Package 'PROTOLIDAR'

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Type Package

Title PRocess TOol LIdar DAta in R

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Author Monica Fernanda Rinaldi

Maintainer Monica Fernanda Rinaldi <monica.rinaldi@gmail.com>

Description PROTOLIDAR package contains functions for analyze the LIDAR scan of plants (grapevine) and make 3D maps in GRASS GIS.

License GPL

LazyLoad yes

R topics documented:

PROTOLIDAR-package *PRocess TOol LIdar DAta in R.*

Description

PROTOLIDAR package contains functions for analyze the LIDAR scan of plants (grapevine) and make with the outputs 3D maps in GRASS-GIS.

Details

Package:	PROTOLIDAR
Type:	Package
Version:	1.0
Date:	2012-12-14
License:	GPL(>=2)
LazyLoad:	yes

This package help to analyze the LIDAR scan and extract the grapevine plant for see the plant in 3D GRASS GIS maps.

The package contains the following dataset and functions:

LIDAR_data is the dataset of the LIDAR scan. Represent the grapevine plant (BBCH 65).

Extract_plant_grapevine_function: which cuts the excess data.

Extract_plant_3D_function: helps to position the axis in the center of the plant.

Height_canopy_function: to measure the height of canopy from the LIDAR scan.

Width_canopy_function:to measure the width of canopy from the LIDAR scan.

Number_LIDAR_points_function: to calculate the number of points into the canopy.

LAI_function: to calculate the leaf area index.

LWA_lidar_function:to calculate the leaf wall area.

TRV_lidar_function: to calculate tree row volume in m^3*ha^-1.

Rotate_function: to rotate plants to match with the planting line.

Replicate_plants_function: to replicate plants.

Author(s)

Monica Fernanda Rinaldi<monica.rinaldi@gmail.com>

Emilio Gil<emilio.gil@upc.edu>

Jordi Llorens<jordi.llorens.calveras@upc.edu>

Maintainer: Monica Fernanda Rinaldi<monica.rinaldi@gmail.com>

References

Rinaldi, M. F.,2012. Modelling the impact of climate change on the Interaction between host and pest/pathogen phenologies at regional level: Trentino - Italy. Unpublished PhD diss. Doctoral School on the Agro-food System - Agrisystem - Cycle XXIV - Universita Cattolica del Sacro Cuore -UNICATT - Piacenza- Italy.

See Also

PROTOLIDAR-package

Examples

```
## Should be DIRECTLY executable !!
## For example:
   data (LIDAR_data)
   x <- LIDAR_data [,1]
   y <- LIDAR_data [,2]
   z <- LIDAR_data [,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).

## The function is currently defined as
  Extract_plant_grapevine_function <- function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz){
      y <- -y
      y <- y-min(y)
      z<- (z*zdistance)/max(z)
      x_cm <- 0
      y_cm <- 0
      z_cm <- 0
      for (i in 1:length(x)){
        if (x[i] >= minx  && x[i] <= maxx && y[i] >= miny && y[i] <= maxy &&  z[i] >= minz  && z[i] <= maxz
          y_cm[i] <- y[i]
          x_cm[i] <- x[i]
          z_cm[i] <- z[i]
        }
      }
      y_cm <- na.omit(y_cm[2:length(y_cm)])
      y_cm <- as.numeric((y_cm-min(y_cm))/1000)
      x_cm <- as.numeric(na.omit(x_cm[2:length(x_cm)])/1000)
      z_cm <- as.numeric(na.omit(z_cm[2:length(z_cm)])/100)
      return <- data.frame(x_cm,y_cm,z_cm)
    }
    out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)

       x = out[,1]
       y = out[,2]
       z = out[,3]
      # plot
       par(mfcol=c(2,2))
       plot(x,y,pch=20,cex=.4,xlab='Width (m)', ylab='Height (m)', main='Grapevine BBCH')
       plot(x,z,pch=20,cex=.4,xlab='Width (m)', ylab='Front (m)', main='Grapevine BBCH')
       plot(z,y,pch=20,cex=.4,xlab='Front (m)', ylab='Height (m)', main='Grapevine BBCH')
```

Extract_plant_3D_function

Extract plant 3D (grapevine).

Description

This function move the axes x,y,z to the center of the plant. This output could be exported and transformed in GRASS GIS in 3D maps.

