120	Rhizosphere soil_Glucosamine content	mg/g		Concentration of glucosamine measured in rhizosphere soil.
F01121	Rhizosphere soil_Muramic acid content	mg/kg		Concentration of muramic acid measured in rhizosphere soil.
F01122	Rhizosphere soil_Fungal C content	mg/g		Concentration of fungal organic carbon in rhizosphere soil, estimated based on calculated mean conversion factor of glucosamine to fungal C.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01123	Rhizosphere soil_Bacterial C content	mg/g		Concentration of bacterial carbon in rhizosphere soil, estimated based on calculated mean conversion factor of muramic acid to fungal C.
F01124	Rhizosphere soil_Fungal C/bacterial C ratio	ratio		Ratio of rhizosphere soil fungal carbon to rhizosphere soil bacterial carbon.
F01128	Soil N_Daily net soil N mineralization_Lower bound	mg/kg/d		Lower net nitrogen mineralization per unit soil mass per day.
F01129	Soil N_Daily net soil N mineralization_Upper bound	mg/kg/d		Upper net nitrogen mineralization per unit soil mass per day.
F01130	Soil N_Gross N mineralization rate per ground area	$mg/m^2/d$	n [F01131] SE [F01132]	Milligrams of soil nitrogen mineralized per square meter of ground area per day.
F01133	Soil N_Gross nitrification rate per ground area	$mg/m^2/d$	n [F01134] SE [F01135]	Milligrams of soil mass nitrified per square meter of ground area per day.
F01165	Stand age	yr		Time since establishment of tree stand or plantation.
F01166	Plant age_days	d		Age of plant in days.
F01167	Plant age_years	yr		Age of plant in years.
F01168	Plant age interval_Lower bound_d	d		The minimum plant age when plant age is presented as an interval.
F01169	Plant age interval_Upper bound_d	d		The maximum plant age when plant age is presented as an interval.
F01170	Stem diameter at breast height (DBH)	cm	n [F01171] SE [F01172] Min [F01173] Max [F01174]	Mean diameter of plant at breast height.
F01175	Stand canopy height	m	n [F01176] SE [F01177] Min [F01178] Max [F01179]	Mean height of canopy at measurement site.
F01185	Latitude_main	decimal_degrees		The single latitude value that best describes the data collection location. This is, in order

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
				of priority: a single latitude reported in the original study; the average of a minimum and maximum latitude reported in the original study; or an estimated latitude based on the study location.
F01186	Longitude_Main	decimal_degrees		The single longitude value that best describes the collection location. This is, in order of priority: a single latitude reported in the original study; the average of a minimum and maximum latitude reported in the original study; or an estimated latitude based on the study location.
F01187	Latitude	decimal_degrees		Decimal degrees latitude of data collection location as reported in the original study.
F01188	Longitude	decimal_degrees		Decimal degrees longitude of data collection location as reported in the original study.
F01189	Latitude_Estimated	decimal_degrees		When original source does not specify coordinates, latitude estimated using available location description.
F01190	Longitude_Estimated	decimal_degrees		When original source does not specify coordinates, longitude estimated using available location description.
F01191	Min_Latitude	decimal_degrees		Minimum latitude of data collection location when a range of locations is listed in original source.
F01192	Max_Latitude	decimal_degrees		Maximum latitude of data collection location when a range of locations is listed in original source.
F01193	Min_Longitude	decimal_degrees		Minimum longitude of data collection location when a range of locations is listed in original source.
F01194	Max_Longitude	decimal_degrees		Maximum longitude of data collection location when a range of locations is listed in original source.
F01221	Notes_Location			Miscellaneous information about data collection location, given in original data source.
F01156	Notes_In situ, pot, or hydroponic	“in situ”,“pot”, “hydroponic”		Whether plant was studied in field or grown under controlled conditions.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01158	Notes_Indoor or outdoor	Indoors or Outdoors		Whether data were collected indoors or outdoors.
F01146	Sample collection_Measurement year			Year of sample collection.
F01147	Sample collection_Measurement month			Month of sample collection.
F01148	Sample collection_Measurement day			Day of sample collection.
F01149	Sample collection_Year beginning collection			The first year of sample collection for data collected over multiple years.
F01150	Sample collection_Month beginning collection			The first month of sample collection for data collected over multiple months.
F01151	Sample collection_Day beginning collection			The first day of sample collection for data collected over multiple days.
F01152	Sample collection_Year ending collection			The final year of sample collection for data collected over multiple years.
F01153	Sample collection_Month ending collection			The final month of sample collection for data collected over multiple months.
F01154	Sample collection_Day ending collection			The final day of sample collection for data collected over multiple days.
F01159	Notes_Treatment types			Broad description of the type of experimental manipulation involved. This column differs from Notes_Treatments [F01160] in that the latter is a non-standardized description of the treatment in the original data source, whereas "Notes_Treatment types" attempts to group treatments together into standardized types.
F01160	Notes_Treatments			Experimental treatment group of data in row.
F01161	Notes_Treatment extent	numeral		Amount or extent of treatment applied
F01162	Notes_Units for extent of treatment			Unit for value in "extent of treatment".

