

# Inventory & Monitoring Division

National Park Service



## Standard Operating Procedure 2.11.15

### *Processing Land Cover Source Data to Derive Landscape Dynamics Metrics: Pattern*

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### **Summary**

This SOP summarizes processes used to produce seamless pattern morphology and density datasets.

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# Overview

This SOP describes the preparation and processing steps to produce seamless morphology and density datasets for select land cover types for CONUS. At a later date, seamless outputs for Alaska, Hawaii, the Virgin Islands, and outlying Pacific territories may be added.

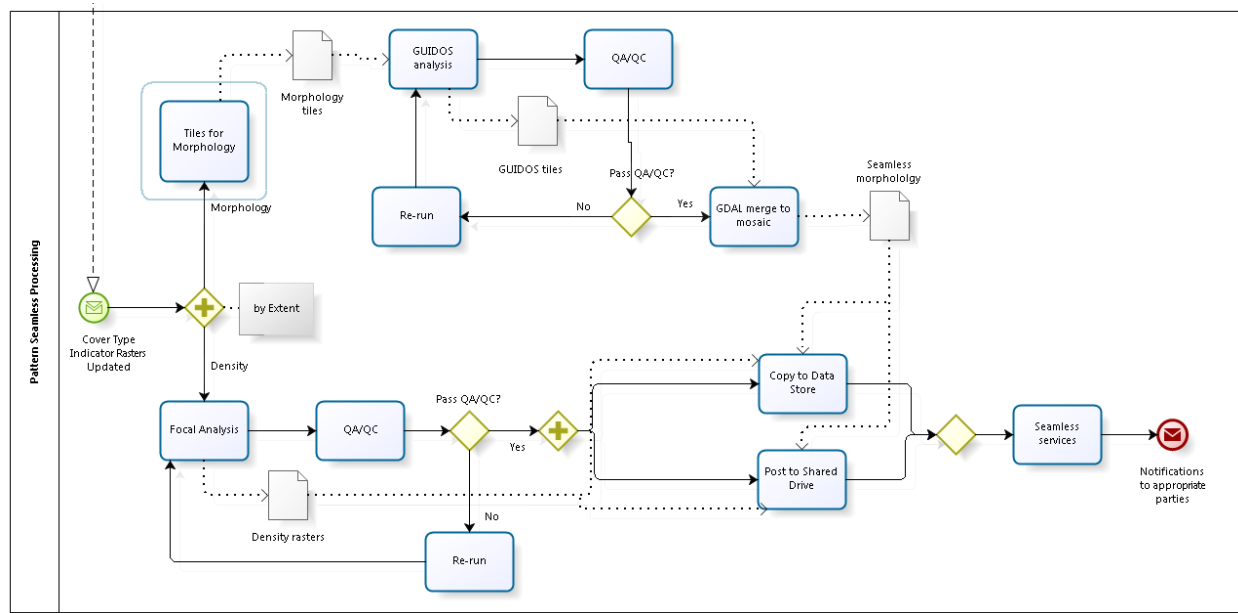


**Figure 1.** Summary of seamless pattern processing workflow

It is assumed users of this SOP have prior knowledge of data paths, file locations, and repositories referenced in this SOP.

## Requirements

ArcGIS software is required to generate the outputs. The data sources and tools used are assumed to be in ESRI ArcGIS™ format, version 10.4.1 or higher. 64-bit Background Processing must be installed. **All scripts should be run in 64 bit Python with either 64 bit PyScripter or 64 bit IDLE.**

For morphology processing, GUIDOS software (Vogt 2017) is used to calculate morphological types.

All data should be on a local hard drive for processing performance and reliability.

The toolbox used is Pattern.pyt located in the Landscape Dynamics code repository.

### Pattern Source Data

Source data are the seamless land cover level 2 datasets processed into GeoTIFF format (Homer et al. 2015, Kinseth and Nelson 2018a): on the X: drive at

\\LandscapeDynamics\\Landcover\\Products\\Seamless\\CONUS, or  
\\LandscapeDynamics\\Landcover\\Products\\Seamless\\Alaska

### Terrestrial Area Boundaries

For specific geographic areas, the terrestrial area feature class is used to set the extent of the road tiles used in seamless processing. These feature classes are in geodatabase format: on the X: drive at \\LandscapeDynamics\\SourceData\\Boundary\\LandscapeDynamics\_Geographical\_Boundaries.gdb

### Morphology Tiles

4096 x 4096 pixel tiles are generated for each geographic extent using the Split Raster tool. See the pre-processing section for details.

