

Package: climniche (via r-universe)

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Type Package

Title Climate Exposure Relative to a Species' Climatic Niche

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Description Quantifies climate exposure by comparing projected conditions with the climates associated with a species' current distribution. Location weights define an empirical climatic niche reference, summarised by a weighted centre and radial boundary. The analysis measures local climatic change, movement towards or away from the reference centre, climatic reconfiguration, and distance beyond the boundary. Occurrence records, range maps, and binary or continuous species distribution model outputs can define location weights. Matrix and spatial workflows provide location-level results, distribution-wide summaries, climatic variable contributions and comparisons across future periods.

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URL <https://github.com/Bohao0813/climniche>,
<https://bohao0813.github.io/climniche/>

BugReports <https://github.com/Bohao0813/climniche/issues>

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boundary_exceedance	<i>Niche Boundary Exceedance</i>
---------------------	----------------------------------

Description

Niche Boundary Exceedance

Usage

```
boundary_exceedance(
  psi_future,
  boundary_value,
  scale = c("radial", "potential")
)
```

Arguments

psi_future	Future squared niche distance.
boundary_value	Empirical boundary of the current climatic niche reference in squared-distance units.
scale	"radial" returns exceedance beyond the niche boundary distance; "potential" returns exceedance in squared-distance units.

Value

Numeric vector.

Examples

```
psi <- c(0.5, 1, 2)
boundary_exceedance(psi, boundary_value = 1)
```

climniche_change_rate	<i>Summarise interval changes in range summaries of Niche Boundary Exceedance</i>
-----------------------	---

Description

Summarise interval changes in range summaries of Niche Boundary Exceedance

Usage

```
climniche_change_rate(
  x,
  metric = c("exposed_fraction", "range_wide_relative_exceedance",
    "mean_niche_boundary_exceedance"),
  scope = c("current", "all"),
  aggregation_weight = NULL,
  area_weight = FALSE,
  boundary_exceedance_tolerance = NULL
)
```

Arguments

x A `climniche_series` object.

metric Range summary used to quantify increase.

scope, aggregation_weight, area_weight, boundary_exceedance_tolerance Arguments passed to `climniche_range_summary()`.

Details

For a selected range summary X_t , interval rates are

$$g_k = \frac{X_{t_{k+1}} - X_{t_k}}{t_{k+1} - t_k}.$$

The function reports the largest positive g_k and its interval. Rates should only be compared among analyses using compatible temporal units and projection resolution.

Value

A data frame with one row per model and scenario.

climniche_departure	<i>Summarise Niche Boundary Exceedance through time</i>
---------------------	---

Description

Summarise Niche Boundary Exceedance through time

Usage

```
climniche_departure(
  x,
  scope = c("current", "all"),
  persistence = 1L,
  boundary_exceedance_tolerance = NULL
)
```

Arguments

x	A climniche_series object.
scope	"current" for positive reference weights or "all" for every evaluated cell.
persistence	Minimum number of consecutive projections required to identify persistent Niche Boundary Exceedance. This setting affects persistence summaries, not the continuous exceedance values.
boundary_exceedance_tolerance	Optional non-negative boundary tolerance. The fitted value is used by default.

Details

At projection time t_k , let e_{ik} be Niche Boundary Exceedance for cell i , divided by the fitted niche boundary distance after the boundary tolerance is applied. Cumulative relative exceedance is

$$J_i = \sum_{k=1}^{K-1} (t_{k+1} - t_k) \frac{e_{ik} + e_{i,k+1}}{2}.$$

Mean relative exceedance is $J_i / (t_K - t_1)$. The Time Weighted Niche Boundary Exceedance Fraction applies the same trapezoidal calculation to the binary exceedance indicator. Numeric, Date and POSIXct times may be irregularly spaced. Cumulative values use the reported time unit; mean values are dimensionless.

Persistent Niche Boundary Exceedance is a run of at least persistence sampled projections above the selected boundary tolerance. Its onset is the first sampled projection in that run, not an estimated crossing time between projections.

Value

A data frame with one row per cell, model and scenario. Primary temporal fields give the first sampled Niche Boundary Exceedance (first_boundary_exceedance) and the fraction of supplied projections beyond the boundary (boundary_exceedance_projection_fraction). Persistent onset and interval-weighted summaries are also returned.

Examples

```
sim <- simulate_climniche(n = 160, p = 6, seed = 2)
future <- lapply(c(0.2, 0.5, 0.8, 1), function(fraction) {
  sim$current + fraction * (sim$future_away - sim$current)
})
series <- fit_climniche_series(
  sim$current,
  future,
  time = c(2030, 2050, 2070, 2090),
  occupied = sim$occupied,
  sensitivity = sim$sensitivity
)
head(climniche_departure(series))
```

climniche_dominant_contribution

Summarise dominant climatic contributions by cell

Description

Identifies the climate variable with the largest absolute contribution to future minus current squared niche distance at each evaluated cell.

Usage

```
climniche_dominant_contribution(x, scope = c("current", "all"))
```

```
## S3 method for class 'climniche_contribution'
summary(object, ...)
```

Arguments

x	A fitted <code>climniche_fit</code> object.
scope	"current" retains cells with positive current reference weight; "all" retains every evaluated cell.
object	A <code>climniche_contribution</code> object.
...	Additional arguments passed to methods.

Details

Let V_{ij} be the contribution returned by `variable_contribution()` for cell i and variable j . The dominant variable has the largest $|V_{ij}|$. Its dominance share is

$$H_i = \frac{\max_j |V_{ij}|}{\sum_j |V_{ij}|}.$$

The share is undefined when every contribution is zero. Equal largest absolute contributions are reported as "Tied" rather than being assigned according to column order.

Contributions sum exactly to future minus current squared niche distance. This total is also $(r_{1i} - r_{0i})(r_{1i} + r_{0i})$. The terms therefore attribute the squared-distance change underlying Niche Distance Shift. For a non-diagonal metric matrix, each variable term includes its part of the cross-variable terms in the chosen climatic basis. They are not SDM variable importance or causal effects. Current-scope summaries use the fitted reference weights; all-scope summaries give each evaluated cell equal weight.

Value

A `climniche_contribution` object. `table` contains the dominant variable, signed contribution and dominance share for each cell. `summary` contains mean contribution shares and signed contributions by variable, together with the fraction of non-zero analysis weight for which each variable

is uniquely dominant. `squared_niche_distance_change` is the row sum of the signed variable contributions. The legacy field `niche_potential_change` is retained as an exact alias. Spatial fits also return raster layers.

Examples

```
sim <- simulate_climniche(n = 300, p = 6, seed = 31)
fit <- fit_climniche(
  sim[["current"]],
  sim[["future_away"]],
  occupied = sim[["occupied"]],
  sensitivity = sim[["sensitivity"]]
)
contribution <- climniche_dominant_contribution(fit)
summary(contribution)
head(contribution[["table"]])
```

climniche_model_agreement

Summarise agreement among projected climate models

Description

Summarise agreement among projected climate models

Usage

```
climniche_model_agreement(
  x,
  scope = c("current", "all"),
  boundary_exceedance_tolerance = NULL,
  interval = 0.8
)
```

Arguments

<code>x</code>	A <code>climniche_series</code> object.
<code>scope</code>	"current" or "all".
<code>boundary_exceedance_tolerance</code>	Optional non-negative boundary tolerance.
<code>interval</code>	Central interval reported for Niche Boundary Exceedance across models.

Details

model_agreement is the proportion of supplied climate models with positive Niche Boundary Exceedance. It is an ensemble agreement measure, not an occurrence probability. Agreement is NA when fewer than two finite model projections are available for a cell, time and scenario. For M available models,

$$G_{it} = \frac{1}{M} \sum_{m=1}^M I(E_{imt} > \tau),$$

where τ is boundary_exceedance_tolerance.

