

## **Welcome to PolyFrag!**

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### **Summary:**

PolyFrag has been created to calculate the Landscape Metrics of a vector-based land cover map and is designed to be run within the ESRI ArcGIS 10 platform. Recent advances in mapping techniques, such as object-based image analysis (OBIA) have made polygon based maps more prevalent, so this program allows these maps to be assessed without first converting into a raster format.

### **Basics of PolyFrag:**

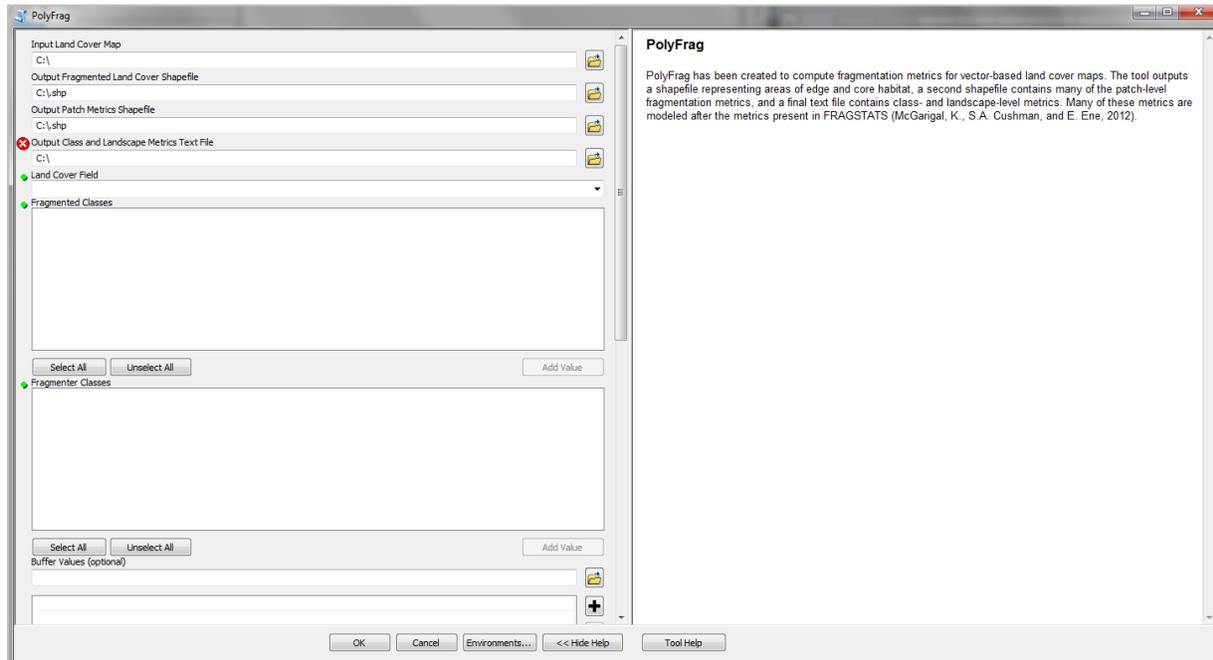
PolyFrag is an open source piece of software that computes landscape fragmentation metrics for vector-based land cover maps. The program's script is written in Python, runs in ESRI ArcGIS 10, but can also be customized by anyone with Python scripting knowledge. The script outputs both a fragmentation shapefile showing areas of edge, patch, and core habitat, a statistics file that contains the landscape metrics of each of the input polygons, as well as a text file with all of the class and landscape metrics. Since the software is open source, updates will be done whenever possible, however, there likely will not be a regular schedule of updates. For more information, please contact Meghan using the contact given below. Users are also more than welcome to alter/update/improve the software to meet their needs.

### **Opening the Tool:**

- ▷ Open ArcMap
- ▷ Open ArcToolbox
- ▷ Right click on the ArcToolbox folder at the top of the list of toolboxes
- ▷ Select 'Add Toolbox'
- ▷ Navigate to 'PolyFrag.tbx' (wherever you saved the program when you downloaded it) and select
- ▷ Expand the PolyFrag toolbox now found in your ArcToolbox
- ▷ Double click the PolyFrag script, the tool should now open like any other Arc tool

## Inputs and Outputs:

All inputs and outputs are defined in the tool window in ArcMap (shown below). The program as well as each option have their own set of instructions in the Help window (press the Show Help >> button at the bottom of the window if it is not already shown).