### Input data spatial references

The landscape dynamics protocol uses standard spatial references for the geographic areas produced (Table 1).

**Table 1.** Standard spatial references by processing extent

| Processing Extent                  | Spatial Reference Name (datum)                              | Well-known ID (WKID) |
|------------------------------------|-------------------------------------------------------------|----------------------|
| North America (US, Canada, Mexico) | USA Contiguous Albers Equal Area Conic USGS (NAD83)         | WKID: 102039         |
| CONUS                              | USA Contiguous Albers Equal Area Conic USGS (NAD83)         | WKID: 102039         |
| Puerto Rico and USVI               | USA Contiguous Albers Equal Area Conic USGS (NAD83)         | WKID: 102039         |
| Alaska                             | Alaska Albers Equal Area Conic (NAD83)                      | WKID: 3338           |
| Hawaii                             | UTM Zone 5N (NAD83)                                         | WKID: 26905          |
| American Samoa                     | NAD_1983_HARN_UTM_Zone_2S (NAD83 HARN)                      | WKID: 2195           |
| <i>Transform (if needed):</i>      | WGS_1984_(ITRF00)_To_NAD_1983 + NAD_1983_HARN_To_WGS_1984_2 |                      |
| Guam                               | WGS_1984_UTM_Zone_55N (WGS84)                               | WKID: 32655          |
| <i>Transform (if needed):</i>      | WGS_1984_(ITRF00)_To_NAD_1983                               |                      |
| CN Mariana Islands                 | WGS_1984_UTM_Zone_55N (WGS84)                               | WKID: 32655          |
| <i>Transform (if needed):</i>      | WGS_1984_(ITRF00)_To_NAD_1983                               |                      |

## Pre-Processing

### Step 1: Create Indicator Rasters

The pre-processing tools can be run in the ArcGIS for Desktop or ArcGIS Pro applications or via a batch script executed from the command line. The latter technique may be more efficient.

1. To create or update the cover type indicator rasters used in this SOP, run the “Create Indicator Rasters” tool from the Pattern.pyt toolbox, in ArcCatalog. Note: do not use ArcMap to run this tool.

