

Package ‘NUETON’

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Type Package

Title Nitrogen Use Efficiency Toolkit on Numerics

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Description

A comprehensive toolkit for calculating and visualizing Nitrogen Use Efficiency (NUE) indicators in agricultural research. The package implements 23 parameters categorized into fertilizer-based, plant-based, soil-based, isotope-based, ecology-based, and system-based indicators based on Congreves et al. (2021) <[doi:10.3389/fpls.2021.637108](https://doi.org/10.3389/fpls.2021.637108)>. Key features include vectorized calculations for paired-plot experimental designs, batch processing capabilities for handling large datasets, and built-in visualization tools using 'ggplot2'. Designed to streamline the workflow from raw agronomic data to publication-ready metrics and plots.

License GPL-3

Encoding UTF-8

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Contents

NUETON-package	2
AE	3
calculate_nue_batch	3
ecoNUE	5
IE	6
NBI	6
NdfF	7

NHI	8
NP	8
NRE	9
NRE15	10
NUEbal	10
NUEcrop	11
NUEFC	11
NUEsoil	12
NUEyield	13
NUpE	13
NUtE	14
PE	15
PFP	15
plot_nue_compare	16
PNB	17
sNBI	17
sNUE	18
TNdfF	18
VNF	19
Index	20

NUETON-package	<i>NUETON: Nitrogen Use Efficiency Toolkit on Numerics</i>
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Description

The NUETON package provides a comprehensive suite of tools for calculating Nitrogen Use Efficiency (NUE) indicators from agricultural experimental data. It includes vector-based calculations for 23 different parameters, batch processing capabilities, and automated visualization tools.

Getting Started

The quickest way to learn the package is to run the included demo script, which demonstrates the batch processing and visualization features on a built-in dataset.

```
# Run the master walkthrough
demo("nueton_walkthrough", package = "NUETON")
```

Key Functions

- `calculate_nue_batch`: Automatically calculates all 23 indicators from a dataframe.
- `plot_nue_compare`: Visualizes the results with error bars.
- `AE`, `NRE`, `NUEsoil`: Individual parameter calculators.

Author(s)

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AE	<i>Calculate Agronomic Efficiency (AE)</i>
----	--

Description

The contribution of fertilizer N towards yield, compared to a non-fertilized control. Formula: $AE = (YieldF - Yield0) / FertN$

Usage

```
AE(YieldF, Yield0, FertN)
```

Arguments

YieldF	A numeric vector for yield in fertilized conditions.
Yield0	A numeric vector of non-fertilized control yield values.
FertN	A numeric value or vector for fertilizer N input.

Value

A numeric vector of AE values.

Examples

```
YieldF <- c(10, 12, 15)
Yield0 <- c(5, 5, 5)
FertN <- 50
AE(YieldF, Yield0, FertN)
```

calculate_nue_batch	<i>Calculate All NUE Indicators (Batch Processing)</i>
---------------------	--

Description

Automatically detects available data columns and calculates all 23 NUE indicators.

Usage

```
calculate_nue_batch(
  data,
  yield_f = "YieldF",
  yield_0 = "Yield0",
  fert_n = "FertN",
  plant_n_f = "PlantNf",
  plant_n_0 = "PlantN0",
```

```

yield_n = "YieldN",
soil_n = "SoilN",
plant_bm = "PlantBM",
plant_15n = "Plant15N",
fert_15n = "Fert15N",
gr = "GR",
n_con = "Ncon",
n_rec = "Nrec",
n_loss = "Nloss",
n_in = "Ni",
n_out = "No",
delta_soil_n = "delSoilN",
mrt = "MRT"
)

