



Measuring *Landscape Parcellation*.

Available in the free software *GuidosToolbox*. This is a living document, please check for the latest version at: <https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/>

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1. Background

Patch-based metrics can be used to provide a simple summary message on the number, area and degree of dissection of different land cover classes. This document outlines an approach following this idea.

Scope of this report and for consideration:

Illustration of an analysis methodology to measure the degree of landscape dissection (Parcellation), or splitting into individual parcels, on a given land cover map. The methodology outlined in this document has been designed with the goal to

- a) be applicable to any kind of categorical maps and at any scale.
- b) be applicable to both, binary as well as multi-class land cover maps.
- c) provide normalized values for the parameter Parcellation describing the degree of landscape fragmentation/parcellation within the range [0, 100] %.
- d) provide a concise summary of additional Parcellation attributes: the number of land cover classes, the total number of individual parcels per class and in the image, the Parcellation per class and for the entire image.

Parcellation could be used as a state variable to quantify the degree of splitting/fragmentation and to account for the number of land cover classes and fragments per type. As a normalized measure, Parcellation can also be used to directly measure changes in fragmentation over time as well as directly compare the degree of fragmentation of different sites.

2. Parcellation

2.1 The methodology

The presence of roads and/or different land cover types generates landscape patterns, segmenting a theoretical homogeneous surface of a single land cover type. An increase in the total number of land cover classes and the fragments therein leads to more segregation or fragmentation of a given landscape. This process of dividing continuous land cover into smaller parcels is driven by

- a) the increase of road networks
- b) heritage to several new owners, who then build roads/fences and conduct different land cover management on the smaller parcels
- c) urbanization
- d) conversion of natural land for agricultural use
- e) human induced and natural disturbances, i.e., fires, logging of forests, etc.

Parcellation is a summary descriptor accounting for every individual land cover parcel, regardless of its type, location, or the process it was created. The degree of division is calculated for each land cover class as well as for the entire set of existing land cover classes. By accounting for the number of all land cover types Parcellation reflects the heterogeneity of the landscape and will have higher values on landscapes with a higher number of land cover classes. If the number of land cover classes is 2, Parcellation can be used to investigate the degree of division on a binary map, i.e. a forest – non-forest map or when using a road map, looking at the pressure of grey infrastructure.

With the notation:

j : the number of unique land cover classes

$a_{i,j}$: area of patch i in a given class j

n : the number of patches in a given land cover class

A_j = total area of a given land cover class j

A = image data area: all classes in the image = image area – missing pixels

Parcellation provides a statistical summary file (txt/csv-format) with details for each unique class found in the image: class value, total number of objects, total area plus the full image summary:

- Class: Sequential number of individual land cover classes
- Value: Land cover class value in the image
- Count: Total number of patches in the given land cover class j
- Area: Total area of a given land cover class j :
 A_j (Unit: area, measured in pixels)
- APS: Average Patch Size of a given land cover class j :

$$APS = \frac{1}{n} * \sum_{i=1}^n a_{i,j}$$
 (Unit: area, measured in pixels)
- AWAPS: Area Weighted APS of a given land cover class j :

$$AWAPS = \frac{1}{A_j} * \sum_{i=1}^n a_{i,j}^2$$
 (Unit: area, measured in pixels)
- AWAPS/data: AWAPS with respect to the entire data area A :

$$AWAPS = \frac{1}{A} * \sum_{i=1}^n a_{i,j}^2$$
 (Unit: area, measured in pixels)
- DIVISION: Degree of division of a given land cover class j :

$$DIVISION = 1 - S = 1 - \sum_{i=1}^n \left(\frac{a_{i,j}}{A_j}\right)^2$$
 (Unit: index in [0, 1])
- PARC: A logarithmic conversion and normalization of the Division complement

$$S = \sum_{i=1}^n \left(\frac{a_{i,j}}{A_j}\right)^2$$
:
 - a) Convert/constrain S into the range $R = [-\ln(1.0e^{-6}) \leq -\ln(S)]$
 - b) Normalize: $PARC = \frac{100}{-\ln(1.0e^{-6})} * R$ (Unit: index in [0, 100] %)

In general, the value of Parcellation will increase with increasing number of feature classes, number of objects per class, and decreasing object areas.