## **Inputs:**

- Input Land Cover Map
  - The vector land cover map you are analyzing. The map should be a shapefile and have a coordinate system that uses meters or feet. If your map is a raster file or is not projected, please properly prepare your data prior to using PolyFrag.
- Land Cover Field
  - The field within the attribute table that defines the land cover type for each object. You will select this field from a list of all fields available in your Input Land Cover Map.
- Fragmented Classes
  - The classes being fragmented in the landscape (e.g. Forest). You will select these classes from a list populated using the Land Cover Field. **\*\*\* WARNING \*\*\*** if 'and' or '=' is used in the class label, an error will occur and the buffer values will not be acquired properly. Please re-label your classes if this is the case.
- Fragmenter Classes

- The classes doing the fragmenting in the landscape (e.g. Developed). You will select these classes from a list populated using the Land Cover Field. \*\*\*WARNING\*\*\* if 'and' or '=' is used in the class label, an error will occur and the buffer values will not be acquired properly. Please re-label your classes if this is the case.
- Buffer Values
  - The string that defines the depth of the edge into a Fragmented Class where it interacts with a Fragmenter Class. The string should follow the following format:
 

Fragmented Class and Fragmenter Class = Edge Depth

 For example:
 

Forest and Developed = 30

 where Forest is the Fragmented Class, Developed is the Fragmenter Class, and the Edge Depth is 30 units (meters or feet depending on the coordinate system). \*\*\*WARNING\*\*\* You must follow the exact format, including spaces around 'and' and '=' and do not put quotes around your class names. The string is not case sensitive. Also, please include a string for every interaction you are interested in, if there isn't an Edge Depth defined for an interaction between a Fragmented and Fragmenter Class, it is automatically set to zero.
- Minimum Patch Area
  - The minimum size of a polygon to be considered 'core'. If the polygon does not meet the minimum patch area requirement it will be labeled 'patch'.
- Nearest Distance
  - The maximum distance allowed to locate a polygon with the same label (which can be related to dispersal for different species). This value is used when computing Proximity Metrics.
- Metrics (optional, choose appropriate metrics)
  - All metrics are listed below. Please pick the appropriate metrics to compute for your specific study. \*\*\* WARNING \*\*\* if you select all metrics, PolyFrag may take a very long time when there are many polygons

## Outputs:

- Output Fragmented Land Cover Shapefile
  - The output shapefile that will contain polygons classified as core, edge, etc., as well as some patch-level metrics for the core habitats. The input polygons in Fragmented Classes will be classified as either 'core', 'edge', or 'patch' polygons based on their distance to polygons in the Fragmenter Classes and

size. Polygons in the Fragmenter Classes will be classified as 'fragmenting' and all other polygons will be classified as 'matrix'.

- Output Patch Metrics Shapefile
  - The output shapefile that will contain patch-level metrics for each of the input patches.
- Output Class and Landscape Metrics Text File
  - The output text file containing class- and landscape-level metrics. All metrics will be provided in the text file, either under the Class Metrics section and under a specific Fragmented Class, or under the Landscape Metrics section.

### **Fragmentation Metrics:**

Many of these metrics have been modeled after those present in FRAGSTATS (McGarigal, K., S.A. Cushman, and E. Ene, 2012). However, there are some differences, so please ensure that you read the description of each of the metrics carefully before you use it.

### **Patch Metrics:**

Metrics Automatically Computed in PolyFrag:

- AREA = patch area
  - This is the area of each polygon and is computed for both the polygons in the output fragmented land cover shapefile, and the output patch metrics shapefile. The output is in either acres or hectares depending on the input units. AREA is output as a new column in each attribute table.
- PERIM = patch perimeter
  - This is the perimeter of each polygon and is computed for both the polygons in the output fragmented land cover shapefile, and the output patch metrics shapefile. PERIM is output as a new column in each attribute table.
- $PARA = \frac{PERIM}{AREA}$ 
  - PARA is a shape metric that expresses the ratio between perimeter and area of an individual polygon. The metric is computed for both the polygons in the output fragmented land cover shapefile, and the output patch metrics shapefile. PARA is output as a new column in each attribute table.