```

Arguments

data	A dataframe containing experimental data.
yield_f	Column name for Fertilized Yield. Default: "YieldF"
yield_0	Column name for Control Yield. Default: "Yield0"
fert_n	Column name for Fertilizer N input. Default: "FertN"
plant_n_f	Column name for Plant N (fertilized). Default: "PlantNf"
plant_n_0	Column name for Plant N (control). Default: "PlantN0"
yield_n	Column name for N removed as yield. Default: "YieldN"
soil_n	Column name for Soil N. Default: "SoilN"
plant_bm	Column name for Plant Biomass. Default: "PlantBM"
plant_15n	Column name for Plant 15N excess. Default: "Plant15N"
fert_15n	Column name for Fertilizer 15N excess. Default: "Fert15N"
gr	Column name for Plant Growth Rate. Default: "GR"
n_con	Column name for N available for consumption. Default: "Ncon"
n_rec	Column name for N recycled. Default: "Nrec"
n_loss	Column name for N lost from system. Default: "Nloss"
n_in	Column name for Total N Input (System). Default: "Ni"
n_out	Column name for Total N Output (System). Default: "No"
delta_soil_n	Column name for Change in Soil N. Default: "delSoilN"
mrt	Column name for Mean Residency Time. Default: "MRT"

Value

A dataframe with new columns appended for every calculable metric.

Examples

```
# Create a simple dataset
df <- data.frame(
  YieldF = c(3.5, 4.2, 5.0),
  Yield0 = c(2.0, 2.5, 3.0),
  FertN = c(10, 10, 10)
)

# Run the batch calculator
result <- calculate_nue_batch(df)

# View calculated AE column
print(result$AE)
```

ecoNUE*Calculate Ecological NUE (ecoNUE)*

Description

The product of N productivity and mean residency time (MRT). Formula: $\text{ecoNUE} = \text{NP} * \text{MRT}$

Usage

```
ecoNUE(NP, MRT)
```

Arguments

NP	Nitrogen Productivity Value.
MRT	Mean Residency Time value.

Value

A numeric vector of ecoNUE values.

Examples

```
NP <- c(10, 12)
MRT <- c(4, 5)
ecoNUE(NP, MRT)
```

IE	<i>Calculate Internal Efficiency (IE)</i>
----	---

Description

The fraction of plant tissue N that is contained in the yield component. Formula: $IE = \text{YieldNF} / \text{PlantNf}$

Usage

```
IE(YieldNF, PlantNf)
```

Arguments

YieldNF	A numeric vector for yield N in fertilized conditions.
PlantNf	A numeric vector for plant N in fertilized conditions.

Value

A numeric vector of IE values.

Examples

```
YieldNF <- c(80, 90, 100)
PlantNf <- c(3.5, 4.0, 4.2)
IE(YieldNF, PlantNf)
```

NBI	<i>Calculate N Balance Intensity (NBI)</i>
-----	--

Description

The difference between fertilizer N applied and the N removed as yield (N Surplus). Formula: $NBI = \text{FertN} - \text{YieldN}$

Usage

```
NBI(YieldN, FertN)
```

Arguments

YieldN	A numeric vector of the N removed as yield.
FertN	A numeric value or vector for fertilizer N input.

Value

A numeric vector of NBI values.

Examples

```
YieldN <- c(80, 90, 100)
FertN <- 50
NBI(YieldN, FertN)
```

NdfF

Calculate N derived from Fertilizer (NdfF)

Description

The percentage of plant or soil N that is derived from the fertilizer. Formula: $NdfF = (Plant15N / Fert15N) * 100$

Usage

```
NdfF(Plant15N, Fert15N)
```

Arguments

Plant15N A vector of 15N atom percent excess in plant or soil.
Fert15N 15N atom percent excess of fertilizer N.

Value

A numeric vector of NdfF percentages.

Examples

```
Plant15N <- c(0.4, 0.5)
Fert15N <- 2.5
NdfF(Plant15N, Fert15N)
```

NHI	<i>Calculate N Harvest Index (NHI)</i>
-----	--

Description

The percent of plant tissue N that is contained in the yield component. Formula: $NHI = YieldF / PlantNf$

Usage

```
NHI(YieldF, PlantNf)
```

Arguments

YieldF	A numeric vector of final yield values.
PlantNf	A numeric vector for total plant tissue N.

Value

A numeric vector of NHI values.

