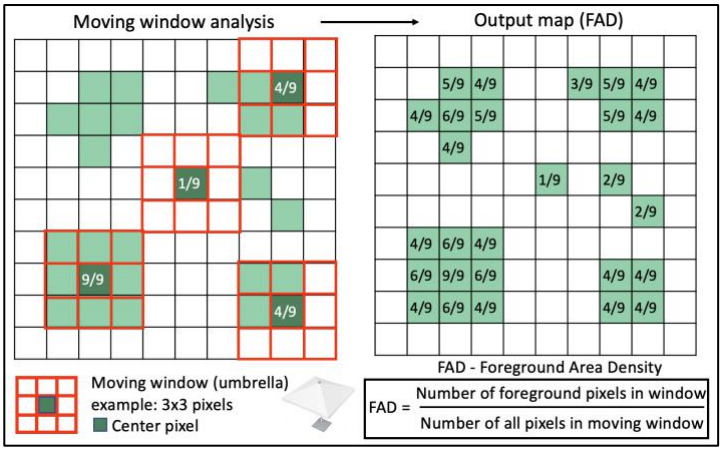
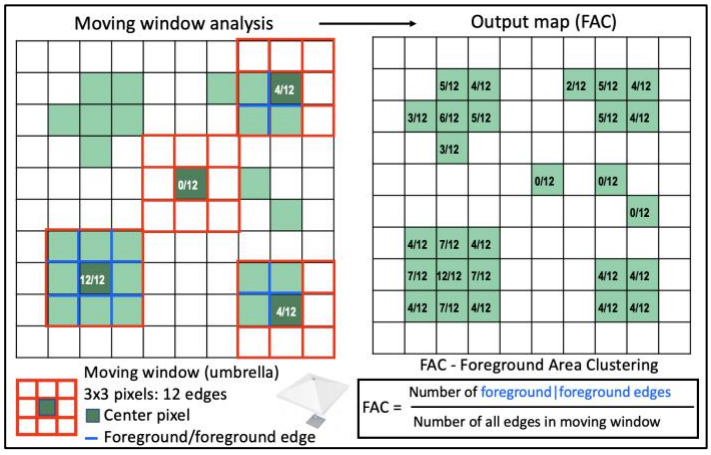
GTB-tools in container: Image Analysis → Fragmentation
Task: summarize degree of fragmentation/connectivity

Fixed Observation Scale (← click for product sheet)

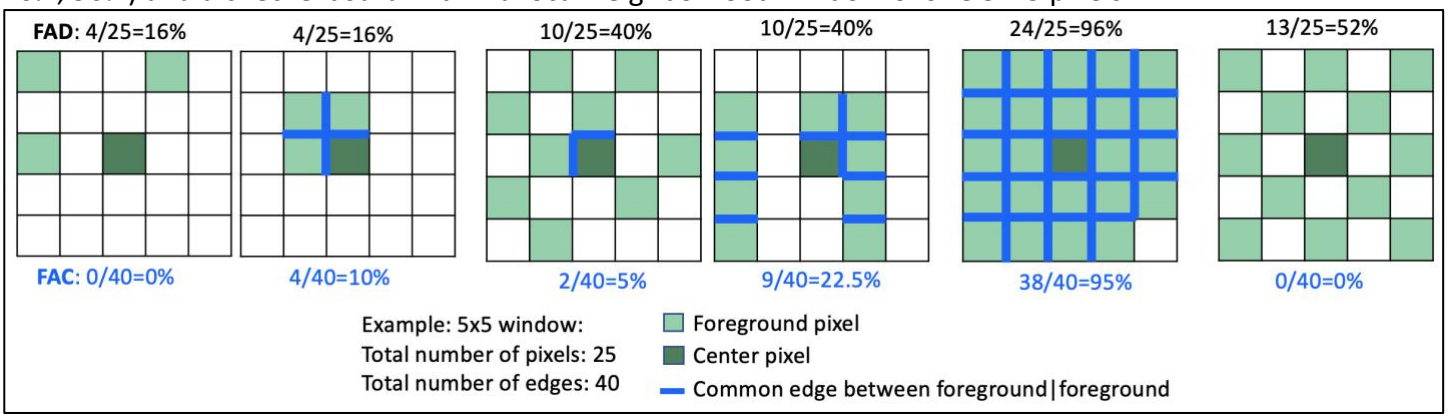
Question: what is the degree of fragmentation/connectivity of the foreground pixels (2 byte)?

