Appendix C - Manual for LSM etrics v. 1.0.0

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Welcome to the LSM etrics wiki manual!



LandScape Metrics (LSMetrics) is a free and open-source package that calculates landscape connectivity and other ecologically-scaled landscape metrics. It is intended to be used as a tool for environmental research as well as for landscape management, conservation, and restoration. It uses land use or binary class (e.g., habitat/non-habitat) maps to calculate metrics of structural and functional connectivity, edge-based landscape metrics, and landscape diversity indices. It incorporates edge depth and the capacity of organisms on crossing gaps between habitat patches to re-classify and calculate metrics considering the landscape at the perspective of different species and functional groups. Besides, metrics are spatially explicit and may be assessed at multiple scales.

LS Metrics was developed in Python 2.7 and runs within a GRASS GIS environment (currently, GRASS 7.0.x or newer). Here you will find a brief description of the program functionalities so you can quickly use it. We wish to make sure you can easily install GRASS, import your input maps, run LSMetrics and export or use its output in various ways.

If you have suggestions on how to improve this tutorial, feel free to contact us or open an issue.

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Citation

Please cite LSMetrics when using the package in your work:

Niebuhr, B. B. S.; Martello, F.; Ribeiro, J. W.; Vancine, M. H.; Muylaert, R. L.; Campos, V. E. W.; Santos, J. S.; Tonetti, V. R.; Ribeiro, M. C. Landscape Metrics (LSMetrics): a spatially explicit tool for calculating connectivity and other ecologically-scaled landscape metrics. *In preparation*.

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If you want to know more about free and open source software, look this and that.

Brief description

The package

LandScape metrics (LSMetrics) is a free and open source package developed calculates multiple landscape metrics for raster data.

The package uses input raster maps with integer values only, in which each cell represents an area considered to be homogeneous, such as a land use or vegetation type. The maps can be either binary (1 = habitat, 0 = non-habitat) or multi-class (e.g. land use and land cover maps). The majority of landscape metrics are calculated using binary class raster maps, except for the landscape diversity indices, which only make sense for multi-class raster maps. LSMetrics may also transform multiple class maps into binary ones before the calculation of metrics.

Once a GRASS project is created and raster maps are imported into it, using r.import or r.in.gdal (or other r.in.*) modules, for instance, LSMetrics may be run in two ways (see the Figure below). The first is calling a python application and opening the GUI; the second is building a Python script (or opening a Python shell inside GRASS GIS prompt) and calling each landscape metric as a Python function. Both methods allow the users to run multiple metrics with various parameters and scales, for multiple maps, in a single run.

The output maps consist in raster maps for each chosen landscape metric, as well as text files with statistics of some of the metrics at the patch or class level, to be analyzed with any statistical software.



Metrics

LSMetrics currently perform the following calculations: Preparation of inputs:

• Transformation of land use maps in binary class maps

Metrics of *structural connectivity*:

• Patch size

- Fragment size
- Structural connectivity
- Proportion of habitat

Metrics of *functional connectivity*:

- Functionally connected area
- Functional connectivity
- Complete functionally connected area

Edge-based metrics:

- Classification in core/edge/matrix
- Classification in landscape elements: edge/core/stepping stones/corridors/branches/matrix
- Binary maps: edge/non-edge
- Binary maps: core/non-core
- Proportion of edge area
- Proportion of core area
- Area of clumps of edge and core areas

Landscape diversity (through the r.diversity GRASS addon):

- Shannon
- Simpson
- Pielou
- Rényi

For more information on the metrics calculated and details on implementation, look at the publication:

Niebuhr, B. B. S.; Martello, F.; Ribeiro, J. W.; Vancine, M. H.; Muylaert, R. L.; Campos, V. E. W.; Santos, J. S.; Tonetti, V. R.; Ribeiro, M. C. Landscape Metrics (LSMetrics): a spatially explicit tool for calculating connectivity and other ecologically-scaled landscape metrics. *In preparation*.

The repository

The LSMetrics repository is organized in 7 folders:

- _LSMetrics_v1_0_0: Here the main pieces of the LSMetrics code are located:
 - 1. LSMetrics_v1_0_0.py: main script.

- 2. test_LSMetrics.py: a Python script with the list of functions of LSMetrics and their usage as Python functions (outside GUI).
- 3. r_diversity.py: The r.diversity GRASS addon as python code, used to calculate landscape diversity indices in LSMetrics.
- previous_versions: Old versions of the code.
- grassdb_test: raster maps for testing. This includes:
 - 1. APA_Sao_Joao_RJ_cut_SIRGAS_UTM23S.tif: A land use map in Rio de Janeiro state, Brazil, inside the Golden Lion Tamarin occurrence region. The map was classified based on LANDSAT 7 satellite images.
 - 2. SP_RioClaro_use_raster.tif: A land use raster of the municipality of Rio Claro, State of São Paulo, Brazil.

Using LSMetrics

Here we describe how to install and use LSM etrics step-by-step. If you have questions or suggestions to make it more didatic, please contact us!

1. Downloading LSMetrics

First download the .zip package or clone it into your local environment using GitHub Desktop or git:

```
# Choose the directory where to clone LSMetrics
cd path/to/LSMetrics_dir
```

```
# Clone it
git clone "https://github.com/LEEClab/LS_METRICS.git"
```

2. Have GRASS GIS installed

LSMetrics runs within GRASS GIS and uses many of its modules and functionalities, so you first need to have GRASS installed in your computer. We recommend you install GRASS version 7.2.2. Follow the instructions.

Installing GRASS GIS

LSMetrics was developed and runs inside GRASS GIS environment, version 7.2.x. Thus, we strongly recommend the use of one of these GRASS versions. It is possible to download this software at the GRASS GIS website.



MS Windows

GRASS GIS is available for different versions of Windows. Download the .exe file and install it in your computer. Alternativelly, you may download the OSGeo4W package, which includes QGIS, GDAL, GRASS and other GIS tools. More information on GRASS installation on Windows can be found here.

