Raster-Based Landscape Metrics and Simulations in ArcGIS

These instructions enable you to calculate metrics comparable to those in FragStats 3.3, but applied within the ArcGIS 9 environment. Using simulated layers, you may batch process patch-, class-, and landscape-level metrics for use in landscape ecology analyses. The first set of metrics is derived from a multiple class landscape; the second set is from binary landscape simulations.

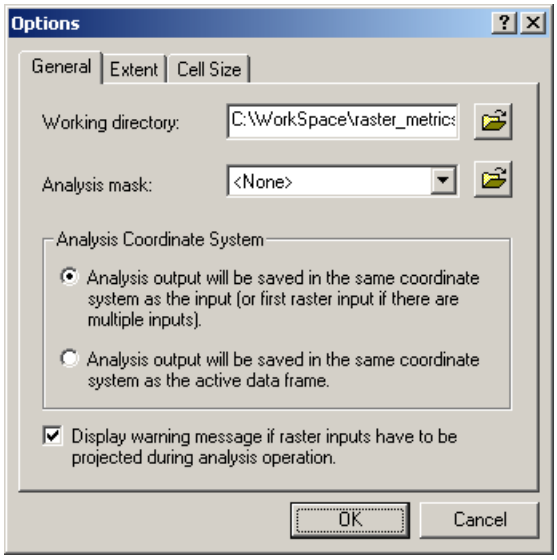
The example data are generated randomly. For real-world analyses, substitute your file names and field headings. The **Spatial Analyst** extension for ArcGIS is required.

CREATED DATA

Extent	100 x 100 grid
Normal	Random value grid based on a normal distribution
Classes	Multi-class grid reclassified from random data
Patches	Multi-class grid of patches (grouped grid values)
Metrics	Table of patch-level metrics for multi-classes
P1, P2, P3	Specified proportion binary grids generated randomly
G1, G2, G3	Binary patch grids
T1, T2, T3	Tables of patch-level metrics for binary proportions
***.dbf**	Exported tables for use in other software

Simulate the landscapes:

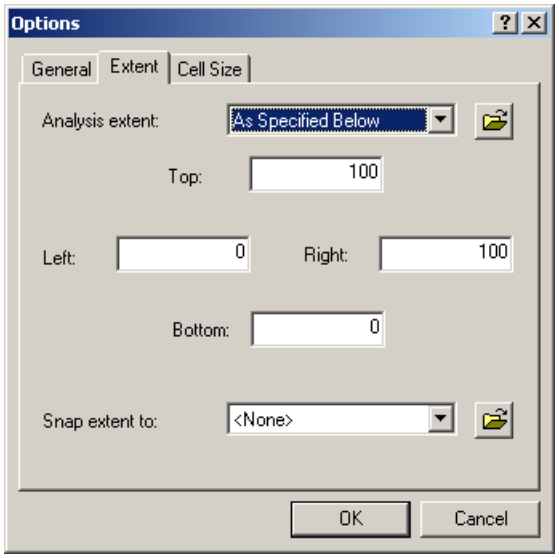
The following explains how to randomly simulate landscapes based on multiple categorical classes (i.e. land cover) and proportions of binary classes (i.e. habitat/non-habitat):