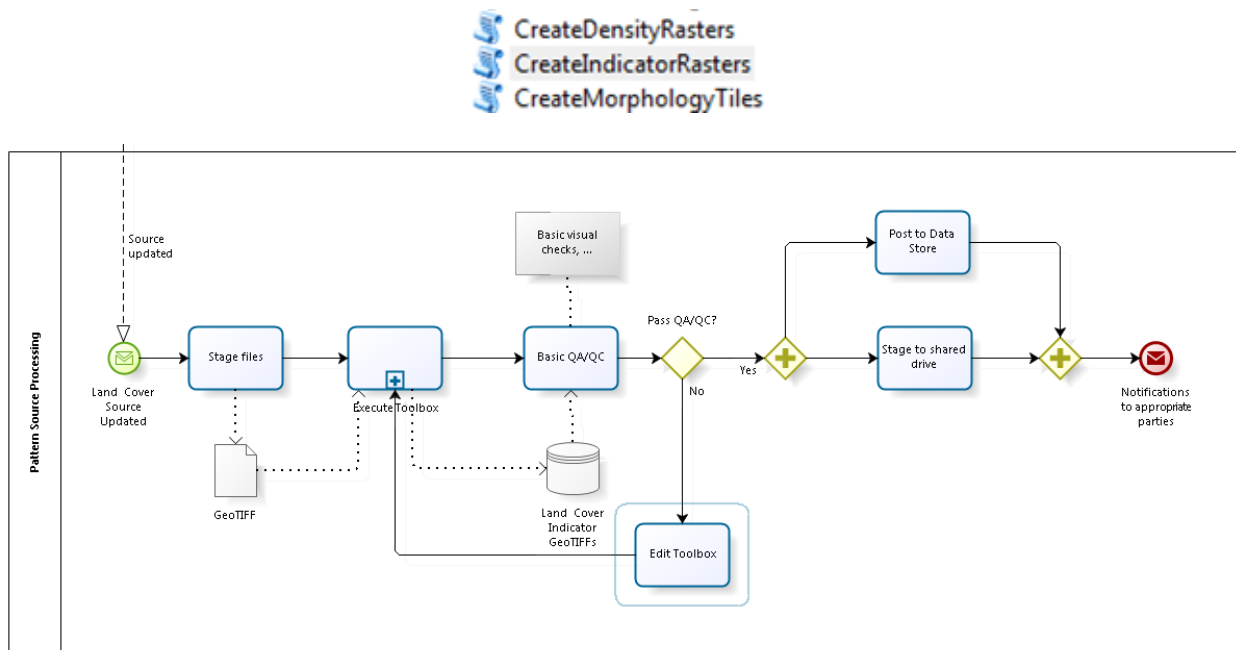


**Figure 2.** Workflow for indicator raster creation

2. The indicator rasters are used for generating the seamless morphology and density outputs. See Appendix 2 for details on which input land cover values are used to derive indicators for Forest, Grassland, Shrubland, and Wetland.

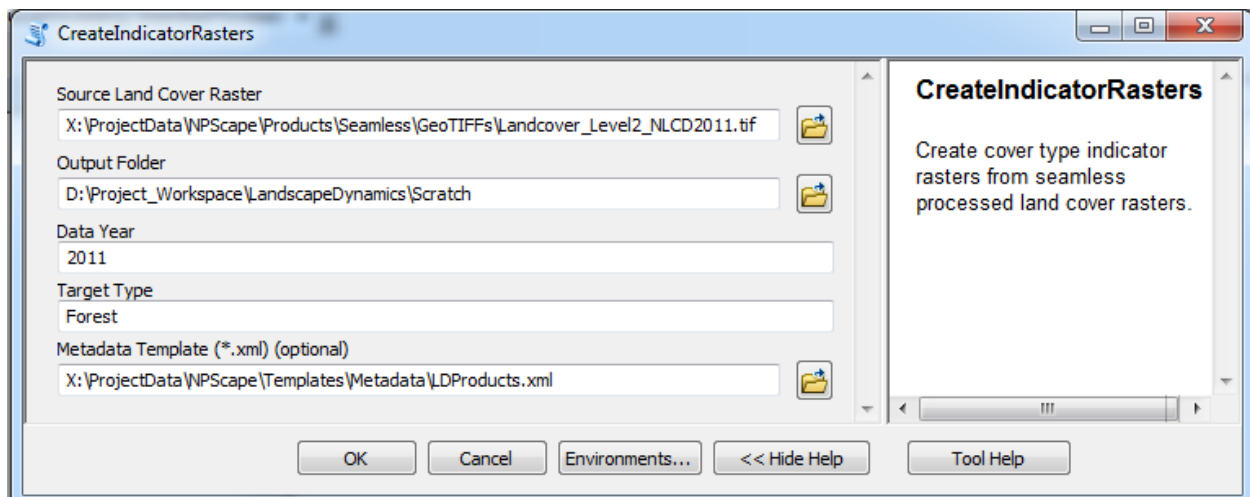


**Figure 3.** Example of Create Indicator Raster tool

3. Quality Assurance: After the tool completes, add the indicator raster(s) to ArcMap or ArcPro and verify:
  - a. Pixel alignment with source land cover raster (snapped)
  - b. Pixels for indicator cover type align with source land cover raster cover type class
  - c. Pixel bit-depth is 8-bit unsigned
  - d. Attribute table contains only 1(target cover type) and 0 (everything else) values
4. Update the metadata as needed.
5. Copy GeoTIFF files to \LandscapeDynamics\Pattern\SourceData and upload to Data Store, see post processing.
6. Update Appendices 4 and 5.

## Step 2: Create Morphology Tiles

To create or update the processing tile polygons used in this SOP, run the Create Morphology Tiles tool in the Pattern toolbox (\LandscapeDynamics\Processing\Tools).

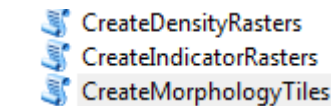


**Figure 4.** Create Morphology Tiles tool in the Pattern toolbox

1. Run the Create Morphology Tiles tool to generate tiles from cover type indicator rasters (snapped to NLCD land cover). The tool reclassifies the tiles for use in the GUIDOS processing tool: 1 (no cover type/background) and 2 (cover type/foreground). **Script must be run with 64 bit Python because of high memory needs.** Run for each land cover type (see appendices 3 and 4).

