Package ‘landscapemetrics’

October 13, 2022

**Type**  Package

**Title**  Landscape Metrics for Categorical Map Patterns

**Version**  1.5.4

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**Description**  Calculates landscape metrics for categorical landscape patterns in a tidy workflow. 'landscapemetrics' reimplements the most common metrics from 'FRAGSTATS' (<https://www.umass.edu/landeco/research/fragstats/fragstats.html>) and new ones from the current literature on landscape metrics. This package supports 'raster' spatial objects and takes RasterLayer, RasterStacks, RasterBricks or lists of RasterLayer from the 'raster' package as input arguments. It further provides utility functions to visualize patches, select metrics and building blocks to develop new metrics.

**License**  GPL-3

**URL**  https://r-spatialecology.github.io/landscapemetrics/

**BugReports**  https://github.com/r-spatialecology/landscapemetrics/issues

**Depends**  R (>= 3.1)

**Imports**  cli, ggplot2, methods, raster, Rcpp, sp, stats, tibble

**Suggests**  covr, dplyr, knitr, rgeos, rmarkdown, terra, testthat

**Enhances**  stars, sf,

**LinkingTo**  Rcpp, RcppArmadillo

**ByteCompile**  true

**Encoding**  UTF-8

**LazyData**  true

**RoxygenNote**  7.1.1

**SystemRequirements**  C++11

**VignetteBuilder**  knitr

**NeedsCompilation**  yes
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Repository  CRAN

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calculate_correlation

augusta_nlcd  Augusta NLCD 2011

Description

A real landscape of area near Augusta, Georgia obtained from the National Land Cover Database (NLCD)

Usage

augusta_nlcd

Format

A raster layer object.

Source


References


calculate_correlation  Calculate correlation

Description

Calculate correlation

Usage

calculate_correlation(
    metrics,
    method = "pearson",
    diag = TRUE,
    simplify = FALSE
  )
Arguments

metrics Tibble with results of as returned by the landscapemetrics package.
method Type of correlation. See link{cor} for details.
diag If FALSE, values on the diagonal will be NA.
simplify If TRUE and only one level is present, only a tibble is returned.

Details

The functions calculates the correlation between all metrics. In order to calculate correlations, for the landscape level more than one landscape needs to be present. All input must be structured as returned by the landscapemetrics package.

Value

list

Examples

metrics <- calculate_lsm(landscape, what = c("patch", "class"))
calculate_correlation(metrics, method = "pearson")

describe:
calculate_lsm

Description

Calculate a selected group of metrics

Usage

calculate_lsm(
    landscape,
    level = NULL,
    metric = NULL,
    name = NULL,
    type = NULL,
    what = NULL,
    directions = 8,
    count_boundary = FALSE,
    consider_boundary = FALSE,
    edge_depth = 1,
    cell_center = FALSE,
    classes_max = NULL,
    neighbourhood = 4,
    ordered = TRUE,
base = "log2",
full_name = FALSE,
verbose = TRUE,
progress = FALSE)
)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
level Level of metrics. Either 'patch', 'class' or 'landscape' (or vector with combination).
metric Abbreviation of metrics (e.g. 'area').
name Full name of metrics (e.g. 'core area').
type Type according to FRAGSTATS grouping (e.g. 'aggregation metrics').
what Selected level of metrics: either "patch", "class" or "landscape". It is also possible to specify functions as a vector of strings, e.g. what = c("lsm_c_ca", "lsm_l_ta").
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
count_boundary Include landscape boundary in edge length.
consider_boundary Logical if cells that only neighbour the landscape boundary should be considered as core.
edge_depth Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.
cell_center If true, the coordinates of the centroid are forced to be a cell center within the patch.
classes_max Potential maximum number of present classes.
neighbourhood The number of directions in which cell adjacencies are considered as neighbours: 4 (rook’s case) or 8 (queen’s case). The default is 4.
ordered The type of pairs considered. Either ordered (TRUE) or unordered (FALSE). The default is TRUE.
base The unit in which entropy is measured. The default is "log2", which compute entropy in "bits". "log" and "log10" can be also used.
full_name Should the full names of all functions be included in the tibble.
verbose Print warning messages.
progress Print progress report.

Details

Wrapper to calculate several landscape metrics. The metrics can be specified by the arguments what, level, metric, name and/or type (combinations of different arguments are possible (e.g. level = "class", type = "aggregation metric"). If an argument is not provided, automatically all possibilities are selected. Therefore, to get all available metrics, don’t specify any of the above arguments.
check_landscape

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
list_lsm

Examples
## Not run:
calculate_lsm(landscape, progress = TRUE)
calculate_lsm(landscape, what = c("patch", "lsm_c_te", "lsm_l_pr"))
calculate_lsm(landscape, level = c("class", "landscape"), type = "aggregation metric")

## End(Not run)

check_landscape Check input landscape

Description
Check input landscape

Usage
check_landscape(landscape, verbose = TRUE)

Arguments
landscape Raster* Layer, Stack, Brick, Stars or a list of rasterLayers
verbose Print warning messages.

Details
This function extracts basic information about the input landscape. It includes a type of coordinate reference system (crs) - either "geographic", "projected", or NA, units of the coordinate reference system, a class of the input landscape’s values and the number of classes found in the landscape.

Value
tibble
Examples

check_landscape(augusta_nlcd)
check_landscape(podlasie_cciic)
check_landscape(raster::stack(landscape, landscape))

Description

Extract metrics

Usage

extract_lsm(
  landscape,
  y,
  extract_id = NULL,
  metric = NULL,
  name = NULL,
  type = NULL,
  what = NULL,
  directions = 8,
  progress = FALSE,
  verbose = TRUE,
  ...
)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
y 2-column matrix with coordinates, SpatialPoints, SpatialLines or sf point geometries.
extract_id Vector with id of sample points. If not provided, sample points will be labelled 1...n.
meterc Abbreviation of metrics (e.g. 'area').
name Full name of metrics (e.g. 'core area')
type Type according to FRAGSTATS grouping (e.g. 'aggregation metrics').
what Selected level of metrics: either "patch", "class" or "landscape". It is also possible to specify functions as a vector of strings, e.g. what = c("lsm_c_ca", "lsm_l_ta").
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
progress Print progress report.
verbose Print warning messages.
... Arguments passed to calculate_lsm().
Details

This function extracts the metrics of all patches the spatial object(s) \( y \) (e.g., spatial points) are located within. Only patch level metrics are possible to extract. Please be aware that the output is slightly different to all other lsm-function of landscapemetrics. Returns a tibble with chosen metrics and the ID of the spatial objects.

Value

tibble

See Also

calculate_lsm

Examples

```r
points <- matrix(c(10, 5, 25, 15, 5, 25), ncol = 2, byrow = TRUE)
extract_lsm(landscape, y = points)
extract_lsm(landscape, y = points, type = "aggregation metric")

points_sp <- sp::SpatialPoints(points)
extract_lsm(landscape, y = points_sp, what = "lsm_p_area")

## Not run:
# use lines (works only if rgeos is installed)
x1 <- c(1, 5, 15, 10)
y1 <- c(1, 5, 15, 25)

x2 <- c(10, 25)
y2 <- c(5, 5)

sample_lines <- sp::SpatialLines(list(sp::Lines(list(sp::Line(cbind(x1, y1)),
sp::Line(cbind(x2, y2))), ID = "a")))
extract_lsm(landscape, y = sample_lines, what = "lsm_p_area")
## End(Not run)
```
**Usage**

fragstats_class_augusta_nlcd

**Format**

A tibble object.

---

**Description**

Fragstats results for landscapemetrics::landscape (class level)

---

**Usage**

fragstats_class_landscape

**Format**

A tibble object.

---

**Description**

Fragstats results for landscapemetrics::podlasie (class level)

---

**Usage**

fragstats_class_podlasie

**Format**

A tibble object.
### fragstats_landscape_augusta_nlcd

Fragstats results for landscapemetrics::augusta_nlcd (landscape level)

**Description**

A single tibble for every spatial dataset included in landscapemetrics that contains the FRAGSTAT results for every implemented metric on landscape level.

**Usage**

```r
fragstats_landscape_augusta_nlcd
```

**Format**

A tibble object.

---

### fragstats_landscape_landscape

Fragstats results for landscapemetrics::landscape (landscape level)

**Description**

A single tibble for every spatial dataset included in landscapemetrics that contains the FRAGSTAT results for every implemented metric on landscape level.

**Usage**

```r
fragstats_landscape_landscape
```

**Format**

A tibble object.
fragstats_landscape_podlasie

Fragstats results for landscapemetrics::podlasie_ccilc (landscape level)

Description

A single tibble for every spatial dataset included in landscapemetrics that contains the FRAGSTAT results for every implemented metric on landscape level.

Usage

fragstats_landscape_podlasie

Format

A tibble object.

---

fragstats_patch_augusta_nlcd

Fragstats results for landscapemetrics::augusta_nlcd (patch level)

Description

A single tibble for every spatial dataset included in landscapemetrics that contains the FRAGSTAT results for every implemented metric on patch level.

Usage

fragstats_patch_augusta_nlcd

Format

A tibble object.
fragstats_patch_landscape

_Fragstats results for landscapemetrics::landscape (patch level)_

**Description**

A single tibble for every spatial dataset included in landscapemetrics that contains the FRAGSTAT results for every implemented metric on patch level.

**Usage**

`fragstats_patch_landscape`

**Format**

A tibble object.

fragstats_patch_podlasie

_Fragstats results for landscapemetrics::podlasie (patch level)_

**Description**

A single tibble for every spatial dataset included in landscapemetrics that contains the FRAGSTAT results for every implemented metric on patch level.

**Usage**

`fragstats_patch_podlasie`

**Format**

A tibble object.
get_adjacencies

Description

Fast calculation of adjacencies between classes in a raster

Usage

get_adjacencies(landscape, neighbourhood = 4, what = "full", upper = FALSE)

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **neighbourhood**: The number of directions in which cell adjacencies are considered as neighbours: 4 (rook’s case), 8 (queen’s case) or a binary matrix where the ones define the neighbourhood. The default is 4.
- **what**: Which adjacencies to calculate: "full" for a full adjacency matrix, "like" for the diagonal, "unlike" for the off diagonal part of the matrix and "triangle" for a triangular matrix counting adjacencies only once.
- **upper**: Logical value indicating whether the upper triangle of the adjacency matrix should be returned (default FALSE).

Details

A fast implementation with Rcpp to calculate the adjacency matrix for raster. The adjacency matrix is most often used in landscape metrics to describe the configuration of landscapes, is it is a cellwise count of edges between classes.

The "full" adjacency matrix is double-count method, as it contains the pairwise counts of cells between all classes. The diagonal of this matrix contains the like adjacencies, a count for how many edges a shared in each class with the same class.

The "unlike" adjacencies are counting the cellwise edges between different classes.

Value

matrix with adjacencies between classes in a raster and between cells from the same class.

Examples

# calculate full adjacency matrix
get_adjacencies(landscape, 4)

# count diagonal neighbour adjacencies
diagonal_matrix <- matrix(c(1, NA, 1,
                      NA, 0, NA,
                      1, NA, 1), 3, 3, byrow = TRUE)
get_adjacencies(landscape, diagonal_matrix)
# equivalent with the raster package:
adjacencies <- raster::adjacent(landscape, 1:raster::ncell(landscape), 4, pairs=TRUE)
table(landscape[adjacencies[,1]], landscape[adjacencies[,2]])

get_boundaries get_boundaries

Description

Get boundary cells of patches

Usage

get_boundaries(
  landscape,
  consider_boundary = FALSE,
  edge_depth = 1,
  as_NA = FALSE,
  patch_id = FALSE,
  return_raster = TRUE
)

Arguments

landscape RasterLayer or matrix.
consider_boundary Logical if cells that only neighbour the landscape boundary should be considered as edge.
edge_depth Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.
as_NA If true, non-boundary cells area labelled NA.
patch_id If true, boundary/edge cells are labeled with the original patch id.
return_raster If false, matrix is returned.

Details

All boundary/edge cells are labeled 1, all non-boundary cells 0. NA values are not changed. Boundary cells are defined as cells that neighbour either a NA cell or a cell with a different value than itself. Non-boundary cells only neighbour cells with the same value than themselves.

Value

List with RasterLayer or matrix
Examples

class_1 <- get_patches(landscape, class = 1)[[1]]

get_boundaries(class_1)
get_boundaries(class_1, return_raster = FALSE)

get_centroids

Description

Centroid of patches

Usage

get_centroids(
  landscape,
  directions = 8,
  cell_center = FALSE,
  return_sp = FALSE,
  verbose = TRUE
)

Arguments

landscape: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
cell_center: If true, the coordinates of the centroid are forced to be a cell center within the patch.
return_sp: If true, a SpatialPointsDataFrame is returned.
verbose: Print warning messages

Details

Get the coordinates of the centroid of each patch. The centroid is by default defined as the mean location of all cell centers. To force the centroid to be located within each patch, use the cell_center argument. In this case, the centroid is defined as the cell center that is the closest to the mean location.

Examples

# get centroid location
get_centroids(landscape)
get_circumscribingcircle

Description

Diameter of the circumscribing circle around patches

Usage

get_circumscribingcircle(landscape, directions = 8, level = "patch")

Arguments

landscape: RasterLayer or matrix (with x, y, id columns)
directions: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
level: Either ’patch’ or ’class’ for the corresponding level.

Details

The diameter of the smallest circumscribing circle around a patch in the landscape is based on the maximum distance between the corners of each cell. This ensures that all cells of the patch are included in the patch.

References

Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).

Examples

# get circle around each patch
get_circumscribingcircle(landscape)

# get circle around whole class
get_circumscribingcircle(landscape, level = "class")
get_nearestneighbour

Description

Euclidean distance to nearest neighbour

Usage

get_nearestneighbour(landscape, return_id = FALSE)

Arguments

landscape RasterLayer or matrix (with x,y,id columns).
return_id If TRUE, also the patch ID of the nearest neighbour is returned.

Details

Fast and memory safe Rcpp implementation for calculating the minimum Euclidean distances to the nearest patch of the same class in a raster or matrix. All patches need an unique ID (see get_patches). Please be aware that the patch ID is not identical to the patch ID of all metric functions (lsm_). If return_ID = TRUE, for some focal patches several nearest neighbour patches might be returned.

References

Based on RCpp code of Florian Privé <florian.prive.21@gmail.com>

Examples

# get patches for class 1
class_1 <- get_patches(landscape, class = 2)[[1]][[1]]

# calculate the distance between patches
get_nearestneighbour(class_1)
get_nearestneighbour(class_1, return_id = TRUE)
Description

Connected components labeling to derive patches in a landscape.

Usage

```r
get_patches(
    landscape,
    class = "all",
    directions = 8,
    to_disk = getOption("to_disk", default = FALSE),
    return_raster = TRUE
)
```

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **class**: Either "all" (default) for every class in the raster, or specify class value. See Details.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **to_disk**: Logical argument, if FALSE results of get_patches are hold in memory. If true, get_patches writes temporary files and hence, does not hold everything in memory. Can be set with a global option, e.g. option(to_disk = TRUE). See Details.
- **return_raster**: If false, matrix is returned

Details

Searches for connected patches (neighbouring cells of the same class i). The 8-neighbours rule ('queen's case) or 4-neighbours rule (rook’s case) is used. Returns a list with raster. For each class the connected patches have the value 1 - n. All cells not belonging to the class are NA.

Landscape metrics rely on the delineation of patches. Hence, get_patches is heavily used in landscapemetrics. As raster can be quite big, the fact that get_patches creates a copy of the raster for each class in a landscape becomes a burden for computer memory. Hence, the argument to_disk allows to store the results of the connected labeling algorithm on disk. Furthermore, this option can be set globally, so that every function that internally uses get_patches can make use of that.

Value

List
**References**


**Examples**

```r
# check for patches of class 1
patched_raster <- get_patches(landscape, class = 1)

# count patches
length(raster::unique(patched_raster[[1]]))

# check for patches of every class
patched_raster <- get_patches(landscape)
```

---

**Description**

This function returns the unique values of an object.

**Usage**

```r
get_unique_values(x, simplify = FALSE, verbose = TRUE)
```

**Arguments**

- `x` Vector, matrix, raster, stars, or terra object or list of previous.
- `simplify` If true, a vector will be returned instead of a list for 1-dimensional input
- `verbose` If true, warning messages are printend

**Details**

Fast and memory friendly Rcpp implementation to find the unique values of an object.

**Examples**

```r
get_unique_values(landscape)

landscape_stack <- raster::stack(landscape, landscape, landscape)
get_unique_values(landscape_stack)

landscape_matrix <- raster::as.matrix(landscape)
get_unique_values(landscape_matrix)

x_vec <- c(1, 2, 1, 1, 2, 2)
```
get_unique_values(x_vec)

landscape_list <- list(landscape, landscape_matrix, x_vec)
get_unique_values(landscape_list)

**landscape**

*Example map (random cluster neutral landscape model).*

**Description**

An example map to show landscapetools functionality generated with the nlm_randomcluster() algorithm.

**Usage**

landscape

**Format**

A raster layer object.

**Source**

Simulated neutral landscape model with R. https://github.com/ropensci/NLMR/

---

**landscapemetrics**

**Description**

Calculates landscape metrics for categorical landscape patterns in a tidy workflow. 'landscapemetrics' reimplements the most common metrics from FRAGSTATS and new ones from the current literature on landscape metrics. This package supports raster spatial objects and takes RasterLayer, RasterStacks, RasterBricks or lists of RasterLayer from the 'raster' package as input arguments. It further provides utility functions to visualize patches, select metrics and building blocks to develop new metrics.

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- Project Nayuki (Original author of underlying C++ code for get_circumscribingcircle and lsm_p_circle) [contributor]
- Matt Strimas-Mackey (Bugfix in sample_metrics()) [contributor]

See Also

Useful links:

- https://r-spatialecology.github.io/landscapemetrics/
- Report bugs at https://github.com/r-spatialecology/landscapemetrics/issues

---

**landscape_as_list**

### Landscape as list

**Description**

Convert raster input to list

**Usage**

```r
landscape_as_list(landscape)
```

```r
## S3 method for class 'RasterLayer'
landscape_as_list(landscape)
```

```r
## S3 method for class 'RasterStack'
landscape_as_list(landscape)
```

```r
## S3 method for class 'RasterBrick'
landscape_as_list(landscape)
```

```r
## S3 method for class 'stars'
landscape_as_list(landscape)
```

```r
## S3 method for class 'SpatRaster'
landscape_as_list(landscape)
```

```r
## S3 method for class 'list'
landscape_as_list(landscape)
```
## S3 method for class 'matrix'
landscape_as_list(landscape)

## S3 method for class 'numeric'
landscape_as_list(landscape)

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, Stars or a list of rasterLayers

### Details

Mainly for internal use

### Value

- **list**

### Examples

```r
landscape_as_list(raster::stack(landscape, landscape))
```

---

**list_lsm**  
*List landscape metrics*

### Description

List landscape metrics

### Usage

```r
list_lsm(
  level = NULL,
  metric = NULL,
  name = NULL,
  type = NULL,
  what = NULL,
  simplify = FALSE,
  verbose = TRUE
)
```
Arguments

- **level**
  - Level of metrics. Either 'patch', 'class' or 'landscape' (or vector with combination).
- **metric**
  - Abbreviation of metrics (e.g. 'area').
- **name**
  - Full name of metrics (e.g. 'core area').
- **type**
  - Type according to FRAGSTATS grouping (e.g. 'aggregation metrics').
- **what**
  - Selected level of metrics: either "patch", "class" or "landscape". It is also possible to specify functions as a vector of strings, e.g. what = c("lsm_c_ca", "lsm_l_ta").
- **simplify**
  - If true, function names are returned as vector.
- **verbose**
  - Print warning messages

Details

List all available landscape metrics depending on the provided filter arguments. If an argument is not provided, automatically all possibilities are selected. Therefore, to get all available metrics, use simply `list_lsm()`. For all arguments with exception of the what argument, it is also possible to use a negative subset, i.e. all metrics but the selected ones. Therefore, simply use e.g. level = "-patch". Furthermore, it is possible to only get a vector with all function names instead of the full tibble.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

Examples

```r
list_lsm(level = c("patch", "landscape"), type = "aggregation metric")
list_lsm(level = "-patch", type = "area and edge metric")
list_lsm(metric = "area", simplify = TRUE)
list_lsm(metric = "area", what = "lsm_p_shape")
list_lsm(metric = "area", what = c("patch", "lsm_l_ta"))
list_lsm(what = c("lsm_c_tca", "lsm_l_ta"))
```
lsm_abbreviations_names

Tibble of abbreviations coming from FRAGSTATS

Description
A single tibble for every abbreviation of every metric that is reimplemented in landscapemetrics and its corresponding full name in the literature.

Usage
lsm_abbreviations_names

Format
A tibble object.

Details
Can be used after calculating the metric(s) with a join to have a more readable results tibble or for visualizing your results.

Examples
patch_area <- lsm_p_area(landscape)
patch_area <- merge(x = patch_area, y = lsm_abbreviations_names, by = c("level", "metric"))

lsm_c_ai

AI (class level)

Description
Aggregation index (Aggregation metric)

Usage
lsm_c_ai(landscape)

Arguments
landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers
Details

\[ AI = \left( \frac{g_{ii}}{\text{max} - g_{ii}} \right) (100) \]

where \( g_{ii} \) is the number of like adjacencies based on the single-count method and \( \text{max} - g_{ii} \) is the classwise maximum number of like adjacencies of class \( i \).

AI is an 'Aggregation metric'. It equals the number of like adjacencies divided by the theoretical maximum possible number of like adjacencies for that class. The metric is based on the adjacency matrix and the single-count method.

**Units:** Percent

**Range:** \( 0 \leq AI \leq 100 \)

**Behaviour:** Equals 0 for maximally disaggregated and 100 for maximally aggregated classes.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

`lsm_l_ai`

**Examples**

`lsm_c_ai(landscape)`
Description

Coefficient of variation of patch area (Area and edge metric)

Usage

\texttt{lsm\_c\_area\_cv(landscape, directions = 8)}

Arguments

- \texttt{landscape}: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers
- \texttt{directions}: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ \text{\textit{AREA}}_{CV} = \text{cv}(\text{\textit{AREA}}[\text{\textit{patch}}_{ij}]) \]

where \( \text{\textit{AREA}}[\text{\textit{patch}}_{ij}] \) is the area of each patch in hectares.

\textit{AREA\_CV} is an 'Area and Edge metric'. The metric summarises each class as the Coefficient of variation of all patch areas belonging to class \( i \). The metric describes the differences among patches of the same class \( i \) in the landscape and is easily comparable because it is scaled to the mean.