Value

A data frame with one row per cell, time and scenario.

climniche_priority	<i>Screen ecological criteria against climate exposure</i>
--------------------	--

Description

Screen ecological criteria against climate exposure

Usage

```
climniche_priority(
  x,
  exposure = c("niche_distance_change", "niche_boundary_exceedance",
    "climate_reconfiguration", "climate_change_amount", "outside_niche_exceedance",
    "composition_change"),
  criterion = NULL,
  criterion_name = NULL,
  criterion_direction = c("maximize", "minimize"),
  scope = c("current", "all"),
  positive_only = NULL,
  exposure_direction = c("maximize", "minimize")
)

## S3 method for class 'climniche_priority'
summary(object, ...)
```

Arguments

x	A fitted climniche_fit object.
exposure	Climatic quantity used as the exposure objective. Available choices are "niche_distance_change", "niche_boundary_exceedance", "climate_reconfiguration", and "climate_change_amount". Legacy metric aliases are accepted.

criterion	Optional second decision criterion. A numeric vector may contain one value per evaluated row or, for a spatial fit, one value per raster cell. A matching one-layer RasterLayer or SpatRaster is also accepted. When omitted, current reference weights are used.
criterion_name	Display name for criterion.
criterion_direction	Whether larger or smaller criterion values are preferred.
scope	"current" ranks cells with positive current reference weight; "all" ranks every evaluated cell with finite criteria.
positive_only	If TRUE, only cells with a positive value of the selected exposure quantity are ranked. The default, NULL, uses TRUE when exposure is maximised and FALSE when it is minimised.
exposure_direction	Whether larger or smaller exposure values are preferred in the Pareto comparison. Use "maximize" to screen for greater exposure and "minimize" to screen for lower exposure.
object	A climniche_priority object.
...	Unused.

Details

The function ranks cells on two objectives: the selected climatic exposure quantity and one reference or decision criterion. Cell i dominates cell k when it is at least as preferred on both objectives and strictly preferred on one. Non-dominated cells form Pareto rank 1. Removing that front and repeating the comparison produces ranks 2, 3, and subsequent fronts.

If an analysis contains K Pareto fronts, `pareto_depth_score` is $(K - r_i)/(K - 1)$ for the rank r_i of cell i ; it is 1 when all cells occupy one front. The score does not order cells within a front and is not comparable among separate analyses. Pareto dominance is invariant to monotonic rescaling, so the two criteria are not combined with fitted weights.

When current reference weights are constant, the default second criterion does not distinguish cells and ranking is determined by exposure alone. When the weights vary, the default compares exposure with the current distribution weights. Supply `criterion` to use another ecological quantity.

Only one exposure quantity is used at a time. This avoids counting Climatic Displacement, Niche Distance Shift and Climatic Reconfiguration as independent objectives even though their values satisfy the fitted geometric identity. With current habitat suitability as the second criterion, preferring higher suitability and larger positive Niche Distance Shift targets potential exposure hotspots. Preferring higher suitability and lower Climatic Displacement guides the search for potential climatic refugia. Locations on the same front can trade a better value of one criterion for a poorer value of the other.

`summary()` reports the first-front fraction and the Spearman correlation between the preference-oriented forms of the two objectives. These describe how strongly the objectives separate the ranked cells; they are not inferential tests.

Value

A `climniche_priority` object containing the two decision criteria, Pareto ranks, Pareto depth score (`pareto_depth_score`) and, for spatial fits, map layers. `relative_priority` is retained as a compatibility alias for `pareto_depth_score`.

`summary()` returns a `summary.climniche_priority` object with the fitted settings and Pareto diagnostics.

References

Tracey JA, Rochester CJ, Hathaway SA, et al. (2018). Prioritizing conserved areas threatened by wildfire and fragmentation for monitoring and management. *PLOS ONE*, 13, e0200203. doi:10.1371/journal.pone.0200203

Sacre E, Bode M, Weeks R, Pressey RL (2019). The context dependence of frontier versus wilderness conservation priorities. *Conservation Letters*, 12, e12632. doi:10.1111/conl.12632

Examples

```
sim <- simulate_climniche(n = 500, p = 6, seed = 18)
fit <- fit_climniche(
  sim[["current"]],
  sim[["future_away"]],
  occupied = sim[["occupied"]],
  sensitivity = sim[["sensitivity"]]
)
priority <- climniche_priority(fit)
priority
priority_table <- priority[["table"]]
head(priority_table[priority_table[["included"]], ])
summary(priority)
```

```
climniche_range_summary
```

Summarise Niche Boundary Exceedance across a study domain

Description

Summarise Niche Boundary Exceedance across a study domain

Usage

```
climniche_range_summary(
  x,
  scope = c("current", "all"),
  aggregation_weight = NULL,
  area_weight = FALSE,
  boundary_exceedance_tolerance = NULL
)
```

Arguments

x	A climniche_fit or climniche_series object.
scope	"current" restricts the summary to positive reference weights. "all" uses every evaluated cell.
aggregation_weight	Optional non-negative cell weights used only for the range summary. Numeric vectors and, for spatial fits, matching RasterLayer or SpatRaster objects are accepted. These weights multiply the reference weights when scope = "current".
area_weight	If TRUE, multiply the summary weights by raster cell area. This option requires a spatial fit.
boundary_exceedance_tolerance	Optional non-negative tolerance used to identify positive Niche Boundary Exceedance. By default, the fitted descriptor tolerance is used.

Details

Let a_i be the range summary weight, let τ be the boundary tolerance, and define

$$\tilde{E}_i = E_i I(E_i > \tau), \quad e_i = \tilde{E}_i / B_q.$$

The Weighted Niche Boundary Exceedance Fraction is

$$F = \frac{\sum_i a_i I(e_i > 0)}{\sum_i a_i}.$$

Conditional Relative Niche Boundary Exceedance is

$$S = \frac{\sum_i a_i e_i I(e_i > 0)}{\sum_i a_i I(e_i > 0)}.$$

Range Mean Relative Niche Boundary Exceedance is

$$X = \frac{\sum_i a_i e_i I(e_i > 0)}{\sum_i a_i} = FS.$$

Here, $I(\cdot)$ is the indicator function. For scope = "current", a_i contains the reference weight. Optional aggregation and cell area weights multiply it. For scope = "all", the reference weight is omitted. These quantities summarise Niche Boundary Exceedance and do not add further cell-level exposure metrics.

Value

A data frame containing Weighted Niche Boundary Exceedance Fraction (exposed_fraction), Conditional Relative Niche Boundary Exceedance (conditional_relative_exceedance) and Range Mean Relative Niche Boundary Exceedance (range_wide_relative_exceedance). For a climniche_series, one row is returned for each time, model and scenario combination.

Examples

```

sim <- simulate_climniche(n = 250, p = 6, seed = 8)
fit <- fit_climniche(
  sim$current,
  sim$future_away,
  occupied = sim$occupied,
  sensitivity = sim$sensitivity
)
climniche_range_summary(fit)

```

climniche_report	<i>Build a climniche report</i>
------------------	---------------------------------

Description

Build a climniche report

Usage

```

climniche_report(
  x,
  species = NULL,
  scope = c("current", "all"),
  top_variables = 5
)

```

Arguments

x	A fitted climniche_fit object.
species	Optional species name used in printed reports.
scope	"current" for current reference cells or "all" for all evaluated cells. Current-scope summaries use reference weights.
top_variables	Number of variable contributions to show.

