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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

`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.

Author(s)

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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

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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