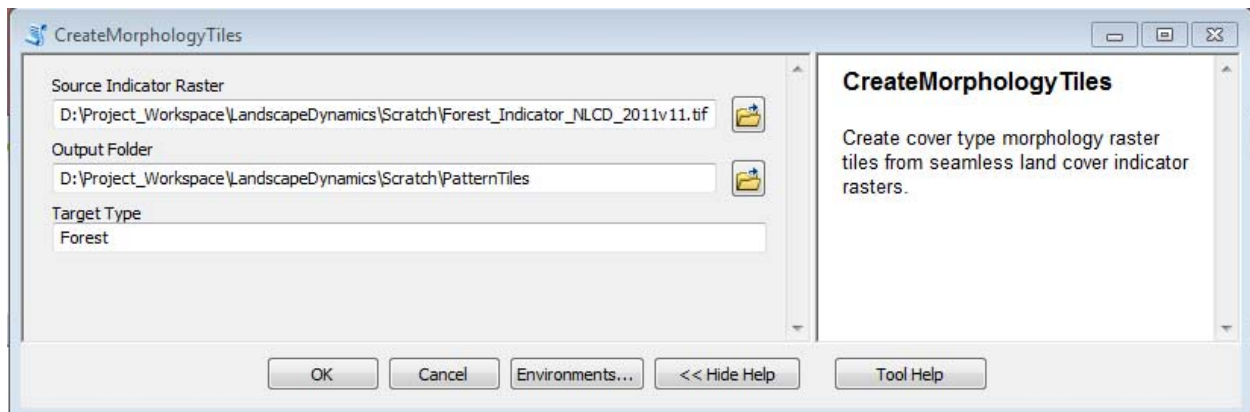


**Figure 5.** Input examples for Create Morphology Tiles tool

2. Quality Assurance: After the tool completes, add a few tiles of each cover type to ArcMap or ArcPro and verify:
  - a. Pixel alignment with source land cover indicator raster (snapped)
  - b. Pixels for cover type core areas align with source land cover indicator raster pixels
  - c. Pixel bit-depth is 8-bit unsigned

## Processing – Morphology

Follow the steps outlined below for each cover type, using the appropriate inputs specific to that cover type (see appendix 5). Morphology rasters are snapped to land cover and inherit the cell sizes of that raster. The tile rasters are used as inputs for calculating morphological patterns for the selected cover type. This is done with software called GUIDOS (Vogt 2017). Processed tiles are merged (mosaicked) into a seamless extent raster using GDAL (Open Source Geospatial Foundation 2017).

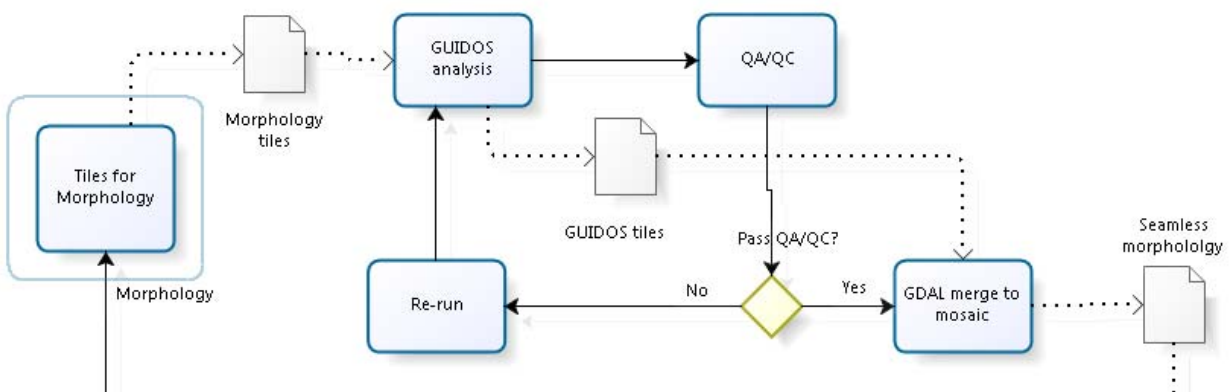


**Figure 6.** Processing workflow for pattern morphology

### Step 1: Run GUIDOS

GUIDOS (Vogt 2017) generates Morphological Spatial Pattern Analysis (MSPA) rasters that map core, edge, and connector pixels from input land cover indicators. Two edge widths are used: 30m (1 pixel) and 150m (5 pixels). The transition option is set to Off. Using the morphology tiles created in the pre-processing step, run GUIDOS for all tiles for the target cover type in the output folder.

1. When opening GUIDOS, navigate to folder where tiles are located.

File → Batch Process → Pattern → MSPA

2. Select all tiles for a cover type. The batch processing dialog opens. Choose either EdgeWidth 1 or 5 and Transition = off. Retain other default options.
3. Click Accept to start processing which takes approximately four hours.