Value

An object of class climniche_report.

```
climniche_series_report
```

Build a report for a climniche time series

Description

Build a report for a climniche time series

Usage

```
climniche_series_report(
  x,
  species = NULL,
  scope = c("current", "all"),
  aggregation_weight = NULL,
  area_weight = FALSE,
  boundary_exceedance_tolerance = NULL,
  persistence = 1L,
  agreement_interval = 0.8
)
```

Arguments

<code>x</code>	A <code>climniche_series</code> object.
<code>species</code>	Optional species or study label.
<code>scope</code> , <code>aggregation_weight</code> , <code>area_weight</code> , <code>boundary_exceedance_tolerance</code>	Range-summary settings.
<code>persistence</code>	Consecutive projection count used to identify persistent Niche Boundary Exceedance.
<code>agreement_interval</code>	Central interval used for model agreement.

Value

A `climniche_series_report` object.

```
climniche_series_table
```

Extract a long table from a climniche series

Description

Extract a long table from a climniche series

Usage

```
climniche_series_table(x, scope = c("current", "all"))
```

Arguments

x A climniche_series object.

scope "current" for positive reference weights or "all" for all evaluated cells.

Value

A data frame with one row per cell and projection.

climniche_summary	<i>Summarise climniche results</i>
-------------------	------------------------------------

Description

Summarise climniche results

Usage

```
climniche_summary(x, scope = c("current", "all"))
```

Arguments

x A fitted climniche_fit object.

scope "current" for current reference cells or "all" for all evaluated cells. Current-scope summaries use reference weights.

Value

A one-row data frame with summaries of the four continuous reported quantities, descriptor proportions and fitted descriptor thresholds.

`climniche_summary_figure_data`*Build data for the climniche summary figure*

Description

Build data for the climniche summary figure

Usage

```
climniche_summary_figure_data(  
  x,  
  scope = c("current", "all"),  
  max_points = 6000L,  
  seed = 1L,  
  plane_bins = 35L,  
  boundary_probs = seq(0.5, 0.99, 0.01),  
  top_variables = 6L  
)
```

Arguments

<code>x</code>	A fitted climniche object.
<code>scope</code>	"current" for current reference cells; "all" for all evaluated cells.
<code>max_points</code>	Maximum number of rows retained in the returned plane table. Figure bins are calculated from all cells in the selected scope.
<code>seed</code>	Random seed used when subsampling the returned plane table.
<code>plane_bins</code>	Number of fixed bins used to summarize the exposure plane.
<code>boundary_probs</code>	Boundary quantiles retained in the returned boundary table for downstream inspection.
<code>top_variables</code>	Number of variables to show.

Value

A list of data frames used by `plot_climniche_summary_figure()`.

climniche_table	<i>Extract a tidy climniche table</i>
-----------------	---------------------------------------

Description

Extract a tidy climniche table

Usage

```
climniche_table(x, scope = c("current", "all"))
```

Arguments

x	A fitted climniche_fit object.
scope	"current" for current reference cells or "all" for all evaluated cells.

Value

A data frame with one row per evaluated cell, including occupied_weight, the four reported quantities and the old field aliases.

fit_climniche	<i>Fit climate exposure relative to a climatic niche from matrices</i>
---------------	--

Description

Compares the amount of climatic change at each location with movement towards or away from the current reference centre and distance beyond its estimated climatic range.

Usage

```
fit_climniche(
  current,
  future,
  occupied = NULL,
  occupied_threshold = NULL,
  cnfa = NULL,
  center = NULL,
  sensitivity = NULL,
  A = NULL,
  metric = c("diag", "factor"),
  boundary = 0.95,
  scale = TRUE,
  global_mean = NULL,
  global_sd = NULL,
```

```

preprocess = TRUE,
preprocess_correlation = 0.95,
preprocess_min_sd = 1e-08,
tolerance = NULL,
tolerance_quantile = 0.1,
boundary_exceedance_tolerance = 0
)

```

Arguments

current	Numeric matrix or data frame of current climate values. Rows are cells, sites, or samples. Columns are climate variables.
future	Numeric matrix or data frame of future climate values with the same rows and variables as current. Complete row and variable names are matched before fitting.
occupied	Location weights used to estimate the empirical climatic niche reference. Use NULL to give every row weight 1, a logical vector to mark reference rows, a numeric vector of length <code>nrow(current)</code> for continuous reference weights, or positive integer row indices for 0/1 reference cells. Complete names are matched to the row names of current. With NULL, the reference is the climatic distribution of all current analysis rows.
occupied_threshold	Optional cutoff for numeric reference weights. Values at or below the cutoff are set to 0. Values above it keep their original continuous value.
cnfa	Optional compatible CENFA object. Its <code>mf</code> and <code>sf</code> components can supply the niche centre and diagonal metric weights; <code>metric = "factor"</code> requires <code>co</code> and <code>eig</code> . The object and climatic inputs must use the same variables and standardisation.
center	Optional current niche centre on the scale used for distance calculations. With <code>scale = TRUE</code> , supply a centre in the standardised climatic space. If omitted, the centre is the weighted mean of current reference rows.
sensitivity	Optional non-negative climatic variable weights defining relative contributions to distance. Retained variables receive equal weights by default. These are separate from the location weights in <code>occupied</code> .
A	Optional square metric matrix defined for the fitted climatic space. When supplied, it overrides <code>sensitivity</code> , <code>cnfa</code> , and <code>metric</code> for distance calculations.
metric	Method used to build A when A is missing. <code>"diag"</code> uses variable-level climatic metric weights. <code>"factor"</code> constructs a weighted metric from the <code>co</code> and <code>eig</code> components of a compatible CENFA object.
boundary	Weighted quantile used to define the empirical radial boundary of the empirical climatic niche reference. Must be between 0 and 1.
scale	Logical. If TRUE, current and future values are centred and scaled with the current-layer mean and standard deviation before distances are calculated.
global_mean	Optional means used for centering when <code>scale = TRUE</code> . If omitted, column means of current are used.

global_sd	Optional standard deviations used for scaling. If scale = TRUE and this argument is omitted, column standard deviations of current are used.
preprocess	Logical. If TRUE, remove near-zero variance variables and highly correlated variables before metric fitting.
preprocess_correlation	Maximum absolute pairwise correlation retained among current climate variables during preprocessing.
preprocess_min_sd	Minimum current-climate standard deviation as a fraction of the largest finite current standard deviation. Variables at or below this value are removed during preprocessing.
tolerance	Optional tolerance around zero for Niche Distance Shift. If NULL, the fitted object uses tolerance_quantile.
tolerance_quantile	Quantile of absolute Niche Distance Shift used to set tolerance when tolerance = NULL.
boundary_exceedance_tolerance	Tolerance used to label Niche Boundary Exceedance in descriptor summaries.

Details

The empirical climatic niche reference summarises the current distribution of climatic conditions by a weighted centre and radial boundary. It is a proxy for the species' current climatic niche. With occupied = NULL, it instead describes the study region.

Let c_i and f_i be current and future climatic conditions at location i in the fitted climatic space, μ the reference centre, and $d_A(x, y)$ the distance under climatic weighting matrix A . The four quantities are:

Climatic Displacement, the amount of local climatic change:

$$D_i = d_A(f_i, c_i)$$

Niche Distance Shift, the signed change in distance from the centre:

$$R_i = d_A(f_i, \mu) - d_A(c_i, \mu)$$

Climatic Reconfiguration, the displacement not expressed as a distance shift:

$$C_i = \sqrt{\max(0, D_i^2 - R_i^2)}$$

Niche Boundary Exceedance, the distance beyond the fitted boundary:

$$E_i = \max(0, d_A(f_i, \mu) - B_q)$$

Here B_q is the q -th location-weighted quantile of current distances from the centre. Negative Niche Distance Shift indicates movement towards the centre; positive values indicate movement away. When current and future distances are equal, Niche Distance Shift is zero and Climatic Reconfiguration equals Climatic Displacement. Niche Boundary Exceedance is zero at or within the boundary and positive beyond it.