Ubuntu Linux

The installation of GRASS GIS in Ubuntu is simple. In the terminal, it is necessary to enter all following lines:

sudo add-apt-repository ppa:ubuntugis/ubuntugis-unstable sudo apt-get update sudo apt-get install grass

For more information or previous versions of GRASS, click here.

GRASS GIS is also available for other Linux distributions, but we have not tested LSMetrics on them. If you wish to test it, please informs us either by e-mail or by an issue, so that we can include information about it here (and thanks in advance!).

MacOS

For information on GRASS GIS installation on MacOS, take a look here.

LSMetrics was not tested through the Graphical User Interface (GUI) in MacOS yet. If you want to do it, please tell us so that we can adapt the GUI slightly to it. However, LSMetrics package is expected to run in any MacOS platform through Python command line.

3. Preparation of inputs

Prepare your input maps outside GRASS GIS

LSMetrics input maps can be binary maps or non-binary land use maps. Binary maps contain "1" and "0" values; "1" represent a kind of habitat or land use of interest, while "0" represents all other land use classes. Non-binary maps can include different land use classes, such as different types of forests and matrices (pasture, plantations, highways). Each class is then assigned a integer code. For example, in the map shown below forest pixels have code "6", pastures are "12", water equals "8", and roads equals "3". The user must to define the codes of each class of the land use map using GRASS GIS or any other GIS software, so that they can select the codes of their interest in LSMetrics.

See in the figure below a land use raster representation with several classes, using as example a location in Rio de Janeiro, near the Poço das Antas Biological Reserve.



Note that the codes are showed as integers. See the main codes meaning below, in comparison with a satellite image for the same area:



The LS metrics repository also contains a map with land use classes in the municipality of Rio Claro, for testing purposes. We used the Rio Claro map to run the examples of metrics in the Output links.

Satellite images can be classified by image interpretation or automatic classification algorithms (supervised or unsupervised). If you still need to map your study area, consider the following auxiliary readings and video:

- QGIS tutorial by LEEC team
- Supervised and unsupervised classification
- Tutorial 1: Your First Land Cover Classification

There are many alternatives of land use maps and binary maps for different geographic regions. Take a look at some examples:

- MapBiomas
- Global Forest Watch
- Land use and land cover in Brazil

Reference system

As LSMetrics uses meters and hectares the default units for calculating distances and areas, raster input maps must be exported in a metric coordinate reference system (CRS), such as Albers or UTM coordinate systems. Please, check the next sessions on creating a GRASS Location and be sure about your working EPSG code.

4. Starting

To start calculating metrics, first you need to create or open a GRASS GIS project (called location) and then open the LSM etrics GUI through command line.

Open or load a GRASS project

Open GRASS GIS and load or create your project location. If you do not know how to configure a project in GRASS, take a look here. Here we show one way of creating a GRASS location.

A GRASS location is a project that keeps all maps and spatial data cohesive under the same Datum and Projection. To work with your own GIS data, you must create a location with an **EPSG** (a code that represent a combination of datum and projection) that is similar to your data's. For example, if your rasters are in UTM 23 South projection with a SIRGAS 2000 datum, your GRASS location should be exactly on this projection. Follow the next steps to create a projection and import a raster map, so you can run LSMetrics with your own data.

Click on New Location wizard as follows:

	** – 🗆 ×
G	RASS GIS
Bringing advance	ed geospatial technologies to the world
1. Select GRASS GIS database directory	Browse
GRASS GIS database directory contains Locations.	
2. Select GRASS Location	3. Select GRASS Mapset
New Rename Dejete	New Rename Delete
All data in one Location is in the same coordinate reference system (projection). One Location can be one project. Location	Mapset contains GIS data related to one project, task within one project, subregion or
contains Mapsets.	user.

Browse the file containing the rasters of interest:

Define new GRASS Location						×
and the second second		Define GRASS	Database an	d Location	Name	
	GIS Data Directory: Project Location: Location Title:	D:\my_gis_data newLocation Set default region ext Create user mapset	ent and resolution		Browse	
			A	juda < Vo	oltar <u>P</u> róximo >	<u>C</u> ancelar

Choose a simple name for your Location (Here we keep as the default **newLocation**): (Please avoid using spaces and special characters on the name of the location!!!)

Define new GRASS Location			\times
and the second s		Define GRASS Database and Location Name	
	GIS Data Directory: Project Location: Location Title:	D:\my_gis_data Browse newLocation Set default region extent and resolution Create user mapset	
		Ajuda < Voltar Próximo > Cancela	r

Now it is time to select your working EPSG, which is basically the spatial reference system of your data. If you don't know which one is it, figure it out here.

Define new GRASS Location		×						
and a	Choose method for creating a new location							
	Simple methods: © Select EPSG code of spatial reference system Read projection and datum terms from a georeferenced data file Read projection and datum terms from a Well Known Text (WKT) .prj file Create a generic Cartesian coordinate system (XY) Advanced methods: Select coordinate system parameters from a list Specify projection and datum terms using custom PROJ.4 parameters							
	<u>Aj</u> uda < <u>V</u> oltar <u>P</u> róximo >	<u>C</u> ancelar						

Define new GRASS Location						×
			Choose EPSG Cod	le		
	Path to the EPSC	3-codes file:	Im Files\GRASS GIS 7.2.2\share\proj\epsg 31983 Q 31983]	Browse	
	Code	Description			Parameters	
	31983	SIRGAS 20	00 / UTM zone 23S		+proj=utm +zone=23 +sou	th +ellps≕
	<				_	>
			Ajuda		< Voltar Próximo >	Cancelar
			200			

You also can easily read the right spatial references system from a georeferenced file.