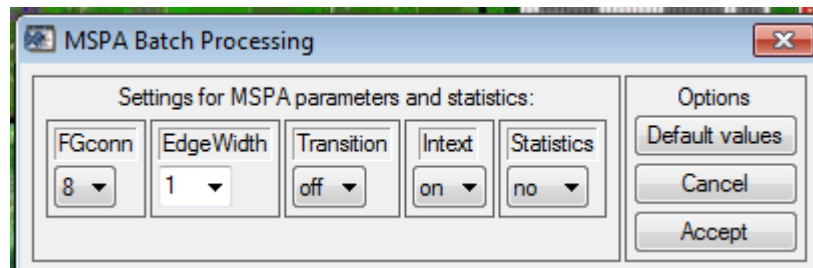


**Figure 7.** Parameter settings for MSPA batch processing

4. Quality Assurance: After the tool completes, move output MSPA GeoTIFF tiles to a separate folder.
  - a. Review the `batch_mspa.log` file to find any invalid tiles. Inspect these GeoTIFFs visually in ArcMap to determine why the MSPA process failed. Typically, this is due to lack of target cover type pixels in the raster tile.
5. For the successful MSPA files, add a few MSPA GeoTIFFs to ArcMap and verify:
  - a. Pixel alignment with source land cover indicator raster (snapped)
  - b. Pixels for cover type core areas align with source land cover indicator raster pixels
  - c. Pixel bit-depth is 8-bit unsigned

## Step 2: Create Mosaicked Morphology Rasters

By cover type and edge width, use gdal libraries in OSGeo4W utility (Open Source Geospatial Foundation 2017) to mosaic MSPA tiles into seamless morphology rasters.

1. Open OSGeo4W, change directory to folder where source MSPA GeoTIFF files are located:

```
C:\Users\PubliDesktop>cd D:\Project_Workspace\Landscape_Dynamics\Scratch
C:\Users\PubliDesktop>D:
D:\Project_Workspace\Landscape_Dynamics\Scratch
```

2. Run this DOS command to generate a file listing all GeoTIFFs (tiles). Example is forest cover type for edge width 1.

```
dir coverytype*_8_1_0_1.tif /b /s > Forest_EW1_list.txt
```

3. Then, run the `gdal_merge` command using the file list text file:

```
gdal_merge -o ForestMosaic\Pattern_ForestMorphology_EW1_NLCD2011v11.tif
-of GTiff -pct -co TFW=YES -n 129 -init 0 --optfile Forest_EW1_list.txt
```

4. Quality Assurance: After the tool completes, verify spatial reference and nodata value using `gdalinfo`:

```
gdalinfo Pattern_ForestMorphology_EW1_NLCD2011v11.tif
```

5. Then, add the mosaicked raster to ArcMap and verify:
  - a. Pixel bit-depth is 8-bit unsigned
  - b. Pixel alignment with source land cover indicator raster (snapped)
  - c. Pixels for cover type core areas align with source land cover indicator raster pixels
6. Build raster attribute table, choosing the Overwrite option.

```
arcpy.BuildRasterAttributeTable_management(in_raster="Pattern_ForestMorphology_EW1_NLCD2011v11.tif", overwrite="Overwrite")
```

7. Run JoinField on the raster with the MSPA\_Reclassifications.gdb\MSPA\_NoTransition\_Reclass\_RasterDisplay table to add the classname fields (note colormap is embedded from MSPA tiles):

```
"Pattern_ForestMorphology_EW1_NLCD2011v11.tif"
arcpy.JoinField_management(in_data="Pattern_ForestMorphology_EW1_NLCD2011v11.tif", in_field="Value",
join_table="D:/Project_Workspace/LandscapeDynamics/Data/SourceData/MSPA_Reclassifications.gdb/MSPA_NoTransition_Reclass", join_field="TO_VAL",
fields="BASE_CLASSNAME;CLASSNAME")
```

8. Import metadata (LD\_Pattern\_Morphology\_Product.xml) using ArcCatalog Metadata Importer tool, then upgrade and update.

```
arcpy.MetadataImporter_conversion(source="D:/Project_Workspace/LandscapeDynamics/Templates/LD_Pattern_Morphology_Product.xml",
target="D:/Project_Workspace/LandscapeDynamics/Data/PatternTiles_EW1/Forest/ForestMosaic/Pattern_ForestMorphology_EW1_NLCD2011v11.tif")
```

```
arcpy.UpgradeMetadata_conversion(Source_Metadata="D:/Project_Workspace/LandscapeDynamics/Data/PatternTiles_EW1/Forest/ForestMosaic/Pattern_ForestMorphology_EW1_NLCD2011v11.tif", Upgrade_Type="FGDC_TO_ARCGIS")
```

**\*\*If not automatically prompted for the upgrade, run the tool and manually edit the metadata with the proper titles, years, and other elements as needed.**

9. Copy GeoTIFF files to \LandscapeDynamics\Pattern\Products\Seamless and upload to Data Store, see post processing.
10. Update Appendix 5.