Value

A `climniche_fit` object containing the reported quantities, reference weights, fitted niche centre, metric matrix and effective settings.

Reported fields

Fitted fields are `climate_change_amount`, `niche_distance_change`, `climate_reconfiguration`, and `niche_boundary_exceedance`. The legacy names `composition_change` and `outside_niche_exceedance` are retained as aliases for old code.

User-settable thresholds

`boundary` controls the empirical radial boundary. `tolerance` controls the zero band for Niche Distance Shift. `boundary_exceedance_tolerance` controls the boundary descriptor. The fitted values are stored in `descriptor_settings`.

Boundary scale

`boundary_distance` and `boundary_radius` store the fitted boundary in distance units. `boundary_potential` stores its squared value and is the quantity accepted by `boundary_exceedance()`. `boundary_value` is retained as a legacy alias of `boundary_distance`.

Scaling and preprocessing

`preprocess` selects retained variables. `scale` then converts those variables to z scores using current-climate means and standard deviations. Both are enabled by default. When fitted CENFA components are used, preprocessing must be disabled because the component dimensions are fixed. Inputs must either already use the CENFA standardisation with `scale = FALSE` or provide its exact means and standard deviations through `global_mean` and `global_sd`. `climniche` reads the required components from the supplied object and does not call CENFA package functions.

Choosing a fit function

Use `fit_climniche()` for matrices or data frames, `fit_climniche_raster()` for `RasterLayer`, `RasterStack` or `RasterBrick` objects, and `fit_climniche_terra()` for `SpatRaster` objects. All three functions calculate the same quantities. The spatial functions add domain masking and return map layers in `x$rasters`. Use `fit_climniche_series()` for ordered projections.

Examples

```
sim <- simulate_climniche(n = 250, p = 6, seed = 7)
fit <- fit_climniche(
  current = sim$current,
  future = sim$future_away,
  occupied = sim$occupied,
  sensitivity = sim$sensitivity
)
climniche_summary(fit)
```

fit_climniche_raster *Fit climniche to raster data*

Description

Fit climniche to raster data

Usage

```
fit_climniche_raster(
  current,
  future,
  occupied = NULL,
  occupied_threshold = NULL,
  domain = NULL,
  domain_threshold = 0,
  cnfa = NULL,
  center = NULL,
  sensitivity = NULL,
  A = NULL,
  metric = c("diag", "factor"),
  boundary = 0.95,
  scale = TRUE,
  global_mean = NULL,
  global_sd = NULL,
  preprocess = TRUE,
  preprocess_correlation = 0.95,
  preprocess_min_sd = 1e-08,
  tolerance = NULL,
  tolerance_quantile = 0.1,
  boundary_exceedance_tolerance = 0
)
```

Arguments

current	RasterLayer, RasterStack or RasterBrick object of current climate layers.
future	Matching RasterLayer, RasterStack or RasterBrick object of future climate layers with the same geometry and variables as current. Named layers are matched before fitting.
occupied	Optional RasterLayer with binary or continuous occurrence, range, or SDM suitability values. Continuous values are retained on their supplied numerical scale.
occupied_threshold	Values at or below this threshold receive zero reference weight. Values above it keep their original value.
domain	Optional RasterLayer limiting cells where exposure is analysed.

domain_threshold	Values greater than this threshold define the domain.
cnfa	Optional compatible CENFA object. Its mf and sf components can supply the niche centre and diagonal metric weights; metric = "factor" requires co and eig. The object and climatic inputs must use the same variables and standardisation.
center	Optional current niche centre on the scale used for distance calculations. With scale = TRUE, supply a centre in the standardised climatic space. If omitted, the centre is the weighted mean of current reference rows.
sensitivity	Optional non-negative climatic variable weights defining relative contributions to distance. Retained variables receive equal weights by default. These are separate from the location weights in occupied.
A	Optional square metric matrix defined for the fitted climatic space. When supplied, it overrides sensitivity, cnfa, and metric for distance calculations.
metric	Method used to build A when A is missing. "diag" uses variable-level climatic metric weights. "factor" constructs a weighted metric from the co and eig components of a compatible CENFA object.
boundary	Weighted quantile used to define the empirical radial boundary of the empirical climatic niche reference. Must be between 0 and 1.
scale	Logical. If TRUE, current and future values are centred and scaled with the current-layer mean and standard deviation before distances are calculated.
global_mean	Optional means used for centering when scale = TRUE. If omitted, column means of current are used.
global_sd	Optional standard deviations used for scaling. If scale = TRUE and this argument is omitted, column standard deviations of current are used.
preprocess	Logical. If TRUE, remove near-zero variance variables and highly correlated variables before metric fitting.
preprocess_correlation	Maximum absolute pairwise correlation retained among current climate variables during preprocessing.
preprocess_min_sd	Minimum current-climate standard deviation as a fraction of the largest finite current standard deviation. Variables at or below this value are removed during preprocessing.
tolerance	Optional tolerance around zero for Niche Distance Shift. If NULL, the fitted object uses tolerance_quantile.
tolerance_quantile	Quantile of absolute Niche Distance Shift used to set tolerance when tolerance = NULL.
boundary_exceedance_tolerance	Tolerance used to label Niche Boundary Exceedance in descriptor summaries.

Details

`fit_climniche_raster()` is the spatial workflow for users working with the raster package. It fits the current reference from finite current cells within domain, then evaluates cells with finite current and future values. Future missing values therefore do not alter the fitted current reference. Reported quantities are written back to RasterLayer outputs.

Value

An object of class `climniche_fit` with RasterLayer outputs stored in `x$rasters`.

`fit_climniche_reference`

Fit a current climatic niche reference

Description

Estimates the preprocessing, standardisation, reference centre, climatic weighting matrix and empirical radial boundary once. The resulting object can be reused with `project_climniche()` for several future periods or climate models.

Usage

```
fit_climniche_reference(
  current,
  occupied = NULL,
  occupied_threshold = NULL,
  cnfa = NULL,
  center = NULL,
  sensitivity = NULL,
  A = NULL,
  metric = c("diag", "factor"),
  boundary = 0.95,
  scale = TRUE,
  preprocess = TRUE,
  preprocess_correlation = 0.95,
  preprocess_min_sd = 1e-08,
  global_mean = NULL,
  global_sd = NULL
)
```

Arguments

<code>current</code>	Numeric matrix or data frame of current climatic conditions. Rows are cells or sites and columns are climatic variables.
<code>occupied</code>	Reference cells or weights, following the rules used by <code>fit_climniche()</code> .
<code>occupied_threshold</code>	Optional cutoff for numeric reference weights.

cnfa	Optional compatible CENFA object.
center	Optional current niche centre in the fitted climatic space.
sensitivity	Optional non-negative climatic metric weights.
A	Optional climatic weighting matrix.
metric	Method used to build A when it is not supplied.
boundary	Weighted quantile defining the empirical radial boundary.
scale	If TRUE, standardise retained variables using current-climate means and standard deviations.
preprocess	If TRUE, remove near-zero variance and highly correlated variables before fitting.
preprocess_correlation	Maximum absolute correlation retained during preprocessing.
preprocess_min_sd	Minimum current-climate standard deviation as a fraction of the largest finite current standard deviation.
global_mean, global_sd	Optional centring and scaling values.

Details

The empirical climatic niche reference summarises current climatic conditions by a location-weighted centre and radial boundary. It is a proxy for the species' current climatic niche. The weights in occupied determine the contribution of locations; `sensitivity` or `A` determines the contribution of climatic variables to distance.