2.2 The input data:

The input image for the Parcellation analysis must be a categorical raster map with at least 2 land cover classes. A class value of 0 is reserved for masking no-data pixels.

2.3 The output data:

The result of the Parcellation analysis is a normalized summary index in [0, 100] % describing the overall amount of Parcellation in the image as well as additional per-class statistics featuring:

Class	Value	Count	Area[pixels]	APS	AWAPS	AWAPS/data	DIVISION	PARC[%]
1	1	2	2792	1396.0000	1998.3600	1.3948	0.2843	2.4207
2	2	201	432930	2153.8800	24287.2000	2628.6600	0.9439	20.8507
3	3	35	56446	1612.7400	3655.9400	51.5909	0.9352	19.8106
4	4	5	6131	1226.2000	1335.9000	2.0476	0.7821	11.0293
5	5	1	418	418.0000	418.0000	0.0437	0.0000	0.0000
6	6	2	14708	7354.0000	7779.0500	28.6036	0.4711	4.6105
7	7	14	10134	723.8570	783.5970	1.9852	0.9227	18.5281
8	8	3	1779	593.0000	701.8210	0.3121	0.6055	6.7325
9	9	6	6687	1114.5000	1979.0300	3.3084	0.7040	8.8130
10	10	15	25139	1675.9300	4503.9000	28.3059	0.8208	12.4460
11	11	28	36026	1286.6400	1773.8400	15.9761	0.9508	21.7950
12	12	61	2013006	33000.1000	875187.0000	440439.0000	0.5652	6.0291
13	18	139	278701	2005.0400	7531.4400	524.7550	0.9730	26.1377
14	20	48	80188	1670.5800	2995.8400	60.0575	0.9626	23.7932
15	21	53	77036	1453.5100	2042.6800	39.3399	0.9735	26.2749
16	23	108	308382	2855.3900	38797.6000	2991.1200	0.8742	15.0047
17	24	111	398163	3587.0500	29455.4000	2932.0100	0.9260	18.8483
18	25	93	118067	1269.5400	2976.5900	87.8591	0.9748	26.6402
19	26	4	6717	1679.2500	2505.7000	4.2077	0.6270	7.1374
20	27	1	675	675.0000	675.0000	0.1139	0.0000	0.0000
21	29	1	3828	3828.0000	3828.0000	3.6634	0.0000	0.0000
22	32	1	1022	1022.0000	1022.0000	0.2611	0.0000	0.0000
23	35	2	1577	788.5000	941.6470	0.3712	0.4029	3.7324
24	36	14	57507	4107.6400	22376.6000	321.7020	0.6109	6.8321
25	40	1	2092	2092.0000	2092.0000	1.0941	0.0000	0.0000
26	41	18	59849	3324.9400	32760.4000	490.1690	0.4526	4.3618
8-conn. Parcels:		967	4000000	4136.5049		450657.9072	0.8873	15.8036

Table 1: Parcellation result for the CLC land cover image (Figure 1).

Table 1 shows several parcel information of the investigated image (here, Figure 1, top left):

- Class: Sequential number of individual land cover classes
- Value: Land cover class value in the image
- Count: Total number of patches in the given land cover class
- Area: Total area (measured in pixels) of a given land cover class
- APS: Average Patch Size of a given land cover class
- AWAPS: Area Weighted APS of a given land cover class
- AWAPS/data: AWAPS with respect to the entire image data area
- DIVISION: Division index of a given land cover class
- PARC: Parcellation of a given land cover class

The final line provides the overall image summary, i.e.: The parcels were investigated using the 8-connectivity rule; a total of 26 individual classes and 967 individual parcels were found; the total area of all parcels (= data area) is 4000000 pixels, the Average Patch Size (APS) is 4136 pixels, the Area Weighted Average Patch Size (AWAPS) is 450657 pixels, and the degree of division is 0.8873 corresponding to a Parcellation (PARC) for the entire image of 15.8%.

3. Example application

This section illustrates example images and respective Parcellation results to illustrate the behavior and final values for the indicator Parcellation.

All image processing was done in GuidosToolbox. The following results can be reproduced by using the example data from the workshop material provided for GuidosToolbox.