- **Units:** Hectares
- **Range:** \( \text{\textit{AREA}}_{CV} \geq 0 \)
- **Behaviour:** Equals \( \text{\textit{AREA}}_{CV} = 0 \) if all patches are identical in size. Increases, without limit, as the variation of patch areas increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

- \texttt{lsm\_p\_area\_cv}, \texttt{lsm\_c\_area\_mn}, \texttt{lsm\_c\_area\_sd}, \texttt{lsm\_l\_area\_mn}, \texttt{lsm\_l\_area\_sd}, \texttt{lsm\_l\_area\_cv}
Examples

```r
lsm_c_area_cv(landscape)
```

### Description

Mean of patch area (Area and edge metric)

### Usage

```r
lsm_c_area_mn(landscape, directions = 8)
```

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

### Details

\[
\text{AREA}_{MN} = \text{mean}(\text{AREA}[\text{patch}_{ij}])
\]

where \(\text{AREA}[\text{patch}_{ij}]\) is the area of each patch in hectares

\(\text{AREA}_{MN}\) is an ‘Area and Edge metric’. The metric summarises each class as the mean of all patch areas belonging to class \(i\). The metric is a simple way to describe the composition of the landscape. Especially together with the total class area (\(lsm_c_ca\)), it can also give an idea of patch structure (e.g. many small patches vs. few large patches).

- **Units**: Hectares
- **Range**: \(\text{AREA}_{MN} > 0\)
- **Behaviour**: Approaches \(\text{AREA}_{MN} = 0\) if all patches are small. Increases, without limit, as the patch areas increase.

### Value

- **tibble**

### References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: [http://www.umass.edu/landeco/research/fragstats/](http://www.umass.edu/landeco/research/fragstats/)
See Also

- `lsm_p_area`, `mean`,
- `lsm_c_area_cv`, `lsm_c_area_sd`,
- `lsm_l_area_mn`, `lsm_l_area_sd`, `lsm_l_area_cv`

Examples

```r
lsm_c_area_sd(landscape)
```

---

### Description

Standard deviation of patch area (Area and edge metric)

### Usage

```r
lsm_c_area_sd(landscape, directions = 8)
```

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

### Details

\[
AREA_{SD} = sd(AREA[patch_{ij}])
\]

where `AREA[patch_{ij}]` is the area of each patch in hectares.

`AREA_SD` is an 'Area and Edge metric'. The metric summarises each class as the standard deviation of all patch areas belonging to class i. The metric describes the differences among patches of the same class i in the landscape.

- **Units**: Hectares
- **Range**: `AREA_SD >= 0`
- **Behaviour**: Equals `AREA_SD = 0` if all patches are identical in size. Increases, without limit, as the variation of patch areas increases.

### Value

tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_p_area_sd,
lsm_c_area_mn, lsm_c_area_cv,
lsm_l_area_mn, lsm_l_area_sd, lsm_l_area_cv

Examples

lsm_c_area_sd(landscape)

---

**lsm_c_ca**

*CA (class level)*

**Description**

Total (class) area (Area and edge metric)

**Usage**

lsm_c_ca(landscape, directions = 8)

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
CA = \sum (\text{AREA}[\text{patch}_{ij}])
\]

where \(\text{AREA}[\text{patch}_{ij}]\) is the area of each patch in hectares.

CA is an 'Area and edge metric' and a measure of composition. The total (class) area sums the area of all patches belonging to class i. It shows if the landscape is e.g. dominated by one class or if all classes are equally present. CA is an absolute measure, making comparisons among landscapes with different total areas difficult.

**Units**: Hectares

**Range**: CA > 0

**Behaviour**: Approaches CA > 0 as the patch areas of class i become small. Increases, without limit, as the patch areas of class i become large. CA = TA if only one class is present.
Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_p_area, sum,
lsm_l_ta

Examples

lsm_c_ca(landscape)

Description

Coefficient of variation of core area index (Core area metric)

Usage

lsm_c_cai_cv(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
consider_boundary Logical if cells that only neighbour the landscape boundary should be considered as core
depth edge Distance (in cells) a cell has be away from the patch edge to be considered as core cell
Details

\[ CAI_{CV} = cv(CAI[patch_{ij}]) \]

where \( CAI[patch_{ij}] \) is the core area index of each patch.

\( CAI_{CV} \) is a 'Core area metric'. The metric summarises each class as the Coefficient of variation of the core area index of all patches belonging to class \( i \). The core area index is the percentage of core area in relation to patch area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). The metric describes the differences among patches of the same class \( i \) in the landscape. Because it is scaled to the mean, it is easily comparable.

**Units:** Percent

**Range:** \( CAI_{CV} \geq 0 \)

**Behaviour:** Equals \( CAI_{CV} = 0 \) if the core area index is identical for all patches. Increases, without limit, as the variation of the core area indices increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

\`lsm_p_cai`, \`lsm_c_cai_mn`, \`lsm_c_cai_sd`,  
\`lsm_l_cai_mn`, \`lsm_l_cai_sd`, \`lsm_l_cai_cv`

**Examples**

\`lsm_c_cai_cv(landscape)`
Usage

\[
\text{lsm\_c\_cai\_mn}(
\quad \text{landscape},
\quad \text{directions} = 8,
\quad \text{consider\_boundary} = \text{FALSE},
\quad \text{edge\_depth} = 1
\)
\]

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider\_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge\_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

Details

\[
\text{CAI}_{MN} = \text{mean}(\text{CAI}[\text{patch}_{ij}])
\]

where \( \text{CAI}[\text{patch}_{ij}] \) is the core area index of each patch.

\( \text{CAI}_{MN} \) is a 'Core area metric'. The metric summarises each class as the mean of the core area index of all patches belonging to class \( i \). The core area index is the percentage of core area in relation to patch area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case).

**Units**: Percent

**Range**: \( 0 \leq \text{CAI}_{MN} \leq 100 \)

**Behaviour**: \( \text{CAI}_{MN} = 0 \) when all patches have no core area and approaches \( \text{CAI}_{MN} = 100 \) with increasing percentage of core area within patches.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

`lsm_p_cai`, `mean`,
`lsm_c_cai_sd`, `lsm_c_cai_cv`,
`lsm_l_cai_mn`, `lsm_l_cai_sd`, `lsm_l_cai_cv`

Examples

`lsm_c_cai_mn(landscape)`

---

### Description

Standard deviation of core area index (Core area metric)

### Usage

```r
lsm_c_cai_sd(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

### Details

\[
CAI_{SD} = sd(CAI[patch_{ij}])
\]

where \(CAI[patch_{ij}]\) is the core area index of each patch.

CAI_SD is a ’Core area metric’. The metric summarises each class as the standard deviation of the core area index of all patches belonging to class i. The core area index is the percentage of core area in relation to patch area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). The metric describes the differences among patches of the same class i in the landscape.
**Units:** Percent

**Range:** CAI_SD &ge; 0

**Behaviour:** Equals CAI_SD = 0 if the core area index is identical for all patches. Increases, without limit, as the variation of core area indices increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

lsm_p_cai_sd, lsm_c_cai_mn, lsm_c_cai_cv, lsm_l_cai_mn, lsm_l_cai_sd, lsm_l_cai_cv

**Examples**

lsm_c_cai_sd(landscape)

---

**Description**

Coefficient of variation of related circumscribing circle (Shape metric)

**Usage**

lsm_c_circle_cv(landscape, directions = 8)

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
Details

\[ CIRCLE_{CV} = cv(CIRCLE[patch_{ij}]) \]

where \( CIRCLE[patch_{ij}] \) is the related circumscribing circle of each patch.

\( CIRCLE_{CV} \) is a ‘Shape metric’ and summarises each class as the Coefficient of variation of the related circumscribing circle of all patches belonging to class \( i \). \( CIRCLE \) describes the ratio between the patch area and the smallest circumscribing circle of the patch and characterises the compactness of the patch. \( CIRCLE_{CV} \) describes the differences among patches of the same class \( i \) in the landscape. Because it is scaled to the mean, it is easily comparable.

**Units:** None

**Range:** \( CIRCLE_{CV} \geq 0 \)

**Behaviour:** Equals \( CIRCLE_{CV} \) if the related circumscribing circle is identical for all patches. Increases, without limit, as the variation of related circumscribing circles increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).

**See Also**

\texttt{lsm\_p\_circle\_mean},
\texttt{lsm\_c\_circle\_mn}, \texttt{lsm\_c\_circle\_sd},
\texttt{lsm\_l\_circle\_mn}, \texttt{lsm\_l\_circle\_sd}, \texttt{lsm\_l\_circle\_cv}

**Examples**

\texttt{lsm\_c\_circle\_cv(landscape)}
CIRCLE_MN (Class level)

Description
Mean of related circumscribing circle (Shape metric)

Usage
```r
lsm_c_circle_mn(landscape, directions = 8)
```

Arguments
- `landscape` Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions` The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details
\[
CIRCLE_{MN} = \text{mean}(CIRCLE[patch_{ij}])
\]

where \(CIRCLE[patch_{ij}]\) is the related circumscribing circle of each patch.

CIRCLE_MN is a 'Shape metric' and summarises each class as the mean of the related circumscribing circle of all patches belonging to class \(i\). CIRCLE describes the ratio between the patch area and the smallest circumscribing circle of the patch and characterises the compactness of the patch.

**Units:** None

**Range:** CIRCLE_MN > 0

**Behaviour:** Approaches CIRCLE_MN = 0 if the related circumscribing circle of all patches is small. Increases, without limit, as the related circumscribing circles increase.

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).
See Also

lsm_p_circle, mean,
lsm_c_circle_sd, lsm_c_circle_cv,
lsm_l_circle_mn, lsm_l_circle_sd, lsm_l_circle_cv

Examples

lsm_c_circle_mn(landscape)

\[
\text{lsm_c_circle_sd (landscape)}
\]

Description

Standard deviation of related circumscribing circle (Shape metric)

Usage

lsm_c_circle_sd(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
CIRCLE_{SD} = sd(CIRCLE[patch_{ij}])
\]

where \( CIRCLE[patch_{ij}] \) is the related circumscribing circle of each patch.

CIRCLE_SD is a ‘Shape metric’ and summarises each class as the standard deviation of the related circumscribing circle of all patches belonging to class \( i \). CIRCLE describes the ratio between the patch area and the smallest circumscribing circle of the patch and characterises the compactness of the patch. The metric describes the differences among patches of the same class \( i \) in the landscape.

Units: None

Range: CIRCLE_SD \( \geq 0 \)

Behaviour: Equals CIRCLE_SD if the related circumscribing circle is identical for all patches. Increases, without limit, as the variation of related circumscribing circles increases.

Value
tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).

See Also

lsm_p_circle, mean,

lsm_c_circle_mn, lsm_c_circle_cv,

lsm_l_circle_mn, lsm_l_circle_sd, lsm_l_circle_cv

Examples

lsm_c_circle_sd(landscape)

Description

Clumpiness index (Aggregation metric)

Usage

lsm_c_clumpy(landscape)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers

Details

Given \( G_i = \left( \frac{g_{ii}}{\sum_{k=1}^{m} g_{ik} - mine_i} \right) \)

\( CLUMPY = \left[ \frac{G_i - P_i^*}{P_i^*} \right] \text{ for } G_i < P_i^* \& P_i^* < .5; \text{ else } \frac{G_i - P_i^*}{1 - P_i^*} \) \]

where \( g_{ii} \) is the number of like adjacencies, \( g_{ik} \) is the classwise number of all adjacencies including the focal class, \( mine_i \) is the minimum perimeter of the total class in terms of cell surfaces assuming total clumping and \( P_i^* \) is the proportion of landscape occupied by each class.
CLUMPY is an 'Aggregation metric'. It equals the proportional deviation of the proportion of like adjacencies involving the corresponding class from that expected under a spatially random distribution. The metric is based on the adjacency matrix and the double-count method.

**Units:** None

, directions = directions

**Range:** -1 <= CLUMPY <= 1

**Behaviour:** Equals -1 for maximally disaggregated, 0 for randomly distributed and 1 for maximally aggregated classes.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**Examples**

lsm_c_clumpy(landscape)

---

**lsm_c_cohesion**  
*COHESION (class level)*

**Description**

Patch Cohesion Index (Aggregation metric)

**Usage**

lsm_c_cohesion(landscape, directions = 8)

**Arguments**

| landscape | Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers. |
| directions | The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case). |
Details

\[
COHESION = 1 - \left( \frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} p_{ij} \sqrt{A_{ij}}} \right) \ast \left( 1 - \frac{1}{\sqrt{Z}} \right)^{-1} \ast 100
\]

where \( p_{ij} \) is the perimeter in meters, \( A_{ij} \) is the area in square meters and \( Z \) is the number of cells.

COHESION is an 'Aggregation metric'. It characterises the connectedness of patches belonging to class \( i \). It can be used to assess if patches of the same class are located aggregated or rather isolated and thereby COHESION gives information about the configuration of the landscape.

**Units:** Percent

**Ranges:** 0 < COHESION < 100

**Behaviour:** Approaches COHESION = 0 if patches of class \( i \) become more isolated. Increases if patches of class \( i \) become more aggregated.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_p_perim, lsm_p_area, lsm_l_cohesion

**Examples**

lsm_c_cohesion(landscape)
Description

Coefficient of variation of Contiguity index (Shape metric)

Usage

```r
lsm_c_contig_cv(landscape, directions = 8)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
\text{CONTIGCV} = \text{cv}(\text{CONTIG}[\text{patch}_{ij}])
\]

where \( \text{CONTIG}[\text{patch}_{ij}] \) is the contiguity of each patch.

\( \text{CONTIGCV} \) is a ‘Shape metric’. It summarises each class as the mean of each patch belonging to class \( i \). \( \text{CONTIGCV} \) assesses the spatial connectedness (contiguity) of cells in patches. The metric coerces patch values to a value of 1 and the background to NA. A nine cell focal filter matrix:

```r
define_filter_matrix <- function()
{
  matrix(c(1, 2, 1,
           2, 1, 2,
           1, 2, 1), 3, 3, byrow = T)
}
```

... is then used to weight orthogonally contiguous pixels more heavily than diagonally contiguous pixels. Therefore, larger and more connections between patch cells in the rookie case result in larger contiguity index values.

Units: None

Range: \( \text{CONTIGCV} \geq 0 \)

Behaviour: \( \text{CONTIGCV} = 0 \) if the contiguity index is identical for all patches. Increases, without limit, as the variation of \( \text{CONTIG} \) increases.

Value

tibble


References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_contig, lsm_c_contig_mn, lsm_c_contig_cv,
lsm_l_contig_mn, lsm_l_contig_sd, lsm_l_contig_cv

Examples

lsm_c_contig_cv(landscape)

---

lsm_c_contig_mn

**CONTIG_MN (class level)**

Description

Mean of Contiguity index (Shape metric)

Usage

lsm_c_contig_mn(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ \text{CONTIG}_M = \text{mean}(\text{CONTIG}[\text{patch}_{ij}]) \]

where \( \text{CONTIG}[\text{patch}_{ij}] \) is the contiguity of each patch.

\( \text{CONTIG}_M \) is a ’Shape metric’. It summarises each class as the mean of each patch belonging to class \( i \). \( \text{CONTIG}_M \) assesses the spatial connectedness (contiguity) of cells in patches. The metric coerces patch values to a value of 1 and the background to NA. A nine cell focal filter matrix:

```
filter_matrix <- matrix(c(1, 2, 1, 2, 1, 2, 1, 2, 1), 3, 3, byrow = T)
```
... is then used to weight orthogonally contiguous pixels more heavily than diagonally contiguous pixels. Therefore, larger and more connections between patch cells in the rookie case result in larger contiguity index values.

**Units:** None

**Range:** 0 >= CONTIG_MN <= 1

**Behaviour:** CONTIG equals the mean of the contiguity index on class level for all patches.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_p_contig, lsm_c_contig_sd, lsm_c_contig_cv, lsm_l_contig_mn, lsm_l_contig_sd, lsm_l_contig_cv

**Examples**

lsm_c_contig_mn(landscape)

---

### lsm_c_contig_sd

*CONTIG_SD (class level)*

**Description**

Standard deviation of Contiguity index (Shape metric)

**Usage**

lsm_c_contig_sd(landscape, directions = 8)

**Arguments**

- **landscape** Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions** The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
Details

\[
CONTIG_{SD} = sd(CONTIG[patch_{ij}])
\]

where \(CONTIG[patch_{ij}]\) is the contiguity of each patch.

\(CONTIG_{SD}\) is a ‘Shape metric’. It summarises each class as the mean of each patch belonging to class \(i\). \(CONTIG_{SD}\) assesses the spatial connectedness (contiguity) of cells in patches. The metric coerces patch values to a value of 1 and the background to NA. A nine cell focal filter matrix:

```r
filter_matrix <- matrix(c(1, 2, 1,
                          2, 1, 2,
                          1, 2, 1), 3, 3, byrow = T)
```

... is then used to weight orthogonally contiguous pixels more heavily than diagonally contiguous pixels. Therefore, larger and more connections between patch cells in the rookie case result in larger contiguity index values.

**Units:** None

**Range:** \(CONTIG\_CV \geq 0\)

**Behaviour:** \(CONTIG_{SD} = 0\) if the contiguity index is identical for all patches. Increases, without limit, as the variation of \(CONTIG\) increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_p_contig, lsm_c_contig_mn, lsm_c_contig_cv, lsm_l_contig_mn, lsm_l_contig_sd, lsm_l_contig_cv

**Examples**

lsm_c_contig_sd(landscape)
**Description**

Coefficient of variation of core area (Core area metric)

**Usage**

```r
lsm_c_core_cv(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- `consider_boundary`: Logical if cells that only neighbour the landscape boundary should be considered as core.
- `edge_depth`: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

**Details**

\[
CORE_{CV} = cv(CORE[patch_{ij}])
\]

where \(CORE[patch_{ij}]\) is the core area in square meters of each patch.

CORE_CV is a 'Core area metric'. It equals the Coefficient of variation of the core area of each patch belonging to class i. The core area is defined as all cells that have no neighbour with a different value than themselves (rook’s case). The metric describes the differences among patches of the same class i in the landscape and is easily comparable because it is scaled to the mean.

**Units**: Hectares

**Range**: \(CORE_{CV} \geq 0\)

**Behaviour**: Equals \(CORE_{CV} = 0\) if all patches have the same core area. Increases, without limit, as the variation of patch core areas increases.

**Value**

tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_p_core_cv,
lsm_c_core_mn, lsm_c_core_sd,
lsm_l_core_mn, lsm_l_core_sd, lsm_l_core_cv

Examples

lsm_c_core_cv(landscape)

---

lsm_c_core_mn CORE_MN (class level)

Description

Mean of core area (Core area metric)

Usage

lsm_c_core_mn(
    landscape,
    directions = 8,
    consider_boundary = FALSE,
    edge_depth = 1
)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
consider_boundary Logical if cells that only neighbour the landscape boundary should be considered as core
depth Distance (in cells) a cell has the be away from the patch edge to be considered as core cell
Details

\[ CORE_{MN} = \text{mean}(CORE[patch_{ij}]) \]

where \( CORE[patch_{ij}] \) is the core area in square meters of each patch.

\( CORE_{MN} \) is a ‘Core area metric’ and equals the mean of core areas of all patches belonging to class i. The core area is defined as all cells that have no neighbour with a different value than themselves (rook’s case).

**Units:** Hectares

**Range:** \( CORE_{MN} \geq 0 \)

**Behaviour:** Equals \( CORE_{MN} = 0 \) if \( CORE = 0 \) for all patches. Increases, without limit, as the core area indices increase.

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

\( \text{lsm}_p\_\text{core}, \text{mean}, \)
\( \text{lsm}_c\_\text{core}_\text{sd}, \text{lsm}_c\_\text{core}_\text{cv}, \)
\( \text{lsm}_l\_\text{core}_\text{mn}, \text{lsm}_l\_\text{core}_\text{sd}, \text{lsm}_l\_\text{core}_\text{cv} \)

Examples

\( \text{lsm}_c\_\text{core}_\text{mn}(\text{landscape}) \)

\[ \text{lsm}_c\_\text{core}_\text{sd} \quad CORE_{SD} \text{ (class level)} \]

Description

Standard deviation patch core area (class level)
Usage

```r
ls_m_c_core_sd(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

Arguments

- **landscape** Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions** The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary** Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth** Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

Details

\[
\text{CORE}_{SD} = \text{sd}(\text{CORE}[\text{patch}_{ij}])
\]

where \(\text{CORE}[\text{patch}_{ij}]\) is the core area in square meters of each patch.

\(\text{CORE}_{SD}\) is a ‘Core area metric’. It equals the standard deviation of the core area of each patch belonging to class \(i\). The core area is defined as all cells that have no neighbour with a different value than themselves (rook’s case). The metric describes the differences among patches of the same class \(i\) in the landscape.

**Units:** Hectares

**Range:** \(\text{CORE}_{SD} \geq 0\)

**Behaviour:** Equals \(\text{CORE}_{SD} = 0\) if all patches have the same core area. Increases, without limit, as the variation of patch core areas increases.

Value

- `tibble`

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

`lsm_p_core, sd, lsm_c_core_mm, lsm_c_core_cv, lsm_l_core_mm, lsm_l_core_sd, lsm_l_core_cv`

Examples

`lsm_c_core_sd(landscape)`

---

### Description

Core area percentage of landscape (Core area metric)

### Usage

```r
lsm_c_cpland(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

### Details

\[
CPLAN D = \left( \frac{\sum_{i=1}^{n} a_{ij}^{core}}{A} \right) \times 100
\]

where \(a_{ij}^{core}\) is the core area in square meters and \(A\) is the total landscape area in square meters.

CPLAN D is a 'Core area metric'. It is the percentage of core area of class \(i\) in relation to the total landscape area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). Because CPLAN D is a relative measure, it is comparable among landscapes with different total areas.
**Units:** Percentage

**Range:** 0 <= CPLAND < 100

**Behaviour:** Approaches CPLAND = 0 if CORE = 0 for all patches. Increases as the amount of core area increases, i.e. patches become larger while being rather simple in shape.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

`lsm_p_core` and `lsm_l_ta`

**Examples**

```r
lsm_c_cpland(landscape)
```

---

**Description**

Disjunct core area density (core area metric)

**Usage**

```r
lsm_c_dcad(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```
Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

Details

\[
DCAD = \left( \sum_{i,j} \frac{n_{ij}^{core}}{A} \right) \times 10000 \times 100
\]

where \( n_{ij}^{core} \) is the number of disjunct core areas and \( A \) is the total landscape area in square meters.

DCAD is a 'Core area metric'. It equals the number of disjunct core areas per 100 ha relative to the total area. A disjunct core area is a 'patch within the patch' containing only core cells. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). The metric is relative and therefore comparable among landscapes with different total areas.

**Units**: Number per 100 hectares

**Range**: DCAD >= 0

**Behaviour**: Equals DCAD = 0 when DCORE = 0, i.e. no patch of class i contains a disjunct core area. Increases, without limit, as disjunct core areas become more present, i.e. patches becoming larger and less complex.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

- `lsm_c_ndca`, `lsm_l_ta`,
- `lsm_l_dcad`

Examples

```r
lsm_c_dcad(landscape)
```
DESCRIPTION

Coefficient of variation number of disjunct core areas (Core area metric)

USAGE

```r
lsm_c_dcore_cv(
   landscape,
   directions = 8,
   consider_boundary = FALSE,
   edge_depth = 1
)
```

ARGUMENTS

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

DETAILS

\[ DCORE_{CV} = \text{cv}(NCORE[patch_{ij}]) \]

where \( NCORE[patch_{ij}] \) is the number of core areas.

DCORE_CV is an ‘Core area metric’. It summarises each class as the Coefficient of variation of all patch areas belonging to class i. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). NCORE counts the disjunct core areas, whereby a core area is a ‘patch within the patch’ containing only core cells. The metric describes the differences among patches of the same class i in the landscape and is easily comparable because it is scaled to the mean.