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01219	Climate_PFT_Biome equivalent_Poulter			Whether the data collection location is tropical, arid, temperate, boreal, or polar, based on Köppen-Geiger designation and Table 3 from the following paper: Poulter B, Ciais P, Hodson E., Lischke H., Maignan F., Plummer S, Zimmermann N.E. 2011. Plant functional type mapping for earth system models. *Geoscientific Model Development* 4: 993-1010. DOI: 10.5194/gmd-4-993-2011.
F01227	Climate			Climate category of sample collection location as described in original data source.
F01220	Climate_Koeppen-Geiger classification			Three-letter Köppen-Geiger climate designation, according to the main latitude and longitude and referenced agained classifications from Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of the Köppen-Geiger climate classification updated. *Meteorol. Z.*, **15**, 259-263. DOI: 10.1127/0941-2948/2006/0130.
F01235	Elevation	m		Elevation of data collection location.
F01228	Mean annual precipitation (MAP)	mm		Mean annual precipitation of sample collection location.
F01230	Air temperature_Coldest month	degrees_C		Mean monthly air temperature for coldest month of year at collection location.
F01229	Air temperature_Warmest month	degrees_C		Mean monthly air temperature for warmest month of year at collection location.
F01231	Mean annual air temperature (MAT)	degrees_C		Mean annual air temperature of collection location.
F01236	Slope	degrees		Slope of data collection location.
F01237	Soil water_Water table depth	m	Min [F01411] Max [F01412]	Depth of water table below soil surface at sampling time.
F01232	Chamber_Photoperiod	h		Daily number of hours of light in growth chamber.
F01233	Chamber_Temperature_day	degrees_C		Maximum daytime temperature in controlled growing environment.
F01234	Chamber_Temperature_night	degrees_C		Minimum nighttime temperature in controlled growing environment.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F00071	Notes_Collection method			Method used to collect data (e.g. minirhizotron, root excavation, sequential coring).
F00079	Notes_Miscellaneous notes			Miscellaneous information about data in row. Notes pertaining specifically to location or soil may be located in Notes_Location [F01221] or Notes_Soil type [F00983] instead.
F00078	Notes_Root dynamics calculation method			Method used to calculate root dynamics data, such as production, mortality, or turnover.
F00590	Notes_Root turnover formula			Formula used to determine root turnover.
F00810	Notes_Temperature of respiration chamber	degrees_C		Temperature at which reported respiration rate occurs (i.e., temperature of respiration chamber during observation period).
F01294	Exposition period_main	d		In-growth duration, production duration, or decomposition duration in days. If exposition period is presented in months, period in days is estimated.
F00076	Notes_Ingrowth duration_d	d		Number of days between installation and collection of in-growth core or mesh bag.
F01283	Notes_Ingrowth duration_mo	mo		Number of months between installation and collection of in-growth core or mesh bag.
F01284	Notes_Production duration_d	d		Number of days during which production has been observed.
F01280	Notes_Production duration_mo	mo		Number of months during which production has been observed.
F01243	Stand density_Stem number per ground area	stems/ha	n [F01244] SE [F01245]	Number of stems per hectare for a given stand of trees.
F01246	Stand density_Stem number per species per ground area	stems/ha		Number of stems per hectare of a specific species for a given stand of trees.
F01247	Basal area_Stem area per species per ground area	m^2/ha	n [F01248] SE [F01249]	Area of plant stems of a specific species per unit ground area.
F01250	Basal area_Stem area per ground area	m^2/ha	n [F01251] SE [F01252]	Area of plant stems per unit ground area.