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 by 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 edges with respect to the total number of edges 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 5 x 5 pixels:

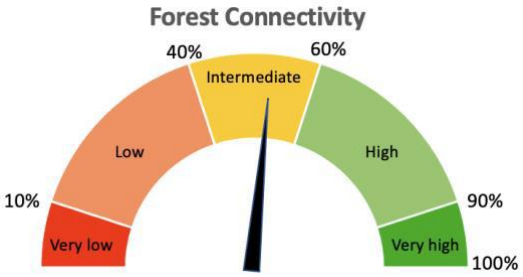


Both measure the degree of connectivity as a normalized index within [0, 100]%. Choosing one of the two depends which connectivity aspect should be focused on: the FAD option is driven by the amount of foreground pixels while the FAC option is driven by local clustering of foreground (for example forest 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:

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

Example for reporting forest connectivity/fragmentation using the default 5-class reporting scheme:

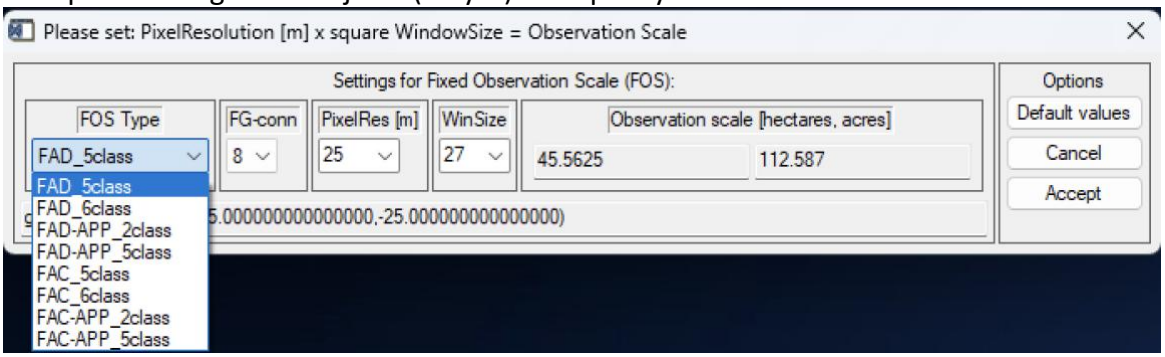


Foreground cover	Color	FAD/FAC	Connectivity	Fragmentation
1-Rare		0% ≤ x < 10%	Very low	Very high
2-Patchy		10% ≤ x < 40%	Low	High
3-Transitional		40% ≤ x < 60%	Intermediate	Intermediate
4-Dominant		60% ≤ x < 90%	High	Low
5-Interior		90% ≤ x ≤ 100%	Very high	Very low

For example, in class 4 the foreground cover within the neighborhood is *dominant*, which is equivalent to FAD or FAC being within the range [60, 90]%, 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/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:

Foreground cover	Color	FAD/FAC	Connected	Fragmented
1-Separated		0% ≤ x < 40%	No	Yes
2-Continuous		40% ≤ x ≤ 100%	Yes	No

How: load a map with foreground objects (2 byte) and specify:



- FOS (Fixed Observation Scale) Type:
  - FAD (Foreground Area *Density* – proportion of foreground pixels) or FAC (Foreground Area *Clustering* – proportion of common edges between neighboring foreground pixels)
  - FAD/FAC (reporting: pixel level) or FAD/FAC-APP (reporting APP: Average-Per-Patch)
  - Number of classes: the fragmentation range [0, 100]% is color-coded and reported into 2, 5, or 6 classes
- FG-conn: 8 – all directions (default) or 4 – connectivity in horizontal/vertical directions only
- PixelRes: spatial pixel resolution in meters

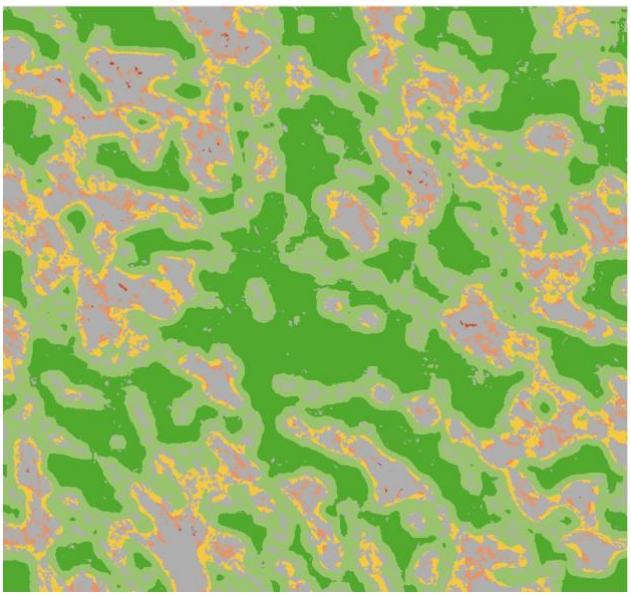
- WinSize: side length (number of pixels) of local neighborhood square window or umbrella.
- Observation scale: (PixelRes * WinSize)^2 = the area of the local neighborhood to be considered when assessing fragmentation/connectivity.

Result:

Statistics: proportion of foreground pixels in each fragmentation class; average degree in fragmentation.

Map product: showing fragmentation at pixel-level, color-coded into the selected number of classes.

```
Fragmentation analysis using Fixed Observation Scale (FOS)
Method options: FAC - Foreground Area Clustering; FAD - Foreground Area Density
Summary analysis for image:
C:\GuidosSource\data\fmap1990.tif
================================================================================
FOS parameter settings:
Foreground connectivity: 8-connectivity
FOS-type selected: FAC_5class
Method: FAC
Reporting style: FAC 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
================================================================================
Image foreground statistics:
Foreground area [pixels]: 468367
Number of foreground patches: 416
Average foreground patch size: 1125.8822
================================================================================
Proportion [%] of foreground area in foreground cover class:
          Rare (FAC-pixel value within: [0 - 9]):      0.0818
       Patchy (FAC-pixel value within: [10 - 39]):     4.0835
  Transitional (FAC-pixel value within: [40 - 59]):    12.5052
     Dominant (FAC-pixel value within: [60 - 89]):     45.4853
     Interior (FAC-pixel value within: [90 - 100]):    37.8443
================================================================================
Average pixel value across all foreground pixels using FAC-method:    78.9796
                Equivalent to average foreground connectivity:    78.9796
                Equivalent to average foreground fragmentation:    21.0204
```