The reference object fixes the climatic space used for all subsequent projections. Future conditions do not alter the centre, weighting matrix, standardisation or empirical radial boundary.

Value

A `climniche_reference` object.

Examples

```
sim <- simulate_climniche(n = 200, p = 6, seed = 4)
reference <- fit_climniche_reference(
  sim$current,
  occupied = sim$occupied,
  sensitivity = sim$sensitivity
)
reference
```

fit_climniche_series *Fit climate exposure through time relative to a fixed climatic niche*

Description

Fits one current climatic niche reference and evaluates an ordered set of future projections. Projections may represent time periods, climate models, scenarios, or their combinations.

Usage

```
fit_climniche_series(
  current,
  future,
  time,
  model = NULL,
  scenario = NULL,
  occupied = NULL,
  occupied_threshold = NULL,
  domain = NULL,
  domain_threshold = 0,
  cnfa = NULL,
  center = NULL,
  sensitivity = NULL,
  A = NULL,
  metric = c("diag", "factor"),
  boundary = 0.95,
  scale = TRUE,
  preprocess = TRUE,
  preprocess_correlation = 0.95,
  preprocess_min_sd = 1e-08,
  global_mean = NULL,
  global_sd = NULL,
  tolerance = NULL,
  tolerance_quantile = 0.1,
  boundary_exceedance_tolerance = 0
)
```

Arguments

current	Current climatic conditions supplied as a numeric matrix, data frame, RasterLayer, RasterStack, RasterBrick or SpatRaster.
future	A list of future objects matching current. A three-dimensional numeric array may also be supplied, with cells, variables and projections in its three dimensions.
time	Numeric, Date or POSIXct projection times, one per future object.

model	Optional climate model identifiers, one per future object or a single value recycled across projections.
scenario	Optional scenario identifiers, one per future object or a single value recycled across projections.
occupied	Current reference rows, weights or a matching one-layer raster.
occupied_threshold	Optional cutoff for continuous reference weights.
domain	Optional one-layer raster limiting a spatial analysis.
domain_threshold	Threshold used when domain is supplied.
cnfa	Optional compatible CENFA object.
center	Optional current niche centre in the fitted climatic space.
sensitivity	Optional non-negative climatic metric weights.
A	Optional climatic weighting matrix.
metric	Method used to build A when it is not supplied.
boundary	Weighted quantile defining the empirical radial boundary.
scale	If TRUE, standardise retained variables using current climate.
preprocess	If TRUE, screen near-zero variance and highly correlated current-climate variables.
preprocess_correlation	Maximum absolute correlation retained during preprocessing.
preprocess_min_sd	Minimum current-climate standard deviation as a fraction of the largest finite current standard deviation.
global_mean, global_sd	Optional centring and scaling values.
tolerance	Optional tolerance around zero for Niche Distance Shift.
tolerance_quantile	Quantile used when tolerance = NULL.
boundary_exceedance_tolerance	Tolerance used by the empirical boundary descriptor and dynamic summaries.

Details

The current niche centre, climatic weighting matrix, standardisation and empirical radial boundary are held fixed. For spatial inputs, this reference is estimated from finite current cells within domain, independently of missing values in future projections. Future comparisons use the common set of finite cells across all projections. All projections also use one Niche Distance Shift tolerance. When tolerance = NULL, it is the requested quantile of pooled absolute Niche Distance Shift values across the fitted series.

Value

A climniche_series object containing one compatible climniche_fit per projection.

Examples

```

sim <- simulate_climniche(n = 180, p = 6, seed = 12)
future <- lapply(c(0.25, 0.50, 0.75, 1), function(fraction) {
  sim$current + fraction * (sim$future_away - sim$current)
})
series <- fit_climniche_series(
  current = sim$current,
  future = future,
  time = c(2030, 2050, 2070, 2090),
  occupied = sim$occupied,
  sensitivity = sim$sensitivity
)
climniche_range_summary(series)

```

fit_climniche_terra	<i>Fit climniche to terra raster data</i>
---------------------	---

Description

Fit climniche to terra raster data

Usage

```

fit_climniche_terra(
  current,
  future,
  occupied = NULL,
  occupied_threshold = NULL,
  domain = NULL,
  domain_threshold = 0,
  cnfa = NULL,
  center = NULL,
  sensitivity = NULL,
  A = NULL,
  metric = c("diag", "factor"),
  boundary = 0.95,
  scale = TRUE,
  global_mean = NULL,
  global_sd = NULL,
  preprocess = TRUE,
  preprocess_correlation = 0.95,
  preprocess_min_sd = 1e-08,
  tolerance = NULL,
  tolerance_quantile = 0.1,
  boundary_exceedance_tolerance = 0
)

```

Arguments

current	terra SpatRaster of current climate layers.
future	terra SpatRaster of future climate layers with the same geometry and variables as current. Named layers are matched before fitting.
occupied	Optional one layer SpatRaster with binary or continuous occurrence, range, or SDM suitability values. Continuous values are retained on their supplied numerical scale.
occupied_threshold	Values at or below this threshold receive zero reference weight. Values above it keep their original value.
domain	Optional one layer SpatRaster limiting cells where exposure is analysed.
domain_threshold	Values greater than this threshold define the domain.
cnfa	Optional compatible CENFA object. Its mf and sf components can supply the niche centre and diagonal metric weights; metric = "factor" requires co and eig. The object and climatic inputs must use the same variables and standardisation.
center	Optional current niche centre on the scale used for distance calculations. With scale = TRUE, supply a centre in the standardised climatic space. If omitted, the centre is the weighted mean of current reference rows.
sensitivity	Optional non-negative climatic variable weights defining relative contributions to distance. Retained variables receive equal weights by default. These are separate from the location weights in occupied.
A	Optional square metric matrix defined for the fitted climatic space. When supplied, it overrides sensitivity, cnfa, and metric for distance calculations.
metric	Method used to build A when A is missing. "diag" uses variable-level climatic metric weights. "factor" constructs a weighted metric from the co and eig components of a compatible CENFA object.
boundary	Weighted quantile used to define the empirical radial boundary of the empirical climatic niche reference. Must be between 0 and 1.
scale	Logical. If TRUE, current and future values are centred and scaled with the current-layer mean and standard deviation before distances are calculated.
global_mean	Optional means used for centering when scale = TRUE. If omitted, column means of current are used.
global_sd	Optional standard deviations used for scaling. If scale = TRUE and this argument is omitted, column standard deviations of current are used.
preprocess	Logical. If TRUE, remove near-zero variance variables and highly correlated variables before metric fitting.
preprocess_correlation	Maximum absolute pairwise correlation retained among current climate variables during preprocessing.
preprocess_min_sd	Minimum current-climate standard deviation as a fraction of the largest finite current standard deviation. Variables at or below this value are removed during preprocessing.

tolerance Optional tolerance around zero for Niche Distance Shift. If NULL, the fitted object uses tolerance_quantile.

tolerance_quantile Quantile of absolute Niche Distance Shift used to set tolerance when tolerance = NULL.

boundary_exceedance_tolerance Tolerance used to label Niche Boundary Exceedance in descriptor summaries.

Details

fit_climniche_terra() is the SpatRaster workflow for users working with terra. It fits the current reference from finite current cells within domain, then evaluates cells with finite current and future values. Future missing values therefore do not alter the fitted current reference. Reported quantities are written back to SpatRaster outputs.