Column ID	Column name	Units / Format	Associated statistical metrics [Column ID]	Description
F01254	Leaf area index (LAI)_Per ground area	m^2/m^2		Leaf area per unit ground area.
F01256	Leaf area index (LAI)_Fraction of peak	unitless	SE [F01257]	Leaf area index (LAI) at a specific time divided by the maximum LAI observed during the entire observation period.
F01258	Stand fertilizer use efficiency (FUE)	ratio	SE [F01260]	Amount of nitrogen acquired by the plants per unit nitrogen available.
F01261	Photosynthesis per leaf area	µmol_CO_2/ m^2/s	n [F01262] SE [F01263]	Mean net photosynthetic rate at light saturation.
F01264	Leaf N retranslocation	g_N/m^2/yr	n [F01265] SE [F01266]	Rate of retranslocation of nitrogen before abscission of leaves.
F01439	Total biomass per plant	g/plant	SE [F01445]	Total aboveground and belowground biomass combined per individual plant.
F01267	Aboveground biomass per ground area	g/m^2	SE [F01268]	Total biomass of aboveground plant parts, not including inflorescences, per square meter of ground area.
F01269	Aboveground biomass per plant	g/plant		Total aboveground mass of an individual plant.
F01270	Stem mass per plant	g/plant		Total mass of individual plant stem.
F01271	Leaf mass per plant	g/plant		Total mass of leaves for an individual plant.
F01272	Leaf mass ratio (LMR, LWR)	ratio		Leaf mass divided by whole plant weight. Also sometimes referred to as leaf weight ratio.
F01273	Aboveground growth_Annual net primary production per ground area	g/m^2/yr	n [F01274] SE [F01275]	Aboveground plant biomass produced in one year per ground area.
F01279	Aboveground annual C production	Mg_C/ha/yr		Amount of aboveground plant carbon produced in one year per ground area.

12. Changes from FRED 2.0 to 3.0:

Compared to FRED 2.0, FRED 3.0 features a total increase of approximately 47,599 root trait observations, collected from over 200 additional sources. Around 20,000 new rows have been added to FRED since version 2. However, some of the original rows of data from FRED 1.0 and 2.0 have been removed due to redundancy or poor data; for this reason, the highest Row ID (57520) exceeds the total number of rows in the dataset (57195). Data are unique to FRED 3.0 for all rows where “3” appears in column F00001 (Version_FRED version number). Rows 35446

to 35459 are attributed to FRED 1.0 in column F00001, although these rows are not present in FRED 1.0. This is because the data in these rows were moved from their original position (listed as covariate with a less-specific pool of roots) to new columns for the sake of greater clarity.

FRED 2.0 contained some erroneous or incomplete data which we corrected before releasing FRED 3.0. Some data which did not stand out during the quality-checking process for FRED 2.0 became more apparent when compared to a larger data pool for FRED 3.0. Other data were reported by users or noticed in the process of entering new data. Users are encouraged to reach out to us through the contact page at https://roots.ornl.gov/contact to report suspicious or erroneous data. Changes to FRED 3.0 data are listed in **Table 6**. Any errors in these data that we correct after the release of FRED 3.0 will be listed at https://roots.ornl.gov/updates.

Our focus during the expansion from FRED 2.0 to FRED 3.0 was to fill existing columns rather than add columns for new attributes (i.e., traits or ancillary data). However, we added new columns if we deemed them particularly useful or if new statistical metrics, such as n, SE, or SD, were available for data of existing values. **Table 7** lists new columns present in FRED 3.0 that were not present in FRED 2.0. Four columns present in FRED 2.0 were deemed redundant with other columns and deleted. **Table 8** lists these columns and their reasons for removal. **Table 9** lists columns which were present in FRED 2.0 but renamed for FRED 3.0 to improve consistency or clarity.

Table 6. Corrections between FRED 2.0 and FRED 3.0.

Correction no.	Column IDs	Row IDs	Correction needed
1	F01289, F01290, F01291	7397-7400	Family, order, and group corrected.
2	F01289, F01290	32539, 32540, 32541	Family and order corrected.
3	F00579, F00580, F00581, F00582, F00583, F00584	1310-1325	Some turnover data had been erroneously entered into F00579 (Root turnover_Annual biomass turnover per ground area), with n and SE, that should have been entered into F00582.
4	F00004, F00005	25555-25559	Citation and DOI corrected.
5	F00934, F00936	10042-10124, 14946-14956, 29170-26191	Data removed; all are erroneously entered duplicates of data from other traits.
6	F00005	16755-16770	DOI corrected.
7	F01342, F01339	25806-25838	Move data from min_root branching intensity to root branching intensity
8	F01254, F01256	18278-18292, 19921-19935, 21551-21565	Data mistakenly placed in Leaf area index (LAI)_Fraction of peak moved to Leaf area index (LAI)_Per ground area
9	F01232, F01233, F01234	14691-14710	Data are incorrect; photoperiod should be 16 and temperature should be 25 or 13.
10	F01229, F01230	3087-3188, 15609-15648	Data had been entered in the wrong columns and were switched.