## Processing – Density

Follow the steps outlined below for each geographic area, using the appropriate inputs specific to that area.

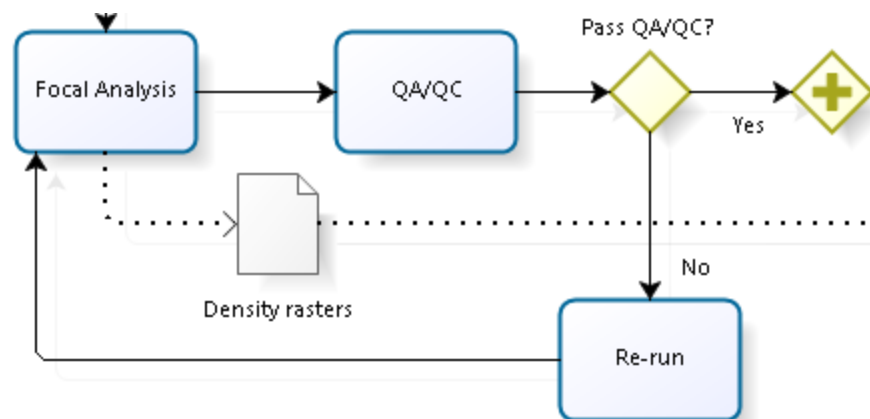


**Figure 8.** Pattern density processing workflow

Using moving window processing, the Create Density Raster tool will output GeoTIFFs for the landscape areas listed in Table 2.

**Table 2.** Moving window pixel and landscape area sizes for pattern density calculations (based on NLCD 30m pixels)

| Window Size (pixels) | Area (hA) | Approximate linear distance (m) | Approximate linear distance (mi) |
|----------------------|-----------|---------------------------------|----------------------------------|
| 7 X 7                | 4.41      | 210                             | 0.13                             |
| 13 X 13              | 15.2      | 390                             | 0.24                             |
| 27 X 27              | 65.61     | 810                             | 0.51                             |
| 81 X 81              | 590.5     | 2,430                           | 1.51                             |
| 243 X 243            | 5,314.4   | 7,290                           | 4.5                              |
| 729 X 729            | 47,829.6  | 12,870                          | 13.6                             |

### Step 1: Run Create Density Rasters tool

1. In ArcCatalog or via a batch script, run **CreateDensityRasters** to generate tiled density rasters (seamless and snapped to NLCD land cover). Note: each cover type may take approximately 24 hours to complete in ArcGIS for Desktop.

