Package 'soiltillr'

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Type Package

Title Analyse Soil Tillage Depth and Erosion Over Time

Version 0.1.0

Description Provides tools to record, validate, and analyse soil tillage
depth and erosion across years and field treatments. Includes functions
for year-wise tillage operation summaries, erosion depth tracking,
compaction detection, soil loss estimation, and visualisation of
temporal changes in tillage and erosion profiles. Methods follow
Lal (2001) <doi:10.1201/9780203739280> and
Renard et al. (1997) ``Predicting Soil Erosion by Water: A Guide to
Conservation Planning with the Revised Universal Soil Loss Equation
(RUSLE)''
<https:
//ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB97153704.xhtml>.

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Contents

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soiltillr-package   *soiltillr: Analyse Soil Tillage Depth and Erosion Over Time*

Description

Provides tools to record, validate, and analyse soil tillage depth and erosion across years and field treatments. Includes functions for year-wise tillage operation summaries, erosion depth tracking, compaction detection, soil loss estimation, and visualisation of temporal changes in tillage and erosion profiles.

Validation

[validate_soil_data](#) Checks a data frame for missing columns, negative values, empty rows, and implausible year values before any analysis.

Tillage analysis

[summarise_tillage](#) Year x field summary: n_operations, mean/max/total depth, dominant operation type.

[tillage_depth_trend](#) Year-on-year change in mean tillage depth per field; classifies each year as "baseline", "increasing", "decreasing", or "stable".

[detect_compaction](#) Compaction risk ("high", "moderate", "low") and estimated plow pan depth from tillage records.

Erosion analysis

track_erosion_depth Annual erosion depth, year-on-year change, cumulative loss, and trend direction per field.

estimate_soil_loss Mass-balance soil loss estimate (t/ha) using erosion depth, bulk density, and an optional McCool LS slope correction.

compare_fields Wide-format year-by-year comparison of erosion depth and organic matter between two or more fields.

Visualisation

plot_tillage_timeline Line plot of mean annual tillage depth by field.

plot_erosion_trend Line plot of annual erosion depth; optional cumulative panel.

plot_om_trend Soil organic matter (\

plot_tillage_erosion Dual-panel figure comparing tillage depth and erosion depth.

Built-in datasets

tillage_operations 20-row hypothetical tillage records for Field_A and Field_B (2018–2023).

erosion_profile 12-row hypothetical annual erosion and soil health measurements for the same fields.

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References

Lal, R. (2001). Soil degradation by erosion. *Land Degradation and Development*, 12(6), 519–539. doi:10.1002/ldr.472

McCool, D. K., Brown, L. C., Foster, G. R., Mutchler, C. K., & Meyer, L. D. (1987). Revised slope steepness factor for the Universal Soil Loss Equation. *Transactions of the ASAE*, 30(5), 1387–1396. doi:10.13031/2013.30576

Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K., & Yoder, D. C. (1997). *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. USDA Agriculture Handbook No. 703. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB97153704.xhtml

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compare_fields   *Compare Erosion and Organic Matter Between Fields*

Description

Produces a year-by-year side-by-side comparison of erosion depth and organic matter content between two or more fields, showing absolute differences and relative change.

Usage

```
compare_fields(data, year_col, field_col, erosion_col, om_col)
```

Arguments

data	A data frame containing annual erosion and soil measurements.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
erosion_col	Character string. Name of the erosion depth column (mm).
om_col	Character string. Name of the organic matter column (percent).

Value

A data frame with one row per year containing erosion and organic matter values for each field as separate columns, plus difference columns.

Examples

```
data(erosion_profile)
comparison <- compare_fields(erosion_profile, "year", "field_id",
                             "erosion_depth_mm", "organic_matter_pct")
print(comparison)
```

---

detect_compaction   *Detect Soil Compaction from Tillage Records*

Description

Identifies years where tillage practices are likely to cause or worsen soil compaction based on tillage depth, frequency, and operation type. Deep primary tillage (moldboard plowing) followed by shallow secondary tillage creates a compaction layer (plow pan) just below tillage depth.

Usage

```
detect_compaction(
  data,
  year_col,
  field_col,
  depth_col,
  op_col = NULL,
  compaction_threshold_cm = 20
)
```

Arguments

data	A data frame containing tillage operation records.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
depth_col	Character string. Name of the tillage depth column (cm).
op_col	Optional character string. Name of the operation type column.
compaction_threshold_cm	
	Numeric. Depth threshold (cm) above which tillage is considered to risk creating a plow pan (default: 20).