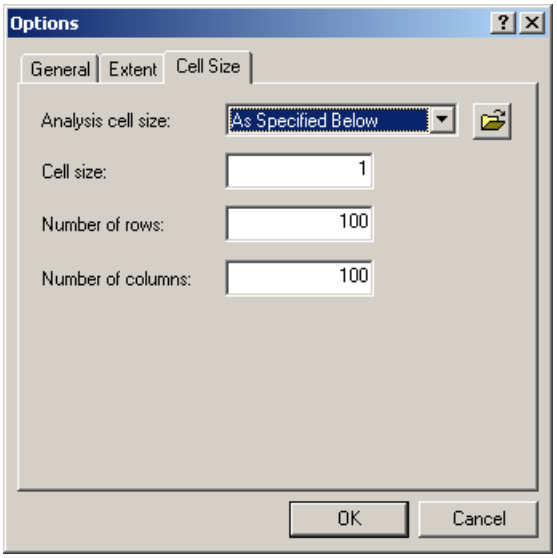


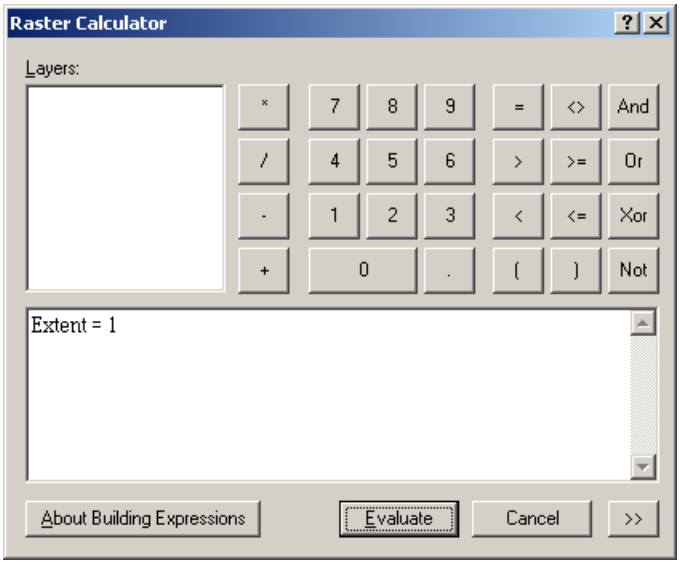
1. Start a new map document in ArcMap
2. Choose TOOLS >>> EXTENSIONS and make sure there is a check beside **Spatial Analyst** to enable it
3. Choose VIEW >>> TOOLBARS and make sure there is a check beside Spatial Analyst so you can view it
4. Choose SPATIAL ANALYST >>> OPTIONS and set the options as follows:
   - General tab – Working directory: **C:\WorkSpace\raster_metrics** (you may need to create a new folder in Windows Exploring beforehand)

- Extent tab – Analysis extent: 'As Specified Below'
  Top: **100**
  Left: **0** Right: **0**
  Bottom: **0**
- Cell Size tab – Analysis cell size: 'As Specified Below'
  Cell size: **1**