Define new GRASS Location	1	×					
a in	Choose method for creating a new location						
	Simple methods: Select EPSG code of spatial reference system Read projection and datum terms from a georeferenced data file Read projection and datum terms from a Well Known Text (WKT) .prj file Create a generic Cartesian coordinate system (XY) Advanced methods: Select coordinate system parameters from a list Specify projection and datum terms using custom PROJ.4 parameters						
	Ajuda < Voltar Próximo >	<u>C</u> ancelar					

Just find the file in you computer and GRASS will get the EPSG code from it. Follow the steps:

Define new GRASS Location									\times
Define new GRASS Location	Georeferenced file:	Selec	t georeferen	ced fil	B	Browse	•		×
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Define new GRASS Location							\times
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Define new GRASS Location		×
and the second second	Summary	
GRASS Databa Location Name Location Title: Projection : PROJ.4 definitive	<pre>se: D:\my_gis_data : newLocation matches file D:\my_gis_data\APA_Sao_Joao_RJ_cut_SIRGAS_UTM23S.tif on: +proj=utm +south +no_defs +zone=23 +a=6378137 +rf=298.257222101 +towgs84=0,0,0,0,0,0,0 +to_meter=1</pre>	
	<u>Aj</u> uda < <u>V</u> oltar	<u>C</u> oncluir <u>C</u> ancelar

Done! Now you created a GRASS GIS location!

Import your maps into GRASS (your own SIG data)

Import maps right after creating the location

After creating a GRASS project, you can readily import the raster used for selecting the EPSG to GRASS environment. If you click "No", then you can also import your rasters easily - see below.

🕸 GRASS GIS 7.2.2 s	tartup	↔	- 🗆 ×
	Bringing advance	RAS.	S GS ogies to the world
1. Select GRASS GIS da	tabase directory		
D:\my_gis_data			Browse
GRASS GIS database din	ectory contains Locations.		
2. Select GRASS Loca newLocation	Do you want to impo <d:\my_gis_data\apa to the newly created</d:\my_gis_data\apa 	ort A_Sao_Joao_RJ_cut_IRGAS_UTM23S location? Sim N	i.tif> New Rename Delete
All data in one Location i coordinate reference sys One Location can be on contains Mapsets.	is in the same tem (projection), e project. Location Start GRASS session	Mapset contains GIS data relate project, task within one project user.	d to one subregion or

Importing data within a GRASS session

First you can start your GRASS session by pressing the START GRASS button.



Now that you opened a grass session, see how GRASS-GIS looks like. Basically you have thee windows - a shell terminal, in which you can run GRASS procedures through command line; and two Graphical User Interface windows:

👻 GRASS GIS 7.2.2 Layer Manager 😁	-		GRASS GIS 7.2.2 Map Display: 1 - Location: newLocation@PERMANENT	*	
File Settings Raster Vector Imagery 3D raster Database Temporal Help				~	
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миар кауста					
Layers Console Modules Data Python					
	-		1 Man display		
Starting GRASS GIS					
WARNING: Concurrent mapset locking is not supported on Windows			1		
GRASS GIS homepage: http://grass.osgeo.org					
This version running through: Command Shell (C:\WINDOWS\system32\cmd.exe) Help is available with the command: g.manual -i					
See the licence terms with: g.version -c					
If required, restart the GUI with: g.gui wxpython					
when ready to quit enter: exit					
Launching <wxpython≻ background,="" gui="" in="" please="" the="" wait<br="">Microsoft Windows [versão 10.0.16299.192]</wxpython≻>					
(c) 2017 Microsoft Corporation. Todos os direitos reservados.					
C:\Users\renatamuy> Command line					
			762028.43; 7504191.95 Coordinates	~	Render

Let's import your raster data using the function r.in.gdal, but clicking:



Where is your raster data? Browse to import:

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	GRASS GIS 7.2.2 Map Display: 1 - Location: newLocation@PERMANENT	U X
File Settings Raster Vector Imagery 3D raster Database Temporal Help	— 🖪 🔍 🐂 🔷 🖉 🗩 🏹 🎗 유 🔍 특취 🎼	2D view V
,		-
Import raster data	Choose file to import	×
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Layers Console Modules Layer id Layer name Projection match Name for output GRASS map (editable)		Abris Conselar
		Cancom
Starting GRASS GIS		
WARNING: Concurrent map		
GRASS GIS homepage:		
This version running th		
See the licence terms u		
See citation options w Allow output files to overwrite existing files		
If required, restart ti □ dow delog on friah		
Close Import		
Launching Goxythony GU Nicrosoft Windows [Vers] Servers sattless [Incode attions]	N	
(c) 2017 Microsoft Corporation reads of arterios reservouss.		
C:\Users\renatamuy>		
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🗄 🔿 Digite aqui para pesquisar 🛛 🔒 💿 😨 📄 💌 🏧	🖻 🚸 🚿 🙆	x ^R ∧ ♥ ■ @ 40 POR 15:19

And finally, click on "Import":

Profiles					
oad:			~	Save	Remove
iource type					
File	Orectory ODatabase OProtocol				
ource input	t				
e: D:\my_	_gis_data\APA_Sao_Joao_RJ_cut_SIRGAS_U	TM235.tif			Browse
ist of raster	lavers - right click to (un)select all				
	ayers ingities to (on josses of				
Layer id	Layer name	Projection match	Name for output GR	ASS map (edit	able)
Layer id	Layer name APA_Seo_Joeo_R1_cut_SIRGAS_UTM23.	Projection match	Name for output GR APA_Sao_Joao_RJ_o	LASS map (edit cut_SIRGAS_U	able) ITM23S
Layer id	Layer name APA_Sao_Joao_RJ_cut_SIRGAS_UTM23	Projection match	Name for output GR	LASS map (edit cut_SIRGAS_U	able) ITM235
Layer id	Layer name APA_Sec_Joeo_R1_cut_SIRGAS_UTM23 rojection check (use current location's proje at files to overwrite existing files ed layers into layer tree	Projection match Yes	Name for output GR	IASS map (edit	able) ITM235

Follow the next session to visualize your imported map(s) in GRASS display with our example data.

If you want more information on importing maps into GRASS, have a look at this and this.

Observation: Make sure that your imported maps are in a projected coordinate reference system (CRS), in which distances are measured in meters, so that areas and distances are calculated in a meaningful way by LSMetrics.