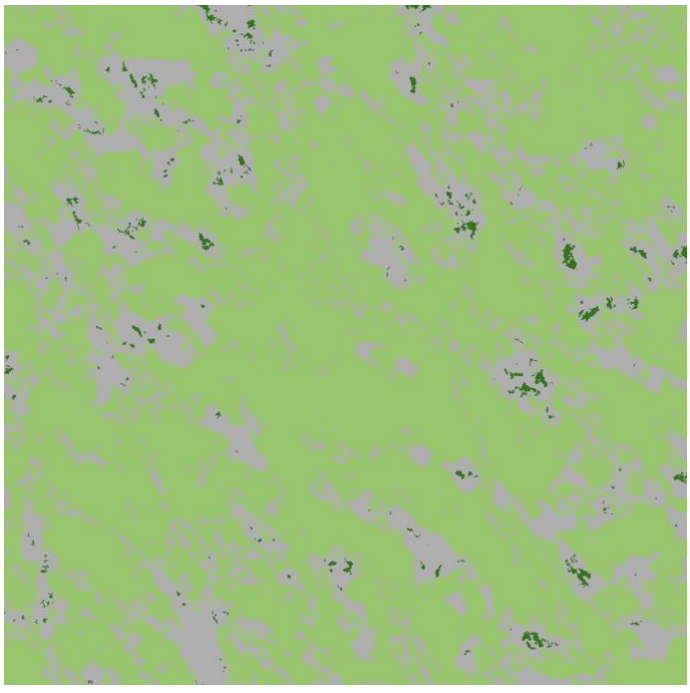


The map above shows an example output of the FOS type: FAC_5class. Note that each pixel shows the actual value in [0, 100]%. The map shows color-coded ranges for easier interpretation.

```
Fragmentation analysis using Fixed Observation Scale (FOS)
Method options: FAC - Foreground Area Clustering; FAD - Foreground Area Density
Summary analysis for image:
C:\GuidosSource\data\fmap1990.tif
================================================================================
FOS parameter settings:
Foreground connectivity: 8-connectivity
FOS-type selected: FAC-APP_2class
Method: FAC
Reporting style: FAC 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
================================================================================
Image foreground statistics:
Foreground area [pixels]: 468367
Number of foreground patches: 416
Average foreground patch size: 1125.8822
================================================================================
Proportion [%] of foreground area in foreground cover class:

FOS-APP_5class:
          Rare (FAC-pixel value within: [0 - 9]):      0.0502
       Patchy (FAC-pixel value within: [10 - 39]):     1.1000
  Transitional (FAC-pixel value within: [10 - 39]):    0.1928
     Dominant (FAC-pixel value within: [60 - 89]):     98.6570
     Interior (FAC-pixel value within: [90 - 100]):    0.0000

FOS-APP_2class:
      Separated  (FAC-pixel value within: [0 - 39]):     1.1502
  Continuous (FAC-pixel value within: [40 - 100]):     98.8498
================================================================================
Average pixel value across all foreground pixels using FAC-method:    78.9796
                Equivalent to average foreground connectivity:    78.9796
                Equivalent to average foreground fragmentation:    21.0204
```



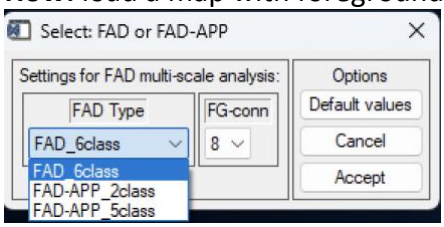
The map above shows an example output of the FOS type: FAC-APP_2class applied to the same input forest map. This type assigns the Average-Per-Patch pixel value to each foreground patch and the reporting style is limited to show 2 classes only: Separated (FAC < 40%, dark green) and Continuous (FAC ≥ 40%,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

Multiple Observation Scale (← click for product sheet)

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

Like the Fixed Observation Scale, this option conducts a FAD analysis but for a series of five observations 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.

How: load a map with foreground objects (2 byte) and specify:

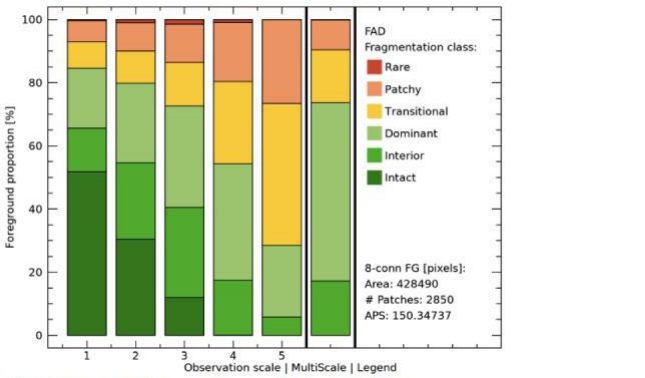


- FAD Type: reporting of FAD at pixel level with 6 classes or FAD-APP at patch-level with 2 or 5 classes
- FG-conn: 8 – all directions (default) or 4 – connectivity in horizontal/vertical directions only

