

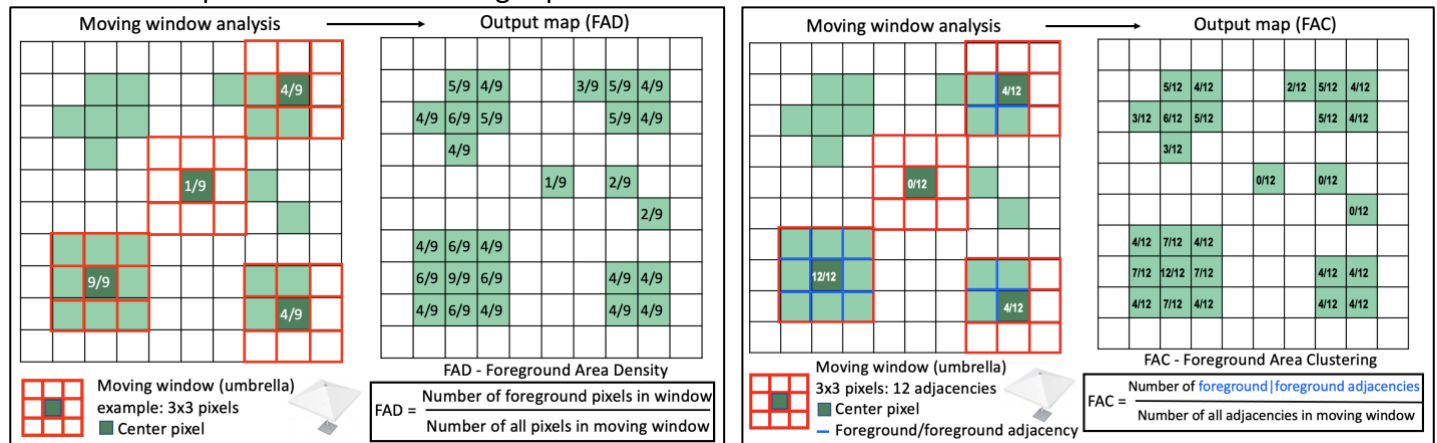
GTB-tools in container: Image Analysis → Fragmentation

Task: summarize degree of fragmentation/connectivity

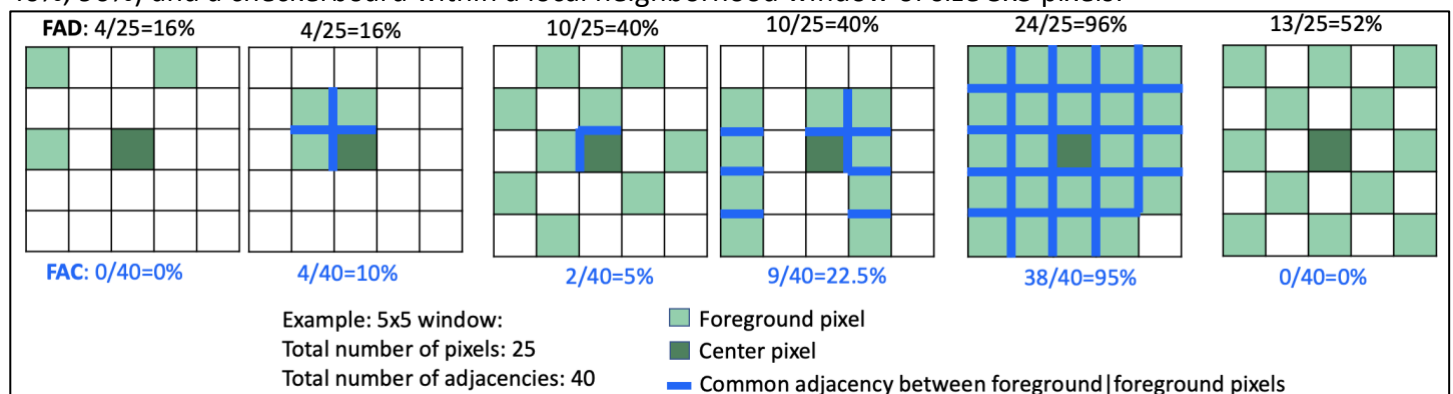
Fixed Observation Scale (FOS) (← click for product sheet)

Question: what is the degree of fragmentation/connectivity of the foreground pixels (2 byte)?

