

Package ‘ISRaD’

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Title Tools and Data for the International Soil Radiocarbon Database

Version 1.0.1

Description This is the central location for data and tools for the development, maintenance, analysis, and deployment of the International Soil Radiocarbon Database (ISRaD). ISRaD was developed as a collaboration between the U.S. Geological Survey Powell Center and the Max Planck Institute for Biogeochemistry. This R package provides tools for accessing and manipulating ISRaD data, compiling local data using the ISRaD data structure, and simple query and reporting functions for ISRaD. For more detailed information visit the ISRaD website at: <<https://soilradiocarbon.org/>>.

Depends R (>= 3.5.0)

Imports openxlsx, devtools, raster, rgdal, dplyr, tidyr, RCurl, ggplot2, maps, assertthat, rcrossref, pangear, tidyverse, stringr

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Encoding UTF-8

LazyData true

RoxygenNote 6.1.1

Suggests knitr,
rmarkdown

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checkTemplateFiles	<i>Check ISRaD Template/Info files</i>
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Description

Check that the template information file and the template file match appropriately.

Usage

```
checkTemplateFiles(outfile = "", verbose = T)
```

Arguments

outfile	file to dump the output report. Defaults to an empty string that will print to standard output.
verbose	if TRUE (default) will print output to specified outfile

Details

Used in compile() function, but primarily a development tool

Value

returns NULL

Examples

```
checkTemplateFiles()
```

compile	<i>Compile ISRaD data product</i>
---------	-----------------------------------

Description

Construct data products to the International Soil Radiocarbon Database.

Usage

```
compile(dataset_directory, write_report = FALSE, write_out = FALSE,
        return_type = c("none", "list")[2], checkdoi = F, verbose = T)
```

Arguments

dataset_directory	string defining directory where completed and QC passed soilcarbon datasets are stored
write_report	boolean flag to write a log file of the compilation. File will be in the specified dataset_directory at "database/ISRaD_log.txt". If there is a file already there of this name it will be overwritten.
write_out	boolean flag to write the compiled database file as .xlsx in dataset_directory
return_type	a string that defines return object. Default is "list". Acceptable values are "none" or "list" depending on the format you want to have the database returned in.
checkdoi	set to F if you do not want the QAQC check to validate doi numbers
verbose	set to TRUE to print results of function to console

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Save as .xlsx file
ISRaD.save.xlsx(database = database,
  template_file = system.file("extdata", "ISRaD_Master_Template.xlsx", package = "ISRaD"),
  outfile = paste0(tempdir(), "/Gaudinski_2001.xlsx"))
# Compile .xlsx file/s in dataset_directory into ISRaD database object
ISRaD.compiled <- compile(tempdir(), write_report = TRUE, write_out = TRUE,
  return_type = 'list', checkdoi = FALSE, verbose = TRUE)
```

Gaudinski_2001

*Gaudinski Harvard Forest example dataset***Description**

Data from Gaudinski, J., 2001, Belowground carbon cycling in three temperate forests of the eastern United States, University of California Irvine, Ph.D. thesis

Usage

```
Gaudinski_2001
```

Format

```
list
```

graven	<i>Graven dataset for delta delta calculation</i>
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Description

Data from Graven et al 2017 <https://www.geosci-model-dev.net/10/4405/2017/gmd-10-4405-2017.pdf>

Usage

```
graven
```

Format

```
dataframe
```

ISRaD.extra	<i>ISRaD.extra</i>
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Description

Fills in transformed and geospatial data where possible, generating an enhanced version of ISRaD.

Usage

```
ISRaD.extra(database, geodata_clim_directory, geodata_soil_directory,
             geodata_pet_directory)
```

Arguments

