

National Park Service
U.S. Department of the Interior

Natural Resource Program Center

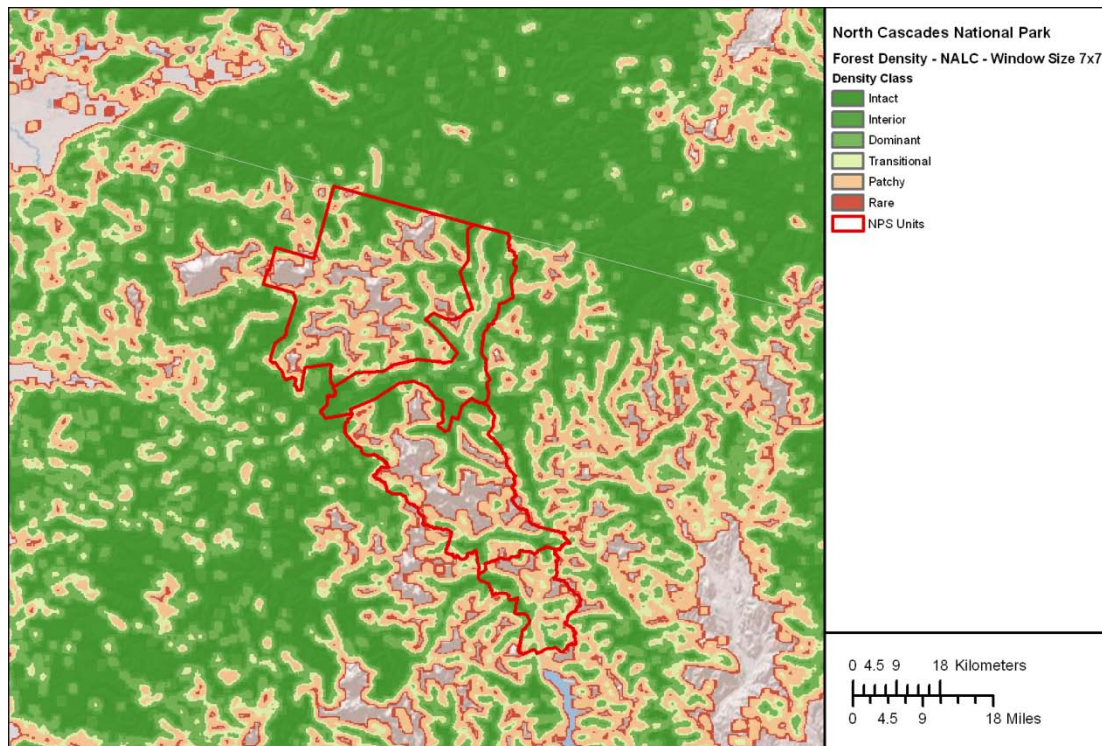


NOTE: This document reflects the processes used to generate the fall 2010 release of NPScape data. There may be revised processes and documentation available. Check Reference Application (<http://nrinfo.nps.gov>) for most current version.

NPScape Pattern Measure – Phase 2 North American Land Cover Pattern Metrics Processing SOP

Forest and Grassland Density

Version: 20110405



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Table of Contents

1.	Overview.....	3
2.	Data Acquisition and Preprocessing.....	4
2.1.	Source Data.....	4
2.2.	Re-Projection of Source Data.....	5
3.	Processing and Analysis.....	5
3.1.	Re-project Source Data.....	5
3.2.	Clip and Reclassify Preprocessed Source Density Raster and Create Summary Tables	5
4.	Quality Control.....	8
4.1.	Verify Spatial and Thematic Integrity.....	8
4.2.	Verify Statistics Outputs.....	8
5.	Literature Cited.....	9
6.	Appendices.....	10
6.1.	Known Issues.....	10
6.2.	Source Processing Details.....	10
6.2.1.	Source Data.....	10
6.2.2.	Re-project Source Data.....	10
6.2.3.	Generate Indicator Raster.....	10
6.2.4.	Calculate Density Values.....	11
6.2.5.	Generate Sector Rasters.....	11
6.3.	Lookup and Reclassification Tables.....	12
6.3.1.	Comparative Landscape Sizes for Pattern Density Analyses.....	12
6.3.2.	Density Category Reclassification Table.....	13
6.4.	NLCD – Density Processing Notes.....	14