5. Click OK



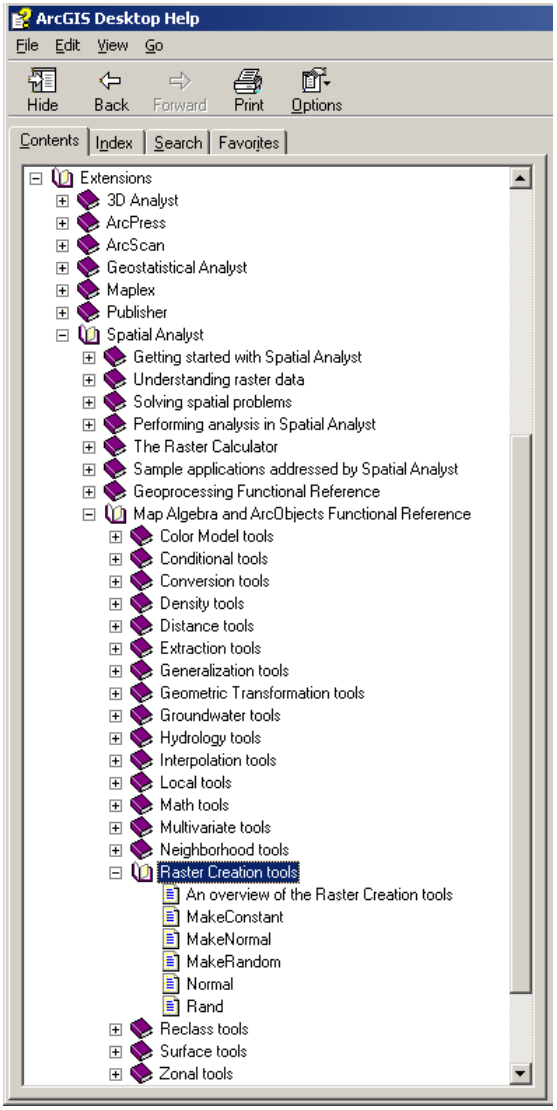




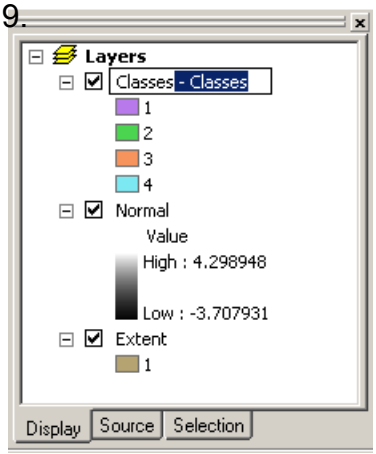
6. Choose SPATIAL ANALYST >>> RASTER CALCULATOR
7. Enter the following expression in the calculator:
   `Extent = 1`
8. Click EVALUATE

This example demonstrates how easy it is to create a grid of specified dimensions where each cell value equals a single value. To randomly generate values, and perform more advanced map algebra in the Raster Calculator, you will need to access some of Spatial Analyst's functions.

9. Choose HELP >>> ARCGIS DESKTOP HELP
10. In the Contents tab, navigate to Extensions > Spatial Analyst > Map Algebra and ArcObjects > Raster Creation tools
11. Review the information for the **Normal** and **Rand** functions – especially the 'Usage tips' and 'Map Algebra syntax'



17. Click OK
18. In the table of contents, rename the layer to simply "**Classes**"
19.

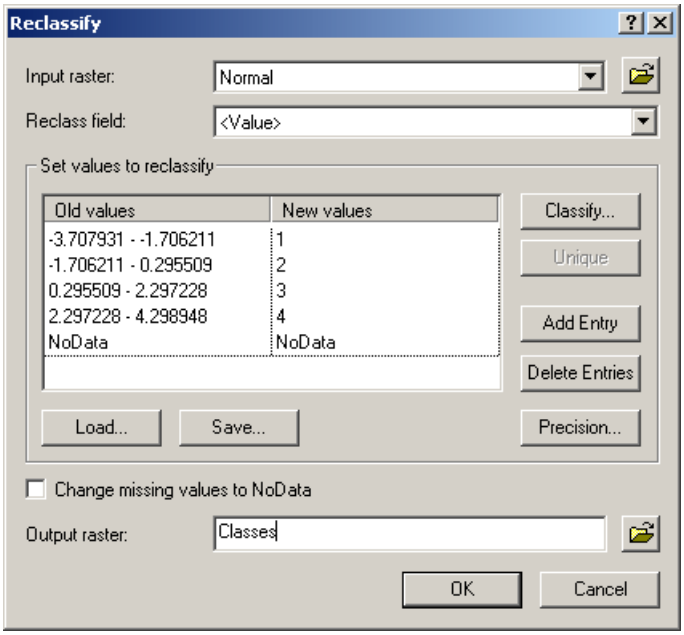


Note that there are comparable tools built upon the map algebra functions and are accessible via tool interfaces in ArcToolbox. Using the ArcToolbox tools and ModelBuilder will also batch the same simulations instructed here using the raster Calculator via the Spatial Analyst toolbar in ArcMap.

Multi-class landscape:

12. Decide on how you wish to randomly generate your landscapes – the examples here use the **Normal()** function
13. Choose SPATIAL ANALYST >>> RASTER CALCULATOR
14. Enter the following expression in the calculator:

    `Normal = Normal()`
15. Click EVALUATE
16. Choose SPATIAL ANALYST >>> RECLASSIFY
    - Select **Normal** as the input raster
    - Click on the CLASSIFY button
    - Choose an appropriate classification method and number of classes; e.g. **Equal Interval** – **4** classes
    - Specify an output raster name; e.g. **Classes**

