



EUROPEAN COMMISSION
DIRECTORATE-GENERAL
JOINT RESEARCH CENTRE
Directorate D – Sustainable Resources
Bio-Economy Unit

Image object *Accounting*.

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

Forest maps show the location and extent of forest patches, which are usually summarized in patch-based metrics. This type of metrics suffers 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. Moreover, patch-based metrics cannot account for the spatial configuration of the forest patches in the landscape. For example, when calculating forest patch attributes, the distance between and/or the spatial aggregation of individual forest patches is not accounted for. Yet, these features are a key aspect in forest maps and of high importance for landscape planning and policy making. While summary statistics and single value indices can always be derived from a given map, they do not permit the localization of hotspots, nor can they describe the spatial heterogeneity of the forest patches in a given landscape or country. Due to the lack of spatial information, single value indices also tend to average out geographic variations. For example, forest growth in the western part of a country and loss in the eastern part may not show up in a total forest area indicator.

The analysis of a spatial forest map provides the basis for the derivation of spatial forest attributes that cannot be derived from statistical forest data or NFI plot-data alone.

Scope of this report and for consideration:

Illustration of a map analysis methodology (Accounting) to describe and measure forest patch area. The methodology outlined in this document has been developed by JRC and is designed to provide a first overview and concise summary of the location and size class distribution of forest patches in a given forest map. The methodology provides a map product together with a statistical summary for a series of forest area classes. The forest area size classes can be used to describe the forest patch distribution at a given point in time, to directly compare the size distribution of different sites, as well as for temporal analysis which is of key importance in questions of landscape connectivity, restoration, risk assessment, habitat suitability and biodiversity studies (Vogt et al., 2019a, 2019b).

2. Accounting

2.1 The methodology

Accounting will label and calculate the area of all foreground objects (coded with 2 byte). A dedicated graphical user interface (Figure 1) allows for selecting or inserting custom values to define the area thresholds (in pixels) of up to six object size categories. The area interval of Class 1 starts with the minimum object area (1 pixel) up to and including the area threshold specified by the user. The following Classes start at the area threshold of the previous Class + 1 pixel up to the Class threshold. Class 6 accounts for all objects larger than the area threshold of Class 5. The interface will automatically adjust the thresholds to ensure a positive progression of the threshold settings. Neighboring classes can be collapsed into a single class by assigning the same area threshold value. Combined with the pixel resolution [meters] the selected threshold settings are automatically converted into respective area size classes in hectares or acres. Accounting settings can be saved and then restored later for application to other image data sets. Accounting produces spatial maps showing the location, area and size class category for each foreground patch as well as a statistical summary report, see below for details.

2.2 The input data:

The input image for the Accounting analysis must be a binary raster map. It must have the values 1 byte for background (non-forest), 2 byte for foreground (forest) and it may have the value 0 byte to mask missing data (i.e. clouds, ocean or no-data area). Additional optional input data values are 3 byte (special background 1, e.g. inland waters shown in dark-blue in the resulting image) and 4 byte (special background 2, e.g. open ocean shown in light-blue in the resulting image).

2.3 The output data:

The result of the Accounting analysis is a graphical image and statistics featuring:

1. **Map:** (GeoTiff) image having the identical coverage as the input map and showing up to 6 foreground patch size classes, background cover, and no-data (if present).
2. **Map:** (GeoTiff) images showing the unique object ID and the area for each foreground patch (optional)
3. **Statistical summary:** number, area and proportions for foreground patches in each size class; the largest 3 patches and the total number and area of foreground.

3. Example application

This section illustrates Accounting on an example forest map of Slovakia derived from CORINE CLC 2012 data (100m spatial resolution). All image processing was done in GuidosToolbox. The following images are screen snapshots, which can be easily reproduced by using a forest mask image in GuidosToolbox.

