Package 'emf'

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Type Package

Title Ecosystem Multifunctionality: Richness, Divergence, and Regularity

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Maintainer Yan He <heyan@njfu.edu.cn>

Description Analyzes and quantifies ecosystem multifunctionality with functions to calculate multifunctionality richness (MFric), multifunctionality divergence (MFdiv), and multifunctionality regularity (MFreg). These indices help assess the relationship between biodiversity and multiple ecosystem functions. For more details, see Byrnes et al. (2014) <doi:10.1111/2041-210X.12143> and Chao et al. (2024) <doi:10.1111/ele.14336>.

License GPL-3

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Author Yan He [aut, cre], Lingfeng Mao [aut]

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Contents

`forestfunctions` *Forest Functions Dataset (forestfunctions)*

Description

A dataset containing 26 ecosystem functions measured across the FunDivEUROPE Exploratory Platform. All functions have been preprocessed to handle missing values and normalized to a range of [0,1] within each country, with higher values indicating better ecosystem functionality (except for soil_cn_ff_10 and wue, where lower values are desirable).

Usage

```
forestfunctions
```

Format

A data frame with 209 rows and 31 columns:

plotid The unique identifier for each forest plot

target_species_richness The planned/designed species richness of the plot

composition Information about the species composition

region_centred_ba Region-centered basal area

region_centred_coniferous Region-centered coniferous proportion

earthworm_biomass.std Biomass of all earthworms (g m-2)

fine_woody_debris.std Snags and standing dead trees shorter than 1.3 m and thinner than 5 cm DBH, and all stumps and other dead wood pieces on the forest floor

microbial_biomass_mineral.std Mineral soil (0-5 cm layer) microbial biomass carbon

soil_c_ff_10.std Total soil carbon stock (Mg ha-1) in forest floor and 0-10 cm mineral soil layer combined

litter_decomp_day.std Decomposition of leaf litter using the litterbag methodology (% daily rate)

nre.std Nitrogen resorption efficiency, difference in N content between green and senescent leaves divided by N content of green leaves (%)

soil_cn_ff_10.std Soil C/N ratio in forest floor and 0-10 cm mineral soil layer combined (smaller values are desirable)

wood_decomp_day.std Decomposition of flat wooden sticks placed on forest floor (% daily rate)

root_biomass.std Total biomass of living fine roots in forest floor and 0-10 mineral soil layer combined (g m-2)

lai.std Leaf area index

leaf_litter_production.std Annual production of foliar litter dry mass (g)

photo_eff_tot.std Chlorophyll fluorescence methodology (ChlF)

tree_growth.std Annual aboveground wood production (Mg C ha-1 year-1)

tree_biomass.std Aboveground biomass of all trees (Mg C ha-1)

total_understorey_weight.std Dry weight of all understory vegetation in a quadrant (g)

sapling_growth.std Growth of saplings up to 1.60 m tall (cm)

regeneration_seedlings.std Number of tree seedlings less than a year old

regeneration_juveniles.std Number of saplings up to 1.60 m tall

wue.std Resistance to drought, difference in carbon isotope composition in wood cores between dry and wet years (smaller values are desirable)

resistance_insects.std Foliage not damaged by insects (%)

lack_browsing.std Twigs not damaged by browsers (%)

no_pathogen_damage.std Foliage not damaged by pathogens (%)

tree.growth.recovery.std Ratio between post-drought growth and growth during the respective drought period

tree.growth.resilience.std Ratio between growth after and before the drought period

tree.growth.resistance.std Ratio of tree growth during a drought period and growth during the previous 5-year high-growth period

tree.growth.stability.std Mean annual tree growth divided by standard deviation in annual tree growth between 1992 and 2011

Details

Missing values (approximately 5% of the data) were imputed using country-level mean values for each function. All functions were then normalized to a range of [0,1] within each country. For most functions, higher values indicate better ecosystem functionality, except for soil_cn_ff_10 and wue, where lower values are desirable.

Source

Scherer-Lorenzen, M., Allan, E., Ampoorter, E., Avacaritiei, D., Baeten, L., Barnoaiea, I. et al. (2023) The functional significance of tree species diversity in European forests—the FunDivEUROPE dataset [dataset]. Dryad Digital Repository. Available from: https://doi.org/10.5061/dryad.9ghx3ffpz

Examples

```
data(forestfunctions)
head(forestfunctions)
```

`MFdiv` *Calculate Multifunctionality Divergence (MFdiv)*

Description

Multifunctionality divergence (MFdiv) was calculated to quantify the degree of difference between different functions of an ecosystem. MFdiv was calculated by the mean pairwise distance method.

Usage

```
MFdiv(data, weights = NULL, cor = FALSE)
```

Arguments

data	A data frame or matrix where rows represent observations and columns represent functions.
weights	A numeric vector of weights for each function (column). If NULL, equal weights are assigned.
cor	Logical. If TRUE, calculates MFdiv with redundancy correction based on correlation between functions. If FALSE, calculates uncorrected MFdiv.

Details

To measure MFdiv quantitatively, we employ the mean pairwise distance method (Webb et al., 2002).