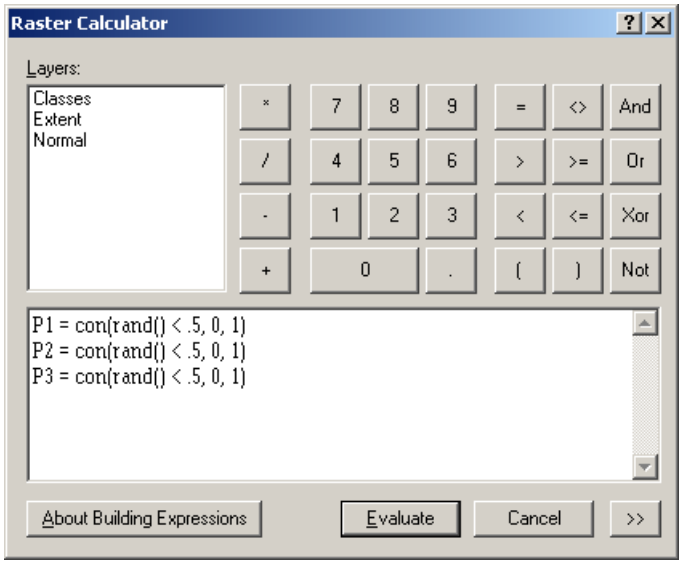


Proportional binary grids:

20. Decide on how you wish to randomly generate your landscapes and what threshold value you wish to use to divide the landscape into binary values – the examples here use the **Rand()** function with a proportional value of around 50%:
21. Choose SPATIAL ANALYST >>> RASTER CALCULATOR
22. Enter the following expression in the calculator:

```
P1 = Con(Rand() < .5, 0, 1)
P2 = Con(Rand() < .5, 0, 1)
P3 = Con(Rand() < .5, 0, 1)
```

23. Click EVALUATE



Check ArcGIS Desktop Help for more details on the CON() function – it is similar to if… then… else logic.

24. Open the attribute tables for the proportional binary grids – *note that approximately 50% of the cells have a value of 1*
25. Simulate a single landscape grid or more if desired and follow the instructions below appropriate to your grid type

Metrics for multi-class landscapes:

Identify patches:

1. Read the ArcGIS Desktop Help topic on **RegionGroup**
2. Decide on how you wish to evaluate the connectivity between cells: four nearest neighbors (direct) or eight nearest neighbors (diagonal) – the default is FOUR and is used here
3. Choose SPATIAL ANALYST >>> RASTER CALCULATOR
4. Enter the following expression in the calculator:

```
Patches = RegionGroup([Classes])
```

5. Click EVALUATE
6. Open the attribute table and view its contents

The VALUE field identifies each unique patch or connected region, the COUNT field tells how many cells belong to that patch, and the LINK field indicates what the original class values are in the input Classes grid. The example here shows that the input Classes grid has a total of 2071 regions according to the four-neighbor rule of connectivity.

Attributes of Patches

ObjectID	Value	Count	Link
0	1	12	2
1	2	2	3
2	3	1	3
3	4	12	2
4	5	4	3
5	6	7	2
6	7	2	3
7	8	29	2
8	9	1	3
9	10	1	4
10	11	1	2
11	12	15	3

Record: 0 Show: All Selected Records (0 out of 2071 Selected.)

Patch-level metrics:

The ZonalGeometry function efficiently calculates useful base metrics for each patch. View the ArcGIS Desktop Help topic for details (especially "How Zonal Geometry works"). Note that you may use individual zonal functions to obtain calculations just for area, perimeter, thickness, or centroids.

7. Choose SPATIAL ANALYST >>> RASTER CALCULATOR
8. Enter the following expression:

```
Metrics = ZonalGeometry([Patches], ALL)
```

9. Click EVALUATE

The table should open automatically. If it gets 'lost' then simply add and open it.