Value

A data frame with columns:

year	Year.
field_id	Field identifier.
mean_depth_cm	Mean tillage depth (cm).
compaction_risk	
	Risk level: "high", "moderate", or "low".
plow_pan_depth_cm	
	Estimated plow pan depth (cm): just below mean tillage depth.

Examples

```
data(tillage_operations)
risk <- detect_compaction(tillage_operations, "year", "field_id",
                          "depth_cm", op_col = "operation")
print(risk)
```

---

erosion_profile   *Soil Erosion Profile Dataset*

Description

Hypothetical annual soil erosion measurements for two agricultural fields (Field_A and Field_B) over six years (2018–2023), including erosion depth, soil loss, bulk density, organic matter, rainfall, and slope.

Usage

```
data(erosion_profile)
```

Format

A data frame with 12 rows and 8 columns:

year integer. Calendar year of measurement.

field_id character. Field identifier: "Field_A" or "Field_B".

erosion_depth_mm numeric. Annual soil erosion depth in millimetres.

soil_loss_t_ha numeric. Annual soil loss in tonnes per hectare.

bulk_density_g_cm3 numeric. Topsoil bulk density in g/cm^3.

organic_matter_pct numeric. Topsoil organic matter content as percentage by weight.

rainfall_mm numeric. Annual rainfall in millimetres.

slope_pct numeric. Field slope as percentage. Fixed at 4.5% for Field_A and 2.8% for Field_B.

Details

Field_A shows declining erosion depth and soil loss as tillage management shifts from conventional to conservation practices over the study period. Bulk density initially increases due to deep plowing compaction, then decreases as conservation tillage improves soil structure. Organic matter follows an inverse pattern, declining under intensive tillage and recovering under conservation management.

Field_B maintains consistently lower erosion and higher organic matter throughout, demonstrating the long-term benefit of reduced tillage.

This dataset is designed for use with `track_erosion_depth()`, `detect_compaction()`, `estimate_soil_loss()`, and `plot_erosion_trend()`.

Source

Hypothetical data generated for package illustration purposes.

References

Lal, R. (2001). Soil degradation by erosion. *Land Degradation and Development*, 12(6), 519–539. doi:10.1002/ldr.472

Examples

```
data(erosion_profile)

# View structure
str(erosion_profile)

# Track erosion depth over years
result <- track_erosion_depth(erosion_profile, "year", "field_id",
                                "erosion_depth_mm")
print(result)
```

---

estimate_soil_loss   *Estimate Annual Soil Loss*

Description

Estimates annual soil loss in tonnes per hectare using a simplified approach based on erosion depth, bulk density, and field slope. If soil_loss_col is already present in the data, it is returned directly with a comparison to the estimated value.

Usage

```
estimate_soil_loss(
  data,
  year_col,
  field_col,
  erosion_col,
  bulk_density_col,
  slope_col = NULL
)
```

Arguments

data	A data frame containing annual erosion and soil measurements.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
erosion_col	Character string. Name of erosion depth column (mm).
bulk_density_col	
	Character string. Name of bulk density column (g/cm^3). Default bulk density of 1.35 g/cm^3 used if column not found.
slope_col	Optional character string. Name of slope column (percent). Used as a weighting factor.

Details

Soil loss is estimated as:

$$SL = (erosion\_depth\_mm/1000) \times bulk\_density \times 10000$$

where 10000 converts from m^3/m^2 to t/ha assuming bulk density in g/cm^3 equals t/m^3. A slope correction factor of $1 + slope\%/100$ is applied when slope data are available.

Value

A data frame with columns:

year Year.

field_id Field identifier.

erosion_depth_mm Measured erosion depth (mm).

estimated_loss_t_ha Estimated soil loss (t/ha).

loss_category Category: "tolerable" (< 5 t/ha/yr), "moderate" (5–10), "severe" (10–20), or "very severe" (> 20).

Examples

```
data(erosion_profile)
loss <- estimate_soil_loss(erosion_profile, "year", "field_id",
                           "erosion_depth_mm", "bulk_density_g_cm3",
                           slope_col = "slope_pct")
print(loss)
```

---

plot_erosion_trend   *Plot Erosion Depth Trend*

Description

Creates a line plot of annual erosion depth over time for each field, with an optional panel showing cumulative erosion loss.