1. Overview

This SOP provides guidance on how to process NPScape outputs for the North American Landcover (NALC) based forest and grassland density metrics used in NPScape. Five metrics are calculated for both forest and grassland areas based on the moving window size used to calculate the cover type density. Forest density outputs are prefixed with 'FDEN' while grassland outputs are prefixed with 'GDEN'. The pixel edge count of the moving window is appended to these prefixes. The equivalent window sizes in hectares are $(7*7) * 6.25\text{hA} = 306.25\text{hA}$ and so on for maps created from NALC 2005 (250 m resolution) data (see Appendix 6.3 for details).

Download the NPScape pattern metrics methods zip file from the NPScape website (<http://science.nature.nps.gov/im/monitor/npscape/methods.cfm>). The zip file includes an ArcGIS™ toolbox containing NPScape pattern script tools, an ArcMap™ document for displaying outputs, and a copy of this SOP document.

The purpose of this SOP is threefold. This SOP provides detailed documentation on methods the NPS Landscape Dynamics Project (NPScape) used to calculate these measures. Second, this SOP provides any user with the ability to re-create NPScape results. Finally, if a Park or Network has a need to generate results using a different area of analysis, this SOP provides a template that will permit others to quickly and efficiently modify the methods to meet these needs.

Forest and grassland area density are calculated using a moving window analysis. First, a square neighborhood (window) for analysis is defined by the number of pixels on each side. The proportion of pixels in the window of a particular type (forest or grassland in this case) is calculated and assigned to the pixel in the center of the window (Riitters et al. 2000, 2002; Wickham et al. 2007, 2008).

NPScape pattern density metrics are intended to assist with monitoring questions related to habitat condition. In general, the value of this metric will be greatest when considered in conjunction with other landscape metrics. Relevant monitoring questions include:

- At fine to broad scales, how has the density of forest or grassland area changed in the lands surrounding parks? For large parks, how has forest or grassland habitat density changed within the park?
- How has the distribution of forest/grassland area density classes (i.e., none to intact) changed?

The area density metrics are calculated for every pixel and, especially for the larger window size, they provide a coarse metric. Riitters et al. (2003) and Riitters (2005) discuss and provide a method for scaling and for mapping and interpreting clusters of pixels with similar scale-dependent characteristics. Results from the clustering technique can be used at the pixel level to identify core, edge, and transitional areas.

The North American Landcover dataset (NALC) is a medium resolution raster of landcover extending from Mexico to the Arctic. Pattern Density metrics derived from this data source include the following rasters where <*> is the moving window size in pixels per edge (see Appendix 6.3 for thematic class details):

1. PFDEN_<*> and PGDEN_<*>: NALC data processed into density categories for forest or grassland areas.
2. PFDEN_<*>_grouped and PGDEN_<*>_grouped: NALC data processed into density classes for forest or grassland areas. Density classes are groupings of density categories.

Density Class Definitions

Density Class	Density Category (p)
Intact	$p = 1.0$
Interior	$0.9 \leq p < 1.0$
Dominant	$0.6 \leq p < 0.9$
Transitional	$0.4 \leq p < 0.6$
Patchy	$0.1 \leq p < 0.4$
Rare	$0.0 \leq p < 0.1$
None	$p = 0.0$

NPScape preprocessed outputs are available for the following window sizes (in number of pixels): 7x7, 11x11, 15x15, 27x27, and 39x39. See Appendix 6.3 for detailed area values for these window sizes.

This document summarizes the methods used to generate these outputs for any area of analysis from the NPScape preprocessed source data. For details on how the prerocessed source data were created, see Appendix 6.2.

Unless noted, the data sources and tools used are assumed to be in ESRI ArcGIS™ format, version 9.3.1 Service Pack 1.

2. Data Acquisition and Preprocessing

2.1. Source Data

Two datasets are required for processing these metrics: forest and grassland landcover rasters and area of analysis polygons.