Connectivity, or its complement fragmentation, is scale dependent. The size of the scale of interest is defined via the size of the local neighborhood that is analyzed when measuring the degree of connectivity at pixel level. Think of it as opening an umbrella over a foreground pixel, do the assessment for the area covered under the umbrella (local neighborhood), and assign the result to the center pixel of the umbrella in the output map. The assessment itself measures the *Foreground Area Density* (FAD), which is the number of foreground pixels with respect to the total number of pixels in the local neighborhood. Alternatively, the option *Foreground Area Clustering* (FAC) counts the number of foreground|foreground adjacencies (common pixel edges) with respect to the total number of adjacencies in the local neighborhood. This focal or moving window analysis is repeated over every foreground pixel, or the umbrella is moved and opened over each foreground pixel. The process is illustrated at four example locations and using a 3x3 neighborhood (umbrella) in the following chart, showing FAD in the left panel and FAC in the right panel:



The next chart shows the difference between FAD and FAC for three amounts of foreground coverage (16%, 40%, 96%) and a checkerboard within a local neighborhood window of size 5x5 pixels:



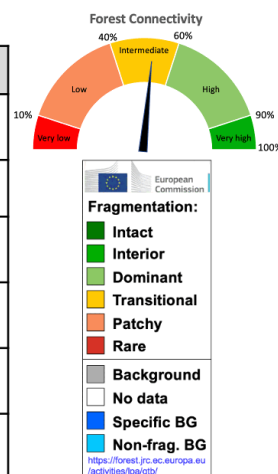
Both measure the degree of connectivity as a normalized index within [0, 100]%. Choosing one of the two depends which connectivity aspect should be focused on: the FAD option is driven by the amount of foreground pixels while the FAC option is driven by local clustering of foreground (for example forest pixels). The difference between the two is most pronounced for low foreground proportion or on a checkerboard constellation and disappears when the foreground proportion is 100%, i.e., the window is fully covered by foreground pixels.

The result of the moving window analysis is a map with the same foreground coverage but showing the degree of connectivity in percent within the neighborhood (under the umbrella) over each foreground pixel. The resulting map of forest connectivity at pixel level can be reported in various ways at:

- pixel level: report each foreground pixel connectivity value, or
- pixel level: same as a) but color-coded into several categories of connectivity/fragmentation, or
- patch level: build the average of the foreground pixel connectivity values for each patch, or
- reporting unit level: a single value, the average over all foreground pixel connectivity values.

Summary of reporting options for forest connectivity/fragmentation:

Range	Pixel level reporting			Patch level reporting		
Indicator [%]	6class	5class	APP_5class	APP_2class	Connectivity	Fragmentation
$0 \leq x < 10$	1-Rare	1-Rare	1-Rare	1-Separated	Very low	Very high
$10 \leq x < 40$	2-Patchy	2-Patchy	2-Patchy		Low	High
$40 \leq x < 60$	3-Transitional	3-Transitional	3-Transitional	2-Continuous	Intermediate	Intermediate
$60 \leq x < 90$	4-Dominant	4-Dominant	4-Dominant		High	Low
$90 \leq x < 100$	5-Interior	5-Interior	5-Interior		Very high	Very low
100	6-Intact				Intact	None



For example, in class 4 the foreground cover within the neighborhood is *dominant*, which is equivalent to FAD/FED or FAC being within the range [60, 89]%, the degree in connectivity is *high*, and the degree in fragmentation is *low*. The 6-class reporting scheme is similar but with a separate class 6, named *Interior*, where FAD/FED/ or FAC = 100%. The 2-class reporting scheme uses a threshold of 40% to divide the full range of connectivity into the two classes *Separate* and *Continuous* foreground cover:

How: load a grayscale map (top) or a binary map (bottom) with foreground objects (2 byte) and specify:

- Grayscale Threshold (only available when using grayscale input maps): Grayscale input data has foreground values within the range [0, 100], for example a tree cover density map. Here, background areas are defined where pixel values are below a user-selected foreground grayscale threshold value *grayt*. For example, if *grayt*=30 then background pixels are in [0, 29] and foreground pixels are in [30, 100]. When using grayscale input maps, missing data must be encoded with 255 byte.