Value

An object of class climniche_fit with SpatRaster outputs stored in x\$rasters.

niche_metric	<i>Build a climatic weighting metric</i>
--------------	--

Description

Build a climatic weighting metric

Usage

```
niche_metric(sensitivity = NULL, cnfa = NULL, type = c("diag", "factor"))
```

Arguments

sensitivity Numeric vector of climatic metric weights used by the diagonal metric. For a factor metric, complete names can be used to order the CENFA loading rows.

cnfa Optional CENFA cnfa object or compatible list. A diagonal metric can use sf; a factor metric requires co and eig.

type Metric type. "diag" uses variable-level climatic weights. "factor" uses a factor metric when CENFA factor coordinates are available.

Details

For climatic weights s_j , the diagonal metric is

$$A = \text{diag}(s/\bar{s}).$$

For a CENFA loading matrix U and factor eigenvalues ρ , the factor metric is

$$A = U \text{diag}(\rho/\bar{\rho}) U^T.$$

The factor metric is constructed from `co` and `eig`; a separate sensitivity vector is not combined with it. This quadratic metric is a climniche construction from CENFA components, not a metric returned by CENFA itself.

The argument name `sensitivity` is retained for API compatibility. Its values define the relative scale of climatic distance; they are not physiological sensitivity estimates unless supplied from an independent analysis.

Value

A positive semi-definite matrix.

Examples

```
niche_metric(c(temperature = 2, salinity = 1, oxygen = 0.5))
```

niche_percentile	<i>Niche percentile shift</i>
------------------	-------------------------------

Description

Niche percentile shift

Usage

```
niche_percentile(psi_current, psi_future, occupied)
```

Arguments

<code>psi_current</code>	Current squared niche distance for all cells.
<code>psi_future</code>	Future squared niche distance for all cells.
<code>occupied</code>	Current reference weights or indices used to define the reference CDF.

Value

Data frame with current, future, and delta percentiles.

niche_potential	<i>Squared niche distance</i>
-----------------	-------------------------------

Description

Squared niche distance

Usage

```
niche_potential(x, center, A)
```

Arguments

x	Climate matrix in the fitted climate space.
center	Current niche reference centre.
A	Niche metric matrix.

Value

Numeric vector of squared distances from the current niche centre in the fitted climatic space.

niche_radius	<i>Niche radius</i>
--------------	---------------------

Description

Niche radius

Usage

```
niche_radius(psi)
```

Arguments

psi	Numeric squared niche distance values.
-----	--

Value

Numeric vector in the distance units of the fitted climatic metric.

plot.climniche_fit	<i>Plot a fitted climniche quantity</i>
--------------------	---

Description

Plot a fitted climniche quantity

Usage

```
## S3 method for class 'climniche_fit'
plot(
  x,
  type = c("distance", "boundary", "amount", "reconfiguration"),
  scope = c("current", "all"),
  breaks = "Sturges",
  ...
)
```

Arguments

x	A fitted climniche_fit object.
type	Quantity to draw.
scope	"current" for a reference-weighted histogram or "all" for an unweighted histogram across evaluated rows.
breaks	Histogram breaks passed to <code>graphics::hist()</code> .
...	Additional arguments passed to the histogram plot.

Value

Invisibly returns x.

plot_climniche_departure_map	<i>Map Niche Boundary Exceedance through time</i>
------------------------------	---

Description

Map Niche Boundary Exceedance through time

Usage

```
plot_climniche_departure_map(
  x,
  metric = c("first_boundary_exceedance", "boundary_exceedance_projection_fraction",
    "first_persistent_departure", "boundary_exceedance_time_fraction",
    "departure_time_fraction", "mean_relative_exceedance", "maximum_relative_exceedance",
    "model_agreement"),
  model = NULL,
  scenario = NULL,
  time = NULL,
  scope = c("current", "all"),
  persistence = 1L,
  boundary_exceedance_tolerance = NULL,
  title = NULL,
  legend_title = FALSE,
  limits = NULL,
  colours = NULL,
  ...
)
```

Arguments

<code>x</code>	A spatial <code>climniche_series</code> object.
<code>metric</code>	Temporal result field to map. Available fields include first sampled boundary exceedance (<code>first_boundary_exceedance</code>), the fraction of projections beyond the boundary (<code>boundary_exceedance_projection_fraction</code>), persistent exceedance onset, interval-weighted exceedance, relative exceedance and climate model agreement.
<code>model, scenario, time</code>	Optional projection selectors. A selector is required when more than one relevant value is present.
<code>scope, persistence, boundary_exceedance_tolerance</code>	Arguments passed to climniche_departure() or climniche_model_agreement() .
<code>title</code>	Optional map title. Use <code>FALSE</code> to suppress it.
<code>legend_title</code>	Optional legend title. The default suppresses a title that would repeat the map title.
<code>limits, colours</code>	Optional colour-scale limits and colours.
<code>...</code>	Additional arguments passed to plot_climniche_map() .

Value

A `ggplot` object.

```
plot_climniche_distribution
```

Plot a climniche reported quantity distribution

Description

Plot a climniche reported quantity distribution

Usage

```
plot_climniche_distribution(
  x,
  metric = c("niche_distance_change", "climate_change_amount",
    "niche_boundary_exceedance", "climate_reconfiguration", "outside_niche_exceedance",
    "composition_change"),
  scope = c("current", "all"),
  title = NULL
)
```

Arguments

x	A fitted climniche object.
metric	Quantity to plot. Accepted values are "climate_change_amount", "niche_distance_change", "climate_reconfiguration", and "niche_boundary_exceedance". Legacy aliases "composition_change" and "outside_niche_exceedance" still work.
scope	"current" for a reference-weighted distribution or "all" for an unweighted distribution across evaluated cells.
title	Optional plot title.

Value

A ggplot object.

```
plot_climniche_dominant_contribution
```

Map dominant climatic contributions

Description

Map dominant climatic contributions

Usage

```
plot_climniche_dominant_contribution(
  x,
  type = c("variable", "share", "both"),
  scope = c("current", "all"),
  variable_labels = NULL,
  colours = NULL,
  title = NULL,
  extent = NULL,
  degree_labels = c("auto", "none", "hemisphere"),
  study_region = NULL,
  legend_position = "bottom",
  legend_variables = NULL
)

## S3 method for class 'climniche_contribution'
plot(x, ...)
```

Arguments

<code>x</code>	A <code>climniche_contribution</code> object or fitted <code>climniche_fit</code> object.
<code>type</code>	Plot the dominant "variable", its "share", or "both".
<code>scope</code>	Scope used when <code>x</code> is a fitted object.
<code>variable_labels</code>	Optional named vector replacing climate variable names.
<code>colours</code>	Optional colours for the climate variables. A final colour may be supplied for tied contributions; otherwise ties are grey.
<code>title</code>	Optional overall title for a combined figure.
<code>extent</code>	Optional <code>c(xmin, xmax, ymin, ymax)</code> map extent.
<code>degree_labels</code>	Longitude-latitude label style.
<code>study_region</code>	Optional study-region boundary accepted by <code>plot_climniche_map()</code> .
<code>legend_position</code>	Legend position.
<code>legend_variables</code>	Optional character vector of fitted variable names to retain in the legend, including variables that are not dominant in any mapped cell. The default shows only observed categories.
<code>...</code>	Additional arguments passed to <code>plot_climniche_dominant_contribution()</code> by the S3 <code>plot()</code> method.

Value

A `ggplot` object, a `patchwork` object, or a named list when `patchwork` is unavailable.