```
database          soilcarbon dataset object
geodata_clim_directory
                  directory where geospatial climate data are found
geodata_soil_directory
                  directory where geospatial soil data are found
geodata_pet_directory
                  directory where geospatial pet data are found
```

Details

Fills fraction modern, delta 14C, delta-delta values, profile coordinates, BD, orgC, and SOC stocks from entered data; fills soil and climatic data from external geospatial data products

Value

returns new ISRaD_extra object with derived, transformed, and filled columns

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill ISRaD.extra data
database.x <- ISRaD.extra(database,
  geodata_clim_directory = tempdir(),
  geodata_soil_directory = system.file("extdata", "geodata_soil_directory", package = "ISRaD"),
  geodata_pet_directory = system.file("extdata", "geodata_pet_directory", package = "ISRaD"))
```

ISRaD.extra.Cstocks	<i>ISRaD.extra.Cstocks</i>
---------------------	----------------------------

Description

Calculates soil organic carbon stock

Usage

```
ISRaD.extra.Cstocks(database)
```

Arguments

database ISRaD dataset object.

Details

Function first fills lyr_bd_samp, lyr_c_org, lyr_c_org, lyr_coarse_tot. Notes: 1) SOC stocks can only be calculated if organic carbon concentration and bulk density data are available, 2) SOC stocks are calculated for the fine earth fraction (<2mm).

Value

returns ISRaD_data object with filled columns "lyr_coarse_tot_filled", "lyr_bd_samp_filled", "lyr_c_inorg_filled", "lyr_c_org_filled", "lyr_soc_filled"

Author(s)

J. Beem-Miller

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
database.x <- ISRaD.extra.Cstocks(database)
```

ISRaD.extra.delta_delta

ISRaD.extra.delta_delta

Description

Calculates the difference between sample delta 14C and the atmosphere for the year of collection (delta-delta)

Usage

```
ISRaD.extra.delta_delta(database)
```

Arguments

database ISRaD dataset object.

Details

Creates new column for delta-delta value. Observation year and profile coordinates must be filled (use `ISRaD.extra.fill_dates`, and `ISRaD.extra.fill_coords` fxs). The relevant atmospheric d14C data (northern or southern hemisphere, or tropics) are determined by profile coordinates.

Value

returns ISRaD_data object with new delta delta columns in relevant tables

Author(s)

J. Beem-Miller and C. Hicks-Pries

References

Graven et al. 2017 <https://www.geosci-model-dev.net/10/4405/2017/gmd-10-4405-2017.pdf>

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill profile coordinates
database.x <- ISRaD.extra.fill_coords(database)
# Fill dates
database.x <- ISRaD.extra.fill_dates(database.x)
# Fill delta 14C from fraction modern
database.x <- ISRaD.extra.fill_14c(database.x)
# Fill delta delta
database.x <- ISRaD.extra.delta_delta(database.x)
```

ISRaD.extra.fill_14c	<i>ISRaD.extra.fill_14c</i>
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Description

: Fills delta 14C from fraction modern if delta 14C not reported.

Usage

```
ISRaD.extra.fill_14c(database)
```

Arguments

database ISRaD dataset object.

Details

: Warning: xxx_obs_date_y columns must be filled for this to work!

Value

returns ISRaD_data object with filled delta 14C columns

Author(s)

: J. Beem-Miller & A. Hoyt

References

: Stuiver and Polach, 1977

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill dates
database.x <- ISRaD.extra.fill_dates(database)
# Fill delta 14C from fraction modern
database.x <- ISRaD.extra.fill_14c(database.x)
# Column flx_14c in the "flux" table is now filled
```

```
ISRaD.extra.fill_coords
  ISRaD.extra.fill_coords
```

Description

Fills profile coordinates from site coordinates if profile coordinates not reported.

Usage

```
ISRaD.extra.fill_coords(database)
```

Arguments

database ISRaD dataset object.

Value

returns ISRaD_data object with filled profile coordinates

Author(s)

J. Beem-Miller

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill profile coordinates
database.x <- ISRaD.extra.fill_coords(database)
```

```
ISRaD.extra.fill_dates
  ISRaD.extra.fill_dates
```

Description

Fills frc_obs_date_y and inc_obs_date_y columns from lyr_obs_date_y if not reported.

Usage

```
ISRaD.extra.fill_dates(database)
```

Arguments

database ISRaD dataset object.