Units: None

Range: \( DCORE_{CV} \geq 0 \)

Behaviour: Equals \( DCORE_{CV} = 0 \) if all patches have the same number of disjunct core areas. Increases, without limit, as the variation of number of disjunct core areas increases.
**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

`lsm_p_ncore.cv`, `lsm_c_dcore_mn`, `lsm_c_dcore_sd`, `lsm_l_dcore_mn`, `lsm_l_dcore_sd`, `lsm_l_dcore_cv`

**Examples**

`lsm_c_dcore_cv(landscape)`

---

**Description**

Mean number of disjunct core areas (Core area metric)

**Usage**

```r
lsm_c_dcore_mn(
    landscape,  # Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
    directions = 8,  # The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
    consider_boundary = FALSE,  # Logical if cells that only neighbour the landscape boundary should be considered as core
    edge_depth = 1  # Distance (in cells) a cell has the be away from the patch edge to be considered as core cell
)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- `consider_boundary`: Logical if cells that only neighbour the landscape boundary should be considered as core
- `edge_depth`: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell
Details

\[ DCore_{MN} = \text{mean}(\text{NCORE}_{patch_{ij}}) \]

where \( \text{NCORE}_{patch_{ij}} \) is the number of core areas.

DCore\_MN is an 'Core area metric'. It summarises each class as the mean of all patch areas belonging to class i. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). NCORE counts the disjunct core areas, whereby a core area is a 'patch within the patch' containing only core cells.

**Units:** None

**Range:** DCore\_MN > 0

**Behaviour:** Equals DCore\_MN = 0 if NCORE = 0 for all patches. Increases, without limit, as the number of disjunct core areas increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html

See Also

lsm\_p\_ncore, mean,
lsm\_c\_dcore\_sd, lsm\_c\_dcore\_cv,
lsm\_l\_dcore\_mn, lsm\_l\_dcore\_sd, lsm\_l\_dcore\_cv

Examples

lsm\_c\_dcore\_mn(landscape)

---

lsm\_c\_dcore\_sd  \hspace{1cm} DCore\_SD (class level)

Description

Standard deviation number of disjunct core areas (Core area metric)
Usage

```r
lsm_c_dcore_sd(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

Details

\[ DCORE_{SD} = sd(NCORE[\text{patch}_{ij}]) \]

where \( NCORE[\text{patch}_{ij}] \) is the number of core areas.

DCORE\_SD is an ‘Core area metric’. It summarises each class as the standard deviation of all patch areas belonging to class \( i \). A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). \( NCORE \) counts the disjunct core areas, whereby a core area is a ‘patch within the patch’ containing only core cells. The metric describes the differences among patches of the same class \( i \) in the landscape.

- **Units**: None
- **Range**: \( DCORE_{SD} \geq 0 \)
- **Behaviour**: Equals \( DCORE_{SD} = 0 \) if all patches have the same number of disjunct core areas. Increases, without limit, as the variation of number of disjunct core areas increases.

Value

- tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
**lsm_c_division**  

**Description**  
Landscape division index (Aggregation metric)

**Usage**  
```r
lsm_c_division(landscape, directions = 8)
```

**Arguments**  
- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.  
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
DIVISION = (1 - \sum_{j=1}^{n} \left( \frac{a_{ij}}{A} \right)^2)
\]

where \(a_{ij}\) is the area in square meters and \(A\) is the total landscape area in square meters.  

DIVISION is an ‘Aggregation metric. It can be in as the probability that two randomly selected cells are not located in the same patch of class i. The landscape division index is negatively correlated with the effective mesh size (`lsm_c_mesh`).

**Units**: Proportion

**Ranges**: \(0 \leqslant \text{Division} < 1\)

**Behaviour**: Equals \(DIVISION = 0\) if only one patch is present. Approaches \(DIVISION = 1\) if all patches of class i are single cells.

**Value**

tibble
References

McGarragal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_area, lsm_l_ta, lsm_l_division

Examples

lsm_c_division(landscape)

lsm_c_ed

**Description**

Edge Density (Area and Edge metric)

**Usage**

lsm_c_ed(landscape, count_boundary = FALSE, directions = 8)

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `count_boundary`: Count landscape boundary as edge.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[ ED = \frac{\sum_{k=1}^{m} e_{ik}}{A} * 10000 \]

where \( e_{ik} \) is the total edge length in meters and \( A \) is the total landscape area in square meters.

ED is an 'Area and Edge metric'. The edge density equals the sum of all edges of class \( i \) in relation to the landscape area. The boundary of the landscape is only included in the corresponding total class edge length if `count_boundary = TRUE`. The metric describes the configuration of the landscape, e.g. because an aggregation of the same class will result in a low edge density. The metric is standardized to the total landscape area, and therefore comparisons among landscapes with different total areas are possible.
Units: Meters per hectare

Range: ED >= 0

Behaviour: Equals ED = 0 if only one patch is present (and the landscape boundary is not included) and increases, without limit, as the landscapes becomes more patchy

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_c_te, lsm_l_ta, lsm_l_ed

Examples
lsm_c_ed(landscape)

---

<table>
<thead>
<tr>
<th>lsm_c_enn_cv</th>
<th>ENN.CV (class level)</th>
</tr>
</thead>
</table>

Description
Coefficient of variation of euclidean nearest-neighbor distance (Aggregation metric)

Usage
lsm_c_enn_cv(landscape, directions = 8, verbose = TRUE)

Arguments

<table>
<thead>
<tr>
<th>argument</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>landscape</td>
<td>Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.</td>
</tr>
<tr>
<td>directions</td>
<td>The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).</td>
</tr>
<tr>
<td>verbose</td>
<td>Print warning message if not sufficient patches are present</td>
</tr>
</tbody>
</table>
Details

\[ ENN_{CV} = cv(ENN[patch_{ij}]) \]

where \( ENN[patch_{ij}] \) is the euclidean nearest-neighbor distance of each patch.

ENN.CV is an 'Aggregation metric'. It summarises each class as the Coefficient of variation of each patch belonging to class i. ENN measures the distance to the nearest neighbouring patch of the same class i. The distance is measured from edge-to-edge. The range is limited by the cell resolution on the lower limit and the landscape extent on the upper limit. The metric is a simple way to describe patch isolation. Because it is scaled to the mean, it is easily comparable among different landscapes.

**Units:** Meters

**Range:** \( ENN_{CV} \geq 0 \)

**Behaviour:** Equals \( ENN_{CV} = 0 \) if the euclidean nearest-neighbor distance is identical for all patches. Increases, without limit, as the variation of ENN increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

`lsm_p_enn`, `cv`, `lsm_c_enn_mn`, `lsm_c_enn_sd`, `lsm_l_enn_mn`, `lsm_l_enn_sd`, `lsm_l_enn_cv`

Examples

`lsm_c_enn_cv(landscape)`
ENN Mn (class level)

Description
Mean of euclidean nearest-neighbor distance (Aggregation metric)

Usage
`lsm_c_enn_mn(landscape, directions = 8, verbose = TRUE)`

Arguments
- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- `verbose`: Print warning message if not sufficient patches are present

Details

\[ ENN_{MN} = \text{mean}(ENN[patch_{ij}]) \]

where \(ENN[patch_{ij}]\) is the euclidean nearest-neighbor distance of each patch.

ENN_MN is an 'Aggregation metric'. It summarises each class as the mean of each patch belonging to class i. ENN measures the distance to the nearest neighbouring patch of the same class i. The distance is measured from edge-to-edge. The range is limited by the cell resolution on the lower limit and the landscape extent on the upper limit.

Units: Meters
Range: \(ENN_{MN} > 0\)

Behaviour: Approaches \(ENN_{MN} = 0\) as the distance to the nearest neighbour decreases, i.e. patches of the same class i are more aggregated. Increases, without limit, as the distance between neighbouring patches of the same class i increases, i.e. patches are more isolated.

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_p_enn, mean, lsm_c_enn_sd, lsm_c_enn_cv, lsm_l_enn_mn, lsm_l_enn_sd, lsm_l_enn_cv

Examples

lsm_c_enn_mn(landscape)

---

**lsm_c_enn_sd**  
*ENN_SD (class level)*

**Description**

Standard deviation of euclidean nearest-neighbor distance (Aggregation metric)

**Usage**

lsm_c_enn_sd(landscape, directions = 8, verbose = TRUE)

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **verbose**: Print warning message if not sufficient patches are present

**Details**

\[
ENN_{SD} = sd(ENN[patch_{ij}])
\]

where \(ENN[patch_{ij}]\) is the euclidean nearest-neighbor distance of each patch.

ENN_CV is an 'Aggregation metric'. It summarises each class as the standard deviation of each patch belonging to class i. ENN measures the distance to the nearest neighbouring patch of the same class i. The distance is measured from edge-to-edge. The range is limited by the cell resolution on the lower limit and the landscape extent on the upper limit. The metric is a simple way to describe patch isolation. Because it is scaled to the mean, it is easily comparable among different landscapes.

**Units**: Meters

**Range**: \(ENN_{SD} \geq 0\)

**Behaviour**: Equals \(ENN_{SD} = 0\) if the euclidean nearest-neighbor distance is identical for all patches. Increases, without limit, as the variation of ENN increases.
**Value**

tibble

**References**

McGariigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_p_enn_sd, lsm_c_enn_mm, lsm_c_enn_cv, lsm_l_enn_mm, lsm_l_enn_sd, lsm_l_enn_cv

**Examples**

```r
lsm_c_enn_sd(landscape)
```

---

**Description**

Coefficient of variation fractal dimension index (Shape metric)

**Usage**

```r
lsm_c_frac_cv(landscape, directions = 8)
```

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
FRAC_{CV} = cv(FRAC_{patchij})
\]

where \(FRAC_{patchij}\) equals the fractal dimension index of each patch.

FRAC.CV is a ‘Shape metric’. The metric summarises each class as the Coefficient of variation of the fractal dimension index of all patches belonging to class i. The fractal dimension index is based on the patch perimeter and the patch area and describes the patch complexity. The Coefficient of variation is scaled to the mean and comparable among different landscapes.
**Units:** None

**Range:** FRAC_CV >= 0

**Behaviour:** Equals FRAC_CV = 0 if the fractal dimension index is identical for all patches. Increases, without limit, as the variation of the fractal dimension indices increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

- `lsm_p_frac_cv`
- `lsm_c_frac_mn`, `lsm_c_frac_sd`
- `lsm_l_frac_mn`, `lsm_l_frac_sd`, `lsm_l_frac_cv`

**Examples**

```r
lsm_c_frac_cv(landscape)
```

---

**Description**

Mean fractal dimension index (Shape metric)

**Usage**

```r
lsm_c_frac_mn(landscape, directions = 8)
```

**Arguments**

- `landscape` Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions` The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
Details

\[ FRAC_{MN} = \text{mean}(FRAC[patch_{ij}]) \]

where \( FRAC[patch_{ij}] \) equals the fractal dimension index of each patch.

FRAC_MN is a 'Shape metric'. The metric summarises each class as the mean of the fractal dimension index of all patches belonging to class i. The fractal dimension index is based on the patch perimeter and the patch area and describes the patch complexity. The Coefficient of variation is scaled to the mean and comparable among different landscapes.

**Units:** None

**Range:** FRAC_MN > 0

**Behaviour:** Approaches FRAC_MN = 1 if all patches are squared and FRAC_MN = 2 if all patches are irregular.

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

- `lsm_p_frac.mean`
- `lsm_c_frac_sd, lsm_c_frac_cv`
- `lsm_l_frac_mn, lsm_l_frac_sd, lsm_l_frac_cv`

Examples

```r
lsm_c_frac_mn(landscape)
```

---

**Description**

Standard deviation fractal dimension index (Shape metric)

**Usage**

```r
lsm_c_frac_sd(landscape, directions = 8)
```
Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>landscape</td>
<td>Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.</td>
</tr>
<tr>
<td>directions</td>
<td>The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).</td>
</tr>
</tbody>
</table>

Details

\[
FRAC_{SD} = sd(FRAC[patch_{ij}])
\]

where \( FRAC[patch_{ij}] \) equals the fractal dimension index of each patch.

FRAC_SD is a ‘Shape metric’. The metric summarises each class as the standard deviation of the fractal dimension index of all patches belonging to class \( i \). The fractal dimension index is based on the patch perimeter and the patch area and describes the patch complexity.

**Units:** None

**Range:** \( FRAC\_SD \geq 0 \)

**Behaviour:** Equals \( FRAC\_SD = 0 \) if the fractal dimension index is identical for all patches. Increases, without limit, as the variation of the fractal dimension indices increases.

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

- \( lsm\_p\_frac\_sd \)
- \( lsm\_c\_frac\_mn, lsm\_c\_frac\_cv \)
- \( lsm\_l\_frac\_mn, lsm\_l\_frac\_sd, lsm\_l\_frac\_cv \)

Examples

\( lsm\_c\_frac\_sd(landscape) \)
Description

Coefficient of variation radius of gyration (Area and edge metric)

Usage

\texttt{lsm\_c\_gyrate\_cv(landscape, directions = 8, cell\_center = FALSE)}

Arguments

- \texttt{landscape}: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- \texttt{directions}: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- \texttt{cell\_center}: If true, the coordinates of the centroid are forced to be a cell center within the patch.

Details

\[ GYRATE\_CV = cv(GYRATE[patch_{ij}]) \]

where \( GYRATE[patch_{ij}] \) equals the radius of gyration of each patch.

GYRATE\_CV is an ‘Area and edge metric’. The metric summarises each class as the Coefficient of variation of the radius of gyration of all patches belonging to class i. GYRATE measures the distance from each cell to the patch centroid and is based on cell center-to-cell center distances. The metrics characterises both the patch area and compactness. The Coefficient of variation is scaled to the mean and comparable among different landscapes.

If \texttt{cell\_center = TRUE} some patches might have several possible cell-center centroids. In this case, the gyrate index is based on the mean distance of all cells to all possible cell-center centroids.

Units: Meters

Range: \( GYRATE\_CV \geq 0 \)

Behaviour: Equals \( GYRATE\_CV = 0 \) if the radius of gyration is identical for all patches. Increases, without limit, as the variation of the radius of gyration increases.

Value

tibble
References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also
lsm_p_gyrate_cv,
lsm_c_gyrate_mn, lsm_c_gyrate_sd,
lsm_l_gyrate_mn, lsm_l_gyrate_sd, lsm_l_gyrate_cv

Examples
lsm_c_gyrate_cv(landscape)

---

**Description**

Mean radius of gyration (Area and edge metric)

**Usage**

lsm_c_gyrate_mn(landscape, directions = 8, cell_center = FALSE)

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **cell_center**: If true, the coordinates of the centroid are forced to be a cell center within the patch.

**Details**

\[
GYRATE_{MN} = \text{mean}(GYRATE[patch_{ij}])
\]

where \( GYRATE[patch_{ij}] \) equals the radius of gyration of each patch.

GYRATE_MN is an 'Area and edge metric'. The metric summarises each class as the mean of the radius of gyration of all patches belonging to class i. GYRATE measures the distance from each cell to the patch centroid and is based on cell center-to-cell center distances. The metrics characterises both the patch area and compactness.
If `cell_center = TRUE` some patches might have several possible cell-center centroids. In this case, the gyrate index is based on the mean distance of all cells to all possible cell-center centroids.

**Units:** Meters

**Range:** GYRATE_MN >= 0

**Behaviour:** Approaches GYRATE_MN = 0 if every patch is a single cell. Increases, without limit, when only one patch is present.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

`lsm_p_gyrate_mn`, `lsm_c_gyrate_sd`, `lsm_c_gyrate_cv`, `lsm_l_gyrate_mn`, `lsm_l_gyrate_sd`, `lsm_l_gyrate_cv`

**Examples**

```r
lsm_c_gyrate_mn(landscape)
```

**Description**

Standard deviation radius of gyration (Area and edge metric)

**Usage**

`lsm_c_gyrate_sd(landscape, directions = 8, cell_center = FALSE)`
Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **cell_center**: If true, the coordinates of the centroid are forced to be a cell center within the patch.

Details

\[
GYRATE_{SD} = sd(GYRATE[patch_{ij}])
\]

where \(GYRATE[patch_{ij}]\) equals the radius of gyration of each patch.

GYRATE_SD is an 'Area and edge metric'. The metric summarises each class as the standard deviation of the radius of gyration of all patches belonging to class i. GYRATE measures the distance from each cell to the patch centroid and is based on cell center-to-cell center distances. The metrics characterises both the patch area and compactness.

If `cell_center = TRUE` some patches might have several possible cell-center centroids. In this case, the gyrate index is based on the mean distance of all cells to all possible cell-center centroids.

**Units**: Meters

**Range**: GYRATE_SD \(\geq 0\)

**Behaviour**: Equals GYRATE_SD = 0 if the radius of gyration is identical for all patches. Increases, without limit, as the variation of the radius of gyration increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

- `lsm_p_gyrate.cv`
- `lsm_c_gyrate_mn`, `lsm_c_gyrate_cv`
- `lsm_l_gyrate_mn`, `lsm_l_gyrate_sd`, `lsm_l_gyrate_cv`

Examples

\[ lsm_c_gyrate_sd(landscape) \]
Interspersion and Juxtaposition index (class level)

Description

Interspersion and Juxtaposition index (Aggregation metric)

Usage

```r
lsm_c_iji(landscape, verbose = TRUE)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `verbose`: Print warning message if not sufficient patches are present

Details

\[
IJI = - \sum_{k=1}^{m} \left[ \left( \frac{c_{ik}}{\sum_{k=1}^{m} c_{ik}} \right) \ln \left( \frac{c_{ik}}{\sum_{k=1}^{m} c_{ik}} \right) \right] \ln(m - 1) \ast 100
\]

where \(c_{ik}\) are the unique adjacencies of all classes (lower/upper triangle of the adjacency table - without the diagonal) and \(m\) is the number of classes.

IJI is an 'Aggregation metric'. It is a so called "salt and pepper" metric and describes the intermixing of classes (i.e. without considering like adjacencies - the diagonal of the adjacency table). The number of classes to calculate IJI must be \(\geq 3\).

- **Units**: Percent
- **Range**: \(0 < IJI \leq 100\)
- **Behaviour**: Approaches 0 if a class is only adjacent to a single other class and equals 100 when a class is equally adjacent to all other classes.

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

\texttt{lsm_c_iji}

Examples

\texttt{lsm_c_iji(landscape)}

\begin{verbatim}
  lsm_c_lpi

\end{verbatim}

\begin{verbatim}
  LPI (class level)
\end{verbatim}

Description

Largest patch index (Area and Edge metric)

Usage

\texttt{lsm_c_lpi(landscape, directions = 8)}

Arguments

- \texttt{landscape}: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- \texttt{directions}: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
LPI = \frac{\max_j(a_{ij})}{A} * 100
\]

where \(\max(a_{ij})\) is the area of the patch in square meters and \(A\) is the total landscape area in square meters.

The largest patch index is an ‘Area and edge metric’. It is the percentage of the landscape covered by the corresponding largest patch of each class \(i\). It is a simple measure of dominance.

Units: Percentage

Range: \(0 < LPI <= 100\)

Behaviour: Approaches \(LPI = 0\) when the largest patch is becoming small and equals \(LPI = 100\) when only one patch is present

Value

tibble
**lsm_c_lsi**

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

- `lsm_p_area`
- `lsm_l_ta`
- `lsm_l_lpi`

Examples

```
lsm_c_lpi(landscape)
```

---

**Description**

Landscape shape index (Aggregation metric)

**Usage**

```
lsm_c_lsi(landscape)
```

**Arguments**

- `landscape`  
  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

**Details**

\[
LSI = \frac{e_i}{\min e_i}
\]

where \(e_i\) is the total edge length in cell surfaces and \(\min e_i\) is the minimum total edge length in cell surfaces.

LSI is an ‘Aggregation metric’. It is the ratio between the actual edge length of class \(i\) and the hypothetical minimum edge length of class \(i\). The minimum edge length equals the edge length if class \(i\) would be maximally aggregated.

**Units:** None

**Ranges:** \(LSI \geq 1\)

**Behaviour:** Equals \(LSI = 1\) when only one squared patch is present or all patches are maximally aggregated. Increases, without limit, as the length of the actual edges increases, i.e. the patches become less compact.
Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_p_shape,
lsm_l_lsi

Examples
lsm_c_lsi(landscape)

---

\[ lsm_c\_mesh \]

\[ MESH (class level) \]

Description
Effective Mesh Size (Aggregation metric)

Usage
lsm_c_mesh(landscape, directions = 8)

Arguments
landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details
\[
MESH = \frac{\sum_{j=1}^{n} a_{ij}^2}{A} \times \frac{1}{10000}
\]

where \( a_{ij} \) is the patch area in square meters and \( A \) is the total landscape area in square meters.

The effective mesh size is an 'Aggregation metric'. Because each patch is squared before the sums for each group \( i \) are calculated and the sum is standardized by the total landscape area, MESH is a relative measure of patch structure. MESH is perfectly, negatively correlated to \( lsm_c\_division \).
Description

Number of disjunct core areas (Core area metric)

Usage

```r
lsm_c_ndca(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```
Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

Details

\[
NDCA = \sum_{j=1}^{n} n_{ij}^{\text{core}}
\]

where \( n_{ij}^{\text{core}} \) is the number of disjunct core areas.

NDCA is a ‘Core area metric’. The metric summarises class i as the sum of all patches belonging to class i. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). NDCA counts the disjunct core areas, whereby a core area is a ‘patch within the patch’ containing only core cells. It describes patch area and shape simultaneously (more core area when the patch is large, however, the shape must allow disjunct core areas). Thereby, a compact shape (e.g. a square) will contain less disjunct core areas than a more irregular patch.

**Units**: None

**Range**: NDCA \( \geq 0 \)

**Behaviour**: NDCA = 0 when TCA = 0, i.e. every cell in patches of class i is an edge. NDCA increases, with out limit, as core area increases and patch shapes allow disjunct core areas (i.e. patch shapes become rather complex).

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

- `lsm_c_tca`
- `lsm_p_ncore`, `lsm_l_ndca`
lsm_c_nlsi

Examples

lsm_c_ndca(landscape)

Description

Normalized landscape shape index (Aggregation metric)

Usage

lsm_c_nlsi(landscape)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

Details

\[ nLSI = \frac{e_i - \min e_i}{\max e_i - \min e_i} \]

where \( e_i \) is the total edge length in cell surfaces and \( \min e_i \) \( \max e_i \) are the minimum and maximum total edge length in cell surfaces, respectively.

nLSI is an ‘Aggregation metric’. It is closely related to the \texttt{lsm_c_lsi} and describes the ratio of the actual edge length of class i in relation to the hypothetical range of possible edge lengths of class i (min/max).

Currently, nLSI ignores all background cells when calculating the minimum and maximum total edge length. Also, a correct calculation of the minimum and maximum total edge length is currently only possible for rectangular landscapes.

Units: None

Ranges: 0 <= nlsi <= 1

Behaviour: Equals nLSI = 0 when only one squared patch is present. nLSI increases the more disaggregated patches are and equals nLSI = 1 for a maximal disaggregated (i.e. a "checkerboard pattern").

Value

tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_c_lsi lsm_l_lsi

Examples

lsm_c_nlsi(landscape)

Description

Number of patches (Aggregation metric)

Usage

lsm_c_np(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ NP = n_i \]

where \( n_i \) is the number of patches.

