Crossing 3D Forest: An R Package for Evaluating Empty Space Structure in Forest Ecosystems

Nicola Puletti[1]*, Rossella Castronuovo[2], Carlotta Ferrara[2]

[1]CREA Research Centre for Forestry and Wood, Viale Santa Margherita, Arezzo, Italy

[2]Department of Food and Environmental Sciences, University of Basilicata, Potenza, Italy

[3]CREA Research Centre for Forestry and Wood, *Via* Valle Della Quistione, Rome, Italy

Research Article

Received: 25-May-2023, Manuscript No. JEAES-23-92792; **Editor assigned:** 28-May-2023, PreQC No. JEAES-23-92792 (PQ); **Reviewed:** 11-Jun-2023, QC No. JEAES-23-92792; **Revised:** 18-Ju n-2023, Manuscript No. JEAES-23-92792 (R); **Published:** 25-Jun-2023, DOI: 10.4172/ 2347-7830.2023.11.001

***For Correspondence:** Nicola Pulleti, CREA Research Centre for Forestry and Wood, Viale Arezzo, Italy

E-mail: nicola.puletti@crea.gov.it

Citation: Pulleti N, et al. Crossing 3D Forest: An R Package for Evaluating Empty Space Structure in Forest Ecosystems. RRJ Ecol Environ Sci.2023;11: 001

Copyright: © 2023 Pulleti N, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use,

ABSTRACT

Traditionally, forest structure is mostly described by vegetative elements; however, the complementary empty space also contributes to the forest spatial structure. We developed an R package (Crossing3DForest) to support the entire processing of Terrestrial Laser Scanning point clouds to quantify the size, shape, and connectivity of empty spaces within the mid and low strata of forest stands, using an approach based on the percolation theory. The package functions, which are designed for step-by-step single stand analysis, can be executed sequentially in a pipeline.

A case study is presented to demonstrate the crossing3Dforest potentials for characterising the forest empty space architecture. Terrestrial Laser Scanning (TLS) point clouds collected in ten different pure beech (*Fagus sylvatica L.*) stands, representative of five distinct forest management regimes, were analysed and characterised. The adopted empty space approach can be integrated into forest structural analysis to identify animal-habitat associations and establish appropriate habitat structure for wildlife management.

Keywords: Terrestrial laser scanning; Percolation theory; Forest spatial structure; Forest 3D space architecture

Import TLS data

Point clouds collected in forest environments require a first step of "point cloud normalisation". The crossing3Dforest package requires already normalised point clouds in .las or .laz format that can be managed using the functionalities of LidR package. Such LidR object is the first argument of the VoxFor function.

Voxel grid definition

The second step of the process is twofold. First, a user defined voxel grid is created, then the number of points within each voxel is calculated. These two phases are particularly important in optimising the computational process. Using the specific arguments of the VoxFor function, the user is able to crop the entire area of interest and define the voxel sizes in the x, y and z dimensions.

VoxFor function computes the number of points within each voxel of the user-defined 3D-grid. Each voxel is then classified as either "vegetated" or "empty space" depending on the threshold parameter min.npXvox: voxels comprising a number of point higher than min.npXvox will be classified as "vegetation" otherwise they are considered "empty space".

The output of this function is a data frame object containing

- The coordinates of the voxels (minimum, maximum and central coordinates)
- The number of points in each voxel
- Their classification (1=empty voxel; 0=vegetation voxel).

Create the array

The df2 array function requires the data frame obtained from VoxFor function and the minimum and maximum values of the Z layer of interest. The output is a list of two elements. The first element of the list is the array that will be used in percolation statistics function. The second element can be used for graphical functions (Table 1).

Table 1. Main functions included in the package.

Figures (arguments)	Description
VoxFor (inLas, minXrect, maxXrect, minYrect, maxYrect, x.vox, y.vox, z.vox, min.npXvox, Zcut)	Voxelization and classification of voxels in "empty space" and "vegetation"
df2array (voxgrid.plot, z.min, z.max)	Creates the input for percolation statistics function
Percolation statistics (x, k)	Defines connections between voxels usinga'von Neumann 3D connections' kernel
plotVoxel (xc,yc, zc, x.vox, y.vox, z.vox, vox.col, alpha)	Add voxels to a rgl 3-dimensional graph

Figure 4. Percentage of the number of links in each forest. This statistic can be derived using the 3^{rd} tibble of the percolation statistics function.

Figure 5. Alluvial diagram illustrating the share of empty space among forest plots and management types. Colours correspond to the number of links as they move through forest stands and management types, with the flow width being proportional to the share percentage. The dimension of rectangles is proportional to the data' prevalence.

When quantifying percolating empty space with percolation statistics, the provided statistics allow to distinguish the principal stand structural traits, which are strictly related to different forest management regimes. In this regard, a hierarchical cluster analysis revealed that