Details

This function must be run prior to the ISRaD.extra.fill_14c, ISRaD.extra.fill_fm, and ISRaD.extra.delta_delta for the layer and fraction tables.

Value

returns ISRaD_data object with filled obs_date_y columns

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill dates
database.x <- ISRaD.extra.fill_dates(database)
# Fraction table now has lyr_obs_date_y values in frc_obs_date_y field
```

ISRaD.extra.fill_fm	<i>ISRaD.extra.fill_fm</i>
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Description

Fills fraction modern from delta 14C if fraction modern not reported.

Usage

```
ISRaD.extra.fill_fm(database)
```

Arguments

database ISRaD dataset object.

Details

: Warning: xxx_obs_date_y columns must be filled for this to work!

Value

returns ISRaD_data object with filled fraction modern columns

Author(s)

: J. Beem-Miller & A. Hoyt

References

: Stuiver and Polach, 1977

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill dates
database.x <- ISRaD.extra.fill_dates(database)
# Fill fraction modern from delta 14C
database.x <- ISRaD.extra.fill_fm(database.x)
```

```
ISRaD.extra.geospatial.climate
      ISRaD.extra.geospatial.climate
```

Description

Extracts values from gridded (2.5' arc) climate data using ISRaD profile coordinates.

Usage

```
ISRaD.extra.geospatial.climate(database, geodata_clim_directory,
                                geodata_pet_directory, fill.PET = TRUE)
```

Arguments

database	ISRaD dataset object.
geodata_clim_directory	directory where geospatial climate datasets are found.
geodata_pet_directory	directory where geospatial pet dataset is found.
fill.PET	should PET data be filled (T/F)? Defaults to TRUE. Should be set to FALSE if no local data are available.

Details

Worldclim climate data (see description of BIO variables below) will be downloaded if not found in geodata_clim_directory. For filling PET data users must have previously downloaded PET data to a local directory. Alternatively the parameter "fill.PET" can be set to FALSE if data are not available. PET data in the ISRaD.extra dataset (ISRaD::ISRaD.getdata) was obtained from the supplementary materials of Kramer and Chadwick (2018) (units are mm/yr, Penman-Monteith method for short-clipped grass w/ worldclim input data). Full citation in references section below.

Adds new climate fields BIO1-BIO19, PET

BIO1 = Annual Mean Temperature, BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp)), BIO3 = Isothermality (BIO2/BIO7) (* 100), BIO4 = Temperature Seasonality (standard deviation *100), BIO5 = Max Temperature of Warmest Month, BIO6 = Min Temperature of Coldest Month, BIO7 = Temperature Annual Range (BIO5-BIO6), BIO8 = Mean Temperature of Wettest Quarter, BIO9 = Mean Temperature of Driest Quarter, BIO10 = Mean Temperature of Warmest Quarter, BIO11 = Mean Temperature of Coldest Quarter, BIO12 = Annual Precipitation, BIO13 = Precipitation of Wettest Month, BIO14 = Precipitation of Driest Month, BIO15 = Precipitation Seasonality (Coefficient of Variation), BIO16 = Precipitation of Wettest Quarter, BIO17 = Precipitation of Driest Quarter, BIO18 = Precipitation of Warmest Quarter, BIO19 = Precipitation of Coldest Quarter PET = Potential evapotranspiration

All BIO## variables are from <http://www.worldclim.org/bioclim> V1.4 at 2.5 resolution and are based on profile lat and long

Value

An ISRaD_data object with additional rows containing values from geospatial datasets. See description for details.

Author(s)

J. Grey Monroe, Alison Hoyt, J. Beem-Miller

References

<http://www.worldclim.org/>; PET data from: Kramer, M. and O. Chadwick. 2018. Climate-driven thresholds in reactive mineral retention of soil carbon at the global scale. *Nature Climate Change* 8:1104–1108.