11	F01191, F01192, F01193, F01194	15934-15969	Values for min & max latitude were switched with those for min & max longitude.
12	F01191, F01192	1564-1621	Data had been entered in the wrong columns and were switched.
13	F01173	23124-23131, 23170-23176, 23200, 23203, 23206, 23209, 23211, 23213, 23233, 23236	Erroneous data corrected.
14	F00986, F00987, F00988, F00989	9845-9997	Misplaced data; data in in F00987 moved to F00986; data in F00988 moved to F00987; data in F00989 moved to F00988.
15	F00989	9845-9997	Erroneous values corrected.
16	F00137, F01313	9697-9792	Data moved from F00137 to F01313.
17	F00617	87-91, 96-102	Data had been entered erroneously and were deleted.
18	F00802, F00803, F00804, F00799, F00800, F00801	6760-6763	Misplaced data moved from F00802 to F00799, F00803 to F00800, and F00804 to F00801.
19	F01159	7760, 31811-31870, 34020-34021, 33290	Changed values to accord with controlled vocabulary.
20	F00020	1496-1527, 5420, 5455, 5480, 5481, 5482, 5483, 5484, 5485, 5486, 5487, 5571, 5592, 5593, 5665, 5793, 5863, 5880, 5896, 5996, 31965-32000	Decapitalized capitalized entries.
21	F00253, F00255, F00261, F00263	55319-55338, 55359-55388	Multiplied data by 10 under assumption that they were erroneous in original data source.
22	F01219, F01220	55781, 55910-57484	Updated Koppen-Geiger designations and Poulter climate designations.
23	F00005	55781, 55910-57484	Added DOI.
24	F00002	Row between 11534 and 11536 was mislabeled as 55769.	Row between 11534 and 11536 was mislabeled as 55769. This row was changed to ID 11535.
25	F01185 F01187 F01186 F01188	32476, 32477	GPS coordinates entered incorrectly. F01185, F01187 changed to following coordinates: 5.326 (row 32476) 5.2936 (row 32477) F01186, F01188 changed to following coordinates: 162.948 (row 32476) 163.0261 (row 32477)
26	F01185 F01187	30407 - 30434	Latitude entered incorrectly.

			F01185, F01187 changed to following coordinates: 43.05 (rows 30407 - 30434)
27	F01185 F01187	34598 - 34603	Latitude entered incorrectly. F01185, F01187 changed to following coordinates: 39.5559 (rows 34598 - 34603)
28	F01186 F01188	29866 29889	Longitude entered incorrectly. F01186, F01188 changed to following coordinates: -2.5000 (rows 29866, 29889)
29	F01185 F01187 F01186 F01188	37347	GPS coordinates entered incorrectly. F01185, F01187 changed to following coordinates: 19.98305 (row 37347) F01186, F01188 changed to following coordinates: -155.22304 (row 37347)
30	F01185 F01187 F01186 F01188	32832	GPS coordinates entered incorrectly. F01185, F01187 changed to following coordinates: coordinates: 45.20318 (row 32832) F01186, F01188 changed to following coordinates: 12.26339 (row 32832)

Table 7. Columns added between FRED 2.0 and FRED 3.0.

Column ID	Column name
F00098	n_Root aerenchyma porosity fraction
F00127	SE_Root stele/root cortex ratio
F00332	n_Root Na+ content
F01415	n_Root branching intensity_root tips per higher order root length
F01416	Root exudation_C exudation rate per root length
F01417	SE_Root exudation_C exudation rate per root length
F01418	Root exudation_C exudation rate per plant
F01419	SE_Root exudation_C exudation rate per plant
F01420	n_Root growth_Daily mass production per ground area
F01421	SE_Root growth_Daily mass production per ground area
F01422	SD_Root growth_Daily mass production per ground area
F01423	SD_Root turnover_Annual biomass turnover per ground area
F01424	SD_Root respiration rate per root dry mass_CO2 release
F01425	Root Rb uptake_Daily uptake of molar Rb+ per root length
F01426	SE_Root Rb uptake_Daily uptake of molar Rb+ per root length
F01427	Root Li uptake_Daily uptake of molar Li per root length