NP is an ’Aggregation metric’. It describes the fragmentation of a class, however, does not necessarily contain information about the configuration or composition of the class.

Units: None

Ranges: \( NP \geq 1 \)

Behaviour: Equals \( NP = 1 \) when only one patch is present and increases, without limit, as the number of patches increases
Description

Perimeter-Area Fractal Dimension (Shape metric)

Usage

\[ \text{lsm\_c\_pafrac(landscape, directions = 8, verbose = TRUE)} \]

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **verbose**: Print warning message if not sufficient patches are present

Details

\[ \text{PAFRAC} = \frac{2}{\beta} \]

where \( \beta \) is the slope of the regression of the area against the perimeter (logarithm) \( n_i \sum_{j=1}^{n} \ln a_{ij} = a + \beta n_i \sum_{j=1}^{n} \ln p_{ij} \)

PAFRAC is a ‘Shape metric’. It describes the patch complexity of class \( i \) while being scale independent. This means that increasing the patch size while not changing the patch form will not change

---

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

lsm\_l\_np

**Examples**

\[ \text{lsm\_c\_np(landscape)} \]
the metric. However, it is only meaningful if the relationship between the area and perimeter is 
linear on a logarithmic scale. Furthermore, if there are less than 10 patches in class i, the metric 
returns NA because of the small-sample issue.

**Units:** None

**Range:** $1 \leq \text{PAFRAC} \leq 2$

**Behaviour:** Approaches $\text{PAFRAC} = 1$ for patches with simple shapes and approaches $\text{PAFRAC} = 2$ for irregular shapes

**Value**
tibble

**References**
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**
`lsm_p_area`, `lsm_p_perim`,

`lsm_l_paf frac`

**Examples**

```r
lsm_c_paf frac(landscape)
```

---

**Description**

Coefficient of variation perimeter-area ratio (Shape metric)

**Usage**

```r
lsm_c_paf frac(landscape, directions = 8)
```

**Arguments**

- `landscape` Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions` The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
\( PARA_{CV} = cv(PARA[\text{patch}_{ij}]) \)

where \( PARA[\text{patch}_{ij}] \) is the perimeter area ratio of each patch.

\( PARA_{CV} \) is a ‘Shape metric’. It summarises each class as the Coefficient of variation of each patch belonging to class \( i \). The perimeter-area ratio describes the patch complexity in a straightforward way. However, because it is not standardised to a certain shape (e.g. a square), it is not scale independent, meaning that increasing the patch size while not changing the patch form will change the ratio.

**Units:** None

**Range:** \( PARA_{CV} \geq 0 \)

**Behaviour:** Equals \( PARA_{CV} = 0 \) if the perimeter-area ratio is identical for all patches. Increases, without limit, as the variation of the perimeter-area ratio increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

\( lsm_p\_para\_cv \),
\( lsm_c\_para\_mn, lsm_c\_para\_sd \),
\( lsm_l\_para\_mn, lsm_l\_para\_sd, lsm_l\_para\_cv \)

**Examples**

\( lsm_c\_para\_cv(landscape) \)

\begin{verbatim}
  lsm_c_para_mn
  PARA_MN (class level)
\end{verbatim}

**Description**

Mean perimeter-area ratio (Shape metric)

**Usage**

\( lsm_c\_para\_mn(landscape, \text{directions} = 8) \)
Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ \text{PARA}_MN = \text{mean}(\text{PARA}[\text{patch}_{ij}]) \]

where \( \text{PARA}[\text{patch}_{ij}] \) is the perimeter area ratio of each patch.

PARA_MN is a 'Shape metric'. It summarises each class as the mean of each patch belonging to class i. The perimeter-area ratio describes the patch complexity in a straightforward way. However, because it is not standarised to a certain shape (e.g. a square), it is not scale independent, meaning that increasing the patch size while not changing the patch form will change the ratio.

- **Units**: None
- **Range**: PARA_MN > 0
- **Behaviour**: Approaches PARA_MN > 0 if PARA for each patch approaches PARA > 0, i.e. the form approaches a rather small square. Increases, without limit, as PARA increases, i.e. patches become more complex.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

- `lsm_p_para`, `mean`,
- `lsm_c_para_sd`, `lsm_c_para_cv`,
- `lsm_l_para_mn`, `lsm_l_para_sd`, `lsm_l_para_cv`

Examples

```r
lsm_c_para_mn(landscape)
```
PARA_SD (class level)

Description
Standard deviation perimeter-area ratio (Shape metric)

Usage
`lsm_c_para_sd(landscape, directions = 8)`

Arguments
- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
PARA_{SD} = sd(PARA[patch_{ij}])
\]

where \(PARA[patch_{ij}]\) is the perimeter area ratio of each patch. PARA_SD is a ‘Shape metric’. It summarises each class as the standard deviation of each patch belonging to class i. The perimeter-area ratio describes the patch complexity in a straightforward way. However, because it is not standardised to a certain shape (e.g. a square), it is not scale independent, meaning that increasing the patch size while not changing the patch form will change the ratio.

**Units**: None

**Range**: PARA_SD \(\geq 0\)

**Behaviour**: Equals PARA_SD = 0 if the perimeter-area ratio is identical for all patches. Increases, without limit, as the variation of the perimeter-area ratio increases.

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

lsm_p_para_sd, lsm_c_para_mn, lsm_c_para_cv, lsm_l_para_mn, lsm_l_para_sd, lsm_l_para_cv

Examples

lsm_c_para_sd(landscape)

---

lsm_c_pd  

\( PD \) (class level)

Description

Patch density (Aggregation metric)

Usage

lsm_c_pd(landscape, directions = 8)

Arguments

- **landscape**  
  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

- **directions**  
  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
PD = \frac{n_i}{A} \times 10000 \times 100
\]

where \( n_i \) is the number of patches and \( A \) is the total landscape area in square meters.

PD is an 'Aggregation metric'. It describes the fragmentation of a class, however, does not necessarily contain information about the configuration or composition of the class. In contrast to lsm_c_np it is standardized to the area and comparisons among landscapes with different total area are possible.

**Units**: Number per 100 hectares

**Ranges**: \( 0 < PD \leq 1e+06 \)

**Behaviour**: Increases as the landscape gets more patchy. Reaches its maximum if every cell is a different patch.

Value

tibble
\textit{lsm\_c\_pladj}  

\textbf{References}  
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/  

\textbf{See Also}  
lsm\_c\_np, lsm\_l\_ta,  
lsm\_l\_pd  

\textbf{Examples}  
lsm\_c\_pd(landscape)  

---  

\textbf{lsm\_c\_pladj}  

\textit{PLADJ (class level)}  

\textbf{Description}  
Percentage of Like Adjacencies (Aggregation metric)  

\textbf{Usage}  
lsm\_c\_pladj(landscape)  

\textbf{Arguments}  
landscape \hspace{1cm} Raster\*, Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.  

\textbf{Details}  
\[ PLADJ = \left( \frac{g_{ij}}{m} \right) \times 100 \sum_{k=1}^{m} g_{ik} \]  
where \( g_{ij} \) is the number of adjacencies between cells of class \( i \) and \( g_{ik} \) is the number of adjacencies between cells of class \( i \) and \( k \).  

PLADJ is an ‘Aggregation metric’. It calculates the frequency how often patches of different classes \( i \) (focal class) and \( k \) are next to each other, and following is a measure of class aggregation. The adjacencies are counted using the double-count method.  

\textbf{Units}: Percent  

\textbf{Ranges}: \( 0 \leq PLADJ \leq 100 \)  

\textbf{Behaviour}: Equals PLADJ = 0 if class \( i \) is maximal disaggregated, i.e. every cell is a different patch. Equals PLADJ = 100 when the only one patch is present.
**Value**

`tibble`

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**Examples**

```r
lsm_c_pladj(landscape)
```

---

**Description**

Percentage of landscape of class (Area and Edge metric)

**Usage**

```r
lsm_c_pland(landscape, directions = 8)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
PLAND = \frac{\sum_{j=1}^{n} a_{ij}}{A} \times 100
\]

where \(a_{ij}\) is the area of each patch and \(A\) is the total landscape area.

PLAND is an 'Area and edge metric'. It is the percentage of the landscape belonging to class i. It is a measure of composition and because of the relative character directly comparable among landscapes with different total areas.

- **Units**: Percentage
- **Range**: 0 < PLAND <= 100
- **Behaviour**: Approaches PLAND = 0 when the proportional class area is decreasing. Equals PLAND = 100 when only one patch is present.
**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

lsm_c_ca, lsm_l_ta

**Examples**

```r
lsm_c_pland(landscape)
```

---

### Description

Covariance of variation shape index (Shape metric)

### Usage

```r
lsm_c_shape_cv(landscape, directions = 8)
```

### Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

### Details

\[
SHAPE_{CV} = \text{cv}(SHAPE[patch_{ij}])
\]

where \(SHAPE[patch_{ij}]\) is the shape index of each patch.

SHAPE\(_{CV}\) is a 'Shape metric'. Each class is summarised as the Coefficient of variation of each patch belonging to class \(i\). SHAPE describes the ratio between the actual perimeter of the patch and the hypothetical minimum perimeter of the patch. The minimum perimeter equals the perimeter if the patch would be maximally compact.

**Units**: None
Range: SHAPE.CV >= 0

Behaviour: Equals SHAPE.CV = 0 if all patches have an identical shape index. Increases, without limit, as the variation of the shape index increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_shape.cv,
lsm_c_shape_mn, lsm_c_shape_sd,
lsm_l_shape_mn, lsm_l_shape_sd, lsm_l_shape_cv

Examples

lsm_c_shape_cv(landscape)

Description

Mean shape index (Shape metric)

Usage

lsm_c_shape_mn(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
Details

\[ SHAPE_{MN} = mean(SHAPE[patch_{ij}]) \]

where \( SHAPE[patch_{ij}] \) is the shape index of each patch.

SHAPE\_MN is a 'Shape metric'. Each class is summarised as the mean of each patch belonging to class \( i \). SHAPE describes the ratio between the actual perimeter of the patch and the hypothetical minimum perimeter of the patch. The minimum perimeter equals the perimeter if the patch would be maximally compact.

**Units:** None

**Range:** SHAPE\_SD >= 1

**Behaviour:** Equals SHAPE\_MN = 0 if all patches are squares. Increases, without limit, as the shapes of patches become more complex.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

- `lsm_p_shape`, `mean`
- `lsm_c_shape_sd`, `lsm_c_shape_cv`
- `lsm_l_shape_mn`, `lsm_l_shape_sd`, `lsm_l_shape_cv`

Examples

```
lsm_c_shape_mn(landscape)
```
Description

Standard deviation shape index (Shape metric)

Usage

```
lsm_c_shape_sd(landscape, directions = 8)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
SHAPE_{SD} = sd(SHAPE[patch_{ij}])
\]

where \(SHAPE[patch_{ij}]\) is the shape index of each patch.

SHAPE_SD is a 'Shape metric'. Each class is summarised as the standard deviation of each patch belonging to class i. SHAPE describes the ratio between the actual perimeter of the patch and the hypothetical minimum perimeter of the patch. The minimum perimeter equals the perimeter if the patch would be maximally compact.

**Units**: None

**Range**: SHAPE_SD \(\geq 0\)

**Behaviour**: Equals SHAPE_SD = 0 if all patches have an identical shape index. Increases, without limit, as the variation of the shape index increases.

Value

- tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**lsm_c_split**

### See Also

- `lsm_p_shape, sd`,
- `lsm_c_shape_mn, lsm_c_shape_cv`,
- `lsm_l_shape_mn, lsm_l_shape_sd, lsm_l_shape_cv`

### Examples

```r
lsm_c_shape_sd(landscape)
```

---

**lsm_c_split**  
**SPLIT (class level)**

### Description

Splitting index (Aggregation metric)

### Usage

```r
lsm_c_split(landscape, directions = 8)
```

### Arguments

- `landscape`  
  Raster*, Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

- `directions`  
  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

### Details

\[
SPLIT = \frac{A^2}{\sum_{j=1}^{n} a_{ij}^2}
\]

where \(a_{ij}\) is the patch area in square meters and \(A\) is the total landscape area.

SPLIT is an 'Aggregation metric'. It describes the number of patches if all patches of class \(i\) would be divided into equally sized patches.

- **Units:** None

- **Range:** \(1 \leq SPLIT \leq \text{Number of cells squared}\)

- **Behaviour:** Equals SPLIT = 1 if only one patch is present. Increases as the number of patches of class \(i\) increases and is limited if all cells are a patch.

### Value

- tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_area, lsm_l_ta, lsm_l_split

Examples

lsm_c_split(landscape)

\[
\text{lsm_c_tca} \quad \text{TCA (class level)}
\]

Description

Total core area (Core area metric)

Usage

lsm_c_tca(landscape, directions = 8, consider_boundary = FALSE, edge_depth = 1)

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

Details

\[
TCA = \sum_{j=1}^{n} a_{ij}^{core} \times \left( \frac{1}{10000} \right)
\]

where here \(a_{ij}^{core}\) is the core area in square meters.
TCA is a 'Core area metric' and equals the sum of core areas of all patches belonging to class i. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). In other words, the core area of a patch is all area that is not an edge. It characterises patch areas and shapes of patches belonging to class i simultaneously (more core area when the patch is large and the shape is rather compact, i.e. a square). Additionally, TCA is a measure for the configuration of the landscape, because the sum of edges increase as patches are less aggregated.

**Units:** Hectares

**Range:** TCA >= 0

**Behaviour:** Increases, without limit, as patch areas increase and patch shapes simplify. TCA = 0 when every cell in every patch of class i is an edge.

---

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

* lsm_p_core, lsm_l_tca

**Examples**

```r
lsm_c_tca(landscape)
```

---

### lsm_c_te

**TE (class level)**

**Description**

Total (class) edge (Area and Edge metric)

**Usage**

```r
lsm_c_te(landscape, count_boundary = FALSE, directions = 8)
```

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **count_boundary**: Include landscape boundary in edge length
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
Details

\[ TE = \sum_{k=1}^{m} e_{ik} \]

where \( e_{ik} \) is the edge lengths in meters. TE is an 'Area and edge metric'. Total (class) edge includes all edges between class i and all other classes k. It measures the configuration of the landscape because a highly fragmented landscape will have many edges. However, total edge is an absolute measure, making comparisons among landscapes with different total areas difficult. If `cound_boundary = TRUE` also edges to the landscape boundary are included.

**Units:** Meters

**Range:** TE >= 0

**Behaviour:** Equals TE = 0 if all cells are edge cells. Increases, without limit, as landscape becomes more fragmented

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html

See Also

`lsm_p_perim` `lsm_l_te`

Examples

`lsm_c_te(landscape)`

```
# AI (landscape level)

lsm_l_ai(landscape)
```

Description

Aggregation index (Aggregation metric)

Usage

`lsm_l_ai(landscape)`
Arguments

landscape: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers

Details

$$AI = \left[ \sum_{i=1}^{m} \left( \frac{g_{ii}}{\text{max} - g_{ii}} \right) P_i \right] \times 100$$  (100)

where $g_{ii}$ is the number of like adjacencies based on the single-count method and $\text{max} - g_{ii}$ is the classwise maximum number of like adjacencies of class $i$ and $P_i$ the proportion of landscape compromised of class $i$.

AI is an ‘Aggregation metric’. It equals the number of like adjacencies divided by the theoretical maximum possible number of like adjacencies for that class summed over each class for the entire landscape. The metric is based on the adjacency matrix and the single-count method.

Units: Percent

Range: $0 \leq AI \leq 100$

Behaviour: Equals 0 for maximally disaggregated and 100 for maximally aggregated classes.

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_c_ai

Examples

lsm_l_ai(landscape)
Description

Coefficient of variation of patch area (Area and edge metric)

Usage

\texttt{lsm\_l\_area\_cv}(landscape, directions = 8)

Arguments

- \texttt{landscape}: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers
- \texttt{directions}: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ AREA_{CV} = cv(AREA[patch_{ij}]) \]

where \( AREA[patch_{ij}] \) is the area of each patch in hectares.

\( AREA_{CV} \) is an 'Area and Edge metric'. The metric summarises the landscape as the Coefficient of variation of all patches in the landscape. The metric describes the differences among patches in the landscape and is easily comparable because it is scaled to the mean.

- **Units**: Hectares
- **Range**: \( AREA_{CV} \geq 0 \)

**Behaviour**: Equals \( AREA_{CV} = 0 \) if all patches are identical in size. Increases, without limit, as the variation of patch areas increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: \url{http://www.umass.edu/landeco/research/fragstats/}

See Also

- \texttt{lsm\_p\_area\_cv}, \texttt{lsm\_c\_area\_mn}, \texttt{lsm\_c\_area\_sd}, \texttt{lsm\_c\_area\_cv}, \texttt{lsm\_l\_area\_mn}, \texttt{lsm\_l\_area\_sd}
Examples

\texttt{lsm\_l\_area\_cv(landscape)}

\begin{itemize}
  \item lsm\_l\_area\_mn
  \item AREA\_MN (landscape level)
\end{itemize}

Description

Mean of patch area (Area and edge metric)

Usage

\texttt{lsm\_l\_area\_mn(landscape, directions = 8)}

Arguments

\begin{itemize}
  \item \texttt{landscape} \hspace{1cm} Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers
  \item \texttt{directions} \hspace{1cm} The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
\end{itemize}

Details

\[
\text{AREA}_{MN} = \text{mean(\text{AREA}[\text{patch}_{ij}])}
\]

where \text{AREA}[\text{patch}_{ij}] is the area of each patch in hectares

AREA\_MN is an ‘Area and Edge metric’. The metric summarises the landscape as the mean of all patch in the landscape. The metric is a simple way to describe the composition of the landscape. Especially together with the total landscape area (\texttt{lsm\_l\_ta}), it can also give an an idea of patch structure (e.g. many small patches vs. few larges patches).

\begin{itemize}
  \item Units: Hectares
  \item Range: AREA\_MN > 0
  \item Behaviour: Approaches AREA\_MN = 0 if all patches are small. Increases, without limit, as the patch areas increase.
\end{itemize}

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

lsm_p_area, mean, lsm_c_area_mn, lsm_c_area_sd, lsm_c_area_cv
lsm_l_area_sd, lsm_l_area_cv

Examples

lsm_l_area_mn(landscape)

---

lsm_l_area_sd  AREA_SD (landscape level)

Description

Standard deviation of patch area (Area and edge metric)

Usage

lsm_l_area_sd(landscape, directions = 8)

Arguments

landscape  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers
directions  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
\text{AREA}_{SD} = \text{sd} (\text{AREA}[\text{patch}_{ij}])
\]

where \(\text{AREA}[\text{patch}_{ij}]\) is the area of each patch in hectares.

\(\text{AREA}_{SD}\) is an 'Area and Edge metric'. The metric summarises the landscape as the standard deviation of all patch in the landscape. The metric describes the differences among all patches in the landscape.

Units:  Hectares

Range:  AREA_SD \(\geq 0\)

Behaviour:  Equals AREA_SD = 0 if all patches are identical in size. Increases, without limit, as the variation of patch areas increases.

Value

tibble
References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_p_area.sd,
lsm_c_area_mn, lsm_c_area_sd, lsm_c_area_cv
lsm_l_area_mn, lsm_l_area_cv

Examples
lsm_l_area_sd(landscape)

Description
Coefficient of variation of core area index (Core area metric)

Usage
lsm_l_cai_cv( 
landscape, 
directions = 8, 
consider_boundary = FALSE, 
edge_depth = 1 
)

Arguments
landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
consider_boundary Logical if cells that only neighbour the landscape boundary should be considered as core
dge_depth Distance (in cells) a cell has the be away from the patch edge to be considered as core cell
Details

\[ CAI_{CV} = cv(CAI[patch_{ij}]) \]

where \( CAI[patch_{ij}] \) is the core area index of each patch.

\( CAI_{CV} \) is a 'Core area metric'. The metric summarises the landscape as the Coefficient of variation of the core area index of all patches in the landscape. The core area index is the percentage of core area in relation to patch area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). The metric describes the differences among all patches in the landscape. Because it is scaled to the mean, it is easily comparable.

**Units:** Percent

**Range:** \( CAI_{CV} \geq 0 \)

**Behaviour:** Equals \( CAI_{CV} = 0 \) if the core area index is identical for all patches. Increases, without limit, as the variation of the core area indices increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

\( lsm_p_cai, cv \),
\( lsm_c_cai_mn, lsm_c_cai_sd, lsm_c_cai_cv, lsm_l_cai_mn, lsm_l_cai_sd \)

Examples

\( lsm_l_cai_cv(landscape) \)

---

\( lsm_l_cai_mn \quad CAI_{MN} \text{ (landscape level)} \)

Description

Mean of core area index (Core area metric)
Usage

```r
lsm_l_cai_mn(
    landscape,
    directions = 8,
    consider_boundary = FALSE,
    edge_depth = 1
)
```

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

Details

\[ CAI_{MN} = \text{mean}(CAI_{patch}) \]

where \( CAI_{patch} \) is the core area index of each patch.

CAI\_MN is a 'Core area metric'. The metric summarises the landscape as the mean of the core area index of all patches in the landscape. The core area index is the percentage of core area in relation to patch area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case).

- **Units**: Percent
- **Range**: \( 0 \leq CAI_{MN} \leq 100 \)
- **Behaviour**: CAI\_MN = 0 when all patches have no core area and approaches CAI\_MN = 100 with increasing percentage of core area within patches.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

lsm_p_cai, mean, lsm_c_cai_sd, lsm_c_cai_cv, lsm_l_cai_sd, lsm_l_cai_cv

Examples

lsm_l_cai_mn(landscape)

---

**lsm_l_cai_sd**  
*CAI_SD (landscape level)*

**Description**

Standard deviation of core area index (Core area metric)

**Usage**

lsm_l_cai_sd(  
landscape,  
directions = 8,  
consider_boundary = FALSE,  
edge_depth = 1  
)

**Arguments**

- **landscape**  
  Raster*, Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

- **directions**  
  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

- **consider_boundary**  
  Logical if cells that only neighbour the landscape boundary should be considered as core.

- **edge_depth**  
  Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

**Details**

\[ CAI_{SD} = sd(CAI[patch_{ij}]) \]

where \( CAI[patch_{ij}] \) is the core area index of each patch.

CAI_SD is a 'Core area metric'. The metric summarises the landscape as the standard deviation of the core area index of all patches in the landscape. The core area index is the percentage of core area in relation to patch area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). The metric describes the differences among all patches in the landscape.
Units: Percent

Range: CAI_SD >= 0

Behaviour: Equals CAI_SD = 0 if the core area index is identical for all patches. Increases, without limit, as the variation of core area indices increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_p_cai_sd, lsm_c_cai_mn, lsm_c_cai_sd, lsm_c_cai_cv, lsm_l_cai_mn, lsm_l_cai_cv

Examples

lsm_l_cai_sd(landscape)

Description

Coefficient of variation of related circumscribing circle (Shape metric)

Usage

lsm_l_circle_cv(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
Details

\[ CIRCLE_{CV} = \text{cv}(\text{CIRCLE}[\text{patch}_{ij}]) \]

where \( \text{CIRCLE}[\text{patch}_{ij}] \) is the related circumscribing circle of each patch.