GRASS database for testing

To make your life easier, we make available a GRASS database with two raster images, for testing. Select the file grassdb_test and **Start GRASS session** as follows:

			↔	-	
Bringing	G	RA geospatial t	SS	ies to t]]S he world
1. Select GRASS GIS database directory					
D:\Coworks\LS_metrics\LS_METRICS-mas	ter\LS_METRICS-ma	aster\grassdb_test			Browse
GRASS GIS database directory contains Loc	cations.				
2. Select GRASS Location newLocation	New	- 3. Select GRASS	Mapset		New
	rename				Rename
	Delete				Delete
All data in one Location is in the same coordinate reference system (projection). One Location can be one project. Location contains Mapsets.	Delete	Mapset contains project, task with user.	GIS data related iin one project, s	to one ubregion or	Delete

Note that you can display the maps either by coding or by clicking. If you choose clicking, then follow the steps to visualize out both example data:



Choose the São João raster map:

	– 🗆 X	GRASS GIS 7.2.2 Map Display: 1 - Location: newLocation@PERMANENT	↔ _	\Box \times
<u>File Settings Raster Vector Imagery 3D raster Database Ten</u>	mporal <u>H</u> elp			
u	1. 🕞 👘			
/				
Display 1	↓ ↓ ×			
Add raster map layer (double click to set properties)	Construction of rate	isplay, graphics, raster) ++ × user-specified raster map in the active graphics frame. action Null cells Optiona Manual rmap to be displayed: (map=name) ap RD, cell CIRGAS_UTM23S@PERMANENT har Aplique OK Copiar Ajuda IPA_Sao_Joao_RJ_cett_SIRGAS_UTM23S@PERMANENT		
Layers Console Modules Data Python				Filmenter
		15102.04; 1490722.24 Coordinates	•	Kender

Choose the Rio Claro raster map:



Now see below how the example maps will appear in GRASS display:

São João, State of Rio de Janeiro:



Rio Claro land use map, State of São Paulo:



On GRASS GIS display, you can evaluate the pixel values using the Query results tool. Se below:



Now see the code for showing the already existent example data: d.rast map=APA_Sao_Joao_RJ_cut_SIRGAS_UTM23S@PERMANENT d.rast map=SP_RioClaro_use_raster@PERMANENT

Run LSMetrics

Now it is finally time to use the package itself. Use the GRASS terminal (the black screen) to start LSM trics. First change to LSM trics directory and run it using python:

```
# Change to the code directory where you saved the program (with the version of LSMetrics you want to use)
cd "LS_METRICS/_LSMetrics_v1_0_0"
```

```
# Run LSMetrics
python LSMetrics_v1_0_0.py
```

Note!

On MS Windows, you may have to change to the partition where the code is located before changing to its directory. E.g.:

```
# If the code is on the directory "D:/"
D:
cd "D:/LS_METRICS/_LSMetrics_v1_0_0"
```

Now take a look at the Windows GUI (the GUI may be slightly different on different operational systems, but is expected to run the same way):

LSMetrics v. 1.0.0		↔	_		×
ecologica	metrics			LE	EC
Single or multiple maps?	APA Sao Joao RJ cut SI	RGAS UTM23S	~		
Multiple	Pattern:	_			
Prepare maps for BioDIM?				Ex	port?
Create binary map:	Codes for habitat:				
Use binary maps to calcul	ate other metrics?				
Metrics of structural connecti	ivity:				
Patch size map:					
Fragment size map:	Edge depths (m):				
Structural connectivity:					
Proportion of habitat:	Window size (m):				
Metrics of functional connect	ivity:				
Functionally connected area:	Crossing distance (m):				
Functional connectivity	Comple	ete funct. connec	ted area		
Metrics of edge:	Map of distance from edges	1			
Classify edge/core/matrix:	Edge depths (m):				
Proportion of edge/core:	Window size (m):				
Calculate area of edge/co	ore dumps?				
Landscape diversity:	Window size (m):				
Index: Shannon	Simpson Pielou	Renyi	Alpha	:	
START CALCULATIONS		EXIT			

Notes on screen resolution

If the GUI does not appear completely in your screen, check your screen resolution (at least 900 pixels in the vertical direction) and your percent of text display (up to 125%) so that the program window entirely appears. (we'll solve that soon!).

5. Running LSMetrics through GUI

Here we briefly explain how to set some important parameters used in LSmetrics. Again, make sure your input raster is using a metric coordinate reference system (CRS) by selecting the right EPSG. If your raster maps are not in a metric system EPSG, you will need to reproject them. For the reprojection, you need to know which is the SRC of your maps with projection different from your location. To do this, take a look at v.import.

Select the input map(s) and after you choose all the parameters that fit your analysis, you can click on "START CALCULATIONS". Note that when choosing Export, the output of calculations (output raster maps and statistics text files) will be exported to a folder chosen by the user.

LSMetrics v. 1.0.0		*	-		×
	metrics			LE	EC
Single or multiple maps?	Select in	put map:			
Single Multiple	SP_RioClaro_use_raster		~		
Omultiple	Pattern:				
Prepare maps for BioDIM?				Ð	iport?
Create binary map:	Codes for habitat:	4			
Use binary maps to calcu	late other metrics?				
Metrics of structural connect	ivity:				
Patch size map:					
Fragment size map:	Edge depths (m):	60			
Structural connectivity:					
Proportion of habitat:	Window size (m):	1000			
Metrics of functional connec	tivity:				
Functionally connected area	: Crossing distance (m):	1	00		
Functional connectivity	Com	plete funct. co	nnected area		
Metrics of edge:	Map of distance from edge				
Classify edge/core/matrix:	Edge depths (m):	6	0		
Proportion of edge/core:	Window size (m):	1000			
Calculate area of edge/co	re clumps?				
Landscape diversity:	Window size (m):	1	000		
Index: Shannon	Simpson Pielou	✓ R	enyi Alph	a: 0.5	
START CALCULATIONS		DUT			

Then, select the output directory where all the rasters with the chosen metrics will be saved, as follows.