Examples

```
YieldF <- c(10, 12, 15)
PlantNf <- c(2.5, 3.0, 3.2)
NHI(YieldF, PlantNf)
```

NP	<i>Calculate Nitrogen Productivity (NP)</i>
----	---

Description

The ratio of the relative growth rate to the concentration of N in plant tissues. Formula: $NP = GR / PlantN$

Usage

```
NP(GR, PlantN)
```

Arguments

GR	A numeric vector for Plant relative growth rate.
PlantN	A numeric vector for plant N concentration.

Value

A numeric vector of NP values.

Examples

```
GR <- c(0.5, 0.6)
PlantN <- c(2.0, 2.2)
NP(GR, PlantN)
```

NRE

Calculate Fertilizer N Recovery Efficiency (NRE)

Description

The percentage of fertilizer N that is taken up by the plant. Formula: $NRE = ((PlantNf - PlantN0) / FertN) * 100$

Usage

```
NRE(PlantNf, PlantN0, FertN)
```

Arguments

PlantNf	A numeric vector of plant N in fertilized conditions.
PlantN0	A numeric vector of plant N in control conditions.
FertN	A numeric value or vector for fertilizer N input.

Value

A numeric vector of NRE percentages.

Examples

```
PlantNf <- c(3.5, 4.0, 4.2)
PlantN0 <- c(2.0, 2.0, 2.0)
FertN <- 50
NRE(PlantNf, PlantN0, FertN)
```

NRE15	<i>Calculate Isotope-Based Recovery Efficiency (NRE15)</i>
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Description

The percent recovery of fertilizer-N in plant and/or soil components. Formula: $NRE15 = (TNdF / FertN) * 100$

Usage

```
NRE15(TNdF, FertN)
```

Arguments

TNdF	Total N derived from Fertilizer (vector).
FertN	Fertilizer N input (numeric vector or single value).

Value

A numeric vector of NRE15 percentages.

Examples

```
TNdF <- c(5.5, 6.0, 4.8)
FertN <- 50
NRE15(TNdF, FertN)
```

NUEbal	<i>Calculate NUE Balance</i>
--------	------------------------------

Description

The fraction of N inputs that are removed from the system. Formula: $NUEbal = No / Ni$

Usage

```
NUEbal(No, Ni)
```

Arguments

No	Sum total of N outputs.
Ni	Sum total of N inputs.

Value

A numeric vector of NUEbal values.

Examples

```
No <- c(50, 60)
Ni <- c(100, 110)
NUEbal(No, Ni)
```

NUEcrop

Calculate NUE Crop

Description

The fraction of fertilizer N that is utilized and allocated to yield N. Formula: $\text{NUEcrop} = \text{YieldN} / \text{FertN}$

Usage

```
NUEcrop(YieldN, FertN)
```

Arguments

YieldN	A numeric vector of the N removed as yield.
FertN	A numeric value or vector for fertilizer N input.

Value

A numeric vector of NUEcrop values.

Examples

```
YieldN <- c(80, 90, 100)
FertN <- 50
NUEcrop(YieldN, FertN)
```

NUEFC

Calculate NUE of a Food Chain (NUEFC)

Description

The N balance of the entire food chain system. Formula: $\text{NUEFC} = \text{Ncon} / \text{Ni}$

Usage

```
NUEFC(Ncon, Ni)
```

Arguments

Ncon	The value of N available for consumption.
Ni	Sum total of new N input.

Value

A numeric vector of NUEFC values.

Examples

```
Ncon <- c(40, 45)
Ni <- c(100, 110)
NUEFC(Ncon, Ni)
```

NUEsoil	<i>Calculate NUE Soil</i>
---------	---------------------------

Description

The biomass production per unit of available N. Formula: $NUE_{soil} = PlantBM / (FertN + SoilN)$

Usage

```
NUEsoil(PlantBM, SoilN, FertN)
```

Arguments

- PlantBM A numeric vector of plant biomass.
- SoilN A numeric value or vector for soil N content.
- FertN A numeric value or vector for fertilizer N input.

Value

A numeric vector of NUEsoil values.

