Spatial Analysis of Forest Fragmentation Using Language R

Rudiney Soares PEREIRA and Juliana MARCHESAN, Brazil

SUMMARY

Numerous image processing technologies in Remote Sensing produce information that makes it possible to diagnose the real situation of land use and coverage. The procedures used in the classification of images produce thematic information, limiting itself to presenting only spatially where a thematic class occurs and as a result, the area covered in a certain geographic region. However, when we need to study some parameters associated with shape, size, distance, connections, densities, borders, neighborhoods among other metrics, image processing applications have technical solution limitations. In this context, the work consisted in developing an R-language package by programming certain metrics with the objective of determining parameters of ecology and land use (metrics) applied to forest resources. The package in language R was denominated of LandscapeMetrics and used as base of development the packages igraph, raster, rgdal, rgeos, devtools, roxigen2 and Rtools. The database for the application of the LandscapeMetrics package originated from image data from the REIS sensor, RapidEye satellite, defining only land use and land cover classes, native forest and other uses. The forest fragments were analyzed in size classes and the results obtained allowed to determine in an area of 14,099.89 ha, 1,995 fragments. Among other conclusions, the development of the R package called LandscapeMetrics has proved to be an efficient and promising tool for spatial analysis of data obtained from remote sensing systems. With the same it is possible to analyze the spatial distribution of forest fragments, thus, the research comes to supply needs of routines in language R for the calculation of landscape ecology metrics.

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1. INTRODUCTION

For several years, deforestation has caused the destruction of natural resources due to the process of anthropization. As a result, the native forest gave way to other uses, resulting in the fragmentation of large forest areas, generating several negative impacts on the environment. Among them, extinction of fauna and flora species, soil erosion, silting of watercourses and local climatic changes (Rudolpho et al., 2013), besides causing species isolation, habitat loss, edge effects, decreasing biodiversity, invasion of exotic species and decreased pollination (Calegari et al., 2010). In general, the fragmentation process changes the dynamics of populations and communities, ecosystem processes and trophic interactions (Laurence and Vasconcelos, 2009).

Thus, there is a need for studies that spatially characterize the distribution of forest fragments in order to develop conservation strategies (Pirovani, 2010). In this context, the landscape ecology metrics that help in the process of understanding the landscape structure of a given location are inserted (Carrão et al., 2001). The metrics are important instruments for the definition of management techniques that aim to recover or conserve forest remnants thus contributing to the maintenance of biodiversity (Juvanhol et al., 2011). For this, several metrics are used to analyze spatial patterns with the aid of geoprocessing and remote sensing tools (Vidolin et al., 2011).

In order to contribute to the landscape studies, different software provide methods to analyze the landscape structure based on satellite images and remote sensing techniques (Zaragozí et al., 2012). However, the authors report that among the most important requirements of a software is to be open source, since they promote better interaction between future or existing projects. Also, it improves ecological research where there are financial restrictions (Steiniger and Hay, 2009). .

In this context, R has several advantages that make it a promising tool, because it is flexible in data type for analysis, is free, allows users to change functions and is compatible with all platforms (Muenchen, 2011). With this, it is possible, through the collaboration of the users, to solve problems of unavailability of packages, allowing to create and make available the packages to the community, which makes it a complete language (Casajus, 2013). Due to the advantages that language provides, it has become universal for data manipulation (Muenchen, 2011).

However, R language functions for the calculation of landscape ecology metrics are incipient, so it is necessary to implement functions to supply this need. The objective of this study was to develop an R-language package for the analysis of forest fragmentation, through the calculation of landscape ecology metrics.

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2. MATERIAL AND METHODS

The functions comprised metrics that were not redundant with the intention of encompassing different groups and thus meeting a greater demand of the users. In this way, the metrics included the following groups: area and density metrics, shape, border, central and proximity area, according to Table 1. The calculation of the metrics was based on the formulas described by McGarigal and Marks (1994).

Table 1 – Metrics used in the development of R-language functions.

Group	Metrics	Unity
Area and density	Class area	ha
	Number of patches	-
	Mean Patch Size	ha
	Patch Size Standard Deviation	ha
	Patch Size Coefficient of Variation	%
Edge	Total Edge	m
	Edge Density	m/ha
Shape	Landscape Shape Index	-
	Mean Shape Index	-
	Area-Weighted Mean Shape Index	-
	Mean Patch Fractal Dimension	-
	Mean Perimeter-Area Ratio	m/ha
Core Area	Total Core Area	ha
	Number of Core Areas	-
	Mean Core Area	ha
	Total Core Area Index	%
Proximity	Mean Nearest-Neighbor Distance	m

Source: McGarigal and Marks (1994).