Procurar Pasta	\times
Select the folder where the output files will be saved:	
> 🤱 renatamuy	^
🗸 🛄 Este Computador	
🛄 Área de Trabalho	
> 🛱 Documentos	
> 🕂 Downloads	
> 📰 Imagens	
> 🁌 Músicas	~
Pasta: Documentos	
Criar Nova Pasta OK Cancela	r .

Single map or multiple maps?

LSMetrics may calculate metrics for a single or multiple maps at once. If you select "single", choose the map name in the list of maps (only maps in you current GRASS GIS mapset will appear) and select the metrics you wish to calculate.

Alternatively, you can run the selected metrics for multiple input maps in a single run, if they share some part of their names, using regular expressions. For instance, **let's say** you have the following three maps within your current mapset:

- APA_Rio_Sao_Joao_tif
- $\bullet \ {\rm SP_RioClaro_North_tif}$
- SP_RioClaro_South

In this case, as some of the maps have sequences of characters in common (e.g., "tif" between the first two, and "SP_RioClaro" between the last two maps), you can choose which ones to use as LSMetrics input using that. For running the calculations for a sequence of rasters with a string common pattern in raster file name, you must use the symbol "*" (asterisk). For example, in the white box of LSmetrics (Pattern):

- if the file names' common pattern is all that starts with "SP", put: SP* (see the image below);
- if you want to select all maps that contain "forest" in any part of the file name, put: ***forest***;
- if you want all maps that end with "SP", type: ***SP**;
- if you want to use all maps loaded in you current mapset as input, type: *.

LSMetrics v. 1.0.0			*	-		\times
	met	rics				EC
Single or multiple maps?	co pieches	Select inp	ut map:			
Single Multiple	Pattern:	sp			ר	
Prepare maps for BioDIM?					Ex	port?
Create binary map:	Codes for hal	bitat:				
Use binary maps to calcul	ate other metri	cs?				
Metrics of structural connect	ivity:					
Patch size map:						
Fragment size map:	Edge depths	(m):				
Structural connectivity:						
Proportion of habitat:	Window size	(m):				
Metrics of functional connect	ivity:					
Functionally connected area	Crossing	distance (m):				
Functional connectivity		Compl	ete funct. conne	ected area		
Metrics of edge:	Map of distar	ice from edge	s			
Classify edge/core/matrix:	Edge dep	ths (m):				
Proportion of edge/core:	Window size	(m):				
Calculate area of edge/co	ore dumps?					
Landscape diversity:	Window size	(m):				
Index: Shannon	Simpson	Pielou	Reny	i Alpha	:	
START CALCULATIONS			EXIT			

Creating binary maps

Most indices caluculated by LSMetrics are currently based on binary class (habitat/non-habitat) raster maps as input. If your map(s) are already classified this way (binary), you can use them straightforwardly as input to calculate metrics. If not, first you should select **Create binary map** and tell the app which pixel unique codes correspond to habitat. Then, you can use the resulting map as input to calculate landscape metrics by clicking in Use binary maps to calculate other metrics.

PS: If you select the option Use binary maps to calculate other metrics, you can already choose the metrics you want to calculate and generate all of them in the same run. If, instead, you create the binary map alone, you should then select the resulting map to then calculate the other metrics (in this case, unselect this option).

LSMetrics v. 1.0.0		*	-	□ ×
ecologie	metric	S		
Single or multiple maps?	Sek	ect input map:		
() Single	SP_RioClaro_use_ra	ister	~	
OMultiple	Pattern:			
Prepare maps for BioDIM?				
				Export?
Create binary map:	Codes for habitat:	12.8	_	
	ate ather matrice?			
Suse binary maps to calcu	ate other metricsri)
Metrics of structural connect	ivity:			
Patch size map:				
Fragment size map:	Edge depths (m):			
Structural connectivity:				
Proportion of habitat:	Window size (m):			
Metrics of functional connect	ivity:			
Functionally connected area	Crossing distance	e (m):		
Functional connectivity		Complete funct. conn	ected area	
Metrics of edge:	Map of distance from	edges		
Classify edge/core/matrix:	Edge depths (m):			
Proportion of edge/core:	Window size (m):			
Calculate area of edge/c	ore dumps?			
Landscape diversity:	Window size (m):			
Index: Shannon	Simpson Pie	elou Reny	i Alpha:	
START CALCULATIONS		EXIT		

Binary maps are useful to investigate classes of interest and their metrics. See examples below:

This is an example of land use map that was transformed in a binary habitat map from specific codes for habitat classes (values from 15 to 20).



Below you may find another classic representation of binary maps. In the first, "1" (yellow) values represent the matrix, on the second the "1" (yellow) values represent the habitat areas.



Structural connectivity metrics

Patch size

Summed area (in hectares) of one or more fragments connected by structural corridors (including the area of the corridors connecting them); if there are no fragments connected to the fragment in question, the value of this metric is equal to "fragment size" (see below). In the illustration map below, each cell has 100 m side.



Fragment size

Area (in hectares) of any structurally isolated fragment, of any size, or the area of a fragment connected to another fragment by a structural corridor. Structural corridors are identified as parts of fragments with a width smaller than two times the specified edge depth.

The definition of what is a fragment then depends on the edge depth parameter chosen by the user.

In the illustration map below, each cell has 100 m side and the edge depth was chosen as 50 m.



Structural connectivity

Area of habitat that is structurally (contiguously) connected to a fragment. In practice, it is the difference (in hectares) between the Patch size and the Fragment size metrics; when a patch has only one fragment, its structural connectivity will be zero.

The definition of this metric depends on what is a fragment and a structural corridor, so it also depends on the edge depth parameter chosen by the user.

In the illustration map below, each cell has 100 m side and the edge depth was chosen as 50 m.

Proportion of habitat

Proportion of the target landscape class (habitat or another class(es) of interest, the one represented by the value 1 in the input binary map) within a given window around each map cell. It depends on the size of the window chosen by the user.

How to choose the window size? The user must decide which window size will be used to calculate metrics. It corresponds to search extent from each pixel where the calculations will be applied. It can be based on the extent of landscape perception of the target species, process or groups analyzed. It is given in meters.