F01428	SE_Root Li uptake_Daily uptake of molar Li per root length
F01429	SE_Belowground biomass per soil volume
F01430	Root exudation_Concentration in soil
F01431	SE_Root exudation_Concentration in soil
F01432	SE_Root mortality_Root N loss per plant N content per ground area
F01433	n_Soil water_Gravimetric water content
F01434	SE_Soil water_Gravimetric water content
F01435	Min_Mycorrhiza_Visual estimate of root colonization intensity
F01436	Max_Mycorrhiza_Visual estimate of root colonization intensity
F01437	n_Root growth_Monthly mass production per soil volume
F01438	SE_Root growth_Monthly mass production per soil volume
F01439	Total biomass per plant
F01441	Median_Mycorrhiza_Fraction root length colonized by AM mycorrhizae
F01442	Upper quartile_Mycorrhiza_Fraction root length colonized by AM mycorrhizae
F01443	Lower quartile_Mycorrhiza_Fraction root length colonized by AM mycorrhizae
F01445	SE_Total biomass per plant
F01446	SE_Root ash content
F01447	n_Root stele cross-sectional area
F01448	SE_root xylem cross-sectional area
F01449	SE_Root xylem cross-sectional fraction
F01450	n_Root water soluble phenol compounds per root mass
F01451	SE_Root water soluble phenol compounds per root mass
F01453	Rhizosphere soil_specific rhizosheath mass by FW
F01454	SE_Rhizosphere soil_specific rhizosheath mass by FW
F01455	SE_Root vessel number per root cross-sectional area
F01456	Plant growth form_Taseski
F01457	Root N uptake_Hourly uptake of molar NH4+ per root mass
F01458	SE_Root N uptake_Hourly uptake of molar NH4+ per root mass
F01459	Root N uptake_hourly NO3- uptake per root mass
F01460	SE_Root N uptake_hourly NO3- uptake per root mass
F01461	Root pH_Water
F01462	SE_Root pH_Water
F01463	n_Root forks per root length
F01464	n_Soil pH_Water
F01465	n_Soil organic matter content
F01466	n_Soil N content
F01467	n_Soil P content
F01468	n_Soil P_Available P content
F01469	SE_Soil P_Available P content
F01470	n_Soil Ca_Exchangeable Ca2+ mass

F01471	n_Soil K content
F01472	SE_Soil K content
F01473	n_Soil Mg_Exchangeable Mg2+ mass
F01474	n_Soil Na_Exchangeable Na+ mass

Table 8. Columns removed between FRED 2.0 and FRED 3.0. These columns were removed due to redundancy with other columns, and all data from deleted columns were transferred to respective remaining columns before deletion.

Column ID	Column name	Reason
F00370	Root acid insoluble fraction (AIF)	Deemed redundant with F00366 (Root non-acid hydrolysable compounds content).
F00371	n_ Root acid insoluble fraction (AIF)	Deemed redundant with F00367 (n_Root non-acid hydrolysable compounds content).
F00373	SE_ Root acid insoluble fraction (AIF)	Deemed redundant with F00369 (n_Root non-acid hydrolysable compounds content).
F01410	Rooting depth_max	Deemed redundant with F00954 (Rooting depth).

Table 9. Columns renamed between FRED 2.0 and FRED 3.0.

Column ID	Name in FRED 2.0	Name in FRED 3.0
F00041	Plant leaf type	Plant leaf type_TRY
F00042	Plant leaf habit	Plant leaf habit_TRY
F00043	Plant photosynthetic pathway	Plant photosynthetic pathway_TRY
F00044	Plant woodiness	Plant woodiness_TRY
F00366	Root non-acid hydrolyzable compounds content	Root non-acid hydrolyzable compounds content (NAH)
F00645	Mycorrhiza_Type	Mycorrhiza_Type_Data source
F00710	n_Root tissue density	n_Root tissue density (RTD)
F00884	Root mass_Fraction per species	Root mass fraction per species
F00924	Root N_Root N mass per soil mass	Root N mass per soil mass
F00926	SE_Root N_Root N mass per soil mass	SE_Root N mass per soil mass
F00933	Root length_Fraction per species	Root length fraction per species
F00956	Rooting depth_Main	Rooting depth_Active
F01035	Soil K_Extractable K	Soil K_Extractable K content
F01286	Accepted genus_TPL	Plant taxonomy_Accepted genus_TPL
F01287	Accepted species_TPL	Plant taxonomy_Accepted species_TPL
F01289	Plant taxonomy_Family_TPL	Plant taxonomy_Accepted family_TPL

F01290	Plant taxonomy_Order_APW	Plant taxonomy_Accepted order_APW
F01291	Plant taxonomy_Group_TPL	Plant taxonomy_Accepted group_TPL
F01344	Accepted subspecies_TPL	Plant taxonomy_Accepted subspecies_TPL
F01346	Upper quartile_Specific Root Length	Upper quartile_Specific Root Length (SRL)
F01347	Lower quartile_Specific root length	Lower quartile_Specific root length (SRL)
F01405	Root N uptake_molar inorganic N uptak e per root area	Root N uptake_Molar inorganic N uptak?e per root area
F01413	Species name unresolved	Plant taxonomy_Species name unresolved