Usage

```
Extract_plant_3D_function(out, z_min, z_max, y_min, y_max, distance_left, distance_right)
```

Arguments

out	out is a data frame output from Extract_plant_grapevine_function.
z_min	the minimum position of the stem in z measured in meters.
z_max	the maximum position of the stem in z measured in meters.
y_min	the minimum position of the stem in y measured in meters.
y_max	the maximum position of the stem in y measured in meters.
distance_left	the left distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.
distance_right	the right distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !!
## out come from Extract_plant_grapevine_function. The other parameters or inputs are needed to write befor
## For example:
   data (LIDAR_data)
   x <- LIDAR_data[,1]
   y <- LIDAR_data[,2]
   z <- LIDAR_data[,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).
   out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)
   z_min <- 1.1
   z_max <- 1.13
   y_min <- 0.4
   y_max <- 0.5
   distance_left <- -0.6
   distance_right <- 0.51


## The function is currently defined as
```

```
Extract_plant_3D_function <- function(out,z_min,z_max,y_min,y_max,distance_left,distance_right){
  x_cm <- y_cm <- z_cm <- NULL
  data_stem <- subset(out,out$y_cm > y_min & out$y_cm<= y_max & out$z_cm >= z_min  & out$z_cm <= z_max,sele
  x_c       <- out$x_cm - min(data_stem$x_cm)
  y_c       <- out$y_cm
  z_c       <- out$z_cm - min(data_stem$z_cm)
  data_cero <- data.frame(x_c,y_c,z_c)
  data_plant <- subset(data_cero, data_cero$z_c >= distance_left & data_cero$z_c <= distance_right,select=c
  x_plant <- data_plant[,1]
  y_plant <- data_plant[,2]
  z_plant <- data_plant[,3]
  return(data.frame(x_plant,y_plant,z_plant))
  }
  data_3D <- Extract_plant_3D_function(out,z_min,z_max,y_min,y_max,distance_left,distance_right)
  x_plant <- data_3D[,1]
  y_plant <- data_3D[,2]
  z_plant <- data_3D[,3]
  # plot
  par(mfcol=c(2,2))
    plot(x_plant,y_plant,pch=20,cex=.4)
    plot(x_plant,z_plant,pch=20,cex=.4)
    plot(z_plant,y_plant,pch=20,cex=.4)
```

`Extract_plant_grapevine_function`
Extract vine plant from the entire dataset.

Description

The function cut the plant at fixes values of x,y and z. Where x is width, y is height and z is front view or path of the tractor.

Usage

```
Extract_plant_grapevine_function(x, y, z, zdistance, miny, maxy, minx, maxx, minz, maxz)
```

Arguments

`x`	the width of the plant measured with LIDAR scan in cm.
`y`	the height of the plant measured with LIDAR scan in cm.
`z`	the front of the plant or path of the tractor measured with LIDAR scan in cm.
`zdistance`	the z distance of LIDAR scan measured in cm.
`miny`	the minimum height at which we cut the plant measured in cm.
`maxy`	the maximum height at which we cut the plant measured in cm.
`minx`	the minimum width to which we want to measure the plant measured in cm.
`maxx`	the maximum width to which we want to measure the plant measured in cm.
`minz`	the minimum distance at which we cut the plant, measured in cm.
`maxz`	the maximum distance at which we cut the plant, measured in cm.

Details

Path or direction of the tractor at constant velocity.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !! --
## First needed the LIDAR_data scan (that is one dataframe with x,y,z columns).
## Second needed define these inputs in cm: zdistance,miny,maxy,minx,maxx,minz,maxz.
## For example:
   data (LIDAR_data)
   x <- LIDAR_data [,1]
   y <- LIDAR_data [,2]
   z <- LIDAR_data [,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).

## The function is currently defined as
Extract_plant_grapevine_function <- function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz){
    y <- -y
    y <- y-min(y)
    z<- (z*zdistance)/max(z)
    x_cm <- 0
    y_cm <- 0
    z_cm <- 0
    for (i in 1:length(x)){
      if (x[i] >= minx  && x[i] <= maxx && y[i] >= miny && y[i] <= maxy &&  z[i] >= minz  && z[i] <= maxz)
        y_cm[i] <- y[i]
        x_cm[i] <- x[i]
        z_cm[i] <- z[i]
      }
    }
    y_cm <- na.omit(y_cm[2:length(y_cm)])
    y_cm <- as.numeric((y_cm-min(y_cm))/1000)
    x_cm <- as.numeric(na.omit(x_cm[2:length(x_cm)])/1000)
    z_cm <- as.numeric(na.omit(z_cm[2:length(z_cm)])/100)
    return <- data.frame(x_cm,y_cm,z_cm)
  }
  out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)

     x = out[,1]
     y = out[,2]
     z = out[,3]
    # plot
     par(mfcol=c(2,2))
     plot(x,y,pch=20,cex=.4,xlab='Width (m)', ylab='Height (m)', main='Grapevine BBCH')
     plot(x,z,pch=20,cex=.4,xlab='Width (m)', ylab='Front (m)', main='Grapevine BBCH')
     plot(z,y,pch=20,cex=.4,xlab='Front (m)', ylab='Height (m)', main='Grapevine BBCH')
```