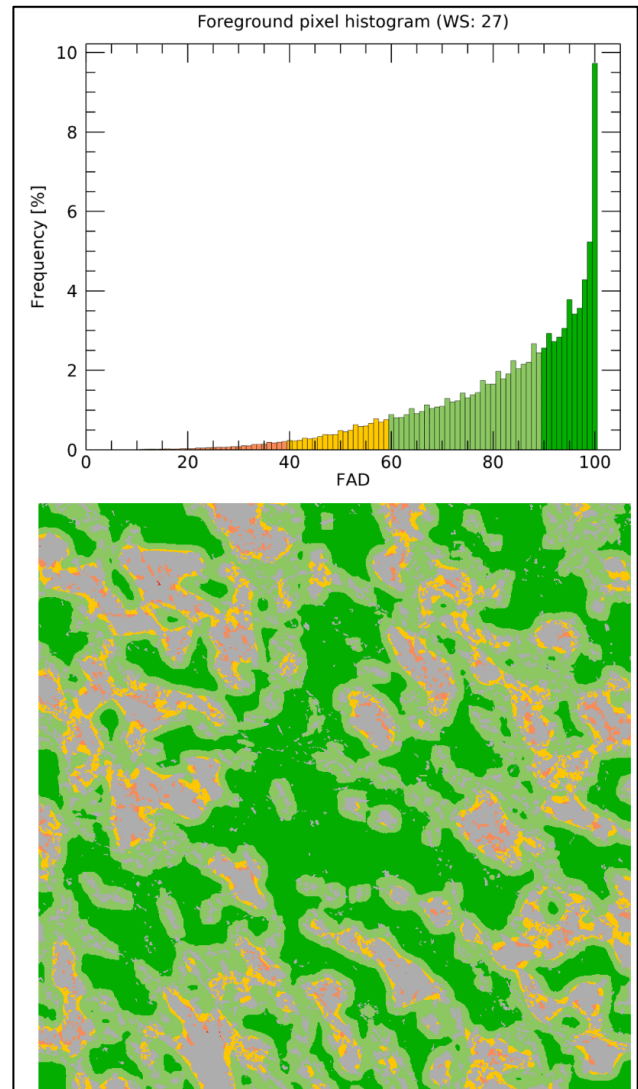
- FOS Method:
 - FAD (Foreground Area *Density* – proportion of foreground pixels); FED (Foreground Edge *Density* – proportion of foreground edges/all edges); or FAC (Foreground Area *Clustering* – proportion of common adjacencies between neighboring foreground pixels)
 - Reporting: the fragmentation range [0, 100]% is color-coded and reported at pixel-level with 5 or 6 classes, or at patch-level (APP - Average-Per-Patch) with 2 or 5 classes
- FG-conn: 8 – all directions (default) or 4 – connectivity in horizontal/vertical directions only
- PixelRes: spatial pixel resolution in meters
- WinSize: side length (number of pixels) of local neighborhood square window or umbrella.
- Observation scale: $(\text{PixelRes} * \text{WinSize})^2$ = the area of the local neighborhood to be considered when assessing fragmentation/connectivity.