10. Click the ADD DATA button and navigate to select Metrics (has a table icon)
11. In the source tab, right click on Metrics and open the table to view its contents

Attributes of metrics

Rowid	VALUE	AREA	PERIMETER	THICKNESS	XCENTROID	YCENTROID	MAJORAXIS	MINORAXIS	ORIENTATION
1	1	12	24	0.707	3.66667	98.5	3.29077	1.16074	156.482
2	2	2	6	0.5	6	99.5	1.12838	0.56419	0
3	3	1	4	0.5	10.5	99.5	0.56419	0.56419	90
4	4	12	26	0.5	10.9167	98.5	3.13032	1.22023	156.891
5	5	4	10	0.5	13.5	99	1.82576	0.697377	31.7175
6	6	7	12	0.707	15.7857	98.5	1.55135	1.43627	90
7	7	2	6	0.5	18	99.5	1.12838	0.56419	0
8	8	29	50	0.707	21.2931	97.1207	3.45479	2.67194	4.79415
9	9	1	4	0.5	20.5	99.5	0.56419	0.56419	90
10	10	1	4	0.5	25.5	99.5	0.56419	0.56419	90
11	11	1	4	0.5	26.5	99.5	0.56419	0.56419	90
12	12	15	30	0.5	26.7	97.1667	2.96027	1.61291	53.2912

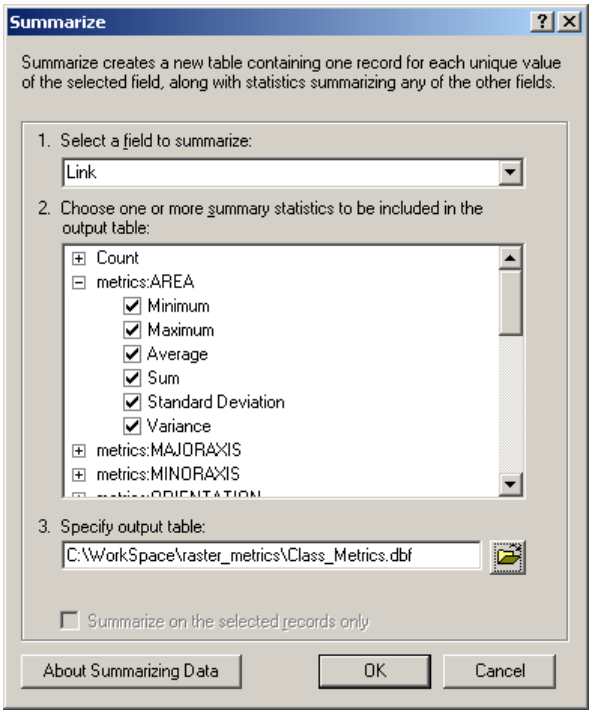
Record: 1 Show: All Selected Records (0 out of 2071 Selected.) Options

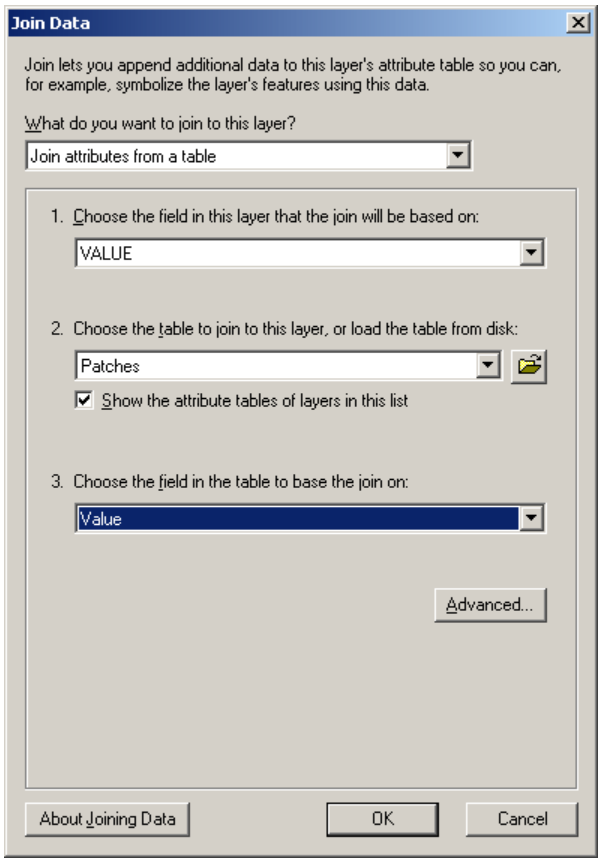
The VALUE field is identical to that of the RegionGroup resulting grid named Patches, and all other fields store the specified geometry measure: the AREA and PERIMETER fields can be incorporated into additional metrics (see FragStats documentation for formulae). ***NOTE: If you wish to access this INFO table outside ArcMap, click OPTIONS and export it to dBase or text for external use!***

Class-level metrics:

The class values need to be associated with the ZonalGeometry output table prior to summarizing for class-level metrics.