Height_canopy_function

Height of the canopy measured with LIDAR scan.

Description

From the LIDAR dataset can be calculate the height of the grapevine plant. The function returns the average, minimum and maximum value of the height measured in meters.

Usage

```
Height_canopy_function(data_3D, distance_left, distance_right, min_canopy, max_canopy)
```

Arguments

data_3D	data_3D is the output from Extract_plant_3D_function.
distance_left	the left distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.
distance_right	the right distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.
min_canopy	the minimum height of the canopy, measured in meters.
max_canopy	the maximum height of the canopy, measured in meters.

Details

Maximum and minimum values of height of canopy could be approximative values.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !! ----
## Data_3D is the output from the Extrac_plant_3D_function.
## For example:
   data (LIDAR_data)
   x <- LIDAR_data[,1]
   y <- LIDAR_data[,2]
   z <- LIDAR_data[,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).
   out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)
   z_min <- 1.1
   z_max <- 1.13
```

```
  y_min <- 0.4
  y_max <- 0.5
  distance_left <- -0.6
  distance_right <- 0.51
  data_3D <- Extract_plant_3D_function(out,z_min,z_max,y_min,y_max,distance_left,distance_right)
  min_canopy <- 0.4 # is the minimum height of the canopy, approximately . Measured in meters.
  max_canopy <- 2   # is the maximum height of the canopy, approximately . Measured in meters.

## The function is currently defined as
Height_canopy_function <- function(data_3D,distance_left,distance_right,min_canopy,max_canopy){
  x_plant <- y_plant <- z_plant <- NULL
  canopy <- subset(data_3D, data_3D$z_plant >= distance_left & data_3D$z_plant <= distance_right & data_3D$
  mean_height_canopy <- mean(canopy[,2])
  min_height_canopy  <- min(canopy[,2])
  max_height_canopy  <- max(canopy[,2])
  return(data.frame(mean_height_canopy,min_height_canopy,max_height_canopy))
  }
  height_canopy <- Height_canopy_function(data_3D,distance_left,distance_right,min_canopy,max_canopy)[,1]
```

`LAI_function` *Leaf Area Index (LAI) calculate from LIDAR scan.*

Description

The LAI need in inputs the number of leaves, the leaf area (m^2),row distance (m) and in row spacing (m).

Usage

```
LAI_function(Number_of_leaves_by_plant, Leaf_Area, row_distance, in_row_distance)
```

Arguments

`Number_of_leaves_by_plant`	here need count the number of leaves of the plant.
`Leaf_Area`	here need calculate the leaf area, measured in m^2.
`row_distance`	the row distance of the orchard measured in meters.
`in_row_distance`	the in row distance or distance between plants of the orchard measured in meters.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !! ----
## Here needed some inputs measured manually like leaf area (m^2) and number of leaves.
  number_of_leaves <- 420
  leaf_area <- 0.010 ## measured in m^2.
  row_distance <- 2.9 ## measured in meters.
  in_row_distance <- 1.4 ## measured in meters.
```

```
## The function is currently defined as
LAI_function <- function(Number_of_leaves_by_plant,Leaf_Area,in_row_distance){

 LAI <- Number_of_leaves_by_plant * Leaf_Area / in_row_distance

return(LAI)

  }
  LAI_function(number_of_leaves,leaf_area,in_row_distance)
```

LIDAR_data *LIDAR data.*

Description

LIDAR scan dataset in BBCH 65 (grapevine).Where x is width, y is height and z is front view or path of the tractor.