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill profile coordinates
database <- ISRaD.extra.fill_coords(database)
# Fill climate variables
# Note that PET geospatial data in pkg is only for Gaudinski_2001 dataset
# Bioclim variables (temp, precip, etc.) will be downloaded if not found
database.x <- ISRaD.extra.geospatial.climate(database,
  geodata_clim_directory = tempdir(),
  geodata_pet_directory = system.file("extdata", "geodata_pet_directory", package = "ISRaD"))
```

ISRaD.extra.geospatial.soil

ISRaD.extra.geospatial.soil

Description

Extracts modeled soil properties from 250m resolution Soil Grids spatial products

Usage

```
ISRaD.extra.geospatial.soil(database, geodata_soil_directory)
```

Arguments

database	soilcarbon dataset object
geodata_soil_directory	directory where geospatial soil data are found

Details

Uses filled geographic coordinates of profiles to extract estimated (observations + machine learning predictions) clay content (kg/kg), organic carbon content (x 5 g/kg), carbon stock (kg/m²), bulk density (kg/m³), and coarse fragments (

Value

returns new ISRaD_extra object with extracted bulk density and clay, carbon, and coarse fragment content up to 200 cm soil depth (reported at the Profile level).

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Fill profile coordinates
database <- ISRaD.extra.fill_coords(database)
# Run function
# Note that geospatial soil data in pkg is only for the Gaudinski_2001 dataset
# Global soils data may be obtained from SoilGrids (see Details).
database.x <- ISRaD.extra.geospatial.soil(database,
  geodata_soil_directory = system.file("extdata", "geodata_soil_directory", package = "ISRaD"))
```

ISRaD.flatten	<i>ISRaD.flatten</i>
---------------	----------------------

Description

: Joins tables in ISRaD based on linking variables and returns "flat" dataframes

Usage

```
ISRaD.flatten(database, table)
```

Arguments

database	ISRaD dataset object: e.g. ISRaD_data, or ISRaD_extra
table	ISRaD table of interest ("flux", "layer", "interstitial", "fraction", "incubation"). Must be entered with "".

Details

: ISRaD.extra.flatten generates flat files (2 dimensional matrices) for user specified ISRaD tables by joining higher level tables (metadata, site, profile, layer) to lower level tables (layer, fraction, incubation, flux, interstitial).

Value

returns a dataframe with nrow=nrow(table) and ncol=sum(ncol(meta),ncol(site),ncol(profile),...,ncol(table))

Author(s)

: J. Beem-Miller

References

:

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
fractions <- ISRaD.flatten(database, "fraction")
layers <- ISRaD.flatten(database, "layer")
```

ISRaD.getdata	<i>ISRaD.getdata</i>
---------------	----------------------

Description

ISRaD.getdata

Usage

```
ISRaD.getdata(directory, dataset = "full", extra = F,
               force_download = F)
```

Arguments

directory	location of ISRaD_database_files folder. If not found, it will be created.
dataset	Specify which data you want. Options are c("full", "flux", "interstitial", "incubation", "fraction", "layer")
extra	T or F. If T, the ISRaD_extra object will be returned. If F, ISRaD_data will be returned. Default is F.
force_download	T or F. If there are already ISRaD_database files in the directory you specify, new data will not be downloaded by default. However, if you set force_downlaod to T, the newest data from github will be downloaded regardless.

Value

ISRaD data object

Examples

```
# Return full dataset ("full")
ISRaD_full <- ISRaD.getdata(tempdir(), dataset = "full", extra = FALSE)
# Return full dataset plus "extra" filled data
ISRaD_extra <- ISRaD.getdata(tempdir(), dataset = "full", extra = TRUE)
# Return only fraction data, including filled fraction data
ISRaD_fractions <- ISRaD.getdata(tempdir(), dataset = "fraction", extra = TRUE)
```

ISRaD.rep.count.all	<i>ISRaD.rep.count.all</i>
---------------------	----------------------------

Description

Generates a report of counts of observations at each level of the database

Usage

```
ISRaD.rep.count.all(database = NULL)
```

Arguments

database	ISRaD data object
----------	-------------------

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
ISRaD.rep.count.all(database)
```

ISRaD.rep.count.frc	<i>ISRaD.rep.count.frc</i>
---------------------	----------------------------