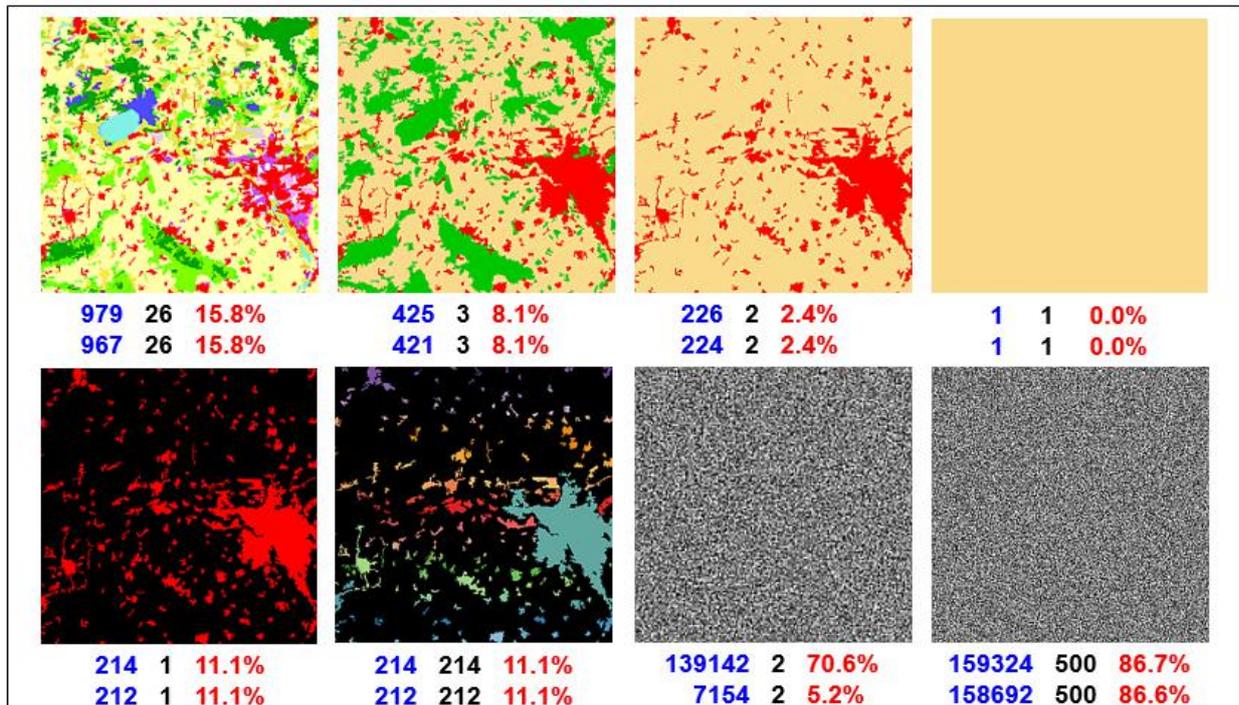


Figure 1: Example images showing: the number of image objects (blue), the number of individual classes (black) and the value of *Parcellation* (red). Results of the top (bottom) row below each image correspond to using the 4- (8-) connectivity rule for the image objects.

The left image of the top row in Figure 1 shows a CORINE land cover image of dimension 2000^2 pixels having a total of 26 individual land cover classes. When using the 4-connectivity rule the image is composed of 979 parcels. When adding the diagonal direction of the 8-connectivity rule some neighboring parcels of the same land cover type become combined resulting in a lower total of now 967 individual parcels. Table 1 provides further details for the latter case on the relative Parcellation of each land cover class. The next three examples in the top row of Figure 1 show the effect of joining the existing 26 land cover classes into 3, 2 and finally a single land cover class: the decrease of the total number of parcels and classes is directly related to the value of Parcellation and reaching the minimum at the lower boundary condition represented by a fully homogeneous land cover.

However, this expected behavior is different when a substantial number of missing pixels or no-data areas are present in the image, represented in the black color in the first two images of the bottom row in Figure 1: assigning all parcels into a single land cover class or each parcel into a different one should not, and in fact it does not change the Parcellation value of the image data area. This behavior is also evident from the Parcellation formula, which is simply building the sum of the relative contribution of each parcel over each land cover class.