Optional Metrics:

- $SHAPE = \frac{PERIM}{2\pi\sqrt{AREA/\pi}}$

- SHAPE is the Shape Index. SHAPE is a measure of shape complexity of a polygon. In the output patch metrics shapefile, SHAPE is computed for all polygons, whereas SHAPE is only computed for core polygons in the output fragmented land cover shapefile. SHAPE is output as a new column, SHAPES, in each attribute table.
- $$\text{FRAC} = \frac{2 \ln(\text{PERIM}/4)}{\ln \text{AREA}}$$
  - FRAC is the Fractal Dimension Index. FRAC is also a measure of shape complexity of a polygon. In the output patch metrics shapefile, FRAC is computed for all polygons, whereas FRAC is only computed for core polygons in the output fragmented land cover shapefile. FRAC is output as a new column in each attribute table.
- $$\text{CIRCLE} = 1 - \frac{\text{AREA}}{\pi(\text{P\_LENGTH}/2)^2}$$
 where:
 

P\_LENGTH = diameter of the smallest circumscribing circle

  - CIRCLE is the Related Circumscribing Circle. CIRCLE is the area of a polygon divided by the smallest circumscribing circle around that polygon. In the output patch metrics shapefile, CIRCLE is computed for all polygons, whereas CIRCLE is only computed for core polygons in the output fragmented land cover shapefile. Both CIRCLE and P\_LENGTH are added as new columns to the attribute tables of the two shapefiles. \*\*\* WARNING \*\*\* CIRCLE may take a long time to compute with many polygons.
- $$\text{CAI} = \frac{\text{CORE AREA}}{\text{AREA}} * 100$$
 where:
 

CORE AREA = area labeled core within that polygon

  - CAI is the Core Area Index. CAI is the percent of the total area of a particular polygon that is actually considered core habitat. The value will be dependent on how much of the polygon becomes edge. The metric is only computed for the polygons in the output patch metrics shapefile. CAI is output as a new column in the attribute table.
- NEAR = x where:
 

x = centroid to centroid distance to the nearest similar polygon

  - NEAR is the Euclidean nearest neighbor distance. NEAR is the distance to the nearest neighboring patch with the same label. In the output patch metrics shapefile, NEAR is computed for all polygons, whereas NEAR is only computed for core polygons in the output fragmented land cover shapefile. NEAR is output as a new column, NEAR\_DIST, in each attribute table. \*\*\* WARNING \*\*\* NEAR may take a long time to compute with many polygons.

- $PROX = \sum_{i=1}^n \frac{AREA_i}{x_i}$  where:
  - $x_i =$   
centroid to centroid distance to a similar polygon within maximum search distance
  - $AREA_i =$  the area of that similar polygon
  - $PROX_{NUM} =$   
the number of polygons with the same label that fall within the max search distance
- PROX is the Proximity Index. PROX is the sum of all of the areas of polygon with the same label divided by the distance to each polygon, limited to only those polygons that fall within a maximum search distance (Nearest Distance). In the output patch metrics shapefile, PROX is computed for all polygons, whereas PROX is only computed for core polygons in the output fragmented land cover shapefile. Both PROX and PROX\_NUM are added as new columns to the attribute tables of the two shapefiles. \*\*\* WARNING \*\*\* PROX may take a long time to compute with many polygons, but must be computed to compute CONNECT (see below).

### **Class and Landscape Metrics:**

Metrics Automatically Computed in PolyFrag (all class and landscape metrics are output in the Class and Landscape Metrics Text File):

- CA = class area
  - CA is the total area of each class. CA is in area units (hectares or acres).
- TA = total area
  - TA is the total area of the landscape (all polygons). TA is in area units (hectares or acres).
- $PLAND = \frac{CA}{TA} * 100$ 
  - PLAND is Percentage of Landscape. PLAND is the percentage of the total landscape each class represents.
- NP = number of patches
  - NP is the number of patches in each class.
- $PD = \frac{NP}{TA} * 100$ 
  - PD is Patch Density. PD is the number of patches in a class per 100 area units.

- $LSI = \frac{P}{2\pi\sqrt{A/\pi}}$  where:
  - P = sum of all of the perimeters for the class(es) in question
  - A = sum of all of the areas for the class(es) in question (= CA for single classes)
    - LSI is the Landscape Shape Index. LSI is the total perimeter of all polygons in a single class (in length units) divided by the minimum perimeter possible for the area covered by that class, as computed by the perimeter of a circle with the same area as the total area of the class(es). LSI is unit less.
- $LPI = \frac{LPA}{TA} * 100$  where: LPA = is the largest patch area for the class(es)
  - LPI is the Largest Patch Index. LPI is the percentage of the total landscape area occupied by the largest patch of the class(es) in question.
- TE = total area of edge for the class(es)
  - TE is Total Edge. TE is the sum of the areas (in area units) of all of the polygons classified as 'edge' for the class(es) in question in the output fragmented land cover shapefile.
- $ED = \frac{TE}{TA} * 100$ 
  - ED is Edge Density. ED is the percentage of the total landscape area occupied by the edge areas of the class(es) in question.
- TCA = total core area
  - TCA is Total Core Area. TCA is the sum of the areas (in area units) of all of the polygons classified as 'core' for the class(es) in question in the output fragmented land cover shapefile.
- $CPLAND = \frac{TCA}{TA} * 100$ 
  - CPLAND is Core Percentage of Landscape. CPLAND is the percentage of the total landscape area occupied by the core areas of the class(es) in question.
- PR = total number of classes
  - PR is Patch Richness. PR is just the total number of classes in the landscape, including any background classes. PR is only a landscape metric.
- $PRD = \frac{PR}{TA} * 100$ 
  - PRD is Patch Richness Density. PRD is the number of classes per 100 area units. PRD is only a landscape metric.