- **Source 1:** Forest and Grassland Landcover Rasters

NPScape preprocessed source version of the pattern density rasters derived from the Commission for Environmental Cooperation (2010) North American Land Change Monitoring System - Land Cover 2005 (for grassland or forest):

http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm

NPScape preprocessed pattern density data includes five file geodatabase density rasters (one for each window size) in either the USA Contiguous Albers Equal Area Conic or Alaska Albers Equal Area Conic spatial reference (see Appendices for details).

- **Source 2:** Area of Analysis Polygons

An Area of Analysis (AOA) polygon may be any topologically correct polygon feature covering an area of interest. AOA polygon geometries must be free of topological errors like slivers or donuts. Example AOAs include buffered NPS park areas, watershed boundaries, study areas, or ecoregion boundaries.

2.2. Re-Projection of Source Data

Each source dataset must be re-projected into a common spatial reference. For CONUS areas (including Puerto Rico and the Virgin Islands), the NPScape project uses USA Contiguous Albers Equal Area Conic USGS as its standard projection. For Alaska, Alaska Albers Equal Area Conic is used. NAD_83 is the datum for both projections. Note that the NPScape preprocessed source data are already re-projected. Therefore, only the area of analysis polygon feature may require re-projection.

3. Processing and Analysis

3.1. Re-project Source Data

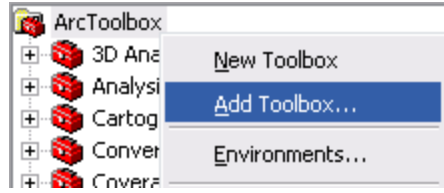
If the AOA polygon is not in the standard projection, use ArcGIS™ to create a re-projected version of it.

ArcToolbox → Data Management Tools → Projections and Transformations → Feature → Project

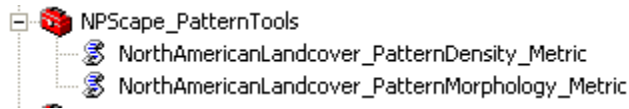
3.2. Clip and Reclassify Preprocessed Source Density Raster and Create Summary Tables

ArcGIS™ script tools using Python scripts are used to produce pattern morphology metric outputs.

Open ArcMap™ and open ArcToolbox. Right-click on ArcToolbox and choose ‘Add Toolbox...’.



Navigate to the folder where the methods zip file was unzipped. Select the NPScape_PatternTools.tbx file to add.

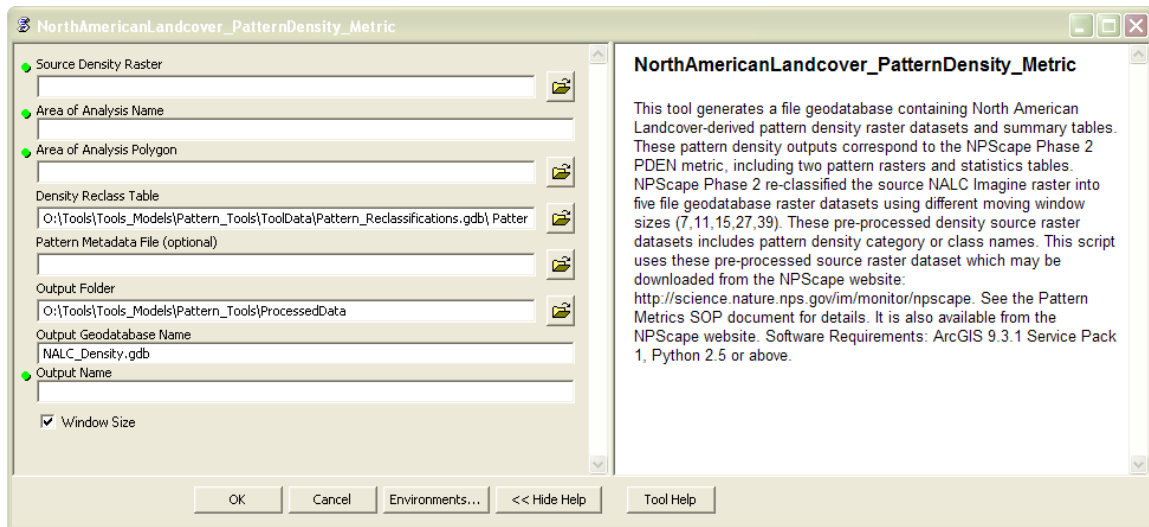


Preprocessed source density rasters are clipped to the AOA and reclassified into density categories and classes categories (Appendix 6.3). Class areas and percent total area values within the AOA are calculated by thematic category.

