Package 'ForestGapR'

January 7, 2019

Type Package

Title Tropical Forest Gaps Analysis

Version 0.0.2

Maintainer Carlos Alberto Silva <carlos_engflorestal@outlook.com>

Depends R (>= 3.4.0)

Imports raster, igraph, VGAM, sp, graphics, stats, viridis, rgeos, spatstat

Description Set of tools for detecting and analyzing Airborne Laser Scanning-derived Tropical Forest Canopy Gaps.

License GPL-3

Encoding UTF-8

LazyData true

RoxygenNote 6.1.0

Author Carlos Alberto Silva [aut, cre, cph],
Ekena Rangel Pinagé [ctb] (Reviews the documentation),
Midhun Mohan [ctb] (Reviews the documentation),
Danilo Roberti Alves de Almeida [ctb] (Reviews the documentation),
Eben North Broadbent [ctb] (Reviews the documentation),
Wan Shafrina Wan Mohd Jaafar [ctb] (Reviews the documentation),
Daniel de Almeida Papa [ctb] (Reviews the documentation),
Adrian Cardil [ctb] (Reviews the documentation),
Ruben Valbuena [cph, ctb],
Carine Klauberg [ctb] (Reviews the documentation)

Repository CRAN

Repository/R-Forge/Project forestgapr

Repository/R-Forge/Revision 11

Repository/R-Forge/DateTimeStamp 2019-01-04 17:19:33

Date/Publication 2019-01-07 19:40:07 UTC

NeedsCompilation no

R topics documented:

`ALS_CHM_CAU_2012` *ALS-derived CHM - Fazenda Cauaxi 2012*

Description

The Airborne Laser Scanning (ALS)-derived Canopy Height Model - (CHM) provided as an example dataset collected in 2012 at Fazenda Cauaxi in the Paragominas Municipality of Pará State, Brazil, in the eastern Amazon.

Usage

```
data(ALS_CHM_CAU_2012)
```

Format

The format is:'RasterLayer'

Details

The 1-m ALS-CHM was generated using Lastools software (Isenburg 2016)

Source

ALS data were acquired with support from USAID and the US Department of State with the technical assistance of the Brazilian Corporation for Agricultural Research (EMBRAPA) and the US Forest Service Office of International Programs via the Sustainable Landscapes Brazil Project (Keller, M. 2018).

References

Keller, M. 2018. Available online: https://www.paisagenslidar.cnptia.embrapa.br/webgis/

Isenburg, M. LAStools—Efficient Tools for Lidar Processing. 2018. Available online: http://www.cs.unc.edu/~isenburg/lastools/ (accessed on 3 October 2018).

Examples

```
data(ALS_CHM_CAU_2012)
## plot(ALS_CHM_CAU_2012)
```

ALS_CHM_CAU_2014 *ALS-derived CHM - Fazenda Cauaxi 2014*

Description

The Airborne Laser Scanning (ALS)-derived Canopy Height Model - (CHM) provided as an example dataset collected in 2014 at Fazenda Cauaxi in the Paragominas Municipality of Pará State, Brazil, in the eastern Amazon.

Usage

```
data(ALS_CHM_CAU_2014)
```

Format

The format is:'RasterLayer'

Details

The 1-m ALS-CHM was generated using Lastools software (Isenburg 2016)

Source

ALS data were acquired with support from USAID and the US Department of State with the technical assistance of the Brazilian Corporation for Agricultural Research (EMBRAPA) and the US Forest Service Office of International Programs via the Sustainable Landscapes Brazil Project (Keller, M. 2018).

References

Keller, M. 2018. Available online: https://www.paisagenslidar.cnptia.embrapa.br/webgis/

Isenburg, M. LAStools—Efficient Tools for Lidar Processing. 2018. Available online: http://www.cs.unc.edu/~isenburg/lastools/ (accessed on 3 October 2018).

Examples

```
data(ALS_CHM_CAU_2014)
## plot(ALS_CHM_CAU_2014)
```

ALS_CHM_DUC *ALS-derived CHM - Adolpho Ducke Forest Reserve 2012*

Description

The Airborne Laser Scanning (ALS)-derived Canopy Height Model - (CHM) provided as an example dataset collected in 2012 at the Adolpho Ducke Forest Reserve in Municipality of Manaus of State of Amazonas, Brazil, in central Amazon.

Usage

```
data(ALS_CHM_DUC)
```

Format

The format is:'RasterLayer'

Details

The 1-m ALS-CHM was generated using Lastools software (Isenburg 2016)

Source

ALS data were acquired with support from USAID and the US Department of State with the technical assistance of the Brazilian Corporation for Agricultural Research (EMBRAPA) and the US Forest Service Office of International Programs via the Sustainable Landscapes Brazil Project (Keller, M. 2018).