Optional Metrics:

- $MESH = \frac{\sum_{i=1}^n AREA_i^2}{TA}$ 
  - MESH is the Effective Mesh Size. MESH is a measure of the size of the patches (in area units) if all patches were evenly distributed throughout the landscape (including any background). MESH is only a landscape metric.
- $COHESION = \frac{1 - \frac{\sum P}{\sum(P\sqrt{A})}}{1 - 1/\sqrt{TA}} * 100$ 
  - COHESION is the Patch Cohesion Index. COHESION is a measure of the connectedness of the class(es) in question. COHESION is reported as a percent.
- $CONNECT = \frac{\sum PROX\_NUM}{n(n-1)/2} * 100$ 
  - CONNECT is the Connectance Index. CONNECT is the percent of the total number of patches that are patches of the same class(es) in question within a maximum search distance (Nearest Distance). CONNECT is reported as a percent. \*\*\* WARNING \*\*\* CONNECT may take a long time to compute with many polygons, and PROX must be computed in order to calculate CONNECT.
- $SHDI = -\sum_{i=1}^n Pr_i * \ln Pr_i$       where:  $Pr_i = \frac{CA_i}{TA}$ 
  - SHDI is Shannon's Diversity Index. SHDI is one measure of diversity used in Landscape Ecology. If SHDI = 0, there is one patch in the landscape, and SHDI  $\geq 0$ , without limit. See Farina (2007) for further discussion.
- $SIDI = 1 - \sum_{i=1}^n Pr_i^2$ 
  - SIDI is Simpson's Diversity Index. SIDI is one measure of diversity used in Community Ecology and is less sensitive to rare patch types than SHDI. The value of SIDI represents the probability that any two polygons selected at random will have different labels.  $0 \leq SIDI < 1$ , where when SIDI = 0, there is only one patch and as SIDI approaches 1, PR increases and the distribution of area among patch types is more even. See Farina (2007) for further discussion.
- $MSIDI = -\ln \sum_{i=1}^n Pr_i^2$ 
  - MSIDI is the Modified Simpson's Diversity Index. MSIDI transforms the SIDI value into a value comparable to SHDI.
- $SHEI = \frac{-\sum_{i=1}^n Pr_i * \ln Pr_i}{\ln PR}$

- SHEI is Shannon's Evenness Index.  $0 \leq \text{SHEI} \leq 1$ , where when  $\text{SHEI} = 0$ , there is only 1 patch, and when  $\text{SHEI} = 1$ , the distribution of area within patch types is completely even.
- $\text{SIEI} = \frac{1 - \sum_{i=1}^n \text{Pr}_i^2}{1 - 1/\text{PR}}$ 
  - SIEI is Simpson's Evenness Index.  $0 \leq \text{SIEI} \leq 1$ , where when  $\text{SIEI} = 0$ , there is only 1 patch, and when  $\text{SIEI} = 1$ , the distribution of area within patch types is completely even.
- $\text{MSIEI} = \frac{-\ln \sum_{i=1}^n \text{Pr}_i^2}{\ln \text{PR}}$ 
  - MSIEI is Modified Simpson's Evenness Index.  $0 \leq \text{MSIEI} \leq 1$ , where when  $\text{MSIEI} = 0$ , there is only 1 patch, and when  $\text{MSIEI} = 1$ , the distribution of area within patch types is completely even.

### **References:**

Farina, A., 2007. *Principles and Methods in Landscape Ecology: Towards a Science of Landscape*. The Netherlands: Springer.

McGarigal, K., SA Cushman, and E Ene. 2012. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: <http://www.umass.edu/landeco/research/fragstats/fragstats.html>

### **Compatibility:**

The code was written with Python 2.6.5, it may not work with earlier versions.

PolyFrag is compatible with ESRI's ArcGIS 10 software package.

### **Contact:**

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