General processing steps of the tools are:

- Clip source raster to the area of analysis
- Reclassify clipped source using the appropriate reclassification table (see Appendix 6.2)
- Add and populate CLASSNAME attribute in reclassified output raster

Generate summary statistics tables for re-classified raster



The following parameters are necessary to run the script tool:

- Source Density Raster: full path to the preprocessed NPScape source density raster (varies by window size)

- AOA Name: name of the area of analysis (60 character limit)
- Area of Analysis: location and name of the AOA polygon feature class
- Density Reclass Table: full path to the pattern reclassification table; located in Pattern_Tools\ToolData
- Pattern Metadata File (optional): full path to the pattern metadata XML file
- Output Folder: full path location of output folder; defaults to Pattern_Tools\ProcessedData
- Output Geodatabase Name: name of the output file geodatabase (must end with .gdb)
- Output Name: Prefix for output raster and table names.
- Window Size: number of pixels on one side of window (7, 11, 15,27, or 39)

Output Rasters (see Appendix 6.3 for classification details):

- < Output Name >_<*> : clipped density category raster for selected window size
- <Output Name>_<*>_grouped: clipped density class raster for selected window size

Attributes of the output rasters include:

- VALUE: pattern class identifier
- COUNT: number of cells in each pattern class
- CLASSNAME: description of pattern density category or class
- AOA_Name: area of analysis name provided as script tool input

Summary Statistics Tables:

- < Output Name >_stats: density category or class areas in km² for the area of analysis

Attributes of the output statistics tables include:

- AOA_AREA_SQKM: total area of AOA in square kilometers
- TAREA_SQKM: total area of raster data within AOA in square kilometers of area of analysis:

$$TAREA_SQKM = (COUNT * cell\ size^2) / 1000000$$
- AREA_SQKM: total area in square kilometers of each pattern class
- PCT_SQKM: percent total area of each pattern class:

$$PCT_SQKM = (AREA_SQKM / TAREA_SQKM) * 100$$

4. Quality Control

4.1. *Verify Spatial and Thematic Integrity*

Use the ArcMap™ document (Pattern_Tools\Landcover_Metrics.mxd) provided to open the pattern rasters. Overlay them with area of analysis polygon. Verify that edges align correctly and that the raster cells align from raster to raster. Use the Effects → Swipe tool to help verify this. Note that the NPScape layer files for pattern (Pattern_Tools\ProcessedData*.lyr) may be used to standardize the raster symbology.

Add the source raster(s) to the map and use the Swipe tool to verify that the processed rasters' pixels align with the source pixels.

If outputs were generated for multiple window sizes, add those rasters to the map and zoom into an area and visually compare the outputs of the 7 cell window width raster with the other cell window width rasters. Check for alignment by swiping the top raster across the other rasters: the edges should. Note, rasters derived from grassland source rasters may not be contiguous for all areas of interest.

Add the density class rasters (< Output Name >_<*>_grouped). Repeat the swiping operation to verify pixel alignment.

4.2. *Verify Statistics Outputs*

Open each raster-derived density statistics table and verify that the TAREA_SQMKM values are equivalent across all the tables. Sort the PCT_SQKM field in descending order and look for outlying (zero or negative values, more than one value near 100, sum of values != 100).

Select one record from each statistics table and double-check the result column values by re-calculating them by hand:

$$\text{PCT_SQKM} = (\text{AREA_SQKM} / \text{TAREA_SQKM}) * 100$$

5. Literature Cited

Commission for Environmental Cooperation. 2010. 2005 Land Cover of North America at 250 meters. <http://www.cec.org/naatlas/>

Riitters, K. H. 2010 (in review). Spatial patterns of land-cover in the United States: A technical document supporting the forest service 2010 RPA assessment. USFS Technical Report (in revision 8/2010).