\( \text{CIRCLE}_{CV} \) is a 'Shape metric' and summarises the landscape as the Coefficient of variation of the related circumscribing circle of all patches in the landscape. \( \text{CIRCLE} \) describes the ratio between the patch area and the smallest circumscribing circle of the patch and characterises the compactness of the patch. \( \text{CIRCLE}_{CV} \) describes the differences among all patches in the landscape. Because it is scaled to the mean, it is easily comparable.

**Units:** None

**Range:** \( \text{CIRCLE}_{CV} \geq 0 \)

**Behaviour:** Equals \( \text{CIRCLE}_{CV} \) if the related circumscribing circle is identical for all patches. Increases, without limit, as the variation of related circumscribing circles increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).

**See Also**

`lsm_p_circle_mean`,
`lsm_c_circle_mn, lsm_c_circle_sd, lsm_c_circle_cv`,
`lsm_l_circle_mn, lsm_l_circle_sd`

**Examples**

`lsm_l_circle_cv(landscape)`
lsm_l_circle_mn

CIRCLE_MN (landscape level)

Description
Mean of related circumscribing circle (Shape metric)

Usage
lsm_l_circle_mn(landscape, directions = 8)

Arguments
- landscape: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- directions: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ CIRCLE_{MN} = \text{mean}(CIRCLE_{patch_{ij}}) \]

where \( CIRCLE_{patch_{ij}} \) is the related circumscribing circle of each patch.

CIRCLE_MN is a 'Shape metric' and summarises the landscape as the mean of the related circumscribing circle of all patches in the landscape. CIRCLE describes the ratio between the patch area and the smallest circumscribing circle of the patch and characterises the compactness of the patch.

Units: None

Range: CIRCLE_MN > 0

Behaviour: Approaches CIRCLE_MN = 0 if the related circumscribing circle of all patches is small. Increases, without limit, as the related circumscribing circles increase.

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following website: http://www.umass.edu/landeco/research/fragstats/


Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).
See Also

lsm_p_circle, mean,
lsm_c_circle_mn, lsm_c_circle_sd, lsm_c_circle_cv,
lsm_l_circle_sd, lsm_l_circle_cv

Examples

lsm_l_circle_mn(landscape)

---

lsm_l_circle_sd  \textit{CIRCLE\_SD (landscape level)}

Description

Standard deviation of related circumscribing circle (Shape metric)

Usage

lsm_l_circle_sd(landscape, directions = 8)

Arguments

- \texttt{landscape}  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- \texttt{directions}  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[CIRCLE_{SD} = \text{sd}(CIRCLE[\text{patch}_{ij}])\]

where \(CIRCLE[\text{patch}_{ij}]\) is the related circumscribing circle of each patch.

\(CIRCLE_{SD}\) is a ‘Shape metric’ and summarises the landscape as the standard deviation of the related circumscribing circle of all patches in the landscape. \(CIRCLE\) describes the ratio between the patch area and the smallest circumscribing circle of the patch and characterises the compactness of the patch. The metric describes the differences among all patches of the landscape.

\textbf{Units}: None

\textbf{Range}:  \(CIRCLE_{SD} \geq 0\)

\textbf{Behaviour}: Equals \(CIRCLE_{SD}\) if the related circumscribing circle is identical for all patches. Increases, without limit, as the variation of related circumscribing circles increases.

Value

tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).

See Also

lsm_p_circle, mean,
lsme_c_circle, lsme_c_circle_sd, lsme_c_circle_cv,
lsm_l_circle, lsm_l_circle_cv

Examples

lsm_l_circle_sd(landscape)

Description

Patch Cohesion Index (Aggregation metric)

Usage

lsm_l_cohesion(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ COHESION = 1 - \left( \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} p_{ij}}{\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} \sqrt{a_{ij}}} \right) \ast \left( 1 - \frac{1}{\sqrt{Z}} \right)^{-1} \ast 100 \]

where \( p_{ij} \) is the perimeter in meters, \( a_{ij} \) is the area in square meters and \( Z \) is the number of cells. COHESION is an 'Aggregation metric'.
Units: Percent

Ranges: Unknown

Behaviour: Unknown

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also
lsm_p_perim, lsm_p_area, lsm_l_cohesion

Examples
lsm_l_cohesion(landscape)

---

**lsm_l_condent**  
*Conditional entropy (landscape level)*

**Description**
Conditional entropy $\{H(ylx)\}$

**Usage**

```
  lsm_l_condent(landscape, neighbourhood = 4, ordered = TRUE, base = "log2")
```

**Arguments**

- `landscape`  
  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

- `neighbourhood`  
  The number of directions in which cell adjacencies are considered as neighbours: 4 (rook’s case) or 8 (queen’s case). The default is 4.

- `ordered`  
  The type of pairs considered. Either ordered (TRUE) or unordered (FALSE). The default is TRUE.

- `base`  
  The unit in which entropy is measured. The default is "log2", which computes entropy in "bits". "log" and "log10" can also be used.
**Details**

Complexity of a landscape pattern configuration. It measures a only a geometric intricacy (configurational complexity) of a landscape pattern.

**Value**

tibble

**References**


**See Also**

`lsm_l_ent`, `lsm_l_mutinf`, `lsm_l_joinent`, `lsm_l_relmutinf`

**Examples**

```r
lsm_l_contag(landscape)
```

---

### `lsm_l_contag`

**Description**

Contagion (Aggregation metric)

**Usage**

```r
lsm_l_contag(landscape, verbose = TRUE)
```

**Arguments**

- `landscape` Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `verbose` Print warning message if not sufficient patches are present

**Details**

\[
CONTAG = 1 + \sum_{q=1}^{n} p_q \ln(p_q) \\
2 \ln(t)
\]

where \(p_q\) the adjacency table for all classes divided by the sum of that table and \(t\) the number of classes in the landscape.
CONTAG is an 'Aggregation metric'. It is based on cell adjacencies and describes the probability of two random cells belonging to the same class. \( p_q \) is the cell adjacency table, where the order is preserved and pairs of adjacent cells are counted twice. Contagion is affected by both the dispersion and interspersion of classes. E.g., low class dispersion (= high proportion of like adjacencies) and low interspersion (= uneven distribution of pairwise adjacencies) lead to a high contagion value.

The number of classes to calculate CONTAG must be \( \geq \) than 2.

**Units:** Percent

**Range:** 0 \(<\) Contag \(<\)=100

**Behaviour:** Approaches CONTAG = 0 if all cells are unevenly distributed and 100 indicates that all cells are equally adjacent to all other classes.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**Examples**

```
lsml_contag(landscape)
```

```
lsml_contig_cv
```

**Description**

Coefficient of variation of Contiguity index (Shape metric)

**Usage**

```
lsml_contig_cv(landscape, directions = 8)
```

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
CONTIG\_CV = cv(CONTIG[patch\_ij])

where CONTIG[patch\_ij] is the contiguity of each patch.

CONTIG\_CV is a 'Shape metric'. It summarises the landscape as the coefficient of variation of all patches in the landscape. CONTIG\_CV assesses the spatial connectedness (contiguity) of cells in patches. The metric coerces patch values to a value of 1 and the background to NA. A nine cell focal filter matrix:

```
filter\_matrix <- matrix(c(1, 2, 1,
    2, 1, 2,
    1, 2, 1), 3, 3, byrow = T)
```

... is then used to weight orthogonally contiguous pixels more heavily than diagonally contiguous pixels. Therefore, larger and more connections between patch cells in the rookie case result in larger contiguity index values.

**Units:** None

**Range:** CONTIG\_CV >= 0

**Behaviour:** CONTIG\_CV = 0 if the contiguity index is identical for all patches. Increases, without limit, as the variation of CONTIG increases.

**Value**

```
tibble
```

**References**

McGarinagal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

```
lsmp\_contig, lsm\_c\_contig\_sd, lsm\_c\_contig\_cv, lsm\_c\_contig\_mn,
lsml\_contig\_sd, lsm\_l\_contig\_mn
```

**Examples**

```
lsml\_contig\_cv(landscape)
```
Description

Mean of Contiguity index (Shape metric)

Usage

```r
lsm_l_contig_mn(landscape, directions = 8)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
CONTIG_{MN} = \text{mean}(CONTIG[patch_{ij}])
\]

where \(CONTIG[patch_{ij}]\) is the contiguity of each patch.

\(CONTIG_{MN}\) is a 'Shape metric'. It summarises the landscape as the mean of all patches in the landscape. \(CONTIG_{MN}\) assesses the spatial connectedness (contiguity) of cells in patches. The metric coerces patch values to a value of 1 and the background to NA. A nine cell focal filter matrix:

```r
filter_matrix <- matrix(c(1, 2, 1,
                           2, 1, 2,
                           1, 2, 1), 3, 3, byrow = T)
```

... is then used to weight orthogonally contiguous pixels more heavily than diagonally contiguous pixels. Therefore, larger and more connections between patch cells in the rookie case result in larger contiguity index values.

- **Units**: None
- **Range**: \(0 \geq \text{CONTIG}_{MN} \leq 1\)
- **Behaviour**: \(\text{CONTIG}_{MN}\) equals the mean of the contiguity index on landscape level for all patches.

Value

tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_contig, lsm_c_contig_sd, lsm_c_contig_cv, lsm_c_contig_mn, lsm_l_contig_sd, lsm_l_contig_cv

Examples

lsm_l_contig_mn(landscape)

---

**lsm_l_contig_sd**

**CONTIG_SD (landscape level)**

Description

Standard deviation of Contiguity index (Shape metric)

Usage

lsm_l_contig_sd(landscape, directions = 8)

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ \text{CONTIG_SD} = \text{sd} (\text{CONTIG}[\text{patch}_{ij}]) \]

where \( \text{CONTIG}[\text{patch}_{ij}] \) is the contiguity of each patch.

\( \text{CONTIG_SD} \) is a 'Shape metric'. It summarises the landscape as the standard deviation of all patches in the landscape. \( \text{CONTIG_SD} \) assesses the spatial connectedness (contiguity) of cells in patches. The metric coerces patch values to a value of 1 and the background to NA. A nine cell focal filter matrix:
... is then used to weight orthogonally contiguous pixels more heavily than diagonally contiguous pixels. Therefore, larger and more connections between patch cells in the rookie case result in larger contiguity index values.

**Units:** None

**Range:** CONTIG_SD >= 0

**Behaviour:** CONTIG_SD = 0 if the contiguity index is identical for all patches. Increases, without limit, as the variation of CONTIG increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_p_contig, lsm_c_contig_sd, lsm_c_contig_cv, lsm_c_contig_mn, 
lsm_l_contig_cv, lsm_l_contig_mn

**Examples**

lsm_l_contig_sd(landscape)

---

**Description**

Coefficient of variation of core area (Core area metric)
Usage

```r
isml_core_cv(
    landscape,
    directions = 8,
    consider_boundary = FALSE,
    edge_depth = 1
)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- `consider_boundary`: Logical if cells that only neighbour the landscape boundary should be considered as core.
- `edge_depth`: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

Details

\[
CORE_{CV} = \text{cv}(CORE[patch_{ij}])
\]

where \(CORE[patch_{ij}]\) is the core area in square meters of each patch.

`CORE_CV` is a ‘Core area metric’. It equals the Coefficient of variation of the core area of each patch in the landscape. The core area is defined as all cells that have no neighbour with a different value than themselves (rook’s case). The metric describes the differences among all patches in the landscape and is easily comparable because it is scaled to the mean.

- **Units**: Hectares
- **Range**: \(CORE_CV \geq 0\)
- **Behaviour**: Equals \(CORE_CV = 0\) if all patches have the same core area. Increases, without limit, as the variation of patch core areas increases.

Value

- `tibble`

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

    lsm_p_core_cv,
    lsm_c_core_mn, lsm_c_core_sd, lsm_c_core_cv,
    lsm_l_core_mn, lsm_l_core_sd

Examples

    lsm_l_core_cv(landscape)

---

**Description**

Mean of core area (Core area metric)

**Usage**

    lsm_l_core_mn(
        landscape,
        directions = 8,
        consider_boundary = FALSE,
        edge_depth = 1
    )

**Arguments**

- `landscape` Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions` The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- `consider_boundary` Logical if cells that only neighbour the landscape boundary should be considered as core.
- `edge_depth` Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

**Details**

\[
CORE_{MN} = \text{mean}(CORE[\text{patch}_{ij}])
\]

where \(CORE[\text{patch}_{ij}]\) is the core area in square meters of each patch.

\(CORE_{MN}\) is a ‘Core area metric’ and equals the mean of core areas of all patches in the landscape. The core area is defined as all cells that have no neighbour with a different value than themselves (rook’s case).
**Units:** Hectares

**Range:** CORE_MN >= 0

**Behaviour:** Equals CORE_MN = 0 if CORE = 0 for all patches. Increases, without limit, as the core area indices increase.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

lsm_p_core, mean,
lsm_c_core_mn, lsm_c_core_sd, lsm_c_core_cv,
lsm_l_core_sd, lsm_l_core_cv

**Examples**

lsm_l_core_mn(landscape)

---

**Description**

Standard deviation of patch core area (class level)

**Usage**

```r
lsm_l_core_sd(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```
Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
consider_boundary Logical if cells that only neighbour the landscape boundary should be considered as core
directions
edge_depth Distance (in cells) a cell has to be away from the patch edge to be considered as core cell

Details

\[
CORE_{SD} = sd(CORE_{[patch_{ij}]})
\]

where \(CORE_{[patch_{ij}]}\) is the core area in square meters of each patch.

CORE_SD is a ‘Core area metric’. It equals the standard deviation of the core area of all patches in the landscape. The core area is defined as all cells that have no neighbor with a different value than themselves (rook’s case). The metric describes the differences among all patches in the landscape.

Units: Hectares

Range: \(CORE_{SD} \geq 0\)

Behaviour: Equals \(CORE_{SD} = 0\) if all patches have the same core area. Increases, without limit, as the variation of patch core areas increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_p_core, sd,
lsm_c_core_mn, lsm_c_core_sd, lsm_c_core_cv,
lsm_l_core_mn, lsm_l_core_cv

Examples

lsm_l_core_sd(landscape)
**Description**

Disjunct core area density (core area metric)

**Usage**

```r
lsm_l_dcad(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

**Details**

\[
DCAD = \left( \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{n_{ij}^{core}}{A} \right) \times 10000 \times 100
\]

where \( n_{ij}^{core} \) is the number of disjunct core areas and \( A \) is the total landscape area in square meters.

DCAD is a ‘Core area metric’. It equals the number of disjunct core areas per 100 ha relative to the total area. A disjunct core area is a ‘patch within the patch’ containing only core cells. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). The metric is relative and therefore comparable among landscapes with different total areas.

**Units**: Number per 100 hectares

**Range**: DCAD >= 0

**Behaviour**: Equals DCAD = 0 when DCORE = 0, i.e. no patch contains a disjunct core area. Increases, without limit, as disjunct core areas become more present, i.e. patches becoming larger and less complex.
Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_c_ndca, lsm_l_ta,
lsm_c_dcad

Examples

lsm_l_dcad(landscape)

--------------------------------------------------------------------------------

lsm_l_dcore_cv  DCORE_CV (landscape level)

--------------------------------------------------------------------------------

Description

Coefficient of variation number of disjunct core areas (Core area metric)

Usage

lsm_l_dcore_cv(  landscape,  directions = 8,  consider_boundary = FALSE,  edge_depth = 1  )

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>landscape</td>
<td>Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.</td>
</tr>
<tr>
<td>directions</td>
<td>The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).</td>
</tr>
<tr>
<td>consider_boundary</td>
<td>Logical if cells that only neighbour the landscape boundary should be considered as core</td>
</tr>
<tr>
<td>edge_depth</td>
<td>Distance (in cells) a cell has the be away from the patch edge to be considered as core cell</td>
</tr>
</tbody>
</table>
Details

\[ DCORE_{CV} = \text{cv}(\text{NCORE}[\text{patch}_{ij}]) \]

where \( \text{NCORE}[\text{patch}_{ij}] \) is the number of core areas.

DCORE_CV is an 'Core area metric'. It summarises the landscape as the Coefficient of variation of all patches belonging to the landscape. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). NCORE counts the disjunct core areas, whereby a core area is a 'patch within the patch' containing only core cells. The metric describes the differences among all patches in the landscape and is easily comparable because it is scaled to the mean.

**Units:** None

**Range:** DCORE_CV >= 0

**Behaviour:** Equals DCORE_CV = 0 if all patches have the same number of disjunct core areas. Increases, without limit, as the variation of number of disjunct core areas increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

lsm_p_ncore, cv,
lsm_c_dcore_mn, lsm_c_dcore_sd, lsm_c_dcore_cv,
lsm_l_dcore_mn, lsm_l_dcore_sd

Examples

lsm_l_dcore_cv(landscape)

<table>
<thead>
<tr>
<th>lsm_l_dcore_mn</th>
<th>DCORE_MN (landscape level)</th>
</tr>
</thead>
</table>

Description

Mean number of disjunct core areas (Core area metric)
Usage

```r
lsm_l_dcore_mn(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell.

Details

\[
DCORE_{MN} = \text{mean}(NCORE[patch_{ij}])
\]

where \( NCORE[patch_{ij}] \) is the number of core areas.

DCORE_MN is an ‘Core area metric’. It summarises the landscape as the mean of all patches in the landscape. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). NCORE counts the disjoint core areas, whereby a core area is a ‘patch within the patch’ containing only core cells.

- **Units**: None
- **Range**: \( DCORE_{MN} > 0 \)
- **Behaviour**: Equals \( DCORE_{MN} = 0 \) if NCORE = 0 for all patches. Increases, without limit, as the number of disjoint core areas increases.

Value

- tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

`lsm_p_ncore.mean`,
`lsm_c_dcore_mn, lsm_c_dcore_sd, lsm_c_dcore_cv`,
`lsm_l_dcore_sd, lsm_l_dcore_cv`

Examples

```r
lsm_l_dcore_mn(landscape)
```

---

### `lsm_l_dcore_sd`

**DCORE SD (landscape level)**

**Description**

Standard deviation number of disjunct core areas (Core area metric)

**Usage**

```r
lsm_l_dcore_sd(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

**Details**

\[
DCORE_{SD} = sd(NCORE[patch_{ij}])
\]

where \( NCORE[patch_{ij}] \) is the number of core areas.

DCORE\_SD is an ‘Core area metric’. It summarises the landscape as the standard deviation of all patches. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). NCORE counts the disjunct core areas, whereby a core area is a ‘patch within the patch’ containing only core cells. The metric describes the differences among all patches in the landscape.


**Units:** None

**Range:** DCORE_SD >= 0

**Behaviour:** Equals DCORE_SD = 0 if all patches have the same number of disjunct core areas. Increases, without limit, as the variation of number of disjunct core areas increases.

### Value

tibble

### References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

### See Also

- `lsm_p_ncore_sd`
- `lsm_c_dcore_mm, lsm_c_dcore_sd`
- `lsm_c_dcore_cv, lsm_l_dcore_mm, lsm_l_dcore_cv`

### Examples

```r
lsm_l_dcore_sd(landscape)
```

---

### Description

Landscape division index (Aggregation metric)

### Usage

```r
lsm_l_division(landscape, directions = 8)
```

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
Details

\[
DIVISION = (1 - \sum_{i=1}^{m} \sum_{j=1}^{n} \left(\frac{a_{ij}}{A}\right)^2)
\]

where \(a_{ij}\) is the area in square meters and \(A\) is the total landscape area in square meters.

DIVISION is an 'Aggregation metric. It can be in as the probability that two randomly selected cells are not located in the same patch. The landscape division index is negatively correlated with the effective mesh size (\(lsm_c\_mesh\)).

**Units:** Proportion

**Ranges:** \(0 \leq Division < 1\)

**Behaviour:** Equals DIVISION = 0 if only one patch is present. Approaches DIVISION = 1 if all patches of class i are single cells.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

\(lsm_p\_area, lsm_l\_ta, lsm_c\_division\)

**Examples**

\(lsm_l\_division(landscape)\)
Description

Edge Density (Area and Edge metric)

Usage

\[ lsm\_l\_ed(landscape, \text{count\_boundary} = \text{FALSE}, \text{directions} = 8) \]

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `count_boundary`: Count landscape boundary as edge
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ ED = \frac{E}{A} \times 10000 \]

where \( E \) is the total landscape edge in meters and \( A \) is the total landscape area in square meters.

ED is an 'Area and Edge metric'. The edge density equals all edges in the landscape in relation to the landscape area. The boundary of the landscape is only included in the corresponding total class edge length if `count_boundary = TRUE`. The metric describes the configuration of the landscape, e.g., because an overall aggregation of classes will result in a low edge density. The metric is standardized to the total landscape area, and therefore comparisons among landscapes with different total areas are possible.

Units: Meters per hectare

Range: ED >= 0

Behaviour: Equals ED = 0 if only one patch is present (and the landscape boundary is not included) and increases, without limit, as the landscapes becomes more patchy

Value

- tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

lsm_l_te, lsm_l_ta, lsm_c_ed

Examples

lsm_l_ed(landscape)

Description

Coefficient of variation of euclidean nearest-neighbor distance (Aggregation metric)

Usage

lsm_l_enn_cv(landscape, directions = 8, verbose = TRUE)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
verbose Print warning message if not sufficient patches are present

Details

\[ ENN_{CV} = cv(ENN[patch_{ij}]) \]

where \( ENN[patch_{ij}] \) is the euclidean nearest-neighbor distance of each patch.

ENN_CV is an ‘Aggregation metric’. It summarises the landscape as the Coefficient of variation of all patches in the landscape. ENN measures the distance to the nearest neighbouring patch of the same class \( i \). The distance is measured from edge-to-edge. The range is limited by the cell resolution on the lower limit and the landscape extent on the upper limit. The metric is a simple way to describe patch isolation. Because it is scaled to the mean, it is easily comparable among different landscapes.

Units: Meters

Range: \( ENN_{CV} \geq 0 \)

Behaviour: Equals \( ENN_{CV} = 0 \) if the euclidean nearest-neighbor distance is identical for all patches. Increases, without limit, as the variation of ENN increases.
Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_enn_cv, lsm_c_enn_mn, lsm_c_enn_sd, lsm_c_enn_cv, lsm_l_enn_mn, lsm_l_enn_sd.

Examples

lsm_l_enn_cv(landscape)

---

lsm_l_enn_mn  

ENN_MN (landscape level)

Description

Mean of euclidean nearest-neighbor distance (Aggregation metric)

Usage

lsm_l_enn_mn(landscape, directions = 8, verbose = TRUE)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
verbose Print warning message if not sufficient patches are present
**lsm_l_enn_mn**

**Details**


\[ ENN_{MN} = cv(mean[patch_{ij}]) \]

where \( ENN[patch_{ij}] \) is the euclidean nearest-neighbor distance of each patch.

**ENN\_CV** is an 'Aggregation metric'. It summarises the landscape as the mean of all patches in the landscape. ENN measures the distance to the nearest neighbouring patch of the same class \( i \). The distance is measured from edge-to-edge. The range is limited by the cell resolution on the lower limit and the landscape extent on the upper limit.