Functional connectivity metrics

Functionally connected area

Represents the total amount of habitat area (in hectares) functionally available for an organism located in a patch, given a gap crossing capability of the organism. This is calculated by generating a buffer of size equal to half of the gap crossing capacity of the organism, around all patches, grouping all habitat patches close enough in the same clusters of patches, and summing up the area of all the grouped patches.


Functional connectivity

The amount of area functionally connected to a habitat patch, given a gap crossing capability of a species or group of interest. First, a buffer of interest equal to half of the width (in meters) that a species is able to cross is created. Then, the habitat patches that are close enough ara grouped within the same buffer. We then sum the area (ha) of all this grouped patches. We refer to these groups of nearby habitat patches as habitat **clumps**. Finally, to obtain the strict functional connectivity, we calculate the difference between each clump size (ha) and patch size (ha);



Complete functional connected area

The total amount of habitat functionally available for any species, given a gap crossing capability. We do all the steps for the "Functional connectivity" calculation, but do not subtract the patch size from the clump size.

Total functional connected area

Input raster: binary raster input parameter: gap crossing distance (meters)



Metrics based on the delimitation of edges

See the charts and brief explanation of each metric below:

Classification of landscape structural elements

These metrics are classifications of landscape in three or more structural elements. The simple version of this metris divides elements in three categories: core, edge and matrix. The more complex version divides elements in: core, edge, corridor, branch, stepping stone and matrix (will be available soon). See below both versions:

Classification of landscape structural elements (simplified version)

Input raster: binary raster Input parameter: edge depth (meters)



Classification of landscape structural elements

Input raster: binary raster Input parameter: edge depth (meters)



Map of distance from edges

The output value of each pixel will represent the distance of this pixel to the nearest edge.



Classify edge/core/matrix

Considering a specified Edge depth, this metric classifies the pixels as belonging to three categories: edge, core and matrix. How species really use habitat area would be represented by the core area, since many species have limitations on using edges or less quality areas than their preferred habitat.

Proportion of edge/core

Percentage of habitat and edge within a search radius (Window size parameter), given a specified edge depth (Edge depths parameter).

Percentage of core

Input raster: binary raster Input parameter: edge depth (meters) Input parameter: window size (meters)



Percentage of edge

Input raster: binary raster Input parameter: edge depth (meters) Input parameter: window size (meters)



Edge depths This parameter is a proxy for investigating the impact of edge influence on the different pixels. It estimates the distance of edge influence and should be carefully thought a priori by the user, since it will be used to calculate the output metrics. It is set in meters, and as larger the value, larger the edge influence and extent through landscape.

Calculate area of edge/core clumps?

(Achei difícil reduzir essa explicação)

Given edge and core areas were identified, contiguous cells are clumped into edge and core clumps (i.e., cells of edge and core that pertain to the same patch), and their areas are calculated (in hectares). Two maps are created for

each one (edge/core) for each landscape: an edge (core) clump ID (edge or core PID) map, which sets a distinct integer number to each clump of edge (core) cells, and a clump size map, which sets the the area of those clumps; non-edge (non-core) cells are set to NULL in both.





Landscape diversity metrics

Diversity indexes require multi-class raster maps. In order to calculate landscape diversity, the user must set which land use class codes are relevant for the calculation. In our example data, we have the land use for Rio Claro municipality. LSMetrics run the landscape diversity measures with **all classes**. We suggest always having more than three classes in your land use map to increase the variability in the landscape diversity measures. The user must choose the window size that will be used to calculate the diversity in landscape. In the example, we set as 1000 m and click to calculate all diversity measures. This means that the search radius will be 1000 meters.

💽 LSMetrics v. 1.0.0 (Não está respondendo) 🛛 😁 🚽 🧹					
ecologie	metrics				
Single or multiple maps?	Select input map:				
Single	SP_RioClaro_use_raster	~			
OMultiple	Pattern:				
Prepare maps for BioDIM?		Export?			
Create binary map:	Codes for habitat:				
Use binary maps to calcula	te other metrics?				
Metrics of structural connectiv	ity:				
Patch size map:					
Fragment size map:	Edge depths (m):				
Structural connectivity:					
Proportion of habitat:	Window size (m):				
Metrics of functional connectivity:					
Functionally connected area:	Crossing distance (m):				
Functional connectivity Complete funct. connected area					
Metrics of edge:	Map of distance from edges				
Classify edge/core/matrix:	Edge depths (m):				
Proportion of edge/core:	Window size (m):				
Calculate area of edge/core clumps?					
Landscape diversity:	Window size (m): 1000				
Index: 🗹 Shannon 💽	Simpson 🗹 Pielou 🗹 Renyi	Alpha: 0.5			
START CALCULATIONS	EXIT				

Maps identifying patches, fragments, and functional patches

PIDs are Patch or Clump identification codes for the respective selected metrics. FIDs are identification codes for each clump generated by connectivity metrics.



6. LSMetrics outputs

After LSMetrics runs, you will see in your screen the following message, with a sound:



By default, LSMetrics outputs are raster maps in ".tiff" format. We will use the palette "byr" from r.colors for coloring our diversity rasters. For practical reasons, we are using different points near the state forest region of FEENA to show their values for each metrics via Query results in GRASS GIS display. If you want to visualize the values of each metric for a same spatial point, you can use r.what in the command line of GRASS GIS:

r.what map=SP_RioClaro_use_raster_diversity_1000m_pielou_size_33@PERMANENT coordinates=241349.630457,75175

If you choose all metrics, you will see them in the output file you've chosen before.