Riitters, K. H. 2005. Downscaling indicators of forest habitat structure from national assessments. *Ecological Indicators* 5:273-279.

Riitters, K. H., J. W. Coulston, and J. D. Wickham. 2003. Localizing national fragmentation statistics with forest type maps. *Journal of Forestry* 101:18-22.

Riitters, K., J. Wickham, R. O'Neill, B. Jones, and E. Smith. 2000. Global-scale patterns of forest fragmentation. *Conservation Ecology* 4(2): 3. [online] URL: <http://www.consecol.org/vol4/iss2/art3/>

Riitters, K. H., J. D. Wickham, R. V. O'Neill, B. K. Jones, E. R. Smith, J. W. Coulston, T. G. Wade, and J. H. Smith. 2002. Fragmentation of continental United States forests. *Ecosystems* 5:815-822.

Wickham, J. D., K. H. Riitters, T. G. Wade, and J. W. Coulston. 2007. Temporal change in forest fragmentation at multiple scales. *Landscape Ecology* 22:481-489.

Wickham, J. D., K. H. Riitters, T. G. Wade, and C. Homer. 2008. Temporal change in fragmentation of continental US forests. *Landscape Ecology* 23:891-898.

6. Appendices

6.1. *Known Issues*

Data Availability

Source NALC data are not available for off-shore parks (e.g. Dry Tortugas), Puerto Rico, the Virgin Islands, Hawaii, or the outlying Pacific Islands.

Data Extent

Source NALC raster data extend a few kilometers off the coasts and lakeshores of North America. Therefore, coastal AOAs may not include seamless coverage of the source data. In these areas, the AOA_AREA_SQKM attribute will be greater than the TAREA_SQKM value.

6.2. *Source Processing Details*

6.2.1. Source Data

Two datasets are required for processing these metrics: forest and grassland landcover rasters and area of analysis polygons.

GIS data were obtained from the following sources:

- **Source 1:** Forest and Grassland Landcover Rasters

The NALC 2005 input datasets were processed into an interim raster used as input for density calculations (see section 6.2.3 for details):

- an indicator raster for the cover type of interest

- **Source 2:** Areas of Analysis - US Fish and Wildlife Service Landscape Conservation Cooperatives (LCCs):

<http://www.fws.gov/GIS/data/national/index.htm>

6.2.2. Re-project Source Data

Each source dataset was re-projected into a common spatial reference. For CONUS areas, the NPScape project uses USA Contiguous Albers Equal Area Conic USGS as its standard projection. For Alaska, Alaska Albers Equal Area Conic is used. NAD_83 is the datum for both projections.

6.2.3. Generate Indicator Raster

Python scripts are used to extract target cover type pixels from the source landcover raster. An indicator raster is generated from the extracted raster by setting all non-target cover type pixels to NoData. The indicator raster excludes all cover types that are not

forest or grassland, including open water and barren land. Conversely, in the processing of 2001 NLCD data, Riitters (2010) appears to have excluded only open water along coastlines and shorelines. Non-target cover type areas become NoData values in the indicator raster.

6.2.4. Calculate Density Values

Three types of density values are calculated: raw density percentages (Pf), scaled byte values (Sf), and categorized scaled densities. These values are generated using a combination of focal (neighborhood) sums and counts.

$$P_{fy} = \frac{\text{adjusted focal sum for cover type } x}{\text{focal count for cover type } x}$$

For each focal landscape area (i.e. moving window), a focal count of candidate pixels is generated from the indicator raster. This value accounts for the proportional occurrence of target cover type pixels within the landscape area. In other words, it adjusts for NoData areas and minimizes edge effects from the target cover type. The adjusted focal sum is calculated from the binary cover type raster. See Appendix 6.3 for details.

$$S_{fy} = \text{Int}((P_{fy} * 254) + 1)$$

The scaled byte values for landscape area y are calculated by adjusting the raw density values (Pf) to a 1-255 scale. This does result in a loss of precision, but this was deemed acceptable given the relative coarseness of the source landcover data.

The categorized scaled densities are generated by reclassifying the scaled byte values into grouped density classes. See Appendix 6.3.2 for reclassification details.

