



EUROPEAN COMMISSION
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Directorate D – Sustainable Resources
Bio-Economy Unit

Measuring *Landscape Parcellation*. **(Available in the free JRC software *GuidosToolbox*)**

<http://forest.jrc.ec.europa.eu/download/software/guidos/>

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1. Background

Patch-based metrics usually describe only certain patch aspects and do not account for outside patch features. These type of metrics suffer from intrinsic limitations valid for all summary indices: a) they provide a single average value only and do not account for the variability of the feature under evaluation, and b) they cannot provide any spatially explicit information. However, in certain cases the user may wish to measure fragmentation as a single index in order to provide a key message. When looking at the degree of landscape fragmentation the logical step would be to calculate patch-based metrics for each land cover type, which are then combined into an index for the entire image in some way. This document outlines an approach following this idea but trying to circumvent typical patch index limitations.

Scope of this report and for consideration:

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

- a) bypass typical limitations of existing patch-based metrics.
- b) be based on geometric concepts providing a generic framework which can be applied to any kind of data type and at any scale.
- c) be applicable to both, binary as well as multi-class land cover maps.
- d) provide normalized values for the parameter Parcellation describing the degree of landscape fragmentation/parcellation within the range [0, 100] %.
- e) provide a concise summary of additional Parcellation attributes: the total number of individual parcels per class, the total number of land cover classes and the main contributor to the overall index of Parcellation.

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. Due to its setup for provision of 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. Parcellation may be a useful measure in questions of landscape planning, monitoring and biodiversity studies.

2. Parcellation

2.1 The methodology

The presence of roads and/or different land cover types generates landscape patterns, which can be seen as a segmentation of a theoretical homogeneous surface having a single land cover type only. An increase in the total number of land cover classes and the fragments therein leads to a higher degree of 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) logging of intact forests

Parcellation has been designed to account for every individual land cover parcel, regardless of its type, location, or the process it was created. Because of this feature Parcellation includes aspects which are typically neglected by common patch-based metrics. For example, Parcellation will account for openings within forests, which are a major driver of fragmentation. Because roads segment land cover, Parcellation will consider but does not require information on road networks. By accounting for the number of all land cover types Parcellation reflects the heterogeneity of the landscape and will have higher values of Parcellation on landscapes with a higher number of land cover classes. If the number of land cover classes is 2 the same methodology can be used to investigate the degree of fragmentation on a binary map, i.e. a forest – non-forest map.

Parcellation is calculated via the following simple formula

$$\text{Parcellation} = (100 - P * 100) \quad \text{where} \quad P = \sum_{i=1}^n \sum_{j=1}^m a_{i,j}^{\sqrt{2-a_{i,j}}}$$

With:

$a_{i,j}$: relative patch area of a given class with respect to the data area in the image

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

m: the number of unique land cover classes

Using the relative patch area size $a_{i,j}$ permits the calculation of a normalized index within [0, 100] %. Using a weighted root function of $a_{i,j}$ will attribute more importance to relatively larger patches. For example, for the boundary conditions if the entire landscape is a single patch then $a_{i,j} = 1$, $P = 1$, and Parcellation = 0%. If we have many very small objects then $a_{i,j}$ as well as P approaches 0, and Parcellation turns to 100%. 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 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	Class-Value	Count	Total Area [pixels]	rel.Parcellation [%]
1	1	2	2792	0.00907851
2	2	201	432930	3.10814
3	3	35	56446	0.221883
4	4	5	6131	0.0171473
5	5	1	418	0.000728281
6	6	2	14708	0.0858189
7	7	14	10134	0.022697
8	8	3	1779	0.00379168
9	9	6	6687	0.0210533
10	10	15	25139	0.107994
11	11	28	36026	0.110583
12	12	61	2.01E+06	86.4786
13	18	139	278701	1.39595
14	20	48	80188	0.296006
15	21	53	77036	0.248528
16	23	108	308382	2.8596
17	24	111	398163	3.48564
18	25	93	118067	0.415337
19	26	4	6717	0.0236857
20	27	1	675	0.00143454
21	29	1	3828	0.0167247
22	32	1	1022	0.00257976
23	35	2	1577	0.00378175
24	36	14	57507	0.472071
25	40	1	2092	0.0071095
26	41	18	59849	0.584074
8-connected Parcels/Classes/Parcellation: 967 26 67.7872 %				

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

Table 1 shows a variety of information used to calculate the overall Parcellation of the investigated image (here, Figure 1, top left) such as:

- Class: Number of individual land cover classes
- Class-Value: Land cover class value in the image
- Count: Total number of patches in the given land cover class
- Total Area: Total area (measured in pixels) of a given land cover class
- Relative Parcellation: Contribution of a given land cover class to the total Parcellation

The final line provides the overall summary, i.e.: The parcels were investigated using the 8-connectivity rule; a total of 26 individual classes were found; the Parcellation for the entire image is 67.7872 %. From the last column one can see that the land cover class 12 contributes 86 % to the total image Parcellation, mainly because it covers the major part of the image area and as such it is fragmented by most of the other classes.