Usage

```
data(LIDAR_data)
```

Format

A data frame with 10108 observations on the following 3 variables.

`V1` a numeric vector that represents x value or width

`V2` a numeric vector that represents y value or height

`V3` a numeric vector that represents z value or front view

Details

The laser scanner used was a LMS-200 model (Sick,Dusseldorf,Germany), a fully-automatic divergent laser scanner based on the measurement of time-of-flight (TOF) with an accurancy of 15 mm in a single shoot measurement and 5 mm standard deviation in a range upto 8m. The time between the transmission and the reception of the pulsed near-infrared laser beam is used to measure the distance between the scanner and the reflecting object surface. The laser beam is deflected by a rotating mirror turning at 4500 rpm, which results in a fan shaped scan pattern where the maximum scanning angle is 180 degree.

Source

LIDAR scan in BBCH 65 stage.

References

Llorens,J.,Gil,E.,Llop,J.,Escola,A.,2011. Ultrasonic and LIDAR Sensors for Electronic Canopy Characterization in Vineyards: Advances to Improve Pesticide Application Methods. Sensors 11, 2177-2194.

Examples

```
## LIDAR_data is the input to Extract_plant_grapevine_function.

data(LIDAR_data, package ='PROTOLIDAR')

x = LIDAR_data[,1]
y = LIDAR_data[,2]
z = LIDAR_data[,3]
```

`LWA_lidar_function` *Leaf Wall Area (LWA) measured in m^2*ha^-1.*

Description

LWA need as inputs the height of canopy (m) the ground area (generally one hectare, measured in m^2) and the row spacing (m).

Usage

```
LWA_lidar_function(height_canopy, ground_area, row_spacing)
```

Arguments

`height_canopy`	height of canopy manually or measured with Height_canopy_function.
`ground_area`	is the orchard area measured in m^2, generally one hectare.
`row_spacing`	row spacing measured in meters.

Author(s)

Monica Fernanda Rinaldi

References

Walklate, P.J., Cross, J.V., 2011. An examination of Leaf-Wall-Area dose expression. Crop Protection 35, 132-134.

Examples

```
## Should be DIRECTLY executable !! ----
  height_canopy = 2 ## this value is the maximum of Height_canopy_function.
  ground_area = 10000 ## generally is one hectare in m^2.
  row_spacing = 2.9 ## measured in meters.

## The function is currently defined as
function(height_canopy,ground_area,row_spacing){

 LWA <- 2* height_canopy * (ground_area/row_spacing)

return(LWA)

  }
  LWA_lidar_function(height_canopy,ground_area,row_spacing)
```

Number_lidar_points_into_canopy_function
Number of LIDAR points into the canopy.

Description

This function describe the number of points measured with LIDAR scan into the canopy.

Usage

```
Number_lidar_points_into_canopy_function(data_3D, distance_left, distance_right, min_canopy, max
```

Arguments

data_3D	data_3D is the output from Extract_plant_grapevine_function.
distance_left	the left distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.
distance_right	the right distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.
min_canopy	the minimum height of the canopy.
max_canopy	the maximum height of the canopy.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !! ----
## For example:
   data (LIDAR_data)
   x <- LIDAR_data[,1]
   y <- LIDAR_data[,2]
   z <- LIDAR_data[,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).
   out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)
   z_min <- 1.1
   z_max <- 1.13
   y_min <- 0.4
   y_max <- 0.5
   distance_left <- -0.6
   distance_right <- 0.51
   data_3D <- Extract_plant_3D_function(out,z_min,z_max,y_min,y_max,distance_left,distance_right)
   min_canopy <- 0.4
```

```
   max_canopy <- 2

## The function is currently defined as
Number_LIDAR_points_into_canopy_function <- function (data_3D,distance_left,distance_right,min_canopy,max_c
  x_plant <- y_plant <- z_plant <- NULL
  canopy <- subset(data_3D, data_3D$z_plant >= distance_left & data_3D$z_plant <= distance_right & data_3DS
  N_points <- length(canopy[,1])
  return (N_points)
  }
  Number_LIDAR_points_into_canopy_function(data_3D,distance_left,distance_right,min_canopy,max_canopy)
```

`Replicate_plants_function` *Replicate plants function.*

Description

This function helped to make 3D maps in GRASS GIS when you have only one scan of a plant. First needed rotate the plants and them could be replicate each plant in the row.

Usage