**Units:** Meters

**Range:** \( ENN\_MN > 0 \)

**Behaviour:** Approaches \( ENN\_MN = 0 \) as the distance to the nearest neighbour decreases, i.e. patches of the same class \( i \) are more aggregated. Increases, without limit, as the distance between neighbouring patches of the same class \( i \) increases, i.e. patches are more isolated.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html


**See Also**

lsm_p_enn, mean, lsm_c_enn_mn, lsm_c_enn_sd, lsm_c_enn_cv, lsm_l_enn_sd, lsm_l_enn_cv

**Examples**

lsm_l_enn_mn(landscape)
Description

Standard deviation of euclidean nearest-neighbor distance (Aggregation metric)

Usage

\texttt{lsml_enn_sd}\texttt{(landscape, directions = 8, verbose = TRUE)}

Arguments

\begin{itemize}
  \item \texttt{landscape} Raster\* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
  \item \texttt{directions} The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
  \item \texttt{verbose} Print warning message if not sufficient patches are present
\end{itemize}

Details

\[
ENN_{SD} = sd(ENN[patch_{ij}])
\]

where \(ENN[patch_{ij}]\) is the euclidean nearest-neighbor distance of each patch.

ENN_CV is an ‘Aggregation metric’. It summarises in the landscape as the standard deviation of all patches in the landscape. ENN measures the distance to the nearest neighbouring patch of the same class \(i\). The distance is measured from edge-to-edge. The range is limited by the cell resolution on the lower limit and the landscape extent on the upper limit. The metric is a simple way to describe patch isolation. Because it is scaled to the mean, it is easily comparable among different landscapes.

- \textbf{Units:} Meters
- \textbf{Range:} \(ENN_{SD} \geq 0\)
- \textbf{Behaviour:} Equals \(ENN_{SD} = 0\) if the euclidean nearest-neighbor distance is identical for all patches. Increases, without limit, as the variation of ENN increases.

Value

\texttt{tibble}

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

### lsm_l_ent

**See Also**

- `lsm_p_enn`, `sd`, `lsm_c_enn_mn`, `lsm_c_enn_sd`, `lsm_c_enn_cv`,
- `lsm_l_enn_mn`, `lsm_l_enn_cv`

**Examples**

```
> lsm_l_ent(landscape)

  lsm_l_ent  ENT (landscape level)

```

**Description**

Marginal entropy $\{H(x)\}$

**Usage**

```
> lsm_l_ent(landscape, neighbourhood = 4, base = "log2")
```

**Arguments**

- `landscape` Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `neighbourhood` The number of directions in which cell adjacencies are considered as neighbours: 4 (rook’s case) or 8 (queen’s case). The default is 4.
- `base` The unit in which entropy is measured. The default is "log2", which compute entropy in "bits". "log" and "log10" can be also used.

**Details**

It measures a diversity (thematic complexity) of landscape classes.

**Value**

tibble

**References**


**See Also**

- `lsm_l_condent`, `lsm_l_mutinf`, `lsm_l_joinent`, `lsm_l_relmutinf`
Examples

lsm_l_ent(landscape)

Description

Coefficient of variation fractal dimension index (Shape metric)

Usage

lsm_l_frac_cv(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ FRAC_{CV} = cv(FRAC[patch_{ij}]) \]

where \( FRAC[patch_{ij}] \) equals the fractal dimension index of each patch.

FRAC_CV is a ‘Shape metric’. The metric summarises the landscape as the Coefficient of variation of the fractal dimension index of all patches in the landscape. The fractal dimension index is based on the patch perimeter and the patch area and describes the patch complexity. The Coefficient of variation is scaled to the mean and comparable among different landscapes.

Units: None
Range: FRAC_CV >= 0

Behaviour: Equals FRAC_CV = 0 if the fractal dimension index is identical for all patches. Increases, without limit, as the variation of the fractal dimension indices increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**Description**

Mean fractal dimension index (Shape metric)

**Usage**

```r
lsm_l_frac_mn(landscape, directions = 8)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

$$ FRAC_{MN} = mean(FRAC[patch_{ij}]) $$

where $FRAC[patch_{ij}]$ equals the fractal dimension index of each patch.

FRAC_MN is a 'Shape metric'. The metric summarises the landscape as the mean of the fractal dimension index of all patches in the landscape. The fractal dimension index is based on the patch perimeter and the patch area and describes the patch complexity. The Coefficient of variation is scaled to the mean and comparable among different landscapes.

**Units:** None

**Range:** FRAC_MN > 0

**Behaviour:** Approaches FRAC_MN = 1 if all patches are squared and FRAC_MN = 2 if all patches are irregular.

**Value**

tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_frac, mean, lsm_c_frac_mn, lsm_c_frac_sd, lsm_c_frac_cv, lsm_l_frac_sd, lsm_l_frac_cv

Examples

lsm_l_frac_mn(landscape)

---

**lsm_l_frac_sd**

*FRAC_SD (landscape level)*

**Description**

Standard deviation fractal dimension index (Shape metric)

**Usage**

lsm_l_frac_sd(landscape, directions = 8)

**Arguments**

landscape: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

directions: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
FRAC_SD = sd(FRAC[patch_{ij}])
\]

where \(FRAC[patch_{ij}]\) equals the fractal dimension index of each patch.

FRAC_SD is a ‘Shape metric’. The metric summarises the landscape as the standard deviation of the fractal dimension index of all patches in the landscape. The fractal dimension index is based on the patch perimeter and the patch area and describes the patch complexity.

**Units:** None

**Range:** FRAC_SD\(\geq 0\)

**Behaviour:** Equals FRAC_SD = 0 if the fractal dimension index is identical for all patches. Increases, without limit, as the variation of the fractal dimension indices increases.
Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_frac_sd,
lsm_c_frac_mn, lsm_c_frac_sd, lsm_c_frac_cv,
lsm_l_frac_mn, lsm_l_frac_cv

Examples

lsm_l_frac_sd(landscape)
Details

\[ GYRATE_{CV} = cv(GYRATE[patch_{ij}]) \]

where \( GYRATE[patch_{ij}] \) equals the radius of gyration of each patch.

\( GYRATE_{CV} \) is an 'Area and edge metric'. The metric summarises the landscape as the Coefficient of variation of the radius of gyration of all patches in the landscape. \( GYRATE \) measures the distance from each cell to the patch centroid and is based on cell center-to-cell center distances. The metrics characterises both the patch area and compactness. The Coefficient of variation is scaled to the mean and comparable among different landscapes.

If \( \text{cell\_center = TRUE} \) some patches might have several possible cell-center centroids. In this case, the gyrate index is based on the mean distance of all cells to all possible cell-center centroids.

**Units:** Meters

**Range:** \( GYRATE_{CV} \geq 0 \)

**Behaviour:** Equals \( GYRATE_{CV} = 0 \) if the radius of gyration is identical for all patches. Increases, without limit, as the variation of the radius of gyration increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

`lsm_p_gyrate.cv`,
`lsm_c_gyrate_mn, lsm_c_gyrate_sd, lsm_c_gyrate_cv`,
`lsm_l_gyrate_mn, lsm_l_gyrate_cv`

**Examples**

`lsm_l_gyrate_cv(landscape)`
Description

Mean radius of gyration (Area and edge metric)

Usage

\texttt{lsml\_gyrate\_mn(landscape, directions = 8, cell\_center = FALSE)}

Arguments

- \texttt{landscape}: Raster\* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- \texttt{directions}: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- \texttt{cell\_center}: If true, the coordinates of the centroid are forced to be a cell center within the patch.

Details

\[ GYRATE_{MN} = \text{mean}(GYRATE_{[\text{patch}_{ij}]}) \]

where \( GYRATE_{[\text{patch}_{ij}]} \) equals the radius of gyration of each patch.

\( GYRATE_{MN} \) is an ‘Area and edge metric’. The metric summarises the landscape as the mean of the radius of gyration of all patches in the landscape. \( GYRATE \) measures the distance from each cell to the patch centroid and is based on cell center-to-cell center distances. The metric characterises both the patch area and compactness.

If \texttt{cell\_center = TRUE} some patches might have several possible cell-center centroids. In this case, the gyrate index is based on the mean distance of all cells to all possible cell-center centroids.

Units: Meters

Range: \( GYRATE_{MN} >= 0 \)

Behaviour: Approaches \( GYRATE_{MN} = 0 \) if every patch is a single cell. Increases, without limit, when only one patch is present.

Value

tibble
References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also
lsm_p_gyrate, mean,
lsm_c_gyrate_mn, lsm_c_gyrate_sd, lsm_c_gyrate_cv,
lsm_l_gyrate_sd, lsm_l_gyrate_cv

Examples
lsm_l_gyrate_mn(landscape)

Description
Standard deviation radius of gyration (Area and edge metric)

Usage
lsm_l_gyrate_sd(landscape, directions = 8, cell_center = FALSE)

Arguments
landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
cell_center If true, the coordinates of the centroid are forced to be a cell center within the patch.

Details
\[ GYRATE_{SD} = sd(GYRATE[patch_{ij}]) \]

where \( GYRATE[patch_{ij}] \) equals the radius of gyration of each patch.

GYRATE_SD is an 'Area and edge metric'. The metric summarises the landscape as the standard deviation of the radius of gyration of all patches in the landscape. GYRATE measures the distance from each cell to the patch centroid and is based on cell center-to-cell center distances. The metrics characterises both the patch area and compactness.
If \texttt{cell\_center} = \texttt{TRUE} some patches might have several possible cell-center centroids. In this case, the gyrate index is based on the mean distance of all cells to all possible cell-center centroids.

**Units:** Meters

**Range:** GYRATE\_SD $\geq 0$

**Behaviour:** Equals GYRATE\_SD = 0 if the radius of gyration is identical for all patches. Increases, without limit, as the variation of the radius of gyration increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

\texttt{lsm\_p\_gyrate\_cv, lsm\_c\_gyrate\_mn, lsm\_c\_gyrate\_sd, lsm\_c\_gyrate\_cv, lsm\_l\_gyrate\_mn, lsm\_l\_gyrate\_cv}

**Examples**

\texttt{lsm\_l\_gyrate\_sd(landscape)}

---

**Description**

Interspersion and Juxtaposition index (Aggregation metric)

**Usage**

\texttt{lsm\_l\_iji(landscape, verbose = TRUE)}

**Arguments**

- \texttt{landscape} Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- \texttt{verbose} Print warning message if not sufficient patches are present
Details

\[ IJI = \frac{-\sum_{i=1}^{m} \sum_{k=i+1}^{m} \left[ \frac{c_{ik}}{E} \right] \ln \left( \frac{c_{ik}}{E} \right)}{\ln(0.5[m(m-1)])} \times 100 \]

where \( c_{ik} \) are the unique adjacencies of all classes (lower/upper triangle of the adjacency table - without the diagonal), \( E \) is the total length of edges in the landscape and \( m \) is the number of classes.

IJI is an 'Aggregation metric'. It is a so called "salt and pepper" metric and describes the intermixing of classes (i.e. without considering like adjacencies - the diagonal of the adjacency table). The number of classes to calculate IJI must be \( \geq 3 \).

**Units:** Percent

**Range:** 0 < IJI <= 100

**Behaviour:** Approaches 0 if a class is only adjacent to a single other class and equals 100 when a class is equally adjacent to all other classes.

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html


See Also

\lsm_c_iji

Examples

\lsm_l_iji(landscape)
<table>
<thead>
<tr>
<th><strong>Description</strong></th>
<th>Joint entropy $H(x, y)$</th>
</tr>
</thead>
</table>

**Usage**

```r
lsm_l_joinent(landscape, neighbourhood = 4, ordered = TRUE, base = "log2")
```

**Arguments**

- `landscape` : Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `neighbourhood` : The number of directions in which cell adjacencies are considered as neighbours: 4 (rook’s case) or 8 (queen’s case). The default is 4.
- `ordered` : The type of pairs considered. Either ordered (TRUE) or unordered (FALSE). The default is TRUE.
- `base` : The unit in which entropy is measured. The default is "log2", which compute entropy in "bits". "log" and "log10" can be also used.

**Details**

Complexity of a landscape pattern. An overall spatio-thematic complexity metric.

**Value**

tibble

**References**


**See Also**

- `lsm_l_ent`, `lsm_l_condent`, `lsm_l_mutinf`, `lsm_l_relmutinf`

**Examples**

```r
lsm_l_joinent(landscape)
```
Description

Largest patch index (Area and Edge metric)

Usage

```r
lsm_l_lpi(landscape, directions = 8)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
LPI = \frac{\max(a_{ij})}{A} \times 100
\]

where \(\max(a_{ij})\) is the area of the patch in square meters and \(A\) is the total landscape area in square meters.

The largest patch index is an 'Area and edge metric'. It is the percentage of the landscape covered by the largest patch in the landscape. It is a simple measure of dominance.

**Units**: Percentage

**Range**: \(0 < LPI \leq 100\)

**Behaviour**: Approaches \(LPI = 0\) when the largest patch is becoming small and equals \(LPI = 100\) when only one patch is present

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

- `lsm_p_area`
- `lsm_l_ta`
- `lsm_c_lpi`
\textit{lsm}\_l\_lsi

\textbf{Examples}

\begin{verbatim}
lsm_l_lsi(landscape)
\end{verbatim}

\begin{tabular}{ll}
\textit{lsm}\_l\_lsi & \textit{LSI (landscape level)}
\end{tabular}

\textbf{Description}

Landscape shape index (Aggregation metric)

\textbf{Usage}

\begin{verbatim}
lsm_l_lsi(landscape)
\end{verbatim}

\textbf{Arguments}

landscape: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

\textbf{Details}

\[ LSI = \frac{E}{\min E} \]

where \( E \) is the total edge length in cell surfaces and \( \min E \) is the minimum total edge length in cell surfaces.

LSI is an 'Aggregation metric'. It is the ratio between the actual landscape edge length and the hypothetical minimum edge length. The minimum edge length equals the edge length if only one patch would be present.

\textbf{Units:} None

\textbf{Ranges:} LSI \( \geq 1 \)

\textbf{Behaviour:} Equals LSI = 1 when only one squared patch is present. Increases, without limit, as the length of the actual edges increases, i.e. the patches become less compact.

\textbf{Value}

tibble

\textbf{References}

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

Description

Effective Mesh Size (Aggregation metric)

Usage

\[
\text{lsm}_l\_\text{mesh}(\text{landscape}, \text{directions} = 8)
\]

Arguments

- \text{landscape} \quad \text{Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.}
- \text{directions} \quad \text{The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).}

Details

\[
MESH = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij}^2}{A} * \frac{1}{10000}
\]

where \(a_{ij}\) is the patch area in square meters and \(A\) is the total landscape area in square meters.

The effective mesh size is an ‘Aggregation metric’. Because each patch is squared before the sum is calculated and the sum is standardized by the total landscape area, MESH is a relative measure of patch structure. MESH is perfectly, negatively correlated to \text{lsm}_c\_\text{division}.

Units: Hectares

Range: cell size / total area <= MESH <= total area

Behaviour: Equals cellsize/total area if class covers only one cell and equals total area if only one patch is present.

Value

tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_area, lsm_l_ta, lsm_c_mesh

Examples

lsm_l_mesh(landscape)

---

lsm_l_msidi  MSIDI (landscape level)

Description

Modified Simpson’s diversity index (Diversity metric)

Usage

lsm_l_msidi(landscape, directions = 8)

Arguments

landscape  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ MSIDI = - \ln \sum_{i=1}^{m} P_i^2 \]

where \( P_i \) is the landscape area proportion of class i.

MSIDI is a 'Diversity metric'.

Units: None

Range: MSIDI \( \geq \) 0

Behaviour: MSIDI = 0 if only one patch is present and increases, without limit, as the amount of patches with equally distributed landscape proportions increases
**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

[1] lsm_l_sidi

**Examples**

```r
lsm_l_msiei(landscape)
```
Details

\[ MSIE_i = -\ln \sum_{i=1}^{m} P_i^2 / \ln m \]

where \( P_i \) is the landscape area proportion of class i. MSIEI is a 'Diversity metric'.

**Units:** None

**Range:** \( 0 \leq MSIEI < 1 \)

**Behaviour:** MSIEI = 0 when only one patch is present and approaches MSIEI = 1 as the proportional distribution of patches becomes more even

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_l_siei

**Examples**

lsm_l_msiei(landscape)

---

lsm_l_mutinf  MUTINF (landscape level)

**Description**

Mutual information \( \text{\em I(y,x)} \)

**Usage**

lsm_l_mutinf(landscape, neighbourhood = 4, ordered = TRUE, base = "log2")
lsm_l_ndca

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
neighbourhood The number of directions in which cell adjacencies are considered as neigh-
bours: 4 (rook’s case) or 8 (queen’s case). The default is 4.
ordered The type of pairs considered. Either ordered (TRUE) or unordered (FALSE).
The default is TRUE.
base The unit in which entropy is measured. The default is "log2", which compute
entropy in "bits". "log" and "log10" can be also used.

Details

It disambiguates landscape pattern types characterize by the same value of an overall complexity
(lsm_l_joinent).

Value
tibble

References

Nowosad J., TF Stepinski. 2019. Information theory as a consistent framework for quantification
and classification of landscape patterns. https://doi.org/10.1007/s10980-019-00830-x

See Also

lsm_l_ent, lsm_l_condent, lsm_l_joinent, lsm_l_relmutinf

Examples

lsm_l_mutinf(landscape)

---

lsm_l_ndca NDCA (landscape level)

Description

Number of disjunct core areas (Core area metric)

Usage

lsm_l_ndca(
    landscape,
    directions = 8,
    consider_boundary = FALSE,
    edge_depth = 1
)
Arguments

landscape  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
consider_boundary  Logical if cells that only neighbour the landscape boundary should be considered as core
edge_depth  Distance (in cells) a cell has the be away from the patch edge to be considered as core cell

Details

\[ NDCA = \sum_{i=1}^{m} \sum_{j=1}^{n} n_{ij}^{core} \]

where \( n_{ij}^{core} \) is the number of disjunct core areas.

NDCA is a 'Core area metric'. The metric summarises the landscape as the sum of all patches in the landscape. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). NDCA counts the disjunct core areas, whereby a core area is a 'patch within the patch' containing only core cells. It describes patch area and shape simultaneously (more core area when the patch is large, however, the shape must allow disjunct core areas). Thereby, a compact shape (e.g. a square) will contain less disjunct core areas than a more irregular patch.

Units:  None

Range:  NDCA >= 0

Behaviour:  NDCA = 0 when TCA = 0, i.e. every cell in the landscape is an edge cell. NDCA increases, with out limit, as core area increases and patch shapes allow disjunct core areas (i.e. patch shapes become rather complex).

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

  lsm_c_tca,
  lsm_p_ncore, lsm_c_ndca
Examples

```r
lsm_l_ndca(landscape)
```

### Description

Number of patches (Aggregation metric)

### Usage

```r
lsm_l_np(landscape, directions = 8)
```

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

### Details

\[ NP = N \]

where \( N \) is the number of patches.

NP is an 'Aggregation metric'. It describes the fragmentation of the landscape, however, does not necessarily contain information about the configuration or composition of the landscape.

**Units**: None

**Ranges**: \( NP \geq 1 \)

**Behaviour**: Equals \( NP = 1 \) when only one patch is present and increases, without limit, as the number of patches increases

### Value

tibble

### References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
lsm_l_paffrac

See Also
lsm_c_np

Examples
lsm_l_np(landscape)

---

lsm_l_paffrac  **PAFRAC (landscape level)**

Description
Perimeter-Area Fractal Dimension (Shape metric)

Usage
lsm_l_paffrac(landscape, directions = 8, verbose = TRUE)

Arguments
- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **verbose**: Print warning message if not sufficient patches are present

Details

\[
PAFRAC = \frac{2}{\beta}
\]

where \( \beta \) is the slope of the regression of the area against the perimeter (logarithm) \( N \sum_{i=1}^{m} \sum_{j=1}^{n} \ln a_{ij} = a + \beta N \sum_{i=1}^{m} \sum_{j=1}^{n} \ln p_{ij} \)

PAFRAC is a ‘Shape metric’. It describes the patch complexity of the landscape while being scale independent. This means that increasing the patch size while not changing the patch form will not change the metric. However, it is only meaningful if the relationship between the area and perimeter is linear on a logarithmic scale. Furthermore, if there are less than 10 patches in the landscape, the metric returns NA because of the small-sample issue.

Units: None

Range: 1 <= PAFRAC <= 2

Behaviour: Approaches PAFRAC = 1 for patches with simple shapes and approaches PAFRAC = 2 for irregular shapes
Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also
lsm_p_area, lsm_p_perim,
lsm_c_pafrac

Examples
lsm_l_pafrac(landscape)

---

**lsm_l_para_cv**

*PARA_CV (landscape level)*

**Description**

Coefficient of variation perimeter-area ratio (Shape metric)

**Usage**
lsm_l_para_cv(landscape, directions = 8)

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[ PARA_{CV} = cv(PARA[patch_{ij}]) \]

where \( PARA[patch_{ij}] \) is the perimeter area ratio of each patch.

PARA_{CV} is a ‘Shape metric’. It summarises the landscape as the Coefficient of variation of each patch belonging in the landscape. The perimeter-area ratio describes the patch complexity in a straightforward way. However, because it is not standarised to a certain shape (e.g. a square), it is not scale independent, meaning that increasing the patch size while not changing the patch form will change the ratio.
**Units:** None

**Range:** PARA.CV >= 0

**Behaviour:** Equals PARA.CV = 0 if the perimeter-area ratio is identical for all patches. Increases, without limit, as the variation of the perimeter-area ratio increases.

### Value

tibble

### References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

### See Also

lsm_p_para_cv,
lsm_c_para_mn, lsm_c_para_sd, lsm_c_para_cv,
lsm_l_para_mn, lsm_l_para_sd

### Examples

lsm_l_para_cv(landscape)

---

**lsm_l_para_mn**  
PARA.MN (landscape level)

### Description

Mean perimeter-area ratio (Shape metric)

### Usage

lsm_l_para_mn(landscape, directions = 8)

### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
PARA_{MN} = \text{mean}(\text{PARA}_{\text{patch}_{ij}})

where \text{PARA}_{\text{patch}_{ij}} is the perimeter area ratio of each patch.

PARA_{MN} is a 'Shape metric'. It summarises the landscape as the mean of each patch in the landscape. The perimeter-area ratio describes the patch complexity in a straightforward way. However, because it is not standardised to a certain shape (e.g. a square), it is not scale independent, meaning that increasing the patch size while not changing the patch form will change the ratio.

**Units:** None

**Range:** PARA_{MN} > 0

**Behaviour:** Approaches PARA_{MN} > 0 if PARA for each patch approaches PARA > 0, i.e. the form approaches a rather small square. Increases, without limit, as PARA increases, i.e. patches become more complex.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

lsm_p_para, mean,

lsm_c_para_mn, lsm_c_para_sd, lsm_c_para_cv,

lsm_l_para_sd, lsm_l_para_cv

**Examples**

lsm_l_para_mn(landscape)
**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
PARA_{SD} = sd(PARA[patch_{ij}])
\]

where \( PARA[patch_{ij}] \) is the perimeter area ratio of each patch.

`PARA_SD` is a ’Shape metric’. It summarises the landscape as the standard deviation of each patch belonging in the landscape. The perimeter-area ratio describes the patch complexity in a straightforward way. However, because it is not standardised to a certain shape (e.g. a square), it is not scale independent, meaning that increasing the patch size while not changing the patch form will change the ratio.