Usage

```
plot_erosion_trend(
  data,
  year_col,
  field_col,
  erosion_col,
  show_cumulative = FALSE,
  title = NULL
)
```

Arguments

`data`	A data frame containing annual erosion measurements.
`year_col`	Character string. Name of the year column.
`field_col`	Character string. Name of the field identifier column.
`erosion_col`	Character string. Name of the erosion depth column (mm).
`show_cumulative`	
	Logical. Whether to add a second panel showing cumulative erosion (default: `FALSE`).
`title`	Optional character string. Plot title.

Value

A ggplot2 object.

Examples

```
data(erosion_profile)

plot_erosion_trend(erosion_profile, "year", "field_id", "erosion_depth_mm")
```

`plot_om_trend`	*Plot Organic Matter Trend*

Description

Creates a line plot showing organic matter content (percent) over years for each field, illustrating the effect of tillage management on soil health.

Usage

```
plot_om_trend(data, year_col, field_col, om_col, title = NULL)
```

Arguments

`data`	A data frame containing annual soil measurements.
`year_col`	Character string. Name of the year column.
`field_col`	Character string. Name of the field identifier column.
`om_col`	Character string. Name of the organic matter column (percent).
`title`	Optional character string. Plot title.

Value

A ggplot2 object.

Examples

```
data(erosion_profile)

plot_om_trend(erosion_profile, "year", "field_id", "organic_matter_pct")
```

---

plot_tillage_erosion   *Plot Tillage vs Erosion Comparison*

Description

Creates a dual-panel plot showing mean tillage depth alongside erosion depth for each field over time, making the relationship between tillage management and erosion outcomes visually clear.

Usage

```
plot_tillage_erosion(
  tillage_data,
  erosion_data,
  year_col,
  field_col,
  depth_col,
  erosion_col,
  title = NULL
)
```

Arguments

tillage_data	A data frame containing tillage operation records.
erosion_data	A data frame containing annual erosion measurements.
year_col	Character string. Name of the year column (must exist in both data frames).
field_col	Character string. Name of the field identifier column (must exist in both data frames).
depth_col	Character string. Name of tillage depth column in `tillage_data`.
erosion_col	Character string. Name of erosion depth column in `erosion_data`.
title	Optional character string. Plot title.

Value

A ggplot2 object with two facet panels.

Examples

```
data(tillage_operations)
data(erosion_profile)

plot_tillage_erosion(tillage_operations, erosion_profile,
                     "year", "field_id", "depth_cm", "erosion_depth_mm")
```

---

plot_tillage_timeline *Plot Tillage Depth Timeline*

Description

Creates a line plot showing mean annual tillage depth over time for each field, making it easy to identify shifts toward conservation tillage.

Usage

```
plot_tillage_timeline(
  data,
  year_col,
  field_col,
  depth_col,
  op_col = NULL,
  title = NULL
)
```

Arguments

data	A data frame containing tillage operation records.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
depth_col	Character string. Name of the tillage depth column (cm).
op_col	Optional character string. Name of the operation type column.
title	Optional character string. Plot title.

Value

A ggplot2 object.

Examples

```
data(tillage_operations)

plot_tillage_timeline(tillage_operations, "year", "field_id", "depth_cm")
```

---

summarise_tillage   *Summarise Tillage Operations by Year and Field*

Description

Computes year-wise summary statistics of tillage depth and operation frequency for each field, including mean depth, maximum depth, total operations, and dominant operation type.

Usage

```
summarise_tillage(
  data,
  year_col,
  field_col,
  depth_col,
  op_col = NULL,
  validate = TRUE
)
```

Arguments

data	A data frame containing tillage operation records.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
depth_col	Character string. Name of the tillage depth column (cm).
op_col	Optional character string. Name of the operation type column. If provided, the dominant operation per year-field is included in output.
validate	Logical. Whether to validate inputs before analysis (default: TRUE).

Value

A data frame with one row per year-field combination containing:

year	Year of tillage operations.
field_id	Field identifier.
n_operations	Number of tillage operations performed.
mean_depth_cm	Mean tillage depth (cm).
max_depth_cm	Maximum tillage depth (cm).
total_depth_cm	Cumulative tillage depth (cm).
dominant_operation	
	Most frequent operation type (if op_col provided).