```
Replicate_plants_function(plants_rotate, data_3D, latitude, longitude)
```

Arguments

`plants_rotate`	here need use the output of Rotate_function.
`data_3D`	here need use the output of Exract_plant_3D_function and Extract_plant_grapevine_function.
`latitude`	here need the latitudine of each plant.
`longitude`	here need the longitude of each plant.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !!
## out come from Extract_plant_grapevine_function. The other parameters or inputs are needed to write befor
## For example:
   data (LIDAR_data)
   x <- LIDAR_data[,1]
   y <- LIDAR_data[,2]
   z <- LIDAR_data[,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).
   out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)
   z_min <- 1.1
```

```
   z_max <- 1.13
   y_min <- 0.4
   y_max <- 0.5
   distance_left <- -0.6
   distance_right <- 0.51
   data_3D <- Extract_plant_3D_function(out,z_min,z_max,y_min,y_max,distance_left,distance_right)
   latitude  <- c(396626.74528,396627.689076,396628.632872,396629.576669,396630.520465)
   longitude <- c(4566489.007441,4566490.032831,4566491.058221,4566492.083612,4566493.109002)
   angle <- 14.96
   plants_rotate <- Rotate_function(data_3D,angle)

## The function is currently defined as

Replicate_plants_function <- function(plants_rotate,data_3D,latitude,longitude){
  x_rot <- plants_rotate[,1]
  y_rot <- plants_rotate[,2]
  z     <- data_3D[,2]
  rep_z <- rep(z,length(latitude))
  rep_X <- rep(x_rot,length(latitude))
  rep_Y <- rep(y_rot,length(latitude))
  dup_xcoord <- rep(latitude ,each=length(x_rot))
  dup_ycoord <- rep(longitude,each=length(y_rot))
  XCOORD <- rep_X + dup_xcoord
  YCOORD <- rep_Y + dup_ycoord
  return (data.frame(XCOORD,YCOORD,z))
  }
  rep <- Replicate_plants_function(plants_rotate,data_3D,latitude,longitude)
   X <- rep[,1]
   Y <- rep[,2]
   Z <- rep[,3]
   ## plot
   par(mfcol=c(1,2))
   plot(X,Y)
   plot(X,Z)
```

Rotate_function *Rotate the plants.*

Description

The function help in rotate the plants to match with the planting line.

Usage

```
Rotate_function(data_3D, angle)
```

Arguments

data_3D	data_3D is the output of Extract_plant_3D_function.
angle	angle is one value like 14.96 degree that needed rotate the plants.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !!
## out come from Extract_plant_grapevine_function. The other parameters or inputs are needed to write befor
## For example:
   data (LIDAR_data)
   x <- LIDAR_data[,1]
   y <- LIDAR_data[,2]
   z <- LIDAR_data[,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).
   out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)
   z_min <- 1.1
   z_max <- 1.13
   y_min <- 0.4
   y_max <- 0.5
   distance_left <- -0.6
   distance_right <- 0.51
   data_3D <- Extract_plant_3D_function(out,z_min,z_max,y_min,y_max,distance_left,distance_right)
   angle <- 14.96

## The function is currently defined as
Rotate_function <- function(data_3D,angle){
  z <- -data_3D[,3]
  x <-  data_3D[,1]
  x_rot <-c(x*cos(angle)-z*sin(angle))
  y_rot <-c(x*sin(angle)+z*cos(angle))
  return(data.frame(x_rot,y_rot))
  }
  Plants_rotate <- Rotate_function(data_3D,angle)
    x_rot <- Plants_rotate[,1]
    y_rot <- Plants_rotate[,2]
    ##plot
    plot(x_rot,y_rot)
```

`TRV_lidar_function` *Tree Row Volume (TRV).*

Description

TRV measured in m^3*ha^-1.

Usage