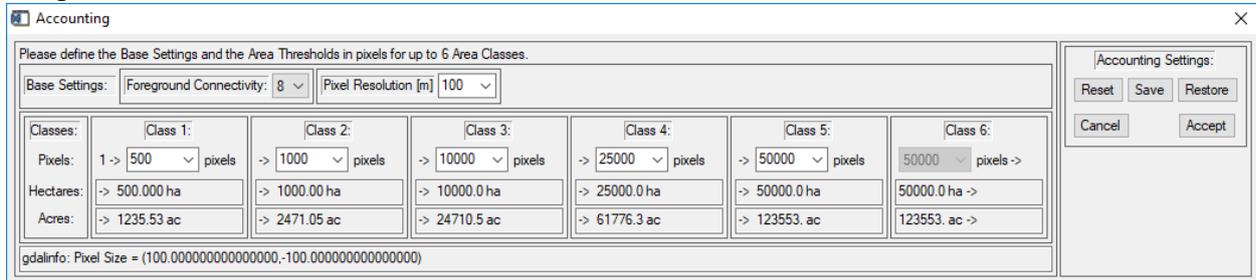


Figure 1: Accounting interface allowing to specify settings for the foreground connectivity (8/4); the spatial pixel resolution [meters]; and 5 area thresholds resulting in 6 area classes shown in hectares and acres.

Figure 1 shows an example of specifying 8-connectivity on an image with pixel resolution 100 meters and 5 area thresholds resulting in the 6 area classes [500, 1000, 10000, 25000, 50000, > 50000] hectares.

Applying these user-specified Accounting settings to the image will create:

- A spatial map product showing color-coded foreground patches in the defined categories plus the 3 largest patches highlighted in pink color (Figure 2).
- A spatial map product showing the unique ID for each foreground patch (optional).
- A spatial map product showing the area for each foreground patch (optional).
- A statistical summary with absolute numbers and relative proportions of foreground patch classes and area, median and average patch size, plus a summary for the 3 largest patches (Figure 3).