**Units:** None

**Range:** \( PARA_{SD} \geq 0 \)

**Behaviour:** Equals \( PARA_{SD} = 0 \) if the perimeter-area ratio is identical for all patches. Increases, without limit, as the variation of the perimeter-area ratio increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

- `lsm_p_para_sd`
- `lsm_c_para_mn, lsm_c_para_sd, lsm_c_para_cv`
- `lsm_l_para_mn, lsm_l_para_cv`

**Examples**

```r
lsm_l_para_sd(landscape)
```
Description
Patch density (Aggregation metric)

Usage
lsm_l_pd(landscape, directions = 8)

Arguments
landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ PD = \frac{N}{A} \times 10000 \times 100 \]

where \( N \) is the number of patches and \( A \) is the total landscape area in square meters.

PD is an ‘Aggregation metric’. It describes the fragmentation the landscape, however, does not necessarily contain information about the configuration or composition of the landscape. In contrast to lsm_l_np it is standardized to the area and comparisons among landscapes with different total area are possible.

Units: Number per 100 hectares

Ranges: \( 0 < PD \leq 1e+06 \)

Behaviour: Increases as the landscape gets more patchy. Reaches its maximum if every cell is a different patch.

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_c_np, lsm_l_ta,
lsm_c_pd
Examples

\texttt{lsm\_l\_pd(landscape)}

\begin{align*}
\textit{Description} \\
\text{Percentage of Like Adjacencies (Aggregation metric)}
\end{align*}

Usage

\texttt{lsm\_l\_pladj(landscape)}

Arguments

\begin{itemize}
\item \texttt{landscape} \hspace{1cm} \text{Raster\* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.}
\end{itemize}

Details

\begin{equation}
\text{PLADJ} = \left( \frac{g_{ij}}{\sum_{k=1}^{m} g_{ik}} \right) \times 100
\end{equation}

where \( g_{ij} \) is the number of adjacencies between cells of class \( i \) and \( g_{ik} \) is the number of adjacencies between cells of class \( i \) and \( k \).

PLADJ is an 'Aggregation metric'. It calculates the frequency how often patches of different classes \( i \) (focal class) and \( k \) are next to each other, and following is a measure of class aggregation. The adjacencies are counted using the double-count method.

\begin{itemize}
\item \textbf{Units:} Percent
\item \textbf{Ranges:} \( 0 \leq \text{PLADJ} \leq 100 \)
\item \textbf{Behaviour:} Equals PLADJ = 0 if class \( i \) is maximal disaggregated, i.e. every cell is a different patch. Equals PLADJ = 100 when the only one patch is present.
\end{itemize}

Value

\begin{itemize}
\item \texttt{tibble}
\end{itemize}

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: \url{http://www.umass.edu/landeco/research/fragstats/}
**Examples**

```r
lsm_l_pladj(landscape)
```

---

**Description**

Patch richness (Diversity metric)

**Usage**

```r
lsm_l_pr(landscape)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

**Details**

\[ PR = m \]

where \( m \) is the number of classes

PR is a 'Diversity metric'. It is one of the simplest diversity and composition measures. However, because of its absolute nature, it is not comparable among landscapes with different total areas.

- **Units**: None
- **Range**: \( PR \geq 1 \)
- **Behaviour**: Equals \( PR = 1 \) when only one patch is present and increases, without limit, as the number of classes increases

**Value**

- tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**Examples**

```r
lsm_l_pr(landscape)
```
**Description**

Patch richness density (Diversity metric)

**Usage**

```
1sm_l_prd(landscape, directions = 8)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
PRD = \frac{m}{A} \times 10000 \times 100
\]

where \(m\) is the number of classes and \(A\) is the total landscape area in square meters.

PRD is a 'Diversity metric'. It is one of the simplest diversity and composition measures. In contrast to `lsm_l_pr`, it is a relative measure and following, comparable among landscapes with different total landscape areas.

- **Units**: Number per 100 hectares
- **Range**: \(PR > 0\)
- **Behaviour**: Approaches \(PR > 1\) when only one patch is present and the landscape is rather large. Increases, without limit, as the number of classes increases and the total landscape area decreases.

**Value**

`tibble`

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: [http://www.umass.edu/landeco/research/fragstats/](http://www.umass.edu/landeco/research/fragstats/)

**Examples**

```
1sm_l_prd(landscape)
```
Description

Relative mutual information

Usage

\texttt{lsm\_l\_relmutinf(landscape, neighbourhood = 4, ordered = TRUE, base = "log2")}

Arguments

- \texttt{landscape}: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- \texttt{neighbourhood}: The number of directions in which cell adjacencies are considered as neighbours: 4 (rook's case) or 8 (queen's case). The default is 4.
- \texttt{ordered}: The type of pairs considered. Either ordered (TRUE) or unordered (FALSE). The default is TRUE.
- \texttt{base}: The unit in which entropy is measured. The default is "log2", which compute entropy in "bits". "log" and "log10" can be also used.

Details

Due to the spatial autocorrelation, the value of mutual information tends to grow with a diversity of the landscape (marginal entropy). To adjust this tendency, it is possible to calculate relative mutual information by dividing the mutual information by the marginal entropy. Relative mutual information always has a range between 0 and 1 and can be used to compare spatial data with different number and distribution of categories. When the value of mutual information equals to 0, then relative mutual information is 1.

Value

tibble

References


See Also

lsm\_l\_ent, lsm\_l\_condent, lsm\_l\_joinent, lsm\_l\_mutinf

Examples

\texttt{lsm\_l\_relmutinf(landscape)}
Description
Relative patch richness (Diversity metric)

Usage
\texttt{lsm\_l\_rpr(landscape, classes\_max = NULL, verbose = TRUE)}

Arguments
\begin{itemize}
  \item \texttt{landscape} \hspace{1cm} Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
  \item \texttt{classes\_max} \hspace{1cm} Potential maximum number of present classes
  \item \texttt{verbose} \hspace{1cm} Print warning message if not sufficient patches are present
\end{itemize}

Details
\[ RPR = \frac{m}{m_{max}} \times 100 \]
where \( m \) is the number of classes and \( m_{max} \) is the (theoretical) maximum number of classes.

RPR is an 'Diversity metric'. The metric calculates the percentage of present classes in the landscape in relation to a (theoretical) number of maximum classes. The user has to specify the maximum number of classes. Note, that if \texttt{classes\_max} is not provided, the function returns \texttt{NA}.

Units: Percentage

Ranges: \( 0 < RPR \leq 100 \)

Behaviour: Approaches \( RPR > 0 \) when only one class type is present, but the maximum number of classes is large. Equals \( RPR = 100 \) when \( m = m_{\text{max}} \)

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: \url{http://www.umass.edu/landeco/research/fragstats/}

Examples
\texttt{lsm\_l\_rpr(landscape, classes\_max = 5)}
Description

Coefficient of variation shape index (Shape metric)

Usage

```r
lsm_l_shape_cv(landscape, directions = 8)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
SHAPE_{CV} = cv(SHAPE[patch_{ij}])
\]

where \(SHAPE[patch_{ij}]\) is the shape index of each patch.

SHAPE\(_{CV}\) is a 'Shape metric'. The landscape is summarised as the Coefficient of variation of all patches in the landscape. SHAPE describes the ratio between the actual perimeter of the patch and the hypothetical minimum perimeter of the patch. The minimum perimeter equals the perimeter if the patch would be maximally compact.

**Units:** None

**Range:** \(SHAPE_{CV} \geq 0\)

**Behaviour:** Equals \(SHAPE_{CV} = 0\) if all patches have an identical shape index. Increases, without limit, as the variation of the shape index increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**lsm_l_shape_mn**

See Also

- lsm_p_shape.cv,
- lsm_c_shape_mn, lsm_c_shape_sd,
- lsm_c_shape_cv, lsm_l_shape_mn, lsm_l_shape_sd

Examples

lsm_l_shape_cv(landscape)

---

| lsm_l_shape_mn | SHAPE_MN (landscape level) |

Description

Mean shape index (Shape metric)

Usage

lsm_l_shape_mn(landscape, directions = 8)

Arguments

- landscape: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- directions: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ SHAPE_{MN} = \text{mean}(SHAPE[patch_{ij}]) \]

where \( SHAPE[patch_{ij}] \) is the shape index of each patch.

SHAPE_MN is a ‘Shape metric’. The landscape is summarised as the mean of all patches in the landscape. SHAPE describes the ratio between the actual perimeter of the patch and the hypothetical minimum perimeter of the patch. The minimum perimeter equals the perimeter if the patch would be maximally compact.

Units: None

Range: SHAPE_SD \( \geq 1 \)

Behaviour: Equals SHAPE_MN \( = 0 \) if all patches are squares. Increases, without limit, as the shapes of patches become more complex.

Value
tibble
References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_p_shape, mean,
lsm_c_shape_mn, lsm_c_shape_sd, lsm_c_shape_cv,
lsm_l_shape_sd, lsm_l_shape_cv

Examples

lsm_l_shape_mn(landscape)

<table>
<thead>
<tr>
<th>lsm_l_shape_sd</th>
<th>SHAPE_SD (landscape level)</th>
</tr>
</thead>
</table>

Description

Standard deviation shape index (Shape metric)

Usage

lsm_l_shape_sd(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ SHAPE_{SD} = sd(SHAPE[patch_{ij}]) \]

where \( SHAPE[patch_{ij}] \) is the shape index of each patch.

SHAPE_SD is a ‘Shape metric’. The landscape summarised as the standard deviation of all patches in the landscape. SHAPE describes the ratio between the actual perimeter of the patch and the hypothetical minimum perimeter of the patch. The minimum perimeter equals the perimeter if the patch would be maximally compact.

Units: None

Range: SHAPE_SD >= 0

Behaviour: Equals SHAPE_SD = 0 if all patches have an identical shape index. Increases, without limit, as the variation of the shape index increases.
Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_p_shape, sd,
lsm_c_shape_mn, lsm_c_shape_sd,lsm_c_shape_cv,
lsm_l_shape_mn, lsm_l_shape_sd

Examples
lsm_l_shape_sd(landscape)

\begin{verbatim}
  lsm_l_shdi(landscape)
\end{verbatim}

\begin{verbatim}
  SHDI (landscape level)
\end{verbatim}

Description
Shannon’s diversity index (Diversity metric)

Usage
lsm_l_shdi(landscape)

Arguments
landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

Details

\[ SHDI = - \sum_{i=1}^{m} (P_i \ast \ln P_i) \]

where \( P_i \) is the proportion of class \( i \).

SHDI is a 'Diversity metric'. It is a widely used metric in biodiversity and ecology and takes both the number of classes and the abundance of each class into account.

Units: None
**Range:** SHDI $\geq 0$

**Behaviour:** Equals SHDI = 0 when only one patch is present and increases, without limit, as the number of classes increases while the proportions are equally distributed.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_c_pland

**Examples**

lsm_l_shdi(landscape)

---

| lsm_l_shei | SHEI (landscape level) |

**Description**

Shannons’s evenness index (Diversity metric)

**Usage**

lsm_l_shei(landscape)

**Arguments**

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
Details

\[
SHEI = -\frac{\sum_{i=1}^{m} (P_i \ln P_i)}{\ln m}
\]

where \(P_i\) is the proportion of class \(i\) and \(m\) is the number of classes.

SHEI is a 'Diversity metric'. It is the ratio between the actual Shannon’s diversity index and the theoretical maximum of the Shannon diversity index. It can be understood as a measure of dominance.

**Units:** None

**Range:** \(0 \leq SHEI < 1\)

**Behaviour:** Equals \(SHEI = 0\) when only one patch present and equals \(SHEI = 1\) when the proportion of classes is completely equally distributed

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_c_pland, lsm_l_pr

Examples

lsm_l_shei(landscape)
Description

Simpson’s diversity index (Diversity metric)

Usage

`lsm_l_sidi(landscape, directions = 8)`

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[
SIDI = 1 - \sum_{i=1}^{m} P_i^2
\]

where \( P_i \) is the proportion of class \( i \) and \( m \) is the number of classes.

SIDI is a 'Diversity metric'. It is widely used in biodiversity and ecology. It is less sensitive to rare class types than `lsm_l_shdi`. It can be interpreted as the probability that two randomly selected cells belong to the same class.

- **Units**: None
- **Range**: \( 0 \leq SIDI < 1 \)
- **Behaviour**: Equals \( SIDI = 0 \) when only one patch is present and approaches \( SIDI < 1 \) when the number of class types increases while the proportions are equally distributed

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

`lsm_c_pland`, `lsm_l_pr`

Examples

`lsm_l_siei(landscape)`

---

### lsm_l_siei

**SIEI (landscape level)**

---

**Description**

Simpson’s evenness index (Diversity metric)

**Usage**

`lsm_l_siei(landscape, directions = 8)`

**Arguments**

- `landscape` Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions` The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
SIEI = 1 - \frac{1 - \frac{m}{\sum_{i=1}^{m} P_i^2}}{1 - \frac{1}{m}}
\]

where \(P_i\) is the proportion of class \(i\) and \(m\) is the number of classes.

SIEI is a ‘Diversity metric’. The metric is widely used in biodiversity and ecology. It is the ratio between the actual Simpson’s diversity index and the theoretical maximum Simpson’s diversity index.

**Units:** None

**Range:** 0 < SIEI <= 1

**Behaviour:** Equals SIEI = 0 when only one patch is present and approaches SIEI = 1 when the number of class types increases while the proportions are equally distributed

**Value**

tibble
References

McGarrigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


See Also

lsm_c_pland, lsm_l_pr

Examples

lsm_l_siei(landscape)

Description

Splitting index (Aggregation metric)

Usage

lsm_l_split(landscape, directions = 8)

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ SSPLIT = \frac{A^2}{\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij}^2} \]

where \( a_{ij} \) is the patch area in square meters and \( A \) is the total landscape area.

SPLIT is an 'Aggregation metric'. It describes the number of patches if all patches the landscape would be divided into equally sized patches.

Units: None

Range: \( 1 \leq SPLIT \leq \text{Number of cells squared} \)

Behaviour: Equals SPLIT = 1 if only one patch is present. Increases as the number of patches increases and is limited if all cells are a patch
Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
  lsm_p_area, lsm_l_ta,
  lsm_c_split

Examples
  lsm_l_split(landscape)

<table>
<thead>
<tr>
<th>lsm_l_ta</th>
<th>TA (landscape level)</th>
</tr>
</thead>
</table>

Description
Total area (Area and edge metric)

Usage
  lsm_l_ta(landscape, directions = 8)

Arguments
  landscape  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
  directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ CA = \text{sum}(\text{AREA}[\text{patch}_{ij}]) \]

where \( \text{AREA}[\text{patch}_{ij}] \) is the area of each patch in hectares.

TA is an ‘Area and edge metric’. The total (class) area sums the area of all patches in the landscape. It is the area of the observation area.
**Units:** Hectares

**Range:** TA > 0

**Behaviour:** Approaches TA > 0 if the landscape is small and increases, without limit, as the size of the landscape increases.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

lsm_p_area, sum,
lsm_c_ca

**Examples**

```r
lsm_l_ta(landscape)
```

---

### Description

Total core area (Core area metric)

### Usage

```r
lsm_l_tca(landscape, directions = 8, consider_boundary = FALSE, edge_depth = 1)
```

### Arguments

- **landscape**  
  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

- **directions**  
  The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

- **consider_boundary**  
  Logical if cells that only neighbour the landscape boundary should be considered as core

- **edge_depth**  
  Distance (in cells) a cell has to be away from the patch edge to be considered as core cell
Details

\[ TCA = \sum_{j=1}^{n} a_{ij}^{\text{core}} * \left( \frac{1}{10000} \right) \]

where here \( a_{ij}^{\text{core}} \) is the core area in square meters.

TCA is a 'Core area metric' and equals the sum of core areas of all patches in the landscape. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). In other words, the core area of a patch is all area that is not an edge. It characterises patch areas and shapes of all patches in the landscape simultaneously (more core area when the patch is large and the shape is rather compact, i.e. a square). Additionally, TCA is a measure for the configuration of the landscape, because the sum of edges increase as patches are less aggregated.

**Units:** Hectares

**Range:** TCA &ge; 0

**Behaviour:** Increases, without limit, as patch areas increase and patch shapes simplify. TCA = 0 when every cell in every patch is an edge.

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

`lsm_p_core, lsm_c_tca`

Examples

`lsm_l_tca(landscape)`
Description

Total edge (Area and Edge metric)

Usage

\texttt{lsm\_l\_te(landscape, count\_boundary = FALSE)}

Arguments

- \texttt{landscape} Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- \texttt{count\_boundary} Include landscape boundary in edge length

Details

\[ TE = \sum_{k=1}^{m} e_{ik} \]

where \( e_{ik} \) is the edge lengths in meters. TE is an 'Area and edge metric'. Total edge includes all edges. It measures the configuration of the landscape because a highly fragmented landscape will have many edges. However, total edge is an absolute measure, making comparisons among landscapes with different total areas difficult. If \texttt{count\_boundary = TRUE} also edges to the landscape boundary are included.

Units: Meters

Range: \( TE \geq 0 \)

Behaviour: Equals \( TE = 0 \) if all cells are edge cells. Increases, without limit, as landscape becomes more fragmented

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

\texttt{lsm\_p\_perim lsm\_l\_te}
### Examples

```r
lsm_p_area(landscape)
```

### Description

Patch area (Area and edge metric)

### Usage

```r
lsm_p_area(landscape, directions = 8)
```

### Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

### Details

\[
AREA = a_{ij} \cdot \left( \frac{1}{10000} \right)
\]

where \(a_{ij}\) is the area in square meters.

AREA is an 'Area and edge metric' and equals the area of each patch in hectares. The lower limit of AREA is limited by the resolution of the input raster, i.e. AREA can't be smaller than the resolution squared (in hectares). It is one of the most basic, but also most important metrics, to characterise a landscape. The metric is the simplest measure of composition.

**Units:** Hectares

**Range:** AREA > 0

**Behaviour:** Increases, without limit, as the patch size increases.

### References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/
See Also

\[ lsm\_c\_area\_mn, lsm\_c\_area\_sd, lsm\_c\_area\_cv, lsm\_c\_ca, lsm\_l\_area\_mn, lsm\_l\_area\_sd, lsm\_l\_area\_cv, lsm\_l\_ta \]

Examples

\[ lsm\_p\_area(landscape) \]

---

### Description

Core area index (Core area metric)

#### Usage

\[ lsm\_p\_cai(landscape, directions = 8, consider\_boundary = FALSE, edge\_depth = 1) \]

#### Arguments

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider\_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge\_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

#### Details

\[ CAI = \left( \frac{a_{ij}^{\text{core}}}{a_{ij}} \right) \times 100 \]

where \( a_{ij}^{\text{core}} \) is the core area in square meters and \( a_{ij} \) is the area in square meters.

CAI is a 'Core area metric'. It equals the percentage of a patch that is core area. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). It describes patch area and shape simultaneously (more core area when the patch is large and the shape is rather compact, i.e. a square). Because the index is relative, it is comparable among patches with different area.

**Units**: Percent

**Range**: 0 <= CAI <= 100

**Behaviour**: CAI = 0 when the patch has no core area and approaches CAI = 100 with increasing percentage of core area within a patch.
Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_p_core, lsm_p_area,
lsm_c_cai_mn, lsm_c_cai_sd, lsm_c_cai_cv, lsm_c_cpland,
lsm_l_cai_mn, lsm_l_cai_sd, lsm_l_cai_cv

Examples
lsm_p_cai(landscape)

\[
\text{CIRCLE} = 1 - \left( \frac{a_{ij}}{a_{circle}^{ij}} \right)
\]

where \(a_{ij}\) is the area in square meters and \(a_{circle}^{ij}\) the area of the smallest circumscribing circle.

CIRCLE is a 'Shape metric’. The metric is the ratio between the patch area and the smallest circumscribing circle of the patch. The diameter of the smallest circumscribing circle is the 'diameter’ of the patch connecting the opposing corner points of the two cells that are the furthest away from each other. The metric characterises the compactness of the patch and is comparable among patches with different area.
**Units:** None

**Range:** 0 <= CIRCLE < 1

**Behaviour:** CIRCLE = 0 for a circular patch and approaches CIRCLE = 1 for a linear patch.

### References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


Based on C++ code from Project Nayuki (https://www.nayuki.io/page/smallest-enclosing-circle).

### See Also

- `lsm_p_area`
- `lsm_c_circle_mn`, `lsm_c_circle_sd`, `lsm_c_circle_cv`
- `lsm_l_circle_mn`, `lsm_l_circle_sd`, `lsm_l_circle_cv`

### Examples

```r
lsm_p_circle(landscape)
```

---

### Description

**CONTIG (patch level)**

Contiguity index (Shape metric)

### Usage

```r
lsm_p_contig(landscape, directions = 8)
```

### Arguments

- **landscape**
  - Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

- **directions**
  - The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
CONTIG \(= \left[ \frac{\sum_{r=1}^{z} c_{ijr}}{a_{ij}} \right] - 1 \)

where \(c_{ijr}\) is the contiguity value for pixel \(r\) in patch \(ij\), \(a_{ij}\) the area of the respective patch (number of cells) and \(v\) is the size of the filter matrix (13 in this case).

CONTIG is a 'Shape metric'. It assesses the spatial connectedness (contiguity) of cells in patches. CONTIG coerces patch values to a value of 1 and the background to NA. A nine cell focal filter matrix:

```r
c(1, 2, 1,
  2, 1, 2,
  1, 2, 1), 3, 3, byrow = T)
```

... is then used to weight orthogonally contiguous pixels more heavily than diagonally contiguous pixels. Therefore, larger and more connections between patch cells in the rookie case result in larger contiguity index values.

**Units:** None

**Range:** \(0 \geq \text{CONTIG} \leq 1\)

**Behaviour:** Equals 0 for one-pixel patches and increases to a limit of 1 (fully connected patch).

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

lsm_c_contig_mn, lsm_c_contig_sd, lsm_c_contig_cv,
lsm_l_contig_mn, lsm_l_contig_sd, lsm_l_contig_cv

**Examples**

lsm_p_contig(landscape)
Description
Core area (Core area metric)

Usage