```
TRV_lidar_function(height_canopy, width_canopy, row_spacing)
```

Arguments

`height_canopy`	use Height_canopy_function, measured in meters.
`width_canopy`	use Width_canopy_function, measured in meters.
`row_spacing`	row spacing measured in meters.

Author(s)

Monica Fernanda Rinaldi

References

Byers, R.E., 1987. Tree-row-volume Spraying Rate Calculator for Apples. HortScience 22, 506-507.

Gil, E., Escola, A., Rosell, J.R., Planas, S., Val, L., 2007. Variable rate application of plant protection products in vineyard using ultrasonic sensors. Crop Prot. 26, 1287-1297.

Gil, E., Escola, A., 2009. Design of a Decision Support Method to Determinate Volume Rate for Vineyard Spraying. ASABE. 25, 145-151.

Examples

```
## Should be DIRECTLY executable !! ----
## Here need use:  Height_canopy_function and Width_canopy_function or values measured manually.
 height_canopy <- 1.995 ## the value is the result of Height_canopy_function.
 width_canopy <- 0.426 ## the value is the result of Width_canopy_function.
 row_spacing = 2.9 ## measured in meters.

## The function is currently defined as
TRV_lidar_function <- function(height_canopy,width_canopy,row_spacing){
TRV <-height_canopy * width_canopy * 10000  / row_spacing
return(TRV)
  }
  TRV <- TRV_lidar_function(height_canopy,width_canopy,row_spacing)
```

Width_canopy_function *Canopy width measured with LIDAR.*

Description

From the LIDAR dataset can be calculate the width of the grapevine plant.The function returns the average, minimum and maximum value of the width measured in meters.

Usage

```
Width_canopy_function(data_3D, distance_left, distance_right, min_canopy, max_canopy)
```

Arguments

data_3D	Here need use the output of the Extract_plant_3D_function
distance_left	the left distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.
distance_right	the right distance of the plant, generally here we can write the half of the distance between plants, but is better the real distance from the center of the plant. Measured in meters.
min_canopy	the minimum height of the canopy, measured in meters.
max_canopy	the maximum height of the canopy, measured in meters.

Details

Maximum and minimum values of height of canopy could be approximative values.

Author(s)

Monica Fernanda Rinaldi

Examples

```
## Should be DIRECTLY executable !! ----
## Data_3D is the output from the Extrac_plant_3D_function.
## For example:
   data (LIDAR_data)
   x <- LIDAR_data[,1]
   y <- LIDAR_data[,2]
   z <- LIDAR_data[,3]
   zdistance <- 190 # total LIDAR scan distance measured in cm.
   miny <- 0 # minimum height of the plant measured in cm.
   maxy <- 2000 # maximum height of the plant measured in cm.
   minx <- 450 # minimum width from where LIDAR starts to measure (cm).
   maxx <- 1470# maximum width from where LIDAR starts to measure (cm).
   minz <- 0 # the beginning of the LIDAR scan measured in cm.
   maxz <- 186 # the end of the LIDAR scan measured in cm (length of interest).
   out <- Extract_plant_grapevine_function(x,y,z,zdistance,miny,maxy,minx,maxx,minz,maxz)
   z_min <- 1.1
   z_max <- 1.13
   y_min <- 0.4
   y_max <- 0.5
   distance_left <- -0.6
   distance_right <- 0.51
   data_3D <- Extract_plant_3D_function(out,z_min,z_max,y_min,y_max,distance_left,distance_right)
   min_canopy <- 0.4 # is the minimum height of the canopy, approximately . Measured in meters.
   max_canopy <- 2   # is the maximum height of the canopy, approximately . Measured in meters.

## The function is currently defined as
Width_canopy_function <- function(data_3D,distance_left,distance_right,min_canopy,max_canopy){

  x_plant <- y_plant <- z_plant <- NULL

  canopy <- subset(data_3D, data_3D$z_plant >= distance_left & data_3D$z_plant <= distance_right & data_3D$

  mean_width_canopy <- mean(abs(canopy[,1]))

  min_width_canopy  <- min(abs(canopy[,1]))

  max_width_canopy  <- max(abs(canopy[,1]))

  return(data.frame(mean_width_canopy,min_width_canopy,max_width_canopy))

  }
  width_canopy <- Width_canopy_function(data_3D,distance_left,distance_right,min_canopy,max_canopy)[,1]
```

Index