Examples

```

sim <- simulate_climniche(n = 300, p = 6, seed = 32)
fit <- fit_climniche(
  sim[["current"]],
  sim[["future_away"]],
  occupied = sim[["occupied"]],
  sensitivity = sim[["sensitivity"]]
)
contribution <- climniche_dominant_contribution(fit)

```

plot_climniche_exposure

Plot the climniche exposure plane

Description

Plot the climniche exposure plane

Usage

```

plot_climniche_exposure(
  x,
  scope = c("current", "all"),
  max_points = 6000,
  seed = 1,
  title = NULL,
  colour_by = "niche_boundary_exceedance"
)

```

Arguments

x	A fitted climniche object.
scope	"current" for current reference cells or "all" for all evaluated cells.
max_points	Maximum number of points to draw.
seed	Random seed used when subsampling.
title	Optional plot title.
colour_by	Quantity used for point colour. The current plotting method uses "niche_boundary_exceedance".

Value

A ggplot object.

plot_climniche_map	<i>Plot a climniche map</i>
--------------------	-----------------------------

Description

Plot a climniche map

Usage

```
plot_climniche_map(
  x,
  metric = c("niche_distance_change", "niche_boundary_exceedance",
    "climate_change_amount", "climate_reconfiguration", "change_alignment",
    "outside_niche_exceedance", "composition_change"),
  occupied = NULL,
  occupied_only = FALSE,
  occupied_threshold = NULL,
  title = NULL,
  midpoint = 0,
  limits = NULL,
  breaks = NULL,
  colours = NULL,
  legend_title = FALSE,
  legend_position = "right",
  show_legend = TRUE,
  symmetric = NULL,
  extent = NULL,
  degree_labels = c("auto", "none", "hemisphere"),
  study_region = NULL,
  region_colour = "black",
  region_linewidth = 0.35,
  region_linetype = 1,
  colour_values = NULL,
  colour_transform = "identity"
)
```

Arguments

x	A fitted climniche object with raster outputs, a RasterLayer, or a terra SpatRaster.
metric	Quantity to plot. Accepted values are "climate_change_amount" for Climatic Displacement, "niche_distance_change" for Niche Distance Shift, "climate_reconfiguration" for Climatic Reconfiguration, "niche_boundary_exceedance" for Niche Boundary Exceedance, and "change_alignment" for the signed ratio used internally. Legacy aliases "composition_change" and "outside_niche_exceedance" still work.

occupied	Optional current reference RasterLayer or terra SpatRaster used for masking or overlaying the current reference distribution.
occupied_only	If TRUE, mask the plotted raster to current occurrence or suitability cells with positive reference weight.
occupied_threshold	Threshold used when occupied contains binary or continuous values. Values above the threshold keep their original value when used as an overlay or mask.
title	Optional plot title. Use FALSE to suppress it.
midpoint	Midpoint for the Niche Distance Shift colour scale.
limits	Optional two-element colour scale limits.
breaks	Optional colour scale breaks.
colours	Optional colour vector replacing the metric palette.
legend_title	Optional colour legend title. The default, FALSE, suppresses a title that would repeat the panel title.
legend_position	Position passed to the ggplot theme. Common values are "right", "bottom", and "none".
show_legend	If FALSE, suppress the colour legend.
symmetric	If TRUE, use limits symmetric around midpoint. If FALSE, the negative and positive colour gradients span their respective limits.
extent	Optional c(xmin, xmax, ymin, ymax) plotting extent.
degree_labels	"auto" uses hemisphere degree labels for longitude-latitude rasters, "hemisphere" always uses them, and "none" uses the default ggplot labels.
study_region	Optional study-region boundary supplied as an sf, sfc, Spatial, SpatVector, or data frame with x and y columns.
region_colour, region_linewidth, region_linetype	Appearance of the optional study-region boundary.
colour_values	Optional positions between zero and one for the colours on the transformed scale.
colour_transform	Colour transformation passed to ggplot2. The default is "identity"; "log1p" can be used for non-negative quantities. Legend labels remain in the original units.

Value

A ggplot object.

plot_climniche_maps	<i>Plot the four reported climniche quantities as maps</i>
---------------------	--

Description

Plot the four reported climniche quantities as maps

Usage

```
plot_climniche_maps(
  x,
  metrics = c("climate_change_amount", "niche_distance_change",
    "climate_reconfiguration", "niche_boundary_exceedance"),
  ncol = 2L,
  legend_title = FALSE,
  metric_options = NULL,
  ...
)
```

Arguments

<code>x</code>	A fitted <code>climniche_fit</code> object with raster outputs.
<code>metrics</code>	Character vector of reported quantity field names.
<code>ncol</code>	Number of map columns when patchwork is available.
<code>legend_title</code>	Shared legend title. The default suppresses repeated quantity names because each panel is titled.
<code>metric_options</code>	Named list of per-metric options passed to <code>plot_climniche_map()</code> . Entries use metric field names and override shared options in
<code>...</code>	Map options passed to <code>plot_climniche_map()</code> . Commonly used arguments are <code>occupied</code> , <code>occupied_only</code> , <code>occupied_threshold</code> , <code>extent</code> , <code>degree_labels</code> , <code>study_region</code> , <code>legend_position</code> , <code>limits</code> , <code>breaks</code> , <code>colours</code> , and <code>show_legend</code> .

Value

A patchwork object when patchwork is installed, otherwise a named list of ggplot objects.

plot_climniche_priority

Plot ecological screening of climate exposure

Description

Plot ecological screening of climate exposure

Usage

```
plot_climniche_priority(
  x,
  type = c("plane", "map", "both"),
  map_value = c("pareto_depth_score", "pareto_rank", "relative_priority"),
  max_points = 6000L,
  seed = 1L,
  title = NULL,
  extent = NULL,
  degree_labels = c("auto", "none", "hemisphere"),
  study_region = NULL,
  legend_position = "bottom"
)

## S3 method for class 'climniche_priority'
plot(x, ...)
```

Arguments

x	A climniche_priority object.
type	"plane", "map", or "both".
map_value	Map "pareto_depth_score", the original "pareto_rank", or the legacy alias "relative_priority".
max_points	Target maximum number of cells drawn in the decision plane. Pareto rank 1 is always retained.
seed	Random seed used when the decision plane is subsampled.
title	Optional overall title for a combined figure.
extent	Optional c(xmin, xmax, ymin, ymax) map extent.
degree_labels	Longitude-latitude label style.
study_region	Optional study-region boundary accepted by plot_climniche_map() .
legend_position	Legend position for the map.
...	Additional arguments passed to plot_climniche_priority() by the S3 plot() method.

Value

A ggplot object, a patchwork object, or a named list of plots when patchwork is unavailable.

Examples

```
sim <- simulate_climniche(n = 400, p = 6, seed = 21)
fit <- fit_climniche(
  sim[["current"]],
  sim[["future_away"]],
  occupied = sim[["occupied"]],
  sensitivity = sim[["sensitivity"]]
)
priority <- climniche_priority(fit)
if (requireNamespace("ggplot2", quietly = TRUE)) {
  plot_climniche_priority(priority, type = "plane")
}
```

plot_climniche_report *Plot a climniche report figure*

Description

Plot a climniche report figure

Usage

```
plot_climniche_report(x, scope = c("current", "all"))
```

Arguments

x	A fitted climniche object.
scope	"current" for current reference cells or "all" for all evaluated cells.

Value

A patchwork object when patchwork is installed, otherwise a named list of ggplot objects.

plot_climniche_summary_figure

Plot the climniche summary figure

Description

Plot the climniche summary figure

Usage

```
plot_climniche_summary_figure(
  x,
  scope = c("current", "all"),
  max_points = 6000L,
  seed = 1L,
  plane_bins = 35L,
  boundary_probs = seq(0.5, 0.99, 0.01),
  top_variables = 6L,
  variable_labels = NULL,
  title = NULL,
  include_contributions = FALSE
)
```

Arguments

x	A fitted climniche object or data returned by climniche_summary_figure_data().
scope	"current" for current reference cells; "all" for all evaluated cells.
max_points	Maximum number of rows retained in the auxiliary plane table. Figure bins use all cells in the selected scope.
seed	Random seed used when subsampling the auxiliary plane table.
plane_bins	Number of fixed bins used to summarize the exposure plane.
boundary_probs	Boundary quantiles retained in the auxiliary figure data.
top_variables	Number of variables to show.
variable_labels	Optional named vector replacing variable labels.
title	Optional overall title when patchwork is installed.
include_contributions	If TRUE, add the variable-contribution panel and use the four-panel layout. The default groups the two joint metric plots with their four metric distributions.