Result:

```

Fragmentation analysis using Fixed Observation Scale (FOS)
(Fragmentation is complementary to Connectivity: Fragmentation = 100% - Connectivity)
Method options: FAD - FG Area Density; FED - FG Edge Density; FAC - FG Area Clustering;
Summary analysis for image:
C:\GuidosToolbox\data\map1990.tif
=====
FOS parameter settings:
Binary
Foreground connectivity: 8-connectivity
FOS-type selected: FAD_5class
Method: FAD
Reporting style: FAD at pixel level
Number of reporting classes: 5
Pixel resolution [m]: 25
Window size [pixels]: 27
Observation scale [(window size * pixel resolution)^2]: 45.5625 hectares <-> 112.587 acres
=====
Proportion [%] of foreground area in foreground cover class:
Rare (FAD-pixel value within: [0 - 9]): 0.0073
Patchy (FAD-pixel value within: [10 - 39]): 2.2452
Transitional (FAD-pixel value within: [40 - 59]): 9.2299
Dominant (FAD-pixel value within: [60 - 89]): 44.4130
Interior (FAD-pixel value within: [90 - 100]): 44.1045
=====
A) Image summary:
=====
Reporting unit area [pixels]: 640000
Foreground area [pixels]: 468367
Foreground area [%]: 73.182342
Number of foreground patches: 416
Average foreground patch size [pixels]: 1125.8822
=====
B) Reporting levels
=====
Foreground (FG) connectivity is available at 4 reporting levels, B1 - B4:
B1) Pixel-level: method FAD/FED/FAC: check the FG pixel value on the map, or aggregated at
B2) Patch-level: method _APP (Average-Per-Patch): check the FG pixel value on the map
B3) Foreground-level: reference area = all foreground pixels
- Average FAD at WS 27 [%]: 82.2628
- ECA (Equivalent Connected Area) [pixels]: 461943.53
- COH (Coherence = ECA/ECA_max*100) [%]: 98.628540
B4) Reporting unit-level: reference area = entire reporting unit
- AVCON (average connectivity) at WS27 [%]: 60.2018
- COH_ru (ECA/Reporting unit area*100) [%]: 72.178677
=====
Histogram of FG-pixel values rounded to the nearest integer, FGcover[%] at window size:
Value WS27
0 0.0000
1 0.0000
2 0.0002
3 0.0000
4 0.0000
5 0.0009
6 0.0011

```



Example output of the FOS type: FAD_5class. Statistics: proportion of foreground pixels in each fragmentation/connectivity class; image summary, reporting levels (left). Histogram: foreground pixel occurrence frequency for connectivity in [0, 100]% (top-right). Color-coded map: foreground pixel connectivity in [0, 100]% (bottom-right).