SP_RioClaro_use_raster_HABMAT	25/02/2018 16:46	Arquivo TIF	1.199 KB	
SP_RioClaro_use_raster_HABMAT_0060m_fid	25/02/2018 16:46	Arquivo TIF	1.198 KB	
SP_RioClaro_use_raster_HABMAT_0060m_fragment_AreaHA	25/02/2018 16:46	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_0100m_func_connect_AreaHA	25/02/2018 16:47	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_0100m_func_connect_complete_AreaHA	25/02/2018 16:47	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_0100m_func_connect_complete_pid	25/02/2018 16:47	Arquivo TIF	2.726 KB	
SP_RioClaro_use_raster_HABMAT_0100m_func_connect_pid	25/02/2018 16:47	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_0100m_functional_connectivity	25/02/2018 16:47	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_CORE_0060m	25/02/2018 16:47	Arquivo TIF	1.199 KB	
SP_RioClaro_use_raster_HABMAT_CORE_0060m_AreaHA	25/02/2018 16:47	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_CORE_0060m_pct_1000m	25/02/2018 16:47	Arquivo TIF	1.199 KB	
SP_RioClaro_use_raster_HABMAT_CORE_0060m_pid	25/02/2018 16:47	Arquivo TIF	1.198 KB	
SP_RioClaro_use_raster_HABMAT_diversity_1000m_pielou_size_33	25/02/2018 16:48	Arquivo TIF	9.387 KB	
SP_RioClaro_use_raster_HABMAT_diversity_1000m_renyi_size_33_alpha_0.5	25/02/2018 16:48	Arquivo TIF	9.387 KB	
SP_RioClaro_use_raster_HABMAT_diversity_1000m_shannon_size_33	25/02/2018 16:48	Arquivo TIF	9.387 KB	
SP_RioClaro_use_raster_HABMAT_diversity_1000m_simpson_size_33	25/02/2018 16:48	Arquivo TIF	9.387 KB	
SP_RioClaro_use_raster_HABMAT_EDGE_0060m	25/02/2018 16:47	Arquivo TIF	1.199 KB	
SP_RioClaro_use_raster_HABMAT_EDGE_0060m_AreaHA	25/02/2018 16:47	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_EDGE_0060m_pct_1000m	25/02/2018 16:47	Arquivo TIF	1.199 KB	
SP_RioClaro_use_raster_HABMAT_EDGE_0060m_pid	25/02/2018 16:47	Arquivo TIF	2.726 KB	
SP_RioClaro_use_raster_HABMAT_habitat_pct_1000m	25/02/2018 16:47	Arquivo TIF	1.199 KB	
SP_RioClaro_use_raster_HABMAT_MECO_0060m	25/02/2018 16:47	Arquivo TIF	1.199 KB	
SP_RioClaro_use_raster_HABMAT_patch_AreaHA	25/02/2018 16:46	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_pid	25/02/2018 16:46	Arquivo TIF	2.752 KB	
SP_RioClaro_use_raster_HABMAT_0100m_func_connect_complete_pid.tif.aux	25/02/2018 16:47	Documento XML	31 KB	
SP_RioClaro_use_raster_HABMAT_EDGE_0060m_pid.tif.aux	25/02/2018 16:47	Documento XML	92 KB	

Next, we are going to briefly present a layout of each landscape metrics outputs, together with their sufix file names and query results in printscreens of GRASS GIS displays.

Take a look on the 27 output suffixes of file names for our example data:

Metric	Sufix of file name
HABMAT	Binary raster of habitat and matrix
_HABMAT_0060m_fid	FID of structural elements map

Metric	Sufix of file name
HABMAT0060mfragmentAreaHA	Fragment area in hectars
_HABMAT_0100m_func_connect_AreaHA	Functional connected area in hectars using a 100 crossing distance
_HABMAT_0060m_structural_connectivity	Classification of structural elements with a 60 m edge depth
_HABMAT_0100m_func_connect_AreaHA	Functional connected area in hectars using a 100 crossing distance
_HABMAT_0100m_func_connect_complete_AreaHA	Complete functionally connected area in hectars using a 100 window
$_HABMAT_0100m_func_connect_complete_pid$	PIDs of Complete functionally connected area in hectars using a 100
_HABMAT_0100m_func_connect_pid	PIDs of clumps for functional connectivity using a 100 m crossing di
_HABMAT_0100m_functional_connectivity	Functional connectivity using a 100 m crossing distance
_HABMAT_EDGE_0060m	Edge area binary map using a 60 m edge depth
_HABMAT_EDGE_0060m_AreaHA	Edge area map using a 60 m edge depth
_HABMAT_EDGE_0060m_pct_1000m	Proportion of edge using a 60 m edge depth
_HABMAT_EDGE_0060m_pid	Identification of edge cumps using a 60 m edge depth
_HABMAT_EDGE_DIST	Map of distances from edge
$_HABMAT_habitat_pct_1000m$	Proportion of habitat using a 1000 m window size
_HABMAT_MECO_0060m	Structural elements (edge, core, matrix)
_HABMAT_patch_AreaHA	Patch area of the habitat matrix map
_HABMAT_pid	Patch identification of the habitat matrix map
_HABMAT_CORE_0060m	Core area binary map using a 60 m edge depth
_HABMAT_CORE_0060m_AreaHA	Core area in hectares
$_HABMAT_0060m_pct_1000m$	Proportion of habitat using a 1000 m window size and a 60 m edge σ
_HABMAT_CORE_0060m_pid	Patch identification of core areas using a $60~{\rm m}$ edge depth value
_HABMAT_diversity_1000m_pielou_size_33	Landscape diversity using Pielou's algorithm and a 1000 m window
_HABMAT_diversity_1000m_shannon_size_33	Landscape diversity using Shannon's algorithm and a 1000 m window
$HABMAT$ diversity_1000m_simpson_size_33	Landscape diversity using Simpson's algorithm and a 1000 m windo
$HABMAT {\rm diversity_1000m_renyi_size_33_alpha_0.5}$	Landscape diversity using Renyis's algorithm and a 1000 m window

Metrics of structural connectivity

Here we will show the outputs of each metric and a print of their Query results in GRASS GIS display.

Create Binary map

See this binary map of Rio Claro based on forest classes (not necessarily native forest).