Value

A patchwork object when patchwork is installed, otherwise a named list of ggplot objects.

plot_climniche_time *Plot range summaries of Niche Boundary Exceedance through time*

Description

Plot range summaries of Niche Boundary Exceedance through time

Usage

```
plot_climniche_time(
  x,
  metric = c("range_wide_relative_exceedance", "exposed_fraction",
    "conditional_relative_exceedance", "mean_niche_boundary_exceedance"),
  scope = c("current", "all"),
  aggregation_weight = NULL,
  area_weight = FALSE,
  boundary_exceedance_tolerance = NULL,
  interval = 0.8,
  show_models = TRUE,
  title = NULL,
  base_size = 9
)
```

Arguments

x	A climniche_series object.
metric	Range summary field to display: exposed_fraction, conditional_relative_exceedance, range_wide_relative_exceedance or mean_niche_boundary_exceedance.
scope, aggregation_weight, area_weight, boundary_exceedance_tolerance	Arguments passed to climniche_range_summary() .
interval	Central interval drawn across climate models.
show_models	If TRUE, draw individual climate model lines behind the ensemble median.
title	Optional plot title.
base_size	Base font size.

Value

A ggplot object.

```
plot_climniche_variable_contribution
```

Plot mean climatic variable contribution

Description

Plot mean climatic variable contribution

Usage

```
plot_climniche_variable_contribution(  
  x,  
  occupied_only = TRUE,  
  variable_labels = NULL,  
  title = NULL  
)
```

Arguments

x	A climniche_fit object.
occupied_only	If TRUE, summarize occupied cells only.
variable_labels	Optional named vector replacing variable labels.
title	Optional plot title. Use FALSE to suppress it.

Value

A ggplot object.

```
print.climniche_summary
```

Print a climniche summary

Description

Prints the four continuous reported quantities.

Usage

```
## S3 method for class 'climniche_summary'  
print(x, ...)
```

Arguments

x	An object returned by <code>climniche_summary()</code> .
...	Additional arguments passed to the data-frame print method.

Value

Invisibly returns x.

project_climniche	<i>Project climatic conditions onto a fitted niche reference</i>
-------------------	--

Description

Project climatic conditions onto a fitted niche reference

Usage

```
project_climniche(
  reference,
  future,
  current = NULL,
  occupied = NULL,
  occupied_threshold = NULL,
  tolerance = NULL,
  tolerance_quantile = 0.1,
  boundary_exceedance_tolerance = 0
)
```

Arguments

reference	A climniche_reference object.
future	Numeric matrix or data frame of projected climatic conditions.
current	Optional current climatic conditions for the projected rows. If omitted, the current rows stored in reference are used.
occupied	Optional reference weights for summaries of the projected rows. When current is omitted, the fitted reference weights are reused. With a supplied current, named rows are matched to the reference; otherwise projected rows receive equal weight.
occupied_threshold	Optional cutoff for numeric occupied weights.
tolerance	Optional tolerance around zero for Niche Distance Shift.
tolerance_quantile	Quantile of absolute Niche Distance Shift used when tolerance = NULL.
boundary_exceedance_tolerance	Non-negative tolerance used by the boundary status descriptor.

Details

Let A be the climatic weighting matrix and μ the fitted reference centre. In the transformed climatic space, write the current and future centred vectors as z_0 and z_1 , with lengths r_0 and r_1 . When both lengths are positive, let θ be the angle between those vectors. Climatic Reconfiguration satisfies

$$C_i^2 = 2r_{0i}r_{1i}(1 - \cos(\theta_i)).$$

Different climatic combinations can have the same distance from the centre. In that case Niche Distance Shift is zero and Climatic Reconfiguration equals Climatic Displacement.

Value

A `climniche_fit` object using the fixed reference.

Examples

```
sim <- simulate_climniche(n = 200, p = 6, seed = 4)
reference <- fit_climniche_reference(
  sim$current,
  occupied = sim$occupied,
  sensitivity = sim$sensitivity
)
fit <- project_climniche(reference, sim$future_away)
climniche_summary(fit)
```

<code>simulate_climniche</code>	<i>Simulate a minimal climatic niche exposure example</i>
---------------------------------	---

Description

Simulate a minimal climatic niche exposure example

Usage

```
simulate_climniche(
  n = 2000,
  p = 6,
  seed = 1,
  rho = 0,
  prevalence = 0.3,
  shift = 0.4
)
```

Arguments

n	Number of climate cells.
p	Number of climate variables.
seed	Random seed.
rho	Pairwise correlation among simulated climate variables.
prevalence	Proportion of background cells treated as true current occurrence locations under the virtual niche.
shift	Climatic Displacement imposed in the closer to niche and farther from niche scenarios.

Value

A list with current, future_toward, future_away, occupied, center, sensitivity and A.

Examples

```
sim <- simulate_climniche(n = 200, p = 6, seed = 7)
dim(sim$current)
mean(sim$occupied)
```

summary.climniche_fit *Summarise a climniche fit*

Description

Summarise a climniche fit

Usage

```
## S3 method for class 'climniche_fit'
summary(object, scope = c("current", "all"), ...)
```

Arguments

object	A fitted climniche_fit object.
scope	"current" for a reference-weighted summary or "all" for an unweighted summary across all evaluated rows.
...	Unused.

Value

A summary.climniche_fit object.

Examples

```

sim <- simulate_climniche(n = 200, p = 6, seed = 5)
fit <- fit_climniche(
  sim$current,
  sim$future_away,
  occupied = sim$occupied,
  sensitivity = sim$sensitivity
)
summary(fit)

```

variable_contribution *Climatic variable contribution to squared niche distance change*

Description

Climatic variable contribution to squared niche distance change

Usage

```
variable_contribution(current, future, center, A)
```

Arguments

current	Current climate matrix in the fitted climate space.
future	Future climate matrix in the fitted climate space.
center	Current niche reference centre.
A	Niche metric matrix.

Details

For centred current and future climatic vectors z_{0i} and z_{1i} , the contribution of variable j is

$$V_{ij} = z_{1ij}(Az_{1i})_j - z_{0ij}(Az_{0i})_j.$$

Consequently,

$$\sum_j V_{ij} = \psi_{1i} - \psi_{0i} = (r_{1i} - r_{0i})(r_{1i} + r_{0i}),$$

where r_{0i} and r_{1i} are current and future niche distances. These values therefore decompose the squared-distance change underlying Niche Distance Shift. They are not SDM variable importance or causal effects.

Value

Matrix whose rows sum to future minus current squared niche distance.

`write_climniche_report`*Write a climniche report to Markdown*

Description

Write a climniche report to Markdown

Usage

```
write_climniche_report(report, file)
```

Arguments

report	An object returned by <code>climniche_report()</code> .
file	Output Markdown file.

Value

Invisibly returns file.

`write_climniche_series_report`*Write a climniche time series report*

Description

Write a climniche time series report

Usage

```
write_climniche_series_report(report, file)
```

Arguments

report	A <code>climniche_series_report</code> object.
file	Output Markdown file.

Value

The file path, invisibly.

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