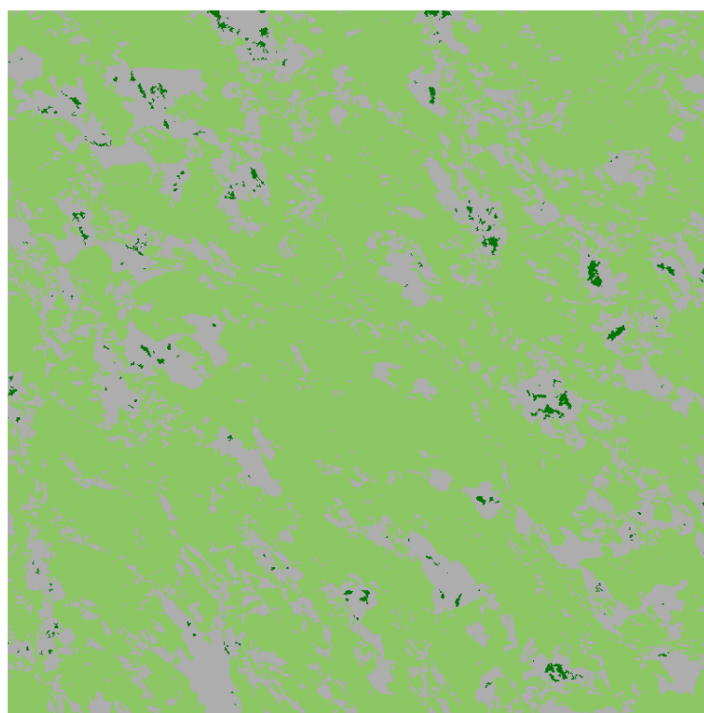
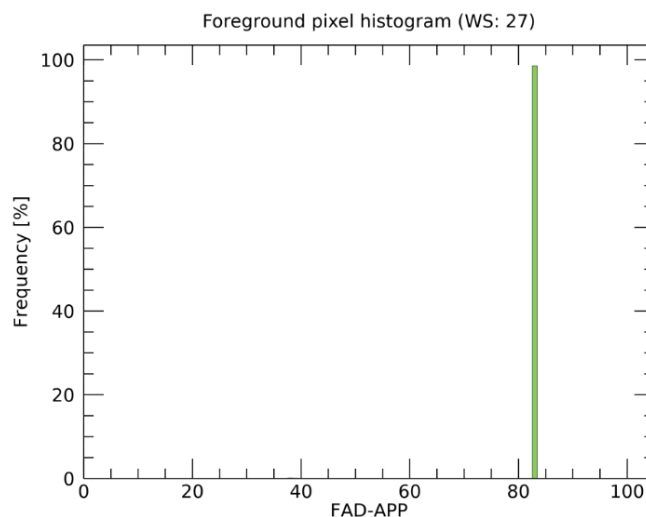
```

Fragmentation analysis using Fixed Observation Scale (FOS)
(Fragmentation is complementary to Connectivity; Fragmentation = 100% - Connectivity)
Method options: FAD - FG Area Density; FED - FG Edge Density; FAC - FG Area Clustering;
Summary analysis for image:
C:\GuidosToolbox\data\map1990.tif
=====
FOS parameter settings:
Binary
Foreground connectivity: 8-connectivity
FOS-type selected: FAD-APP_2class
Method: FAD
Reporting style: FAD at patch level (APP: average per patch)
Number of reporting classes: 2
Pixel resolution [m]: 25
Window size [pixels]: 27
Observation scale [(window size * pixel resolution)^2]: 45.5625 hectares <-> 112.587 acres
=====
Proportion [%] of foreground area in foreground cover class:

FOS-APP_5class:
  Rare (FAD-pixel value within: [0 - 9]): 0.0058
  Patchy (FAD-pixel value within: [10 - 39]): 0.9420
  Transitional (FAD-pixel value within: [40 - 59]): 0.3721
  Dominant (FAD-pixel value within: [60 - 89]): 98.6797
  Interior (FAD-pixel value within: [90 - 100]): 0.0004

FOS-APP_2class:
  Separated (FAD-pixel value within: [0 - 39]): 0.9478
  Continuous (FAD-pixel value within: [40 - 100]): 99.0522
=====
A) Image summary:
=====
Reporting unit area [pixels]: 640000
Foreground area [pixels]: 468367
Foreground area [%]: 73.182342
Number of foreground patches: 416
Average foreground patch size [pixels]: 1125.8822
=====
B) Reporting levels
=====
Foreground (FG) connectivity is available at 4 reporting levels, B1 - B4:
B1) Pixel-level: method FAD/FED/FAC: check the FG pixel value on the map, or aggregated at
B2) Patch-level: method _APP (Average-Per-Patch): check the FG pixel value on the map
B3) Foreground-level: reference area = all foreground pixels
  - Average FAD (before APP) at window size [%]: 82.2628
  - ECA (Equivalent Connected Area) [pixels]: 461943.53
  - COH (Coherence = ECA/ECA_max*100) [%]: 98.628540
B4) Reporting unit-level: reference area = entire reporting unit
  - AVCON (average connectivity) at WS27 [%]: 60.2018
  - COH_ru (ECA/Reporting unit area*100) [%]: 72.178677
=====
Histogram of FG-pixel values rounded to the nearest integer, FGcover[%] at window size:
Value WS27
0 0.0000
1 0.0000
2 0.0002
3 0.0000
4 0.0000
5 0.0000
6 0.0000
7 0.0000
8 0.0041
9 0.0015
10 0.0015
11 0.0032
12 0.0186
13 0.0128
14 0.0105
15 0.0290

```



Example output of the FOS type: FAD-APP_2class applied to the same input forest map. This type assigns the Average-Per-Patch pixel value to each foreground patch and the reporting style is limited to show 2 classes only: Separated (FAD < 40%, dark green) and Continuous (FAD ≥ 40%, light green).

Multiple Observation Scale (← click for product sheet)

FAD_MS - Question: how does the degree of fragmentation change when observed across various scales?