3. Example application

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

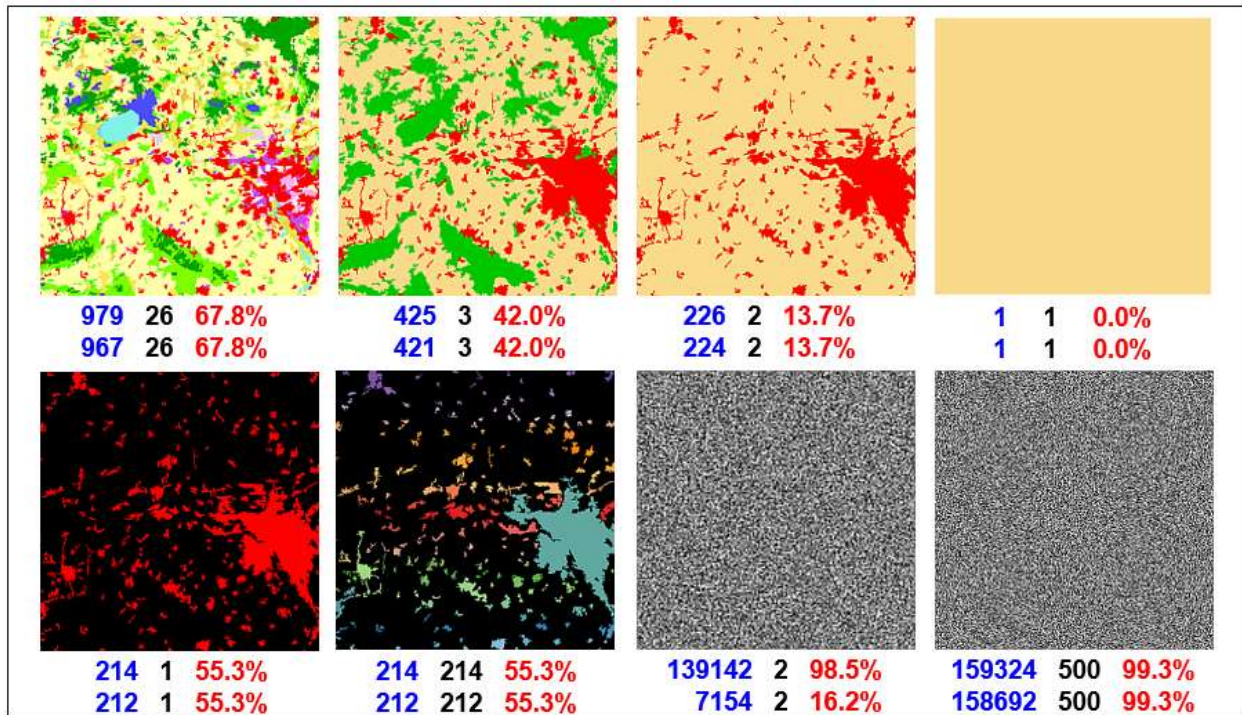


Figure 1: Example images showing: the number of image objects (blue), the number of individual classes (black) and the value of *Parcellation* (red). Results of the top (bottom) row below each image correspond to using the 4- (8-) connectivity rule for the image objects.

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 contribution of each land cover class to the overall Parcellation value of 67.8%. 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 amount 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 drastic 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 contribution permits to detect and measure the degree of the most parcellated land cover type in a given image or region. This fact may also be useful to investigate if a given landscape planning measure actually had a quantifiable influence on a specific land cover type. Finally, the geometric nature of this simple, yet comprehensive index, permits the application to any kind of land cover map and at any scale. With this concept, 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 in the vicinity of 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 contribution of each land cover type to the overall Parcellation of the image.

The Parcellation assessment scheme provides:

- **Generic concept:** The methodology is based on geometric principles only. As such, it 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:** In contrast to many existing patch-based single value indices, the outlined methodology provides a summary of the entire landscape configuration and detailed statistics, including frequency of occurrence, area, and relative contribution for each land cover class to the total Landscape Parcellation.

- **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, yet intuitive 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 fragmentation in different administrative units/counties or ecological regions of the country?
 - **Trend Analysis:** Where and how much has Landscape Parcellation changed over the past decades? How are the trends, and 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 the dominant contributor 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).