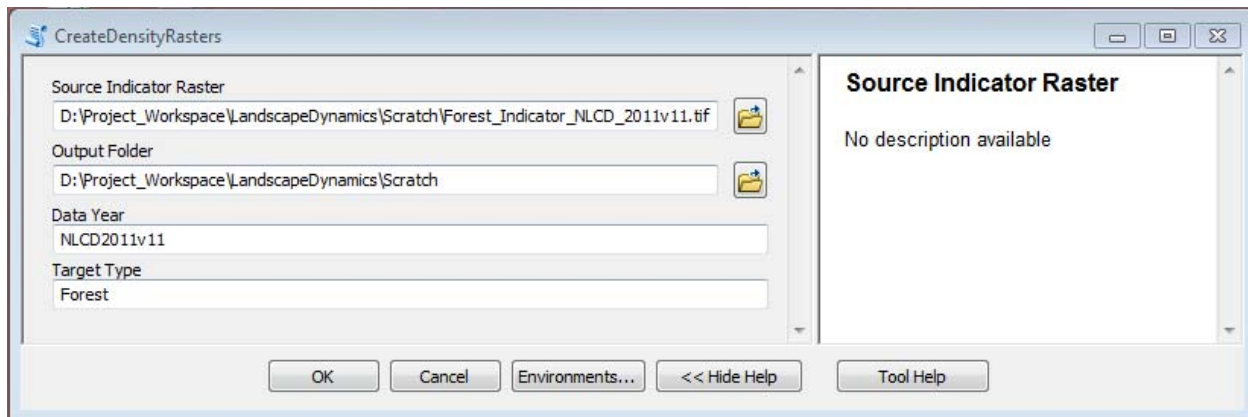


**Figure 9.** Input examples for Create Density Rasters tool

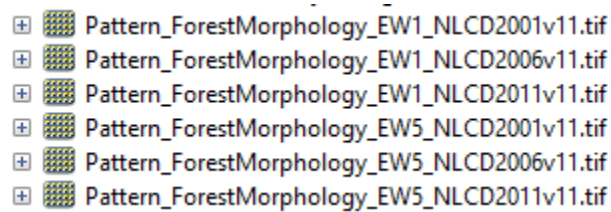
1. Quality Assurance: After the tool completes, add the indicator raster(s) to ArcMap or ArcPro and verify:
  - a. Pixel alignment with source land cover indicator raster (snapped)
  - b. Pixels for density cover type core areas align with source land cover indicator raster pixels
  - c. Pixel bit-depth is 8-bit unsigned
  - d. Attribute table contains 20 values from 2 to 22
  - e. Statistics: Minimum = 2, Maximum = 22
  - f. NoData value = 0
2. Using the MetadataImporter\_conversion tool in ArcCatalog, import the LD\_Pattern\_Density\_Product.xml file from \LandscapeDynamics\Processing\Templates folder. Update the title and other elements of the metadata as needed.
3. Copy GeoTIFF files to \LandscapeDynamics\Pattern\Products\Seamless and upload to Data Store (creating or versioning reference).

## Post-Processing

### Step 1: Move Processed Source Data

1. Move final, processed land cover rasters to the respective folder on \LandscapeDynamics\Landcover\Products\Seamless, and if needed, rename the rasters being moved following the naming conventions present.
  - a. Be sure to append 'vYY' to each new raster to denote the fact the data was re-processed and re-released from NLCD to reflect updates and changes to their methods.

Naming conventions Morphology (example):



Pattern\_ForestMorphology\_EW1\_NLCD2001v11.tif  
Pattern\_ForestMorphology\_EW1\_NLCD2006v11.tif  
Pattern\_ForestMorphology\_EW1\_NLCD2011v11.tif  
Pattern\_ForestMorphology\_EW5\_NLCD2001v11.tif  
Pattern\_ForestMorphology\_EW5\_NLCD2006v11.tif  
Pattern\_ForestMorphology\_EW5\_NLCD2011v11.tif

Density (example):



Pattern\_Forest\_Density\_Categories\_7\_NLCD2011v11.tif  
Pattern\_Forest\_Density\_Categories\_729\_NLCD2001v11.tif  
Pattern\_Forest\_Density\_Categories\_729\_NLCD2006v11.tif  
Pattern\_Forest\_Density\_Categories\_729\_NLCD2011v11.tif  
Pattern\_Forest\_Density\_Categories\_81\_NLCD2001v11.tif  
Pattern\_Forest\_Density\_Categories\_81\_NLCD2006v11.tif

## Step 2: Publish Services

See Environmental Settings Data Services SOP (SOP 4.1.2; Nelson and Kinseth 2018), and use the following information as a guide when creating and publishing the services; see Publishing, Publish Map, Feature, or Image Services to ArcGIS Server or NPS ArcGIS Online, “Landscape Dynamics” section for guidance.

### ***Pattern Seamless***

Publish Map Services only for selected density and morphology data – currently density window size 7 (all cover types) and morphology edge width 1 (all cover types).

When complete, check REST endpoint for update of any new, published services.

<https://irmaservices.nps.gov/arcgis/rest/services/LandscapeDynamics>

See Landscape Dynamics Viewer Maintenance SOP (SOP 2.11.18; Kinseth 2018) to add the new data to the viewer.

## Step 3: Publish to Data Store

See Publishing to Data Store SOP (SOP 4.1.1; Kinseth and Nelson 2018b), and use the following information (Table 3) as a guide when uploading Pattern Source and Seamless data to Data Store.

1. From Environmental Settings Program,  
<https://irma.nps.gov/DataStore/Reference/Profile/2244060>, go to the Landscape Pattern Project.
2. Compress all raster GeoTIFFs into a .zip folder, by respective cover type/geography/year.