6.2.5. Generate Sector Rasters

To facilitate interpretation and comparison, the preprocessed density category rasters and grouped density class rasters are masked for the cover type of interest. These outputs are the following where <*> is the moving window size:

PFDEN_<*>_sector and PGDEN_<*>_sector: NALC data processed into density categories for forest or grassland areas and masked for the cover type of interest. Summary statistics files are produced for each output raster.

PFDEN_<*>_sector_grouped and PGDEN_<*>_sector_grouped: NALC data processed into density classes for forest or grassland areas and masked for the cover type of interest. Summary statistics files are produced for each output raster.

6.3. Lookup and Reclassification Tables

6.3.1. Comparative Landscape Sizes for Pattern Density Analyses

(shaded rows indicate NALC-derived outputs)

Window Size (pixels per edge)	NALC			NLCD		
	Pixel Size (m)	Area (hA)	Area (acres)	Pixel Size (m)	Area (hA)	Area (acres)
5	250	156.25	386.10	30	2.25	5.56
7	250	306.25	756.76	30	4.41	10.90
9	250	506.25	1250.97	30	7.29	18.01
11	250	756.25	1868.73	30	10.89	26.91
13	250	1056.25	2610.05	30	15.21	37.58
15	250	1406.25	3474.92	30	20.25	50.04
21	250	2756.25	6810.84	30	39.69	98.08
27	250	4556.25	11258.74	30	65.61	162.13
33	250	6806.25	16818.61	30	98.01	242.19
39	250	9506.25	23490.46	30	136.89	338.26
45	250	12656.25	31274.27	30	182.25	450.35
51	250	16256.25	40170.07		N/A	N/A
57	250	20306.25	50177.84		N/A	N/A
69	250	29756.25	73529.29		N/A	N/A
81	250	41006.25	101328.65	30	590.49	1459.13
243	250	369056.25	911957.85	30	5314.41	13132.19
729	250	3321506.25	8207620.67	30	47829.69	118189.74

6.3.2. Density Category Reclassification Table

Byte Value Range	Category Value	Category Classname	Grouped Density Class Value	Grouped Density Class Classname
0	0	Missing		
1	1	No focal landcover	1	None
2 - 12	2	>0% to <5%	2	Rare
13 - 25	3	5% to <10%		
26 - 38	4	10% to <15%	3	Patchy
39 - 50	5	15% to < 20%		
51 - 63	6	20% to <25%		
64 - 76	7	25% to <30%		
77 - 88	8	30% to <35%		
89 - 101	9	35% to <40%		
102 - 114	10	40% to <45%	4	Transitional
115 - 127	11	45% to <50%		
128 - 139	12	50% to <55%		
140 - 152	13	55% to <60%		
153 - 165	14	60% to <65%	5	Dominant
166 - 177	15	65% to <70%		
178 - 190	16	70% to <75%		
191 - 203	17	75% to <80%		
204 - 215	18	80% to <85%		
216 - 228	19	85% to <90%		
229 - 241	20	90% to <95%	6	Interior
242 - 254	21	95% to <100%		
255	22	100%	7	Intact

6.4. NLCD – Density Processing Notes

Information in this appendix was excerpted from details provided by Kurt Riitters on 12 June 2009 (original email edited by John Gross). This information applies to the analysis files used in 2010. In this appendix, “NLCD” always refers to the 2001 NLCD land cover dataset. These notes are included because they also generally inform the processing and interpretation of NALC density metrics.

Comparability with NLCD

Generally, the goal was to have a pattern value for every pixel that was not null on the NLCD map. That was accomplished during the processing. But, when I put things together by State later on, I clipped everything to the detailed State boundaries in the ESRI data/maps collection, using a 30-m pixelated version of those detailed state boundaries. So you will not find pattern values for places like extraterritorial ocean, even if those places were included in the computations of the indices.

The projections are the same as the NLCD (including the different projections for AK/HI).

Everything should be overlay-able pixel-by-pixel with the original NLCD (2001). In some instances there may be a 1/2 pixel (or less) offset from NLCD which should not affect intersections with NLCD. There should not be any slivers between states when you recombine the grids for several states.