Examples

```
PlantBM <- c(100, 120, 130)
SoilN <- c(20, 20, 20)
FertN <- 50
NUEsoil(PlantBM, SoilN, FertN)
```

NUEyield*Calculate NUE Yield*

Description

The contribution of N supplied from the soil that is allocated to yield. Formula: $\text{NUEyield} = \text{NUpE} * \text{NUtE}$

Usage

```
NUEyield(NUpE, NUtE)
```

Arguments

NUpE	N Uptake Efficiency value or vector.
NUtE	N Utilization Efficiency value or vector.

Value

A numeric vector of NUEyield values.

Examples

```
NUpE <- c(40, 50)
NUtE <- c(20, 25)
NUEyield(NUpE, NUtE)
```

NUpE*Calculate N Uptake Efficiency (NUpE)*

Description

The percentage of available soil N that is utilized by the plant. Formula: $\text{NUpE} = (\text{PlantN} / (\text{FertN} + \text{SoilN})) * 100$

Usage

```
NUpE(PlantN, SoilN, FertN)
```

Arguments

PlantN	A numeric vector of values for plant N content.
SoilN	A numeric value or vector for soil N content.
FertN	A numeric value or vector for fertilizer N input.

Value

A numeric vector of NUpE percentages.

Examples

```
PlantN <- c(3.0, 3.5, 3.8)
SoilN <- c(20, 20, 20)
FertN <- 50
NUpE(PlantN, SoilN, FertN)
```

NUtE	<i>Calculate N Utilization Efficiency (NUtE)</i>
------	--

Description

The contribution of fertilizer N from the plant tissues towards the yield component. Formula: $NUtE = Yield / PlantN$

Usage

```
NUtE(Yield, PlantN)
```

Arguments

- Yield A numeric vector of yield values.
- PlantN A numeric vector for plant tissue N.

Value

A numeric vector of NUtE values.

Examples

```
Yield <- c(10, 12, 15)
PlantN <- c(2.5, 3.0, 3.2)
NUtE(Yield, PlantN)
```

PE	<i>Calculate Physiological Efficiency (PE)</i>
----	--

Description

The contribution of fertilizer N from the plant tissues towards the yield component. Formula: $PE = (YieldF - Yield0) / (PlantNf - PlantN0)$

Usage

```
PE(YieldF, Yield0, PlantNf, PlantN0)
```

Arguments

YieldF	A numeric vector of final yield values.
Yield0	A numeric vector of non-fertilized control yield values.
PlantNf	A numeric vector of plant N at the end of the experiment.
PlantN0	A numeric vector of plant N at the beginning/control.

Value

A numeric vector of PE values.

Examples

```
YieldF <- c(12, 13, 14)
Yield0 <- c(10, 10, 10)
PlantNf <- c(3.5, 4.0, 4.2)
PlantN0 <- c(2.0, 2.0, 2.0)
PE(YieldF, Yield0, PlantNf, PlantN0)
```

PFP	<i>Calculate Partial Factor Productivity (PFP)</i>
-----	--

Description

The expression of yield per unit of fertilizer N applied. Formula: $PFP = YieldF / FertN$

Usage

```
PFP(YieldF, FertN)
```

Arguments

YieldF	A numeric vector of final yield values.
FertN	A numeric value or vector for fertilizer N input.

Value

A numeric vector of PFP values.

Examples

```
YieldF <- c(10, 12, 15)
FertN <- 50
PFP(YieldF, FertN)
```

plot_nue_compare	<i>Plot NUE Comparison</i>
------------------	----------------------------

Description

Creates a bar chart comparing NUE metrics across different groups (e.g., Treatments or Sites). Includes error bars (Standard Error).

Usage

```
plot_nue_compare(data, x_var, y_var)
```

Arguments

data	A dataframe containing the results.
x_var	The column name to group by (e.g., "Treatment", "Year").
y_var	The NUE metric to plot (e.g., "AE", "NRE").

Value

A ggplot object.