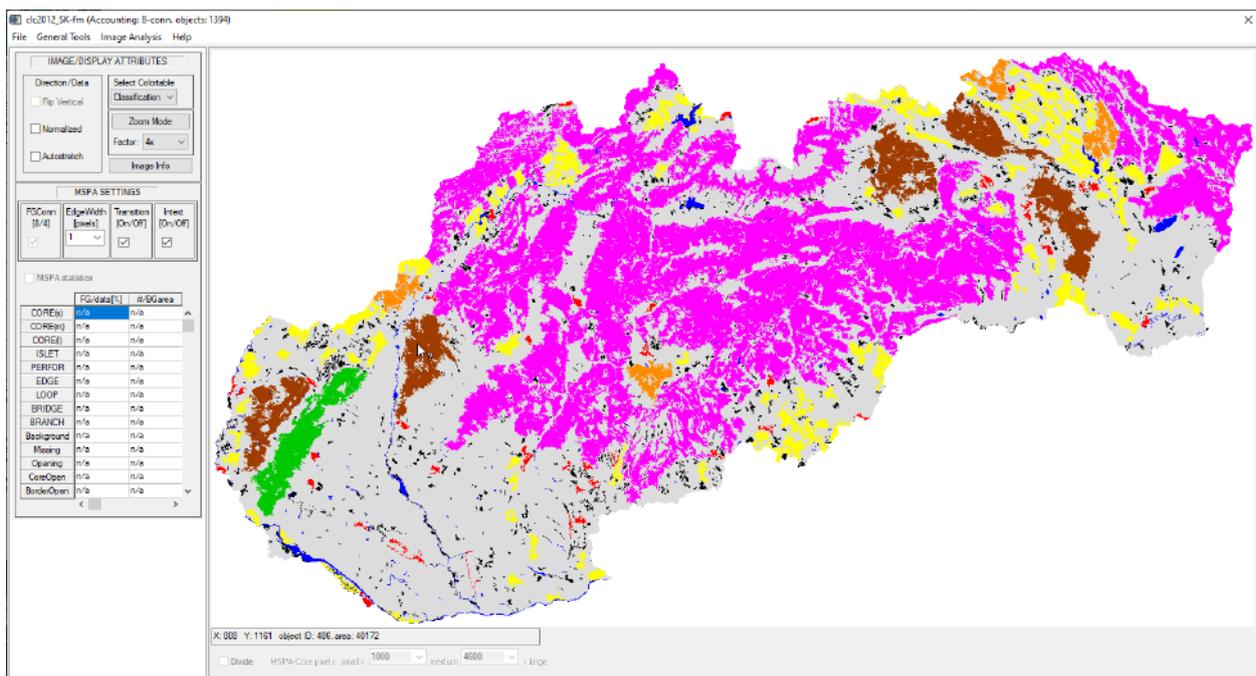


Figure 2: Accounting map product interface showing different area categories in different colors and the unique ID and area for each foreground object.

Figure 2 shows the Accounting for a forest map of Slovakia derived from CORINE CLC 2012 data. The mouse cursor (white arrow) is pointing at the brown object in the left part of the image with related information displayed in the panel below the viewport: the location is at 808/1161, the unique object ID = 486 and the area is 40172 pixels [hectares]. Inland waters (3 byte in the input image) are shown in dark-blue color.

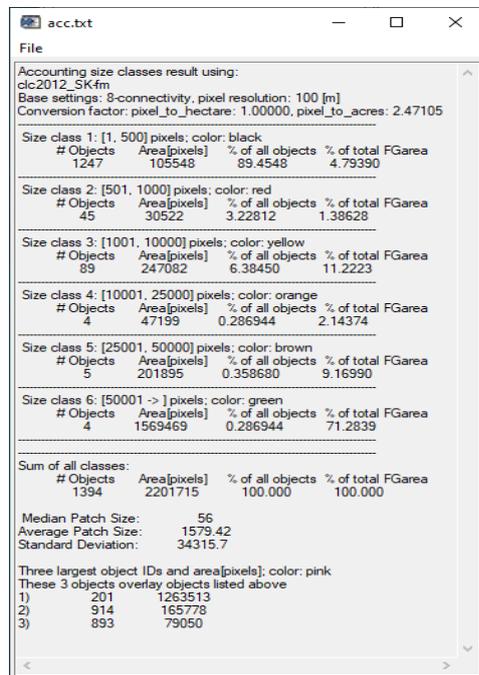


Figure 3: Accounting statistics

While used frequently, the Average Patch Size is not a robust tool since it is largely influenced by outliers. In contrast, the Median Patch Size is the number found at the exact middle of the ordered set of values. Consequently, the Median is better suited for skewed distributions. From Figure 3 it is evident that the Median accounts for the high contribution of small patches and the resulting size (56 ha) is a much better representation of the typical patch size.

Motivation/Purpose: A user or policy maker may be interested to detect geographic areas where larger forest areas or many small-scale features are present. From a statistical perspective, it may be of interest to see how much of the forest area, or the total number of forest patches, is in a specific size class. For example, forest management may target only forest patches of a minimum area, which can be highlighted via Accounting. Accounting may also be of particular importance when looking into temporal changes, where an increase in the small area class is indicative for an increase in fragmentation. In general, the assessment of the spatial location and area categories of forest patches is a key requisite for restoration and conservation projects, land cover and habitat suitability planning, forest management as well as monitoring and progress evaluation of policy programs.

Note: The Accounting procedure as outlined above is flexible, providing the user the option to fine-tune the analysis by specifying up to 6 size classes with user-driven area thresholds. Together with the spatial resolution, this process (Figure 1) allows to easily specify custom area thresholds to derive precise area size classes [hectares or acres] used in forest management programs. Applying the same thresholds to different maps enables a direct comparison of the state of forest cover between these two maps.