The ability to intersect with the original NLCD 2001 is really important, because some of the pattern measures will likely be summarized by original land-cover, and error will occur if the intersection of original and ‘derived’ measures is not accurate.

For example the 'area-density' (fden and gden, for forest and grassland density, respectively) maps show non-null pattern values for all pixels in a State, whether or not a given pixel is the focal class landcover or not. In other words, one can have a 'forest density' context even if one is not forest oneself. The decision to intersect or not depends on if you want to summarize forest (or grass) density in the vicinity of an arbitrary location in a park, or only in the vicinity of the focal class in the park. The former is more descriptive of landscapes, the latter is more descriptive of focal class patterns. I (KR) typically intersect with focal class landcover to make inferences about focal class pattern. The maps are not intersected in this way, to preserve options for other types of summaries, for example forest density in the vicinity of urban pixels, etc. This same consideration also applies to the 'landscape pattern type' (aka 'mosaic') maps.

This consideration does not apply to the 'morphology' (aka 'mspa') maps, for which the patterns are only shown for the focal class pixels (and the nonfocal class pixels are set to the MSPA class 'background', see Vogt 2008).

File nomenclature for state-level input files:

- Forest and grassland area density:
 - a. Have 'fden' and 'gden' in the file name.
 - b. The number (7, 13, ...729) refers to the number of pixels on a side in the moving window analysis. The equivalent window sizes in hectares are $7*7/0.09 = 4.41$ and so on.
 - c. The last two characters are lower case state abbreviations

Recoding of original NLCD land-cover (to make input for the pattern analyses).

The area density and morph maps start by recoding the NLCD to binary input maps as follows:

"Forest" - NLCD 40, 41, 42, and 90 (upland forest plus woody wetlands)
 "Grassland" - NLCD 71,72,73,74 (only the first one appears in the lower 48). There is no grassland in DE, DC, or MD. Furthermore, the amount of mapped grassland is very low in the east, in general.

Legend / Pixel values on the "area density" maps

The values 0-22 appear on the maps/attribute tables. The table below is the translation to "Px" (forest area density, grass area density). The 'Recoded Class' is the pixel 'density class' value in the attribute table (0-22), and the fourth column is the definition of each density class. Min and max values are the bin ranges

Conversion of raw density values to classes for forest and grassland density:

Min Val	Max Val	Recoded	
		Class	Definition of recoded class
0	0	0	true missing (window contains no valid land cover pixels)
1	1	1	exactly zero (window contains land cover, but none of the focal class land cover)
2	12	2	$0 < Px < 5$
13	25	3	$5 \leq Px < 10$ at least 5 but less than 10
26	38	4	$10 \leq Px < 15$
39	50	5	$15 \leq Px < 20$
51	63	6	$20 \leq Px < 25$
64	76	7	$25 \leq Px < 30$
77	88	8	$30 \leq Px < 35$
89	101	9	$35 \leq Px < 40$
102	114	10	$40 \leq Px < 45$
115	127	11	$45 \leq Px < 50$
128	139	12	$50 \leq Px < 55$
140	152	13	$55 \leq Px < 60$
153	165	14	$60 \leq Px < 65$
166	177	15	$65 \leq Px < 70$
178	190	16	$70 \leq Px < 75$
191	203	17	$75 \leq Px < 80$

Min Val	Max Val	Recoded	
		Class	Definition of recoded class
204	215	18	$80 \leq Px < 85$
216	228	19	$85 \leq Px < 90$
229	241	20	$90 \leq Px < 95$ at least 90 but less than 95
242	254	21	$95 \leq Px < 100$ at least 95 but less than 100
255	255	22	exactly 100%

The densities are first calculated as real numbers in the range from 0.0 to 1.0, and then converted to 8-bit integers by:

$$\text{MapValue} = (\text{RealValue} * 254) + 1$$

MapValue = 0 is reserved for 'true' missing.

This conversion results in loss of precision, as does a small window (like 7x7 which only has 49 possible values). If the window is partly missing, the calculations are based on whatever is there, and there is no minimum number of pixels required to calculate a value for a particular window.