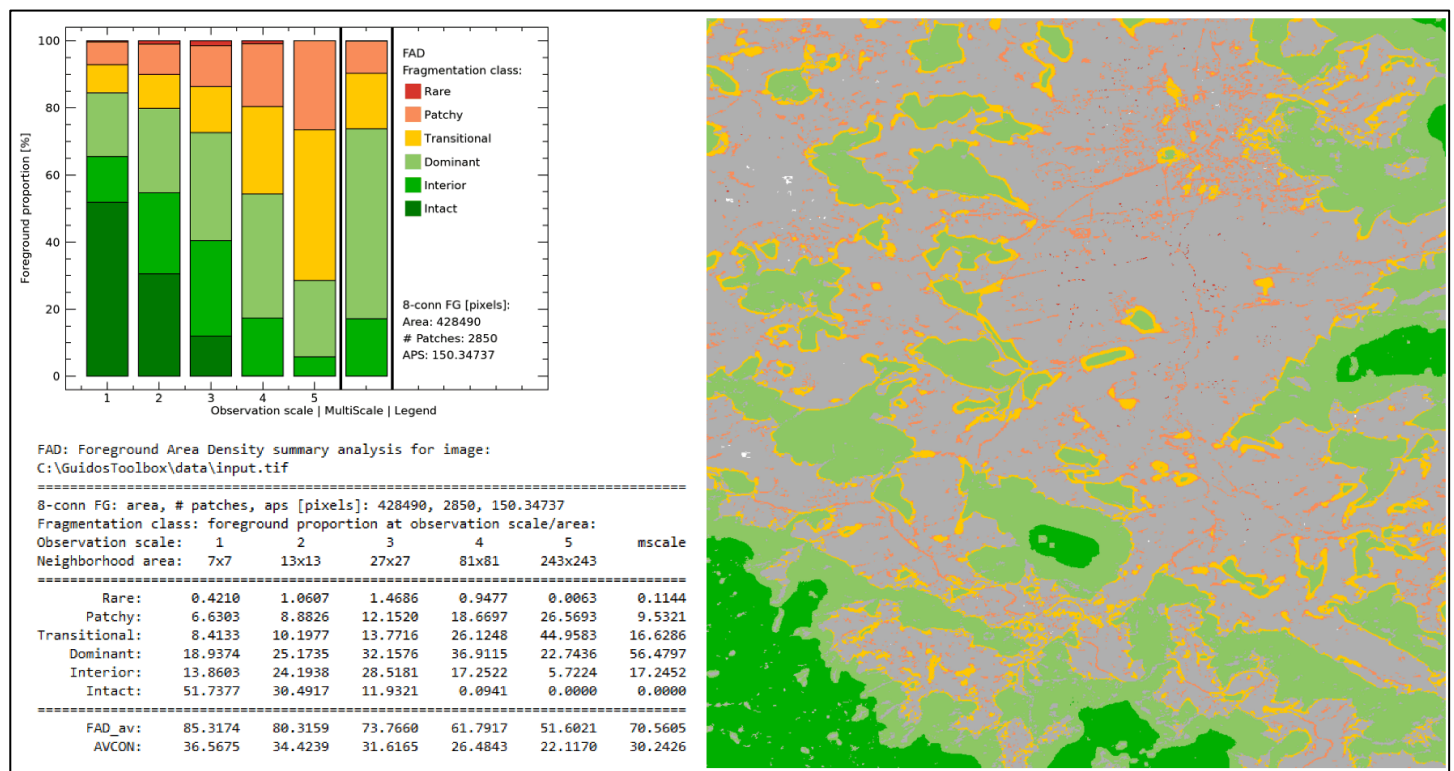
In analogy to FOS, this option conducts a FAD analysis but for a series of five observation scales with window/umbrella dimension 7x7, 13x13, 27x27, 81x81, 243x243 pixels and in addition a summary across all five observation scales. These neighborhood areas were selected to span a wide range of scales representing an approximately geometric progression of window area with observation scale.

Note: The multiscale analysis is limited to the FAD_6class scheme and 8-connectivity rule.

Result:

Statistics: proportion of foreground pixels in each fragmentation class; average degree in connectivity at foreground level (FAD_av) and reporting level (AVCON). For each of the 5 observation scales and multiscale: pixel average across all 5 observation scales.

Map: showing fragmentation at pixel-level, color-coded into the selected number of classes. One map for each observation scale plus a summary map across the 5 observation scales.



The map above shows an example output of the FAD_6class Multiscale processing. The left panel shows the statistical summary and the right panel the summary map across all 5 observation scales.

Legacy

This menu contains various fragmentation assessment schemes that have been used in the past. They are provided here for historic reasons and for the curious reader, who may be interested in alternative assessment schemes. Further information on the legacy assessment options can be found in the [GTB Manual](#).