12. In the table of contents, right click on the Metrics table
13. Choose JOINS AND RELATES >>> JOINS
14. Join by the VALUE field to the Patches attribute table
15. Re-open the Metrics table
16. Scroll to the right to locate the LINK field – *this is the attribute that contains the original class values*
17. Right click on LINK and choose SUMMARIZE





18. Choose the desired output summary statistics; e.g. check Minimum, Maximum, Average, etc. for Metrics:AREA and Metrics:PERIMETER
19. Specify an output table name; e.g. **Class_metrics.dbf**
20. Click OK
21. Open the Class_Metrics.dbf table to view the class-level statistics

The LINK field identified the original landscape class, the COUNT_LINK indicates the number of patches per class, and the following fields tell the specified class-level metric.

Attributes of Class_Metrics

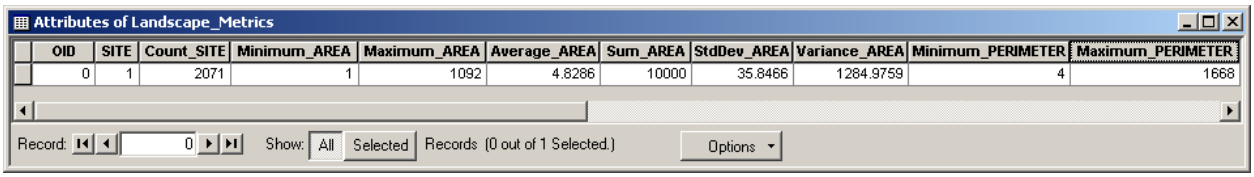
OID	Link	Count_Link	Minimum_AREA	Maximum_AREA	Average_AREA	Sum_AREA	StdDev_AREA	Variance_AREA	Minimum_PERIMETER	Maximum_PERIMETER
0	1	411	1	4	1.0876	447	0.3156	0.0996	4	10
1	2	392	1	1092	14.5612	5708	81.4024	6626.3492	4	1668
2	3	1183	1	54	3.1767	3758	4.276	18.2843	4	96
3	4	85	1	2	1.0235	87	0.1525	0.0232	4	6

Record: 0 Show: All Selected Records (0 out of 4 Selected.) Options

Landscape-level metrics:

The method shown here for how to calculate metrics for the entire landscape involves summarizing the patch metrics table. To be able to add new fields for further calculations, first you must export the table.