Examples

```
# Create dummy data
df <- data.frame(
  Treat = c("A", "A", "B", "B"),
  AE = c(10, 12, 20, 22)
)

# Plot
plot_nue_compare(df, x_var = "Treat", y_var = "AE")
```

PNB	<i>Calculate Partial N Balance (PNB)</i>
-----	--

Description

The expression of plant N content per unit of fertilizer N applied. Formula: $PNB = \text{PlantNf} / \text{FertN}$

Usage

```
PNB(PlantNf, FertN)
```

Arguments

PlantNf	A numeric vector of Plant N content in fertilized conditions.
FertN	A numeric value or vector for fertilizer N input.

Value

A numeric vector of PNB values.

Examples

```
PlantNf <- c(3.5, 4.0, 4.2)
FertN <- 50
PNB(PlantNf, FertN)
```

sNBI	<i>Calculate N Balance Index of a System (sNBI)</i>
------	---

Description

The accumulation or reduction of soil N over a set time. Formula: $sNBI = N_i - N_o - \text{delSoilN}$

Usage

```
sNBI(Ni, No, delSoilN)
```

Arguments

Ni	Sum total of N inputs (vector or value).
No	Sum total of N outputs (vector or value).
delSoilN	Change in total soil N value.

Value

A numeric vector of sNBI values.

Examples

```
Ni <- c(100, 120)
No <- c(80, 90)
delSoilN <- c(5, -2)
sNBI(Ni, No, delSoilN)
```

sNUE

*Calculate NUE of a System (sNUE)***Description**

The fraction of system N outputs that are captured as N yield. Formula: $sNUE = YieldN / (YieldN + Nloss)$

Usage

```
sNUE(YieldN, Nloss)
```

Arguments

YieldN	Observed crop yield N.
Nloss	N lost from the system.

Value

A numeric vector of sNUE values.

Examples

```
YieldN <- c(80, 90, 100)
Nloss <- c(20, 25, 20)
sNUE(YieldN, Nloss)
```

TNdff

*Calculate Total N derived from Fertilizer (TNdff)***Description**

The total quantity of plant or soil N that is derived from fertilizer. Formula: $TNdff = (Ndff/100) * (PlantN \text{ or } SoilN)$

Usage

```
TNdff(Ndff, PlantN = NULL, SoilN = NULL)
```

Arguments

NdffF	N derived from Fertilizer expressed as a percentage (0-100).
PlantN	Optional numeric vector for plant N content.
SoilN	Optional numeric vector for soil N content.

Value

A numeric vector of TNdffF values.

Examples

```
NdffF <- c(15, 20)
PlantN <- c(3.0, 3.5)

# Case 1: Using Plant N
TNdffF(NdffF, PlantN = PlantN)

# Case 2: Using Soil N (must specify SoilN explicitly)
SoilN <- c(100, 120)
TNdffF(NdffF, SoilN = SoilN)
```

VNF

Calculate Virtual N Factor (VNF)

Description

The portion of N released to the environment not contained in food. Formula: $VNF = N_{rec} / N_{con}$

Usage

```
VNF(Nrec, Ncon)
```

Arguments

Nrec	N used to produce food item that ends up recycled.
Ncon	N in food item that is consumed.

Value

A numeric vector of VNF values.

Examples

```
Nrec <- c(10, 12)
Ncon <- c(40, 45)
VNF(Nrec, Ncon)
```

Index

AE, [2](#), [3](#)

calculate_nue_batch, [2](#), [3](#)

ecoNUE, [5](#)

IE, [6](#)

NBI, [6](#)

Ndff, [7](#)

NHI, [8](#)

NP, [8](#)

NRE, [2](#), [9](#)

NRE15, [10](#)

NUEbal, [10](#)

NUEcrop, [11](#)

NUEFC, [11](#)

NUEsoil, [2](#), [12](#)

NUETON (NUETON-package), [2](#)

NUETON-package, [2](#)

NUEyield, [13](#)

NUpE, [13](#)

NUtE, [14](#)

PE, [15](#)

PFP, [15](#)

plot_nue_compare, [2](#), [16](#)

PNB, [17](#)

sNBI, [17](#)

sNUE, [18](#)

TNdff, [18](#)

VNF, [19](#)