For the development of the functions we needed the raster packages (Hijmans, 2017) version 2.6-7, rgdal (Bivand et al., 2017) version1.2-16, rgeos (Bivand and Rundel, 2017) version 0.3-26 e igraph (Csardi and Nepusz, 2006) version 1.0.1. We used the integrated development environment R language version 3.4.3 (R Development Core Team, 2017). Subsequently the functions were compiled into a package, which was denominated *LandscapeMetrics*, for this the packages devtools (Wickham and Chang, 2016) version 1.12.0, roxygen2 (Wickham et al., 2016) version 5.0.1 and Rtools version 3.3.0 were used.

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In order to obtain greater reliability in the generated data, each function was developed and used in a known area that allowed the calculation to be performed manually. In this way it was possible to compare the results generated by the functions with the results found manually. Subsequently, the functions were applied to an image from the Reis sensor, RapidEye satellite, with a special resolution of 5 meters, they were obtained through a project between the Federal University of Santa Maria and the Sindicato Interestadual da Indústria do Tabaco (SINDITABACO), the project aims to monitor the forest cover in deciduous forest areas in the Center-Serra region of Rio Grande do Sul, covering forest fragments of the Atlantic Forest biome. The image was classified using the Bhattacharyya algorithm with 99% acceptance threshold and two classes of use and land cover were defined native forest and other uses.

3. RESULTS AND DISCUSSION

3.1 Development of functions

In order to make the functions easy to use, its development was sought in such a way that it needed few input parameters. In this way, the functions only need the raster file (containing the thematic class that one wants to calculate the metrics), with the exception of edge density that still requires the total value of the study area, in hectares. Each function has a specific acronym, requiring its typing to obtain the corresponding metric, as shown in Table 2.

Table 2 – Metrics available in the LandscapeMetrics package.

Group	Metrics	Command	Input Parameter
Area and density	Class area	CA	Raster
	Number of patches	NP	Raster
	Mean Patch Size	MPS	Raster
	Patch Size Standard Deviation	PSSD	Raster
	Patch Size Coefficient of Variation	PSCOV	Raster
Edge	Total Edge	TE	Raster
	Edge Density	ED	Raster and Area*
Shape	Landscape Shape Index	LSI	Raster
	Mean Shape Index	MSI	Raster
	Area-Weighted Mean Shape Index	AWMSI	Raster
	Mean Patch Fractal Dimension	MPFD	Raster
	Mean Perimeter-Area Ratio	MPAR	Raster
Core Area	Total Core Area	TCA	Raster
	Number of Core Areas	NCA	Raster
	Mean Core Area	MCA	Raster
	Total Core Area Index	TCAI	Raster

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	Mean Nearest-Neighbor Distance	MNN	Raster
Proximity			

*Total landscape area in hectares.

3.2 Examples of using the functions available in the package

In order to be able to calculate the desired metrics at first, you must import the raster file, remembering that this should contain the thematic class that one intends to obtain the results, in our case the native forest obtained by means of the image classification REIS / RapidEye. The following command was used to import the image:

```
library(raster)
raster <- raster("Class.tif")
```

Where "Class.tif" corresponds to the nomenclature of the imported image in .tif format.
With the importation it was possible to obtain the total area of the forest fragments contained in the study area, in which it totaled 14,099.89 hectares.
As previously discussed, the functions were developed so that they only need the raster file (with the thematic class) as the input parameter, thus typing the acronym corresponding to the desired metric and the name of the file containing the thematic class can obtain the result of the same. As an example we have the calculation of the number of fragments (NP), which should proceed as follows:

```
> NP(raster)
[1] 1995
```

Thus, the value generated for NP is the number of fragments in the area. While for the calculation of the total edge (TE) the following command must be used:

```
> TE(raster)
[1] 4882156
```

Another example is obtaining the metric "Average Distance of the Nearest Neighbor" in which it is possible to obtain it by typing:

```
> MNN(raster)
[1] 43.15
```

To obtain the edge density (ED) one must proceed in a different way from the other metrics, since you need to enter the total study area together with the name of the raster file, according to the following command:

```
> ED(raster, 41460.27)
[1] 117.75
```

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In this way, with the exposed examples it is possible to perceive the ease of obtaining each metric, having only the raster file containing the thematic class in which it is intended to calculate. In order to obtain the other metrics (Table 2), proceed in the same way as the examples above.

4. CONCLUSION

With the development of the present work it was noticed that the R language is promising for the spatial analysis of data from remote sensing, which allowed to generate reliable results. The developed package LandscapeMetrics is easy to use, in which the functions only need the raster file as input parameter, being possible to calculate several metrics of landscape ecology. With the same it is possible to analyze the spatial distribution of forest fragments, thus, the research comes to supply needs of routines in language R for the calculation of landscape ecology metrics.

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CONTACTS

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Dr. Pereira, Rudiney
Federal University of Santa Maria, Brazil
Professor
Av. Roraima, 1000 Campus Universitário, UFSM-CCR
Santa Maria
97105-900
Rio Grande do Sul State
Brazil
Tel. +55 55 3220-9468
Fax +55 55 3220-8261
Email rudiney.s.pereira@ufsm.br
Web site: http://www.ufsm.br/labsere

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