```r
lsm_p_core(
  landscape,
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1
)
```

Arguments

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- `consider_boundary`: Logical if cells that only neighbour the landscape boundary should be considered as core.
- `edge_depth`: Distance (in cells) a cell has to be away from the patch edge to be considered as core.

Details

\[ \text{CORE} = a_{ij}^{core} \]

where \(a_{ij}^{core}\) is the core area in square meters.

CORE is a ‘Core area metric’ and equals the area within a patch that is not on the edge of it. A cell is defined as core area if the cell has no neighbour with a different value than itself (rook’s case). It describes patch area and shape simultaneously (more core area when the patch is large and the shape is rather compact, i.e. a square).

**Units:** Hectares

**Range:** CORE >= 0

**Behaviour:** Increases, without limit, as the patch area increases and the patch shape simplifies (more core area). CORE = 0 when every cell in the patch is an edge.

Value

tibble
References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_c_core_mn, lsm_c_core_sd, lsm_c_core_cv, lsm_c_tca, lsm_l_core_mn, lsm_l_core_sd, lsm_l_core_cv, lsm_l_tca

Examples
lsm_p_core(landscape)

lsm_p_enn

<table>
<thead>
<tr>
<th>ENN (patch level)</th>
</tr>
</thead>
</table>

Description
Euclidean Nearest-Neighbor Distance (Aggregation metric)

Usage
lsm_p_enn(landscape, directions = 8, verbose = TRUE)

Arguments

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>landscape</td>
<td>Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.</td>
</tr>
<tr>
<td>directions</td>
<td>The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).</td>
</tr>
<tr>
<td>verbose</td>
<td>Print warning message if not sufficient patches are present</td>
</tr>
</tbody>
</table>

Details

\[ ENN = h_{ij} \]

where \( h_{ij} \) is the distance to the nearest neighbouring patch of the same class \( i \) in meters

ENN is an 'Aggregation metric'. The distance to the nearest neighbouring patch of the same class \( i \). The distance is measured from edge-to-edge. The range is limited by the cell resolution on the lower limit and the landscape extent on the upper limit. The metric is a simple way to describe patch isolation.

Units: Meters

Range: \( ENN > 0 \)

Behaviour: Approaches \( ENN = 0 \) as the distance to the nearest neighbour decreases, i.e. patches of the same class \( i \) are more aggregated. Increases, without limit, as the distance between neighbouring patches of the same class \( i \) increases, i.e. patches are more isolated.
Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_c_enn_mn, lsm_c_enn_sd, lsm_c_enn_cv,
lsm_l_enn_mn, lsm_l_enn_sd, lsm_l_enn_cv

Examples
lsm_p_enn(landscape)

Description
Fractal dimension index (Shape metric)

Usage
lsm_p_frac(landscape, directions = 8)

Arguments
landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details
\[ FRAC = \frac{2 \ln (0.25 \cdot p_{ij})}{\ln a_{ij}} \]

where \( p_{ij} \) is the perimeter in meters and \( a_{ij} \) is the area in square meters
FRAC is a ‘Shape metric’. The index is based on the patch perimeter and the patch area and describes the patch complexity. Because it is standardized, it is scale independent, meaning that increasing the patch size while not changing the patch form will not change the ratio.
**Units:** None

**Range:** $1 \leq \text{FRAC} \leq 2$

**Behaviour:** Approaches $\text{FRAC} = 1$ for a squared patch shape form and $\text{FRAC} = 2$ for a irregular patch shape.

**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/


**See Also**

`lsm_p_area`, `lsm_p_perim`,
`lsm_c_frac_mn`, `lsm_c_frac_sd`, `lsm_c_frac_cv`,
`lsm_l_frac_mn`, `lsm_l_frac_sd`, `lsm_l_frac_cv`

**Examples**

```r
lsm_p_frac(landscape)
```

---

**Description**

Radius of Gyration (Area and edge metric)

**Usage**

```r
lsm_p_gyrate(landscape, directions = 8, cell_center = FALSE)
```

**Arguments**

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>landscape</code></td>
<td>Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.</td>
</tr>
<tr>
<td><code>directions</code></td>
<td>The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).</td>
</tr>
<tr>
<td><code>cell_center</code></td>
<td>If true, the coordinates of the centroid are forced to be a cell center within the patch.</td>
</tr>
</tbody>
</table>
Details

\[ GYRATE = \sum_{r=1}^{z} \frac{h_{ijr}}{z} \]

where \( h_{ijr} \) is the distance from each cell to the centroid of the patch and \( z \) is the number of cells.

GYRATE is an 'Area and edge metric'. The distance from each cell to the patch centroid is based on cell center to centroid distances. The metric characterises both the patch area and compactness.

If `cell_center = TRUE` some patches might have several possible cell-center centroids. In this case, the gyrate index is based on the mean distance of all cells to all possible cell-center centroids.

**Units:** Meters

**Range:** GYRATE >= 0

**Behaviour:** Approaches GYRATE = 0 if patch is a single cell. Increases, without limit, when only one patch is present.

Value
tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.html


See Also

lsm_c_gyrate_mn, lsm_c_gyrate_sd, lsm_c_gyrate_cv, lsm_l_gyrate_mn, lsm_l_gyrate_sd, lsm_l_gyrate_cv

Examples

lsm_p_gyrate(landscape)
**Description**

Number of core areas (Core area metric)

**Usage**

```r
lsm_p_ncore(
    landscape,
    directions = 8,
    consider_boundary = FALSE,
    edge_depth = 1
)
```

**Arguments**

- **landscape**: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell.

# @details

\[ NCORE = n_{ij}^{core} \]

where \( n_{ij}^{core} \) is the number of disjunct core areas.

NCORE is a ‘Core area metric’. A cell is defined as core if the cell has no neighbour with a different value than itself (rook’s case). The metric counts the disjunct core areas, whereby a core area is a ‘patch within the patch’ containing only core cells. It describes patch area and shape simultaneously (more core area when the patch is large, however, the shape must allow disjunct core areas). Thereby, a compact shape (e.g. a square) will contain less disjunct core areas than a more irregular patch.

**Units**: None

**Range**: NCORE \( \geq 0 \)

**Behaviour**: NCORE = 0 when CORE = 0, i.e. every cell in patch is edge. Increases, without limit, as core area increases and patch shape allows disjunct core areas (i.e. patch shape becomes rather complex).

**Value**

- tibble
References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also
lsm_c_dcore_mn, lsm_c_dcore_sd, lsm_c_dcore_cv, lsm_c_ndca,
lsm_l_dcore_mn, lsm_l_dcore_sd, lsm_l_dcore_cv, lsm_l_ndca

Examples
lsm_p_ncore(landscape)

Description
Perimeter-Area ratio (Shape metric)

Usage
lsm_p_para(landscape, directions = 8)

Arguments
landscape Raster* Layer, Stack, Brick, stack, or a list of rasterLayers.
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

Details

\[ PARA = \frac{p_{ij}}{a_{ij}} \]

where \( p_{ij} \) is the perimeter in meters and \( a_{ij} \) is the area in square meters.

PARA is a ‘Shape metric’. It describes the patch complexity in a straightforward way. However, because it is not standardised to a certain shape (e.g. a square), it is not scale independent, meaning that increasing the patch size while not changing the patch form will change the ratio.

Units: None

Range: PARA > 0

Behaviour: Increases, without limit, as the shape complexity increases.
**Value**

tibble

**References**

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

**See Also**

`lsm_p_area`, `lsm_p_perim`,
`lsm_c_para_mn`, `lsm_c_para_sd`, `lsm_c_para_cv`,
`lsm_l_para_mn`, `lsm_l_para_sd`, `lsm_l_para_cv`

**Examples**

```r
lsm_p_para(landscape)
```

---

**Description**

Perimeter (Area and edge metric)

**Usage**

```r
lsm_p_perim(landscape, directions = 8)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[ \text{PERIM} = p_{ij} \]

where \( p_{ij} \) is the perimeter in meters.

PERIM is an 'Area and edge metric'. It equals the perimeter of the patch including also the edge to the landscape boundary. The metric describes patch area (larger perimeter for larger patches), but also patch shape (large perimeter for irregular shapes).

**Units:** Meters
Range: \( \text{PERIM} > 0 \)

Behaviour: Increases, without limit, as patch size and complexity increases.

Value

tibble

References

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

Examples

```r
lsm_p_perim(landscape)
```

---

**Description**

Shape index (Shape metric)

**Usage**

```r
lsm_p_shape(landscape, directions = 8)
```

**Arguments**

- `landscape`: Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
- `directions`: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).

**Details**

\[
\text{SHAPE} = \frac{p_{ij}}{\min p_{ij}}
\]

where \( p_{ij} \) is the perimeter in terms of cell surfaces and \( \min p_{ij} \) is the minimum perimeter of the patch in terms of cell surfaces.

SHAPE is a 'Shape metric'. It describes the ratio between the actual perimeter of the patch and the hypothetical minimum perimeter of the patch. The minimum perimeter equals the perimeter if the patch would be maximally compact.

**Units**: None
**Range:** SHAPE $\geq 1$

**Behaviour:** Equals SHAPE = 1 for a squared patch and increases, without limit, as the patch shape becomes more complex.

Value
tibble

References
McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/

See Also

$lsm_p_perim, lsm_p_area,$
$lsm_c_shape_mn, lsm_c_shape_sd, lsm_c_shape_cv,$
$lsm_l_shape_mn, lsm_l_shape_sd, lsm_l_shape_cv$

Examples

$lsm_p.shape(landscape)$

---

**options_landscapemetrics**

Sets global options for landscapemetrics

**Usage**

options_landscapemetrics(to_disk = NULL)

**Arguments**

`to_disk` Logical argument, if FALSE results of get_patches are hold in memory. If true, get_patches writes temporary files and hence, does not hold everything in memory. Can be set with a global option, e.g. options(to_disk = TRUE). See Details.
Details

Landscape metrics rely on the delineation of patches. Hence, `get_patches` is heavily used in `landscapemetrics`. As raster can be quite big, the fact that `get_patches` creates a copy of the raster for each class in a landscape becomes a burden for computer memory. Hence, the argument `to_disk` allows to store the results of the connected labeling algorithm on disk. Furthermore, this option can be set globally, so that every function that internally uses `get_patches` can make use of that.

Value

Global option to be used internally in the package

---

| podlasie_ccilc | Podlasie ESA CCI LC |

Description

A real landscape of the Podlasie region in Poland from the ESA CCI Land Cover

Usage

`podlasie_ccilc`

Format

A raster layer object.

Source

http://maps.elie.ucl.ac.be/CCI/viewer/

---

| sample_lsm | sample_lsm |

Description

Sample metrics
sample_lsm

Usage

sample_lsm(
    landscape,
    y,
    plot_id = NULL,
    shape = "square",
    size,
    all_classes = FALSE,
    return_raster = FALSE,
    verbose = TRUE,
    progress = FALSE,
    ...
)

Arguments

landscape        Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
y              2-column matrix with coordinates, SpatialPoints, SpatialLines, SpatialPolygons, sf points or sf polygons.
plot_id          Vector with id of sample points. If not provided, sample points will be labelled 1...n.
shape           String specifying plot shape. Either "circle" or "square"
size            Approximated size of sample plot. Equals the radius for circles or half of the side-length for squares in mapunits. For lines size equals the width of the buffer.
all_classes     Logical if NA should be returned for classes not present in some sample plots.
return_raster   Logical if the clipped raster of the sample plot should be returned
verbose         Print warning messages.
progress        Print progress report.
...             Arguments passed on to calculate_lsm().

Details

This function samples the selected metrics in a buffer area (sample plot) around sample points, sample lines or within provided SpatialPolygons. The size of the actual sampled landscape can be different to the provided size due to two reasons. Firstly, because clipping raster cells using a circle or a sample plot not directly at a cell center lead to inaccuracies. Secondly, sample plots can exceed the landscape boundary. Therefore, we report the actual clipped sample plot area relative in relation to the theoretical, maximum sample plot area e.g. a sample plot only half within the landscape will have a percentage_inside = 50. Please be aware that the output is slightly different to all other lsm-function of landscapemetrics.

The metrics can be specified by the arguments what, level, metric, name and/or type (combinations of different arguments are possible (e.g. level = "class", type = "aggregation metric"). If an argument is not provided, automatically all possibilities are selected. Therefore, to get all available metrics, don’t specify any of the above arguments.
Value
tibble

See Also
list_lsm
calculate_lsm

Examples

```r
# use a matrix
sample_points <- matrix(c(10, 5, 25, 15, 5, 25), ncol = 2, byrow = TRUE)
sample_lsm(landscape, y = sample_points, size = 15, what = "lsm_l_np")

# use sp points
points_sp <- sp::SpatialPoints(sample_points)
sample_lsm(landscape, y = points_sp, size = 15, what = "lsm_l_np", return_raster = TRUE)

# Not run:
# use lines (works only if rgeos is installed)
x1 <- c(1, 5, 15, 10)
y1 <- c(1, 5, 15, 25)
x2 <- c(10, 25)
y2 <- c(5, 5)

sample_lines <- sp::SpatialLines(list(sp::Line(cbind(x1, y1)), sp::Line(cbind(x2, y2))), ID = "a")
sample_lsm(landscape, y = sample_lines, size = 10, what = "lsm_l_np")

# use polygons
poly_1 <- sp::Polygon(cbind(2.5, 2.5, 17.5, 17.5), c(-2.5, 12.5, 12.5, -2.5))
poly_2 <- sp::Polygon(cbind(7.5, 7.5, 23.5, 23.5), c(-7.5, 23.5, 23.5, -7.5))
poly_1 <- sp::Polygons(list(poly_1), "p1")
poly_2 <- sp::Polygons(list(poly_2), "p2")
sample_plots <- sp::SpatialPolygons(list(poly_1, poly_2))
sample_lsm(landscape, y = sample_plots, what = "lsm_l_np")

# End(Not run)
```

scale_sample

Description

Metrics on changing sample scale
scale_sample

Usage

scale_sample(
  landscape,
  y,
  shape = "square",
  size,
  max_size,
  verbose = TRUE,
  progress = FALSE,
  ...
)

Arguments

landscape  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
y  2-column matrix with coordinates or SpatialPoints.
shape  String specifying plot shape. Either "circle" or "square"
size  Approximated size of sample plot. Equals the radius for circles or half of the side-length for squares in mapunits. For lines size equals the width of the buffer.
max_size  Maximum size to which sample plot size is summed up.
verbose  Print warning messages.
progress  Print progress report.
...  Arguments passed on to calculate_lsm().

Details

This function calculates the selected metrics in subsequential buffers around a/multiple point(s) of interest.

The size of the actual sampled landscape can be different to the provided size due to two reasons. Firstly, because clipping raster cells using a circle or a sample plot not directly at a cell center lead to inaccuracies. Secondly, sample plots can exceed the landscape boundary. Therefore, we report the actual clipped sample plot area relative in relation to the theoretical, maximum sample plot area e.g. a sample plot only half within the landscape will have a percentage_inside = 50. Please be aware that the output is slightly different to all other lsm-function of landscapemetrics.

The metrics can be specified by the arguments what, level, metric, name and/or type (combinations of different arguments are possible e.g. level = "class", type = "aggregation metric"). If an argument is not provided, automatically all possibilities are selected. Therefore, to get all available metrics, don’t specify any of the above arguments.

Value

tibble
See Also

list_lsm
calculate_lsm
sample_lsm
construct_buffer

Examples

my_points = matrix(c(1265000, 1250000, 1255000, 1257000),
                  ncol = 2, byrow = TRUE)

scale_sample(landscape = augusta_nlcd, y = my_points,
             size = 500, max_size = 5000, what = c("lsm_l_ent", "lsm_l_mutinf"))

Description

Metrics on changing sample scale

Usage

scale_window(landscape,
             percentages_col = NULL,
             percentages_row = NULL,
             what,
             stat,
             verbose = TRUE,
             progress = FALSE,
             ...
            )

Arguments

landscape Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
percentages_col 2-column matrix with coordinates or SpatialPoints.
percentages_row String specifying plot shape. Either "circle" or "square"
what Selected level of metrics: either "patch", "class" or "landscape". It is also possible to specify functions as a vector of strings, e.g. what = c("lsm_l_mutinf", "lsm_l_ta").
stat The function to be applied. See Details
show_cores

verbose If TRUE, warnings are printed.
progress Print progress report.
... Arguments passed on to calculate_lsm().

Details

This function calculates the selected metrics in moving windows over the provided landscape.
Please be aware that the output is slightly different to all other lsm-function of landscapemetrics.
The metrics can be specified by the arguments what, level, metric, name and/or type (combinations of different arguments are possible (e.g. level = "class", type = "aggregation metric").
If an argument is not provided, automatically all possibilities are selected. Only metrics on landscape level are supported for this function.

Value
tibble

See Also

list_lsm
window_lsm
scale_sample

Examples

## Not run:
percentages_col <- c(2, 4, 8, 16, 32, 64, 100)
percentages_row <- c(2, 4, 8, 16, 32, 64, 100)

what = c("lsm_l_pr", "lsm_l_joinent")

stat <- "mean"

scale_window(landscape, percentages_col, percentages_row, what, stat)

## End(Not run)
Usage

```r
show_cores(
    landscape,
    directions = 8,
    class = "all",
    labels = FALSE,
    nrow = NULL,
    ncol = NULL,
    consider_boundary = TRUE,
    edge_depth = 1
)
```

Arguments

- **landscape**: Raster object
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **class**: How to show the core area: "global" (single map), "all" (every class as facet), or a vector with the specific classes one wants to show (every selected class as facet).
- **labels**: Logical flag indicating whether to print or not to print core labels. boundary should be considered as core
- **nrow, ncol**: Number of rows and columns for the facet.
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core.
- **edge_depth**: Distance (in cells) a cell has the be away from the patch edge to be considered as core cell

Details

The functions plots the core area of patches labeled with the corresponding patch id. The edges are the grey cells surrounding the patches and are always shown.

Value

`ggplot`

Examples

- # show "global" core area
  ```r
  show_cores(landscape, class = "global", labels = FALSE)
  ```

- # show the core area of every class as facet
  ```r
  show_cores(landscape, class = "all", labels = FALSE)
  ```

- # show only the core area of class 1 and 3
  ```r
  show_cores(landscape, class = c(1, 3), labels = TRUE)
  ```
show_correlation

show_correlation

Description

Show correlation

Usage

show_correlation(
  data,
  method = "pearson",
  diag = TRUE,
  labels = FALSE,
  vjust = 0,
  text_size = 15
)

Arguments

data Tibble with results of as returned by the landscapemetrics package.
method Type of correlation. See link{cor} for details.
diag If FALSE, values on the diagonal will be NA and not plotted.
labels If TRUE, the correlation value will be added as text.
vjust Will be passed on to ggplot2 as vertical justification of x-axis text.
text_size Text size of the plot.

Details

The functions calculates the correlation between all metrics. In order to calculate correlations, for
the landscape level more than one landscape needs to be present. All input must be structured as
returned by the landscapemetrics package.

Value

ggplot

Examples

metrics <- calculate_lsm(landscape, what = c("patch", "class"))
show_correlation(data = metrics, method = "pearson")

## Not run:
metrics <- calculate_lsm(landscape, what = c("patch", "class"))#
correlations <- calculate_correlation(metrics)
show_correlation(data = correlations, method = "pearson")
show_lsm

## End(Not run)

### show_lsm

Show landscape metrics on patch level printed in their corresponding patch.

#### Usage

```r
show_lsm(
  landscape,
  what,
  class = "global",
  directions = 8,
  consider_boundary = FALSE,
  edge_depth = 1,
  labels = FALSE,
  label_lsm = FALSE,
  nrow = NULL,
  ncol = NULL
)
```

#### Arguments

- **landscape**: *Raster object*
- **what**: Patch level what to plot
- **class**: How to show the labeled patches: "global" (single map), "all" (every class as facet), or a vector with the specific classes one wants to show (every selected class as facet).
- **directions**: The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
- **consider_boundary**: Logical if cells that only neighbour the landscape boundary should be considered as core
- **edge_depth**: Distance (in cells) a cell has to be away from the patch edge to be considered as core cell
- **labels**: Logical flag indicating whether to print or not to print patch labels.
- **label_lsm**: If true, the value of the landscape metric is used as label
- **nrow**, **ncol**: Number of rows and columns for the facet.
show_patches

Details

The function plots all patches with a fill corresponding to the value of the chosen landscape metric on patch level.

Value

ggplot

Examples

show_lsm(landscape, what = "lsm_p_area", directions = 4)
show_lsm(landscape, what = "lsm_p_shape", class = c(1, 2), label_lsm = TRUE)
show_lsm(landscape, what = "lsm_p_circle", class = 3, labels = TRUE)

show_patches

Description

Show patches

Usage

show_patches(
  landscape,
  class = "global",
  directions = 8,
  labels = FALSE,
  nrow = NULL,
  ncol = NULL
)

Arguments

landscape *Raster object
class How to show the labeled patches: "global" (single map), "all" (every class as facet), or a vector with the specific classes one wants to show (every selected class as facet).
directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
labels Logical flag indicating whether to print or not to print patch labels.
nrow, ncol Number of rows and columns for the facet.

Details

The functions plots the landscape with the patches labeled with the corresponding patch id.
spatialize_lsm

Value

ggplot

Examples

show_patches(landscape)
show_patches(landscape, class = c(1, 2))
show_patches(landscape, class = 3, labels = FALSE)

spatialize_lsm  spatialize_Lsm

Description

Spatialize landscape metric values

Usage

spatialize_lsm(
  landscape,
  level = "patch",
  metric = NULL,
  name = NULL,
  type = NULL,
  what = NULL,
  directions = 8,
  progress = FALSE,
  to_disk = getOption("to_disk", default = FALSE),
  ...
)

Arguments

  landscape  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.
  level      Level of metrics. Either 'patch', 'class' or 'landscape' (or vector with combination).
  metric     Abbreviation of metrics (e.g. 'area').
  name       Full name of metrics (e.g. 'core area')
  type       Type according to FRAGSTATS grouping (e.g. 'aggregation metrics').
  what       Selected level of metrics: either "patch", "class" or "landscape". It is also possible to specify functions as a vector of strings, e.g. what = c("lsm_c_ca", "lsm_l_ta").
  directions The number of directions in which patches should be connected: 4 (rook’s case) or 8 (queen’s case).
window_lsm

progress Print progress report.
to_disk If TRUE raster will be saved to disk.
... Arguments passed on to calculate_lsm().

Details

The functions returns a nested list with RasterLayers. The first level contains each input layer (only one element if RasterLayer was provided). The second level contains a RasterLayer for each selected metric (see list_lsm for details) where each cell has the landscape metric value of the patch it belongs to. Only patch level metrics are allowed.

Value

list

See Also

list_lsm
show_lsm

Examples

spatialize_lsm(landscape, what = "lsm_p_area")
Arguments

- **landscape**
  Raster* Layer, Stack, Brick, SpatRaster (terra), stars, or a list of rasterLayers.

- **window**
  Moving window matrix.

- **level**
  Level of metrics. Either 'patch', 'class' or 'landscape' (or vector with combination).

- **metric**
  Abbreviation of metrics (e.g. 'area').

- **name**
  Full name of metrics (e.g. 'core area').

- **type**
  Type according to FRAGSTATS grouping (e.g. 'aggregation metrics').

- **what**
  Selected level of metrics: either "patch", "class" or "landscape". It is also possible to specify functions as a vector of strings, e.g. what = c("lsm_c_ca", "lsm_l_ta").

- **progress**
  Print progress report.

- **...**
  Arguments passed on to calculate_lsm().

Details

The function calculates for each focal cell the selected landscape metrics (currently only landscape level metrics are allowed) for a local neighbourhood. The neighbourhood can be specified using a matrix. For more details, see ?raster::focal(). The result will be a RasterLayer in which each focal cell includes the value of its neighbourhood and thereby allows to show gradients and variability in the landscape (Hagen-Zanker 2016). To be type stable, the actually result is always a nested list (first level for RasterStack layers, second level for selected landscape metrics).

Value

list

References


McGarigal, K., Cushman, S.A., and Ene E. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following website: http://www.umass.edu/landeco/research/fragstats/fragstats.html

See Also

- list_lsm
- calculate_lsm
- focal
Examples

## Not run:
```r
window <- matrix(1, nrow = 5, ncol = 5)
window_lsm(landscape, window = window, what = c("lsm_l_pr", "lsm_l_joinent"))
window_lsm(landscape_stack, window = window, what = c("lsm_l_pr", "lsm_l_joinent"))
```

## End(Not run)
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