For uncorrected MFdiv, the formula is:

$$MFdiv = \frac{\sum_{i=1}^{n}\sum_{j=i+1}^{n} w_i w_j D_{ij}}{\sum_{i=1}^{n}\sum_{j=i+1}^{n} w_i w_j}$$

where $D_{ij} = |f_i - f_j|$

When redundancy correction is applied ('cor = TRUE'), the function accounts for correlations between ecosystem functions. The correction process involves:

1. Calculating a distance matrix based on correlations: $d_{ij} = \sqrt{1 - |r_{ij}|}$
2. Applying threshold-based correction: $d_{ij}(\tau) = \min(d_{ij}, \tau)$
3. Computing effective function values: $F_i(\tau) = \sum_{j=1}^{L}(1 - \frac{d_{ij}(\tau)}{\tau})f_j$
4. Calculating the corrected MFdiv using these effective function values:

$$D_{ij}(\tau) = |F_i - F_j|$$

$$MFdiv = \frac{\sum_{i=1}^{n}\sum_{j=i+1}^{n} w_i w_j D_{ij}(\tau)}{\sum_{i=1}^{n}\sum_{j=i+1}^{n} w_i w_j}$$

5. The final result is the area under the curve (AUC) of MFdiv values across different tau thresholds.

Value

A data frame with MFdiv values for each observation (row) in the input data.

Examples

```
data(forestfunctions)
head(forestfunctions)
MFdiv(forestfunctions[,6:31], cor = FALSE)
```

MFreg *Calculate Multifunctionality Regularity (MFreg)*

Description

Calculates the multifunctionality regularity index, which measures how evenly different ecosystem functions are distributed across the system. The function can account for correlations between functions when specified.

Usage

```
MFreg(data, weights = NULL, cor = FALSE)
```

Arguments

data	A data frame or matrix where rows represent observations and columns represent functions.
weights	A numeric vector of weights for each function (column in data). If NULL, equal weights are assigned.
cor	Logical. If TRUE, function correlations are accounted for using redundancy correction. Default is FALSE.

Details

Multifunctionality Regularity (MFreg) quantifies the evenness of function distribution in an ecosystem. It is calculated as:

$$MFreg = \frac{-\sum_{i=1}^{n} \frac{w_i f_i}{\sum_{i=1}^{n} w_i f_i} \ln \frac{w_i f_i}{\sum_{i=1}^{n} w_i f_i}}{\ln(n)}$$

where fi represents the normalized performance level of function i, wi is the weight of function i, and n is the total number of functions examined.

When redundancy correction is applied ('cor = TRUE'), the function accounts for correlations between ecosystem functions. The correction process involves:

1. Calculating a distance matrix based on correlations: $d_{ij} = \sqrt{1 - |r_{ij}|}$
2. Applying threshold-based correction: $d_{ij}(\tau) = \min(d_{ij}, \tau)$
3. Computing effective function values: $F_i(\tau) = \sum_{j=1}^{L}(1 - \frac{d_{ij}(\tau)}{\tau})f_j$
4. Calculating the corrected MFreg using these effective function values:

$$MFreg = \frac{-\sum_{i=1}^{n} \frac{w_i F_i}{\sum_{i=1}^{n} w_i F_i} \ln \frac{w_i F_i}{\sum_{i=1}^{n} w_i F_i}}{\ln(n)}$$

5. The final result is the area under the curve (AUC) of MFreg values across different tau thresholds.

Value

A data frame with one column named "MFreg" containing the multifunctionality regularity values for each observation (row) in the input data.

Examples

```
data(forestfunctions)
head(forestfunctions)
MFreg(forestfunctions[,6:31], cor = FALSE)
```

`MFric` *Calculate Multifunctionality Richness (MFric)*

Description

This function calculates the Multifunctionality Richness (MFric) for each row in a dataset. MFric represents the average level of multiple ecosystem function indicators, reflecting the overall performance of an ecosystem across various functional metrics.

Usage

```
MFric(data, weights = NULL, cor = FALSE)
```

Arguments

`data`	A numeric data frame or matrix where rows represent observations (e.g., sites, plots) and columns represent different ecosystem functions.
`weights`	A numeric vector of weights for each function (column) in the data. If NULL (default), equal weights of 1 are assigned to all functions.
`cor`	Logical. If FALSE (default), calculates uncorrected MFric. If TRUE, calculates correlation-corrected MFric accounting for redundancy among functions.

Details

The uncorrected MFric is calculated as:

$$MFric = \frac{\sum_{i=1}^{n} w_i f_i}{\sum_{i=1}^{n} w_i}$$

where fi represents the normalized performance level of function i, and wi denotes the weight assigned to function i.

When redundancy correction is applied ('cor = TRUE'), the function accounts for correlations between ecosystem functions. The correction process involves:

1. Calculating a distance matrix based on correlations: $d_{ij} = \sqrt{1 - |r_{ij}|}$

2. Applying threshold-based correction: $d_{ij}(\tau) = \min(d_{ij}, \tau)$

3. Computing effective function values: $F_i(\tau) = \sum_{j=1}^{L}(1 - \frac{d_{ij}(\tau)}{\tau})f_j$
4. Calculating the corrected MFric using these effective function values:

$$MFric = \frac{\sum_{i=1}^{n} w_i F_i}{\sum_{i=1}^{n} w_i}$$

5. The final result is the area under the curve (AUC) of MFric values across different tau thresholds.

Value

A data frame with a single column named "MFric" containing the calculated Multifunctionality Richness values for each row in the input data. Row names are preserved from the input data if available.

Examples

```
data(forestfunctions)
head(forestfunctions)
MFric(forestfunctions[,6:31], cor = FALSE)
```

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