The third image in the bottom row of Figure 1 shows a random distribution of 2 land cover classes generated for an image size of dimension 1024^2 pixels. The purpose of this image is to illustrate the potentially strong impact of applying the 4- or 8-connectivity rule, here resulting in a significant difference in the total number of parcels and the Parcellation itself. Obviously,

this behavior is very pronounced when only 2 classes are present, resulting in a high probability of the same land cover class being present in a diagonal neighborhood. The probability to encounter the same land cover class in the direct neighborhood is far less with more classes present in the image.

The final image in Figure 1 confirms this thought showing a very similar number of parcels and Parcellation on an image of dimension 400^2 pixels but now composed of 500 individual classes in a random distribution. A further increase in the number of individual classes will obviously increase the value of Parcellation up to the boundary condition of 100% when each pixel has its own individual class value.

Motivation/Purpose: A user or policy maker may be interested to detect geographic areas where the landscape shows a higher degree of Parcellation, for example due to dense road networks representing a strong impact of human activity. Parcellation could be calculated for, and then compared between small administrative regions/counties ([NUTS-3](#)) where high values will be found in regions dominated by urban land use and low values are found in regions with predominantly natural or homogeneous land cover. Measuring Parcellation, or the degree of splitting, or the heterogeneity of the landscape from a simple land cover map and without any additional information may also be a powerful tool to quantify temporal changes as well as to directly compare different sites. The fact that Parcellation accounts for all land cover classes and provides details on their relative degree of splitting permits to detect and measure the degree of the most dissected land cover type in a given image or region. This fact may also be useful to investigate if a given landscape planning measure had a quantifiable influence on a specific land cover type. Parcellation provides a generic framework to quantify changes (in percent) over time, compare different sites and to *measure* the progress and outcome of political directives targeted at landscape conservation and restoration of natural areas, or investigating the potential impact of land cover changes on and near protected natural parks.

4. Discussion

This document describes a methodology for the assessment of Landscape Parcellation. The approach is based on measuring the number and relative size of all landscape parcels, including their morphometric aspects such as perforations and connecting pathways. The Parcellation index provides a concise summary of the degree of landscape splitting as well as statistical details highlighting the count, area and relative dissection of each land cover type.

The Parcellation assessment scheme provides:

- **Generic concept:** The methodology can be applied to any kind of raster maps, independent of the number of classes and the spatial resolution of the map.
- **Land cover class statistics:** The outlined methodology provides a statistical summary of number, area, and dissection of each class as well as for the entire landscape.
- **Parcellation maps:** By applying the concept to sub-regions the Parcellation index can be easily transferred into a map product, highlighting hotspots of highly fragmented areas or those dominated by undisturbed natural land cover. The spatial information of the map product may be of high importance for monitoring, planning and risk assessment. For example, the feature to quantify changes (in percent) across time series is an

essential requisite to measure progress or the overall effectiveness of political directives.

- **Communication:** The simple index is easy to communicate and can be related to a variety of land cover planning measures, change in time series of biodiversity or other environmental indicators and direct comparisons with results from other regions. The assessment of Parcellation contributes to answering questions like:
 - **State Analysis:** How high is the degree of dissection in different administrative units/counties or ecological regions of the country?
 - **Trend Analysis:** Where and how much has Parcellation changed over the past decades? How are the trends? What can be expected for the future?
 - **Dominance:** Which land cover type was mainly impacted in the past? How much has it changed and which land cover type is most dissected today?
 - **Monitoring & Assessment:** How strong was the impact of a specific political directive or planning program in the targeted area? How big is the change outside of the monitored region? Does the result of the program merit the money spent? With these findings, what are the implications for future planning and which areas should be targeted first?

5. Conclusions

The Parcellation analysis is available in the free JRC software *GuidosToolbox*. The software can be downloaded and used by anybody and for any kind of analysis. All data analysis schemes in *GuidosToolbox* are based on geometric principles, which permits processing categorical maps of any kind and spatial resolution.

With the outlined setup, and the availability in a free software, each user can test Parcellation and its settings on their own data.

In addition to Parcellation *GuidosToolbox* provides dedicated routines for spatial mapping and quantification of pattern, fragmentation, distance and other aspects derived from land cover maps. Further information is available in related product sheets available on the *GuidosToolbox* homepage.

References:

Vogt P., Riitters, K., 2017. *GuidosToolbox*: universal digital image object analysis. *European Journal of Remote Sensing* 50:1, 352-361, DOI: [10.1080/22797254.2017.1330650](https://doi.org/10.1080/22797254.2017.1330650).