Figure 3 to the left shows the Accounting summary statistics of the image shown in Figure 2. **The first section** shows the base settings (connectivity, pixel resolution, conversion factors). **The second section** details for each size class: Area range, color, number and total area of objects, proportion with respect to the total number and total area of all objects. For example, size class 3 lists objects having an area size in [1001, 10000] pixels (here hectares) and color-coded yellow in Figure 2: There are 89 objects in this size class with a total area of 247082 ha. These 89 objects in size class 3 amount for 6.4% of all objects and account for 11.2% of the total foreground area. The summary at the bottom shows that this image has a total of 1394 objects totaling an area of 2201715 pixels (here hectares). **The last section** provides details on the ID and area of the 3 largest objects shown in pink in Figure 2.

4. Discussion

This document describes a methodology for reporting on forest land cover and its patch size distribution. The approach is based on measuring the amount and number of image objects. The Accounting concept provides a simple summary of spatial and statistical information on forest patch attributes, which may be of interest for the definition, monitoring and evaluation in policy making and land management.

The Accounting assessment scheme provides:

- **Generic concept:** The methodology is based on geometric principles only. As such, it can be applied to any kind of binary map, or any kind of forest raster maps, independent of the definition of forest and the spatial resolution of the forest map. In contrast to many existing patch-based single value indices, the outlined methodology provides more statistics on size class details and additionally a spatially explicit map product including details on and locations of individual forest patches.
- **Forest area size classes:** The often-used average patch size provides a single number for all patch sizes; a number which is often not even representative for the actual size class distribution of all forest patches. In contrast, Accounting provides a more detailed overview on the state of forest cover by detailing up to 6 different size classes: a typical forest patch size can then be easily found by looking through the frequency distribution in these classes. Fragmentation assessments may benefit from the information of temporal changes in the various size classes. Finally, having the spatial information on small and large patches is of importance for spatial planning activities.
- **Forest pattern statistics:** The statistics provide a concise summary of the size class distribution in a tabular format with details on area, percentage and frequency of occurrence for each user-specified size class.
- **Forest pattern maps:** The map product provides additional spatial information, which cannot be retrieved from indices and statistics: A geographic map of forest patches is not only visually appealing but it permits localizing hotspots of fragmentation, which is a crucial information for planning and risk assessment. Moreover, comparing maps over time can show where and in which way forest patches change, or how a given forest network has changed over time. This information is an essential requisite to measure progress or the overall effectiveness of political directives; for example, if a conservation policy aimed at decreasing fragmentation in protected sites was successful or not.
- **Communication:** With user-driven size classes Accounting provides geographic as well as statistical summary information which is easy to communicate. The assessment of patch class attributes contributes to answering questions like:
 - **State Analysis:** Where are large areas of intact forests and where is forest sparse? What are the proportions of large and medium classes in different administrative units/counties or ecological regions of the country?
 - **Trend Analysis:** Where and how much has the area coverage in a given size class changed over the past decades? How are the trends, and what can be expected for the future? Compared to previous decades, how much forest area do we have and how is it distributed over a given set of size classes 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 Accounting patch 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 forest maps of any kind, independent of the definition of forest and/or the spatial data resolution.

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

- A *forest - nonforest* raster map as described in this document is of generic nature. It can be derived from any source such as airborne or satellite or NFI data, rasterizing a vector map, or plot data.
- The definition of *Forest* can be based on land *use* or actual land *cover*. For example, non-stocked forested land can still be defined as Forest even if it appears as non-forest in satellite scenes.
- The user can customize the Accounting analysis to his requirements by modifying the total number and the area thresholds of the Accounting area classes.

In addition to the outlined patch analysis scheme *GuidosToolbox* provides dedicated routines for spatial mapping and quantification of fragmentation, distance, naturalness, Landscape Parcellation 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).

Vogt, P., Riitters, K.H., Caudullo, G., Eckhardt, B. and Raši, R. (2019a). An approach for pan-European monitoring of forest fragmentation, EUR 29944 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-10374-5, DOI: [10.2760/991401](https://doi.org/10.2760/991401), JRC118541.

Vogt, P., Riitters, K.H., Caudullo, G., Eckhardt, B. (2019b). FAO – State of the World’s Forests: Forest Fragmentation, EUR 29972 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-13036-9, DOI: [10.2760/145325](https://doi.org/10.2760/145325), JRC118594.