Patch size map

$patch {\bf Area HA}$

Summed area of one or more fragments connected by structural corridors (including the area of the corridors connecting them); if there are no fragments connected to the fragment in question, the value of this metric is equal to "fragment size";



See query results below:



Fragment size map

0060mfragment_AreaHA

Area (given in ha) of any structurally isolated fragment, of any size, or the area of a fragment connected to another fragment by a structural corridor. Structural corridors are identified as parts of fragments with a width smaller than two times the specified edge depth;





Structural connectivity

0060mstructural_connectivity

Difference (given in ha) between the Patch size and the Fragment size metrics; when a patch has only one fragment, its structural connectivity will be zero.





Proportion of habitat

$habitatpct_{1000m}$

Proportion of the target landscape classes considering a selected window size.





How to choose the window size? The user must decide which window size will be used to calculate metrics. It corresponds to search extent from each pixel where the calculations will be applied. It can be based on the extent of landscape perception of the target species, process or groups analyzed. It is given in meters.

Metrics of functional connectivity

Functional connectivity

The amount of area functionally connected to a habitat patch, given a gap crossing capability of a species or group of interest. First, a buffer of interest equal to half of the width (in meters) that a species is able to cross is created. Then, the habitat patches that are close enough ara grouped within the same buffer. We then sum the area (ha) of all this grouped patches. We refer to these groups of nearby habitat patches as habitat **clumps**. Finally, to obtain the strict functional connectivity, we calculate the difference between each clump size (ha) and patch size (ha);



Query results are below:





FIDs Query results are below:



Functionally connected area

Represents the total amount of habitat area (in hectares) functionally available for an organism located in a patch, given a gap crossing capability of the organism. This is calculated by generating a buffer of size equal to half of the gap crossing capacity of the organism, around all patches, grouping all habitat patches close enough in the same clusters of patches, and summing up the area of all the grouped patches.



Query results are below:





 $\label{eq:PIDs for Functionally connected area} \quad \mbox{Query results are below:} \\$



Complete functional connected area

The total amount of habitat functionally available for any species, given a gap crossing capability. We do all the steps for the "Functional connectivity" calculation, but do not subtract the patch size from the clump size.

$func \texttt{connect_complete_AreaHA}$

Query results are below:



Query results are below:



PIDs of complete functional connected area 0100func_connect_complete_pid





Metrics based on edges

Edge depths In order to run metrics for edge, the user must select a value for edge depths. This parameter is a proxy for investigating the impact of edge influence on the different pixels. It estimates the distance of edge influence and should be carefully thought a priori by the user, since it will be used to calculate the output metrics. It is set in meters, and as larger the value, larger the edge influence and extent through landscape.

See the charts and brief explanation of each metric below:

Map of distance from edges

The output value of each pixel will represent the distance of this pixel to the nearest edge.





Classify edge/core/matrix (MECO)

Considering a specified Edge depth, this metric classifies the pixels as belonging to three categories: edge, core and matrix. How species really use habitat area would be represented by the core area, since many species have limitations on using edges or less quality areas than their preferred habitat.





Binary maps for edge and core

Core binary maps In the core binary map, core are will be set as value "1".





Edge binary maps In the edge binary maps, edge are will be set as value "1".





Proportion of edge/core

Percentage of habitat and edge within a search radius (Window size parameter), given a specified edge depth (Edge depths parameter).

$HABMAT {\rm CORE_0060m_pct_1000m}$





HABMATEDGE_0060m_pct_1000m





Calculate area of edge/core clumps?

Given edge and core areas were identified, contiguous cells are clumped into edge and core clumps (i.e., cells of edge and core that pertain to the same patch), and their areas are calculated (in hectares). Two maps are created for each one (edge/core) for each landscape: an edge (core) clump ID (edge or core PID) map, which sets a distinct integer number to each clump of edge (core) cells, and a clump size map, which sets the the area of those clumps; non-edge (non-core) cells are set to NULL in both.

$HABMAT {\rm CORE_0060m_AreaHA}$



Query results are below:



HABMATCORE_0060m_pid





HABMATEDGE_0060m_AreaHA





HABMATEDGE_0060m_pid





Metrics of landscape diversity

LSMetrics calculates four metrics of Landscape Diversity. See the example outputs below:
Shannon

Given an extent value (or a list of values), the diversity around each pixel is calculated by computing the proportion pi of each land use inside a window of such an extent and calculating the Shannon index from it (Magurran, 2004). Therefore, the landscape diversity around a pixel depends on the number of different land use classes around it and on the amount of each class.



See query results below:



Simpson's diversity (Simpson, 1949)

Diversity is based on the probability that two interacting individuals of a population belong to the same species. In our case, 2 patches belonging to the same land use class



See query results below:





See query results below:



This index compares the measured diversity to the corresponding maximum value in landscape.

Renyi (Rényi, 1961)

The Rényi entropy is a generalization of the Shannon's diversity index. Alpha of example is set as 0.5.



See query results below:



Patch ID maps

The output files with "pid" in file name are basically the patch or clumps identification. We will use the tool "Query results" in GRASS GIS to show the values attributed for the identification of a patch (pid). Note that the large green patch (The FEENA in Rio Claro) has pid equals to 9112.

Note that only habitat patches will present patch identification in the general pid files (sufix HABMAT_pid)



Query results are below:



Contact us

LSMetrics was developed at the Spatial Ecology and Conservation Lab (LEEC), at Universidade Estadual Paulista (UNESP), Rio Claro, SP, Brazil. If you have questions, contact us at one of the e-mails below. You can also contact us if you have any errors running LSMetrics (or you can open an issue here on GitHub).

- Bernardo Niebuhr

bernardo_brandaum@yahoo.com.br>
- Milton C. Ribeiro <mcr@rc.unesp.br>
- Felipe Martello <felipemartello@gmail.com>

Contribute

You are also very welcome to contribute your own changes or new metrics to the LSMetrics tool. We are also open to dicuss the idea and how to implement other metrics needed for environmental research as well as for conservation and nature management purposes. Please submit a pull request or get in contact with us.

About LEEC lab



The LEEC lab team has developed several tools for spatial and landscape analysis:

LSMetrics

LSCorridors

Landscape analysis in R

Other publications

Take a look in our website!