Description

Generates a report of fraction level observations, including fraction scheme and properties

Usage

```
ISRaD.rep.count.frc(database = NULL)
```

Arguments

database	ISRaD data object
----------	-------------------

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
ISRaD.rep.count.frc(database)
```

ISRaD.rep.entry.stats	<i>ISRaD.rep.entry.stats</i>
-----------------------	------------------------------

Description

Generates a report of metadata statistics for all entries

Usage

```
ISRaD.rep.entry.stats(database = NULL)
```

Arguments

database	ISRaD data object
----------	-------------------

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
ISRaD.rep.entry.stats(database)
```

ISRaD.rep.site.map	<i>ISRaD.rep.site.map</i>
--------------------	---------------------------

Description

Generate a world map showing locations of all ISRaD sites

Usage

```
ISRaD.rep.site.map(database = NULL)
```

Arguments

database	ISRaD data object
----------	-------------------

Examples

```
# Obtain current ISRaD data
database <- ISRaD.getdata(tempdir(), dataset = "full", extra = FALSE)
# Generate a map of all ISRaD sites
ISRaD.rep.site.map(database)
```

ISRaD.report	<i>ISRaD.report</i>
--------------	---------------------

Description

Generate basic summary reports of ISRaD data

Usage

```
ISRaD.report(database, report)
```

Arguments

database	ISRaD data object
report	Parameter to define which type of report you want. The default is "count.all" other options include "entry.stats", "count.frc", or "site.map".

Examples

```
# Obtain current ISRaD data
database <- ISRaD.getdata(tempdir(), dataset = "full", extra = FALSE)
# Report metadata statistics
ISRaD.report(database, report = "entry.stats")
# Report summary statistics for all levels of the database
ISRaD.report(database, report = "count.all")
# Generate a map of all ISRaD sites
ISRaD.report(database, report = "site.map")
```

ISRaD.save.xlsx	<i>ISRaD.save.xlsx</i>
-----------------	------------------------

Description

Saves ISRaD data object as .xlsx file in ISRaD template format

Usage

```
ISRaD.save.xlsx(database, template_file = system.file("extdata",
  "ISRaD_Master_Template.xlsx", package = "ISRaD"), outfile)
```

Arguments

- database ISRaD data object.
- template_file path and name of template file to use (defaults to ISRaD_Master_Template).
- outfile path and name to save the excel file

Author(s)

J Grey Monroe

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
ISRaD.save.xlsx(database = database,
  template_file = system.file("extdata", "ISRaD_Master_Template.xlsx", package = "ISRaD"),
  outfile = paste0(tempdir(), "/Gaudinski_2001.xlsx"))
```

QAQC	<i>QAQC</i>
------	-------------

Description

Check the imported soil carbon dataset for formatting and entry errors

Usage

```
QAQC(file, writeQCreport = F, outfile_QAQC = "", summaryStats = T,
  dataReport = F, checkdoi = T, verbose = T)
```


Arguments

file	directory to data file
writeQCreport	if TRUE, a text report of the QC output will be written to the outfile. Default is FALSE
outfile_QAQC	filename of the output file if writeQCreport==TRUE. Default is NULL, and the outfile will be written to the directory where the dataset is stored, and named by the dataset being checked.
summaryStats	prints summary statistics. Default is TRUE
dataReport	prints list structure of database. Default is FALSE
checkdoi	set to F if you do not want the QAQC check to validate doi numbers
verbose	set to TRUE to print results of function

Details

This function is also called by the online QAQC tool available at the ISRaD website <<http://soilradiocarbon.org>>.

Examples

```
# Load example dataset Gaudinski_2001
database <- ISRaD::Gaudinski_2001
# Save as .xlsx file
ISRaD.save.xlsx(database = database,
  template_file = system.file("extdata", "ISRaD_Master_Template.xlsx", package = "ISRaD"),
  outfile = paste0(tempdir(), "/Gaudinski_2001.xlsx"))
# Run QAQC
QAQC(paste0(tempdir(), "/Gaudinski_2001.xlsx"))
```

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