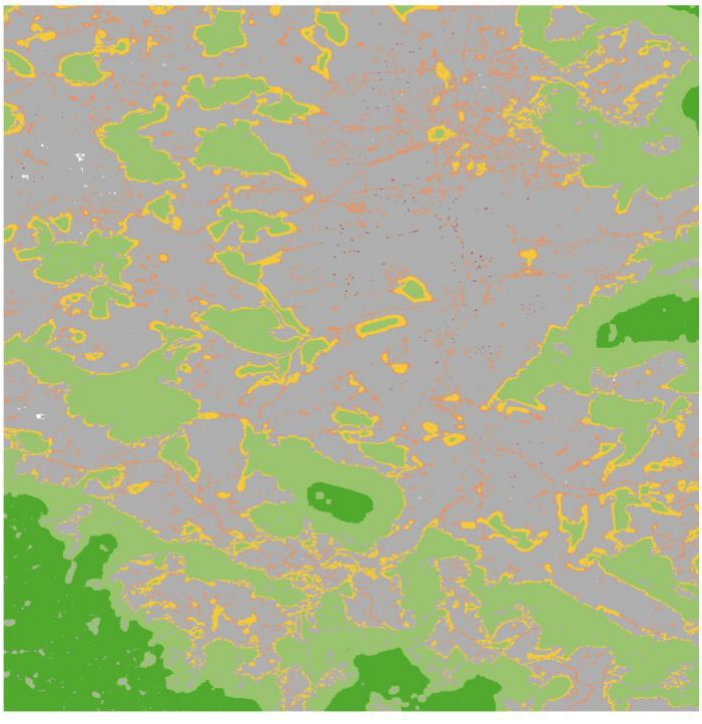
Result:

Statistics: proportion of foreground pixels in each fragmentation class; average degree in connectivity (FAD_av) across all foreground pixels. 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.




```
FAD: Foreground Area Density summary analysis for image:
C:\GuidosToolbox\data\input.tif
================================================================================
8-conn FG: area, # patches, aps [pixels]: 428490, 2850, 150.34737
Fragmentation class: foreground proportion at observation scale/area:
Observation scale:    1         2         3         4         5        mscale
Neighborhood area:   7x7      13x13     27x27     81x81    243x243
================================================================================
       Rare:      0.4210    1.0607    1.4686    0.9477    0.0063    0.1144
      Patchy:     6.6303    8.8826   12.1520   18.6697   26.5693    9.5321
Transitional:     8.4133   10.1977   13.7716   26.1248   44.9583   16.6286
    Dominant:    18.9374   25.1735   32.1576   36.9115   22.7436   56.4797
    Interior:    13.8603   24.1938   28.5181   17.2522    5.7224   17.2452
      Intact:    51.7377   30.4917   11.9321    0.0941    0.0000    0.0000
================================================================================
      FAD_av:    85.3174   80.3159   73.7660   61.7917   51.6021   70.5605
```



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.

b) Dominance - Question: how does the Landscape Mosaic change when observed across various scales?

This option conducts a Landscape Mosaic analysis for a fixed series of five observation scales with window dimension 7x7, 13x13, 27x27, 81x81, 243x243. The Landscape Mosaic is a tri-polar classification of a location accounting for the relative contributions of the three landcover types of *Agriculture*, *Natural*, and *Developed* in the window surrounding that location. The classification model is designed to identify anthropogenic activity (land cover classes falling in the categories Agriculture and Developed) in relation to natural land cover. Further details on the use and reporting options can be found in the Landscape Mosaic product sheet.

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.