Examples

```
data(tillage_operations)
result <- summarise_tillage(tillage_operations, "year", "field_id",
                            "depth_cm", op_col = "operation")
print(result)
```

---

tillage_depth_trend   *Calculate Year-wise Tillage Depth Trend*

Description

Computes the annual mean tillage depth per field and calculates the year-on-year change, helping identify whether tillage intensity is increasing, decreasing, or stable over time.

Usage

```
tillage_depth_trend(data, year_col, field_col, depth_col, validate = TRUE)
```

Arguments

data	A data frame containing tillage operation records.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
depth_col	Character string. Name of the tillage depth column (cm).
validate	Logical. Whether to validate inputs (default: TRUE).

Value

A data frame with columns:

year	Year.
field_id	Field identifier.
mean_depth_cm	Mean tillage depth for that year (cm).
depth_change_cm	
	Change in mean depth from previous year (cm). NA for the first year of each field.
trend	Direction of change: "decreasing", "increasing", "stable", or "baseline".

Examples

```
data(tillage_operations)
trend <- tillage_depth_trend(tillage_operations, "year", "field_id", "depth_cm")
print(trend)
```

`tillage_operations`   *Tillage Operations Dataset*

Description

Hypothetical year-wise tillage operation records for two agricultural fields (Field_A and Field_B) over six years (2018–2023). Field_A transitions from conventional deep tillage to conservation tillage, while Field_B follows a reduced tillage practice throughout.

Usage

```
tillage_operations
```

Format

A data frame with 20 rows and 6 columns:

year integer. Calendar year of the tillage operation.

date Date. Exact date of the tillage operation.

field_id character. Field identifier: `"Field_A"` or `"Field_B"`.

operation character. Type of tillage operation. One of `"moldboard_plow"`, `"chisel_plow"`, `"disc_harrow"`, `"conservation_till"`, or `"no_till"`.

depth_cm numeric. Tillage depth in centimetres. Zero for no-till operations.

speed_kmh numeric. Implement operating speed in km/hr. `NA` for no-till operations.

Details

Field_A represents a field under conventional management that gradually adopts conservation practices: starting with moldboard plowing at 30+ cm depth and transitioning to conservation tillage and no-till by 2022–2023. Field_B maintains reduced tillage (chisel plow and no-till) throughout the study period, serving as a comparison treatment.

This dataset is intended for use with `summarise_tillage()`, `tillage_depth_trend()`, and `plot_tillage_timeline()`.

Source

Hypothetical data generated for package illustration purposes.

Examples

```
data(tillage_operations)

# View structure
str(tillage_operations)

# Summarise by year and field
result <- summarise_tillage(tillage_operations, "year", "field_id", "depth_cm")
print(result)
```

```
track_erosion_depth        Track Erosion Depth Over Years
```

Description

Computes year-on-year change in erosion depth for each field and calculates cumulative erosion since the first recorded year.

Usage

```
track_erosion_depth(data, year_col, field_col, erosion_col, validate = TRUE)
```

Arguments

data	A data frame containing annual erosion measurements.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
erosion_col	Character string. Name of the erosion depth column (mm).
validate	Logical. Whether to validate inputs (default: TRUE).

Value

A data frame with columns:

year Year.

field_id Field identifier.

erosion_depth_mm Annual erosion depth (mm).

change_mm Year-on-year change in erosion depth (mm). NA for the first year of each field.

cumulative_loss_mm Cumulative erosion depth since first year (mm).

trend Direction: "improving", "worsening", "stable", or "baseline".

Examples

```
data(erosion_profile)
result <- track_erosion_depth(erosion_profile, "year", "field_id",
                              "erosion_depth_mm")
print(result)
```

---

validate_soil_data   *Validate Tillage or Erosion Input Data*

Description

Checks a data frame for common issues before passing it to analysis functions: missing columns, missing values, negative depths, and non-positive years.

Usage

```
validate_soil_data(data, year_col, field_col, value_col)
```

Arguments

data	A data frame containing tillage or erosion data.
year_col	Character string. Name of the year column.
field_col	Character string. Name of the field identifier column.
value_col	Character string. Name of the numeric measurement column (depth, soil loss, etc.).

Value

A list with components:

valid	Logical. TRUE if data passed all checks.
issues	Character vector of critical issues found.
warnings	Character vector of non-critical warnings.

Examples

```
data(tillage_operations)
result <- validate_soil_data(tillage_operations, "year", "field_id", "depth_cm")
print(result$valid)
print(result$warnings)
```

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