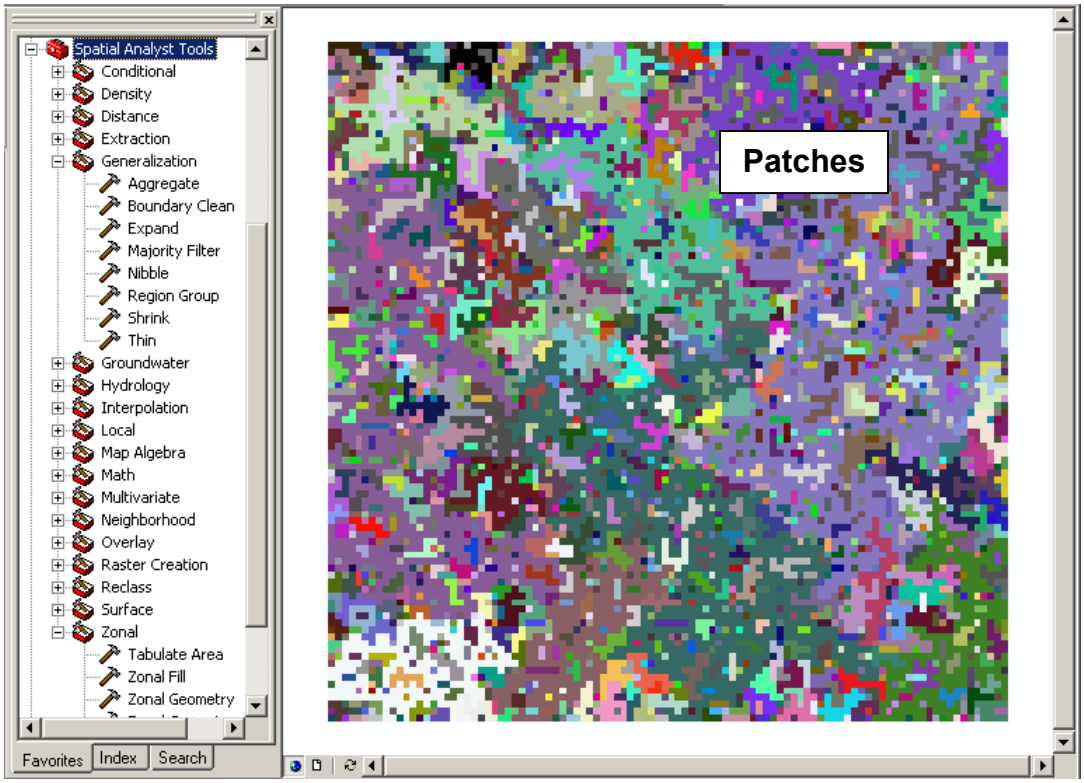
22. Open the Metrics table
23. Choose OPTIONS >>> EXPORT
24. Specify the output table as **Patch_Metrics.dbf** and click OK
25. Open the new table
26. Choose OPTIONS >>> ADD FIELD
27. Type **SITE** as the name, select **Short Integer** as the type, and click OK
28. Right click on SITE and choose CALCULATE VALUES
29. Type **1** and click OK
30. Right click on the SITE heading and choose SUMMARIZE
31. Choose the desired output summary statistics; e.g. check Minimum, Maximum, Average, etc. for Metrics:AREA and Metrics:PERIMETER
32. Specify an output table name; e.g. **Landscape_metrics.dbf** and click OK
33. Open the Landscape_Metrics.dbf table to view the landscape-level statistics


Attributes of Landscape_Metrics

OID	SITE	Count_SITE	Minimum_AREA	Maximum_AREA	Average_AREA	Sum_AREA	StdDev_AREA	Variance_AREA	Minimum_PERIMETER	Maximum_PERIMETER
0	1	2071	1	1092	4.8286	10000	35.8466	1284.9759	4	1668

Record: 0 Show: All Selected Records (0 out of 1 Selected.) Options

The Count_SITE field indicates the total number of patches for the landscape, the Minimum_AREA and Maximum_Area respectively show the smallest and largest patch sizes, and so on. You may add new fields to calculate the average Perimeter /Area ratio and other metrics according to FragStats formulae.



Metrics for specified proportion binary landscapes:

Identify patches:

1. Decide on how you wish to evaluate the connectivity between cells: the default of FOUR is used here
2. Choose SPATIAL ANALYST >>> RASTER CALCULATOR
3. Enter the following expressions:

```
G1 = RegionGroup([P1])
G2 = RegionGroup([P2])
G3 = RegionGroup([P3])
```

4. Click EVALUATE

Patch-level metrics:

5. Choose SPATIAL ANALYST >>> RASTER CALCULATOR
6. Enter the following expressions:

```
T1 = ZonalGeometry([G1], ALL)
T2 = ZonalGeometry([G2], ALL)
T3 = ZonalGeometry([G3], ALL)
```

7. Click EVALUATE

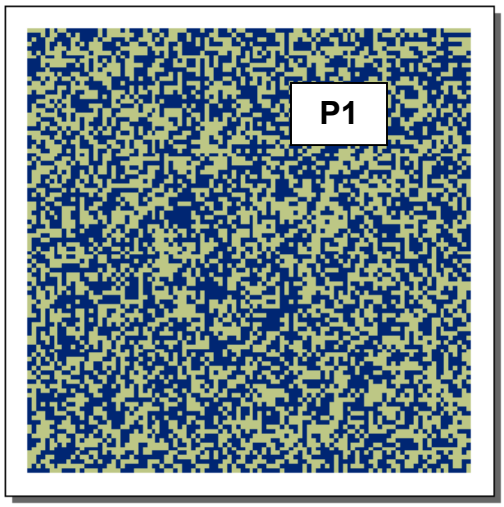
Class-level metrics:

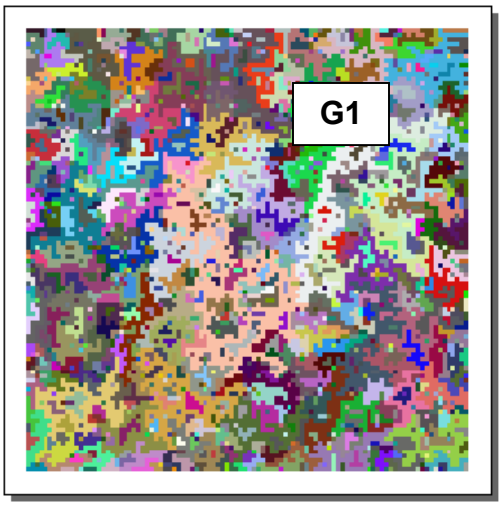
8. For each table, join by the VALUE field to the corresponding group attribute table; i.e. join **T1 to G1**
9. In the joined attribute table, right click on the LINK field and choose SUMMARIZE
10. Choose the desired output summary statistics; e.g. check Minimum, Maximum, Average, etc. for T1:AREA, T1:PERIMETER, and T1:THICKNESS
11. Specify an output table name; e.g. **Class_T1.dbf**
12. Click OK
13. Repeat steps 8 through 12 for T2 to G2 and T3 to G3 and obtain the Class_T2.dbf and Class_T3.dbf tables
14. Open the tables to view the contents

Refer to the ArcGIS Desktop Help topics and information provided in the above multi-class landscape section on class-level metrics.

Landscape-level metrics:

15. Export each table from, the class-level instructions; e.g. **Patch_T1.dbf**
16. Add a SITE field and calculate as the group number e.g. **1**
17. Summarize each table on the SITE field, choosing the desired summary statistics and specifying an appropriate output table name; e.g. **Landscape_T1.dbf**
18. View the table and add any new fields and calculations for additional metrics





Attributes of t1

t1:Rowid	t1:VALUE	t1:AREA	t1:PERIM	t1:THICK	t1:XCENTR	t1:YCENTR	t1:MAJOR	t1:MINOR	t1:ORIENT	Object	Value	Count	Link
1	1	5	12	0.5	2.3	99.3	2.36541	0.672843	169.099	0	1	5	0
2	2	2	6	0.5	4.5	99	1.12838	0.56419			2	2	1
3	3	1	4	0.5	6.5	99.5	0.56419	0.56419			3	1	1
4	4	2	6	0.5	8	99.5	1.12838	0.56419			4	2	0
5	5	18	28	1.707	13	98.2778	2.74222	2.0894	162.695	4	5	18	1
6	6	2	6	0.5	16.5	99	1.12838	0.56419	90	5	6	2	0
7	7	2	6	0.5	17.5	99	1.12838	0.56419	90	6	7	2	1

T1

Record: 0 Show: All Selected Records (0 out of 1386 Selected.) Options

More metrics:

- Consult the FragStats documentation, scientific literature, and other landscape ecology resources to help you calculate additional metrics of use:
  McGarigal, K., and B. J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. USDA For. Serv. Gen. Tech. Rep. PNW-351.
  http://www.umass.edu/landeco/research/fragstats/fragstats.html
  http://www.innovativegis.com/products/fragstatsarc/manual/index.html
  http://flash.lakeheadu.ca/~rrempel/patch
- Try checking your metrics obtained in ArcGIS with those obtained in FragStats 3.3 to see how they correspond.
- Hopefully the above instructions have provided you with the skills to add the base attributes of area, perimeter to your patches; it's now simply a matter of determining the join tables, copy values, and calculate the formulae comprised of the base attributes to obtain more complex patch-, class, and landscape- level metrics.