References

Keller, M. 2018. Available online: https://www.paisagenslidar.cnptia.embrapa.br/webgis/

Isenburg, M. LAStools—Efficient Tools for Lidar Processing. 2018. Available online: http://www.cs.unc.edu/~isenburg/lastools/ (accessed on 3 October 2018).

Examples

```
data(ALS_CHM_DUC)
## plot(ALS_CHM_DUC)
```

GapChangeDec *Forest Gaps Change Detection*

Description

This function detects forest canopy gap changes across two forest gap RasterLayer (raster) objects

Usage

```
GapChangeDec(gap_layer1,gap_layer2)
```

Arguments

gap_layer1	ALS-derived gap as an RasterLayer (raster) object at time 1. (output of getForestGaps function).
gap_layer2	ALS-derived gap as an RasterLayer (raster) object at time 2. (output of getForestGaps function).

Value

A RasterLayer (raster) object representing forest gap change area

Author(s)

Carlos Alberto Silva.

Examples

```
## Not run:
#Loading raster and viridis libraries
library(raster)
library(viridis)

# ALS-derived CHM from Fazenda Cauxi - Brazilian tropical forest
data(ALS_CHM_CAU_2012)
data(ALS_CHM_CAU_2014)

# set height thresholds (e.g. 10 meters)
threshold<-10
size<-c(1,10^4) # m2

# Detecting forest gaps
gaps_cau2012<-getForestGaps(chm_layer=ALS_CHM_CAU_2012, threshold=threshold, size=size)
gaps_cau2014<-getForestGaps(chm_layer=ALS_CHM_CAU_2014, threshold=threshold, size=size)

# Detecting forest gaps changes
Gap_changes<-GapChangeDec(gap_layer1=gaps_cau2012,gap_layer2=gaps_cau2014)

# Plotting ALS-derived CHM and forest gaps
```

```
par(mfrow=c(1,3))
plot(ALS_CHM_CAU_2012, main="Forest Canopy Gap - 2012", col=viridis(10))
plot(gaps_cau2012, add=TRUE, col="red", legend=FALSE)

plot(ALS_CHM_CAU_2014,  main="Forest Canopy Gap - 2014", col=viridis(10))
plot(gaps_cau2014, add=TRUE,col="red", legend=FALSE)

plot(ALS_CHM_CAU_2014,main="Forest Gap Changes Detected",col=viridis(10))
plot(Gap_changes, add=TRUE, col="orange", legend=FALSE)

## End(Not run)
```

GapSizeFDist *Forest Canopy Gap-size Frequency Distributions*

Description

This function quantifies the size frequency distribution of forest canopy gaps using Zeta distribution, which is a discrete power-law probability density.

Usage

```
GapSizeFDist(gaps_stats,...)
```

Arguments

gaps_stats	A data.frame containing basic statistics of forest gaps. Output of (GapStats) function.
...	Supplementary parameters for (plot).

Value

A log-log plot of gap-size Frequency Distributions and a vector containing the λ and minimum value of the likelihood. The parameter λ is the scaling exponent for the power-law Zeta distribution fitted to the data using maximum likelihood. See details section.

Details

For the Zeta distribution with parameter λ, the probability that gap size takes the integer value k is:

$$f(k) = \frac{k^{-\lambda}}{zeta(\lambda)}$$

where the denominator is the Riemann zeta function, and is undefined for $\lambda = 1$. The function calculates maximum likelihood estimates (MLE) of λ by minimizing a negative log-likelihood function (Asner et 2013).

Author(s)

Carlos Alberto Silva. This function was implemented based on the R script provided by Asner et al. (2013)

References

Asner, G.P., Kellner, J.R., Kennedy-Bowdoin, T., Knapp, D.E., Anderson, C. & Martin, R.E. (2013). Forest canopy gap distributions in the Southern Peruvian Amazon. PLoS One, 8, e60875.

White EP, Enquist BJ, Green JL (2008) On estimating the exponent of powerlaw frequency distributions. Ecology 89: 905–912.

Examples

```
#Loading raster library
library(raster)

# ALS-derived CHM over Adolpho Ducke Forest Reserve - Brazilian tropical forest
data(ALS_CHM_DUC)

# set height tresholds (e.g. 10 meters)
threshold<-10
size<-c(1,10^4) # m2

# Detecting forest gaps
gaps_duc<-getForestGaps(chm_layer=ALS_CHM_DUC, threshold=threshold, size=size)

# Computing basic statistis of forest gap
gaps_stats<-GapStats(gap_layer=gaps_duc, chm_layer=ALS_CHM_DUC)

# Gap-size Frequency Distributions
GapSizeFDist(gaps_stats=gaps_stats, col="forestgreen", pch=16, cex=1,
axes=FALSE,ylab="Gap Frequency",xlab=as.expression(bquote("Gap Size" ~ (m^2) )))
axis(1);axis(2)
grid(4,4)
```

GapSPDF *Forest Canopy Gaps as Spatial Polygons*

Description

This function converts forest canopy gaps as RasterLayer (raster) to SpatialPointsDataFrame-class objects

Usage

```
GapSPDF(gap_layer)
```

Arguments

gap_layer	ALS-derived gap layer (output of getForestGaps function). An object of the classs RasterLayer.

Value

A SpatialPointsDataFrame-class object of the forest canopy gaps. The output file can be exported as a ESRI shapefile using writeOGR function in the *rgdal* package.

Author(s)

Carlos Alberto Silva.

Examples

```
## Not run:
#Loading raster and viridis libraries
library(raster)
library(viridis)

# ALS-derived CHM over Adolpho Ducke Forest Reserve - Brazilian tropical forest
data(ALS_CHM_DUC)

# set height thresholds (e.g. 10 meters)
threshold<-10
size<-c(1,10^4) # m2

# Detecting forest gaps
gaps_duc<-getForestGaps(chm_layer=ALS_CHM_DUC, threshold=threshold, size=size)

# Converting raster layer to SpatialPolygonsDataFrame
gaps_spdf<-GapSPDF(gap_layer=gaps_duc)

# Plotting ALS-derived CHM and forest gaps
plot(ALS_CHM_DUC, col=viridis(10), xlim=c(173025,173125), ylim=c(9673100,96731200))
plot(gaps_spdf, add=TRUE, border="red", lwd=2)

# Populating the attribute table of Gaps_spdf with gaps statistics
gaps_stats<-GapStats(gap_layer=gaps_duc, chm_layer=ALS_CHM_DUC)
gaps_spdf<-merge(gaps_spdf,gaps_stats, by="gap_id")
head(gaps_spdf@data)

## End(Not run)
```

GapsSpatPattern *Spatial Pattern Analysis of Forest Canopy Gaps*

Description

This function computes second order statistics of forest canopy gaps (raster) to SpatialPointsDataFrame-class objects

Usage

```
GapsSpatPattern(gap_SPDF_layer,chm_layer)
```

Arguments

gap_SPDF_layer	A SpatialPointsDataFrame-class object of the forest canopy gaps. Output of (GapSPDF) function. An object of the classs SpatialPointsDataFrame-class
chm_layer	ALS-derived Canopy Height Model (CHM) RasterLayer (raster) object. An object of the classs RasterLayer.

Value

A plot with Ripley's K- and L-functions. Value of Clark-Evans index (R) and test for randomness (R=1), aggregation (R<1) or uniform distribution (R>1).

Author(s)

Ruben Valbuena and Carlos Alberto Silva.

References

spatstat package,see Kest,Lest, and clarkevans.test.

Examples

```
## Not run:
#Loading raster and viridis libraries
library(raster)
library(viridis)

# ALS-derived CHM from Fazenda Cauxi - Brazilian tropical forest
data(ALS_CHM_CAU_2012)
data(ALS_CHM_CAU_2014)

# set height thresholds (e.g. 10 meters)
threshold <- 10
size <- c(1,1000) # m2

# Detecting forest gaps
gaps_cau2012 <- getForestGaps(chm_layer = ALS_CHM_CAU_2012, threshold=threshold, size=size)
gaps_cau2014 <- getForestGaps(chm_layer = ALS_CHM_CAU_2014, threshold=threshold, size=size)

# Converting raster layers to SpatialPolygonsDataFrame
gaps_cau2012_spdf <- GapSPDF(gap_layer = gaps_cau2012)
gaps_cau2014_spdf <- GapSPDF(gap_layer = gaps_cau2014)
```

```
# Spatial pattern analysis of each year
gaps_cau2012_SpatPattern <- GapsSpatPattern(gaps_cau2012_spdf, ALS_CHM_CAU_2012)
gaps_cau2014_SpatPattern <- GapsSpatPattern(gaps_cau2014_spdf, ALS_CHM_CAU_2014)

## End(Not run)
```

`GapStats` *Forest Canopy Gaps Stats*

Description

This function computes a series of forest canopy gap statistics

Usage

```
GapStats(gap_layer, chm_layer)
```

Arguments

`gap_layer`	ALS-derived gap as RasterLayer (`raster`) object (output of `getForestGaps` function). An object of the classs RasterLayer.
`chm_layer`	ALS-derived Canopy Height Model (CHM) RasterLayer (`raster`) used in `getForestGaps` function. An object of the classs RasterLayer.

Details

List of forest gaps statistics:

- gap_id: gap id
- gap_area - area of gap (m2)
- chm_max - Maximum canopy height (m) within gap boundary
- chm_min - Minimum canopy height (m) within gap boundary
- chm_mean - Mean canopy height (m) within gap boundary
- chm_sd - Standard Deviation of canopy heights (m) within gap boundary
- chm_gini - Gini Coefficient of canopy heights (m) within gap boundary
- chm_range - Range of canopy heights (m) within gap boundary

Value

A data.frame containing forest canopy gap statistics

Author(s)

Carlos Alberto Silva.

Examples

```
#Loading raster library
library(raster)

# ALS-derived CHM over Adolpho Ducke Forest Reserve - Brazilian tropical forest
data(ALS_CHM_CAU_2012)

# set height thresholds (e.g. 10 meters)
threshold<-10
size<-c(5,10^4) # m2

# Detecting forest gaps
gaps_duc<-getForestGaps(chm_layer=ALS_CHM_DUC, threshold=threshold, size=size)

# Computing basic statistis of forest gap
gaps_stats<-GapStats(gap_layer=gaps_duc, chm_layer=ALS_CHM_DUC)
```

`getForestGaps` *Forest Canopy Gap Detection*

Description

This function detects forest canopy gaps on Airborne Laser Scanning(ALS)-derived Canopy Height Model (CHM).

Usage

```
getForestGaps(chm_layer, threshold=10, size=c(1,10^4))
```

Arguments

`chm_layer`	ALS-derived Canopy Height Model (CHM) RasterLayer (`raster`) object. An object of the classs RasterLayer.
`threshold`	Height threshold for gap detection. Default is 10 m.
`size`	A vector containing the minimum and maximum gap size - area (m2). Gaps with area < size[1] or area > size[2] are not considered. Default is 1 m2 and 1ha.

Value

Forest Gaps. An object of the classs RasterLayer.

Author(s)

Carlos Alberto Silva.

Examples

```
#=========================================================================#
# Importing ALS-derived Canopy Height Model (CHM)
#=========================================================================#
#Loading raster and viridis libraries
library(raster)
library(viridis)

# ALS-derived CHM over Adolpho Ducke Forest Reserve - Brazilian tropical forest
data(ALS_CHM_DUC)

# Plotting chm
plot(ALS_CHM_DUC, col=viridis(10), main= "ALS CHM")
grid()
#=========================================================================#
# Example 1: Forest Gap detection using a fixed canopy height thresholds
#=========================================================================#

# set height thresholds (e.g. 10 meters)
threshold<-10
size<-c(1,10^4) # m2

# Detecting forest gaps
gaps_duc<-getForestGaps(chm_layer=ALS_CHM_DUC, threshold=threshold, size=size)

# Ploting gaps
plot(gaps_duc, col="red", add=TRUE, main="Forest Canopy Gap", legend=FALSE)

#=========================================================================#
# Example 2: Gap detection using multiple canopy height thresholds
#=========================================================================#

# set the height thresholds
nthresholds<-c(10,15,20,25)
size<-c(1,10^4) # m2

# creating an empy raster stack to store multplie gaps as RasterLayers
gaps_stack<-stack()

# Gap detection
for (i in nthresholds){
 gaps_i<-getForestGaps(chm_layer=ALS_CHM_DUC, threshold=i, size=size)
 names(gaps_i)<-paste0("gaps_",i,"m")
 gaps_stack<-stack(gaps_stack,gaps_i)
}

# plot gaps
par(mfrow=c(2,2))
plot(ALS_CHM_DUC, col=viridis(10), main="Height threshold 10m")
plot(gaps_stack$gaps_10m, col="red",add=TRUE, legend=FALSE)
```

```
plot(ALS_CHM_DUC, col=viridis(10), main="Height threshold 15m")
plot(gaps_stack$gaps_15m, col="red",add=TRUE, legend=FALSE)

plot(ALS_CHM_DUC, col=viridis(10), main="Height threshold 20m")
plot(gaps_stack$gaps_20m, col="red",add=TRUE, legend=FALSE)

plot(ALS_CHM_DUC, col=viridis(10), main="Height threshold 25m")
plot(gaps_stack$gaps_25m, col="red",add=TRUE, legend=FALSE)
```

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