<CoverType>\_Pattern\_<Measure>\_<GEOGRAPHY>\_<Source><Year>.zip

CoverType = Forest, Grassland, Shrubland, Wetland

Measure = Density, Morphology  
GEOGRAPHY = CONUS, Alaska  
Source = NLCD  
Year = YYYYvYY

**Table 3.** Required upload parameters for holdings: Landscape Dynamics Source Data – Landscape Pattern; Landscape Dynamics Seamless Data – Landscape Pattern

| Parameter                   | Value                                                                                                                                                              |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Notes (Version/Clone)       | “New release of source data” if adding new data; or, “Corrected source data” if NLCD data is reprocessed because of an error discovered after its initial release. |
| Date of Issue/Publication   | Reference Level; Date of upload                                                                                                                                    |
| Description, Notes, Purpose | Reference Level; Make necessary edits to text in the reference for these two fields. Update years of data, reasons for new reference, etc, as needed.              |
| Permissions                 | Reference/Holding Level; Public, all                                                                                                                               |
| Description (Source Data)   | Holding Level; “<CoverType>_IndicatorRasters_<Geography>”                                                                                                          |
| Description (Seamless Data) | Holding Level; “<CoverType>_Pattern_<Measure>_<Geography>_NLCD<YYYYvYY>” where <Measure> is “Density, or “Morphology”                                              |

3. Add external, source data links (update url’s as needed).

- a. MRLC (<https://www.mrlc.gov/finddata.php>)

## Literature Cited

- Homer, C. G., J. A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. W. Coulston, N. D. Herold, J. D. Wickham, and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States--representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing* 81:345-354.
- Kineth, M. 2018. Maintenance and management of the landscape dynamics data viewer for use as part of the IMD Environmental Settings Protocol. Inventory & Monitoring Division Standard Operating Procedure NPS/IMD/SOP—2.11.18. National Park Service, Fort Collins, Colorado.
- Kineth, M. and L. Nelson. 2018a. Processing land cover source data to derive landscape dynamics metrics: Anderson Level 1 and 2 classification, and natural vs. converted land use Inventory & Monitoring Program Standard Operating Procedure NPS/NRSS/IMD/SOP—2.11.9. National Park Service, Fort Collins, Colorado.
- Kineth, M. and L. Nelson. 2018b. Publishing to Data Store. Inventory & Monitoring Division Standard Operating Procedure NPS/IMD/SOP—4.1.1. National Park Service, Fort Collins, Colorado.
- Nelson, L. and M. Kineth. 2018. Creating and maintaining data services for the IMD Environmental Settings Monitoring Protocol. Inventory & Monitoring Division Standard Operating Procedure NPS/IMD/SOP—4.1.2. National Park Service, Fort Collins, Colorado.
- Open Source Geospatial Foundation. 2017. GDAL - Geospatial Data Abstraction Library website. <http://www.gdal.org/> (accessed 12/13/2017).
- Vogt, P. 2017. GuidosToolbox (Graphical User Interface for the Description of image Objects and their Shapes): Digital image analysis software collection website. <http://forest.jrc.ec.europa.eu/download/software/guidos> (accessed 05/22/2017).

## Appendix 1: Memory Failures

Raster geoprocessing steps (Split Raster, Focal Statistics) needed to create the seamless pattern datasets are memory intensive and time consuming. If the scripts provided are run with 32 bit Python it is highly likely they will crash or produce erroneous results. If possible these scripts should be run on an idle workstation so the machine's maximum available memory can be utilized.

## Appendix 2: Cover Type Indicator Values

Cover type pixels are selected from processed level 2 land cover GeoTIFFs. See the table below for pixel values used.

**Table 1.** Classification values used to produce cover type indicator rasters

| Cover Type | NLCD 2011v11 | NLCD 2006v11 | NLCD 2001v11 | NLCD 2011 Alaska ( <i>not created at this time</i> ) |
|------------|--------------|--------------|--------------|------------------------------------------------------|
| Forest     | 41, 42, 43   | 41, 42, 43   | 41, 42, 43   | 41, 42, 43                                           |
| Grassland  | 71, 81       | 71, 81       | 71, 81       | 71, 81                                               |
| Shrub      | 52           | 52           | 52           | 52                                                   |
| Wetland    | 90, 95       | 90, 95       | 90, 95       | 90, 95                                               |

## Appendix 3: Geographic Areas for Processing

The source datasets for geographic area extents are the terrestrial area of the geographic region. This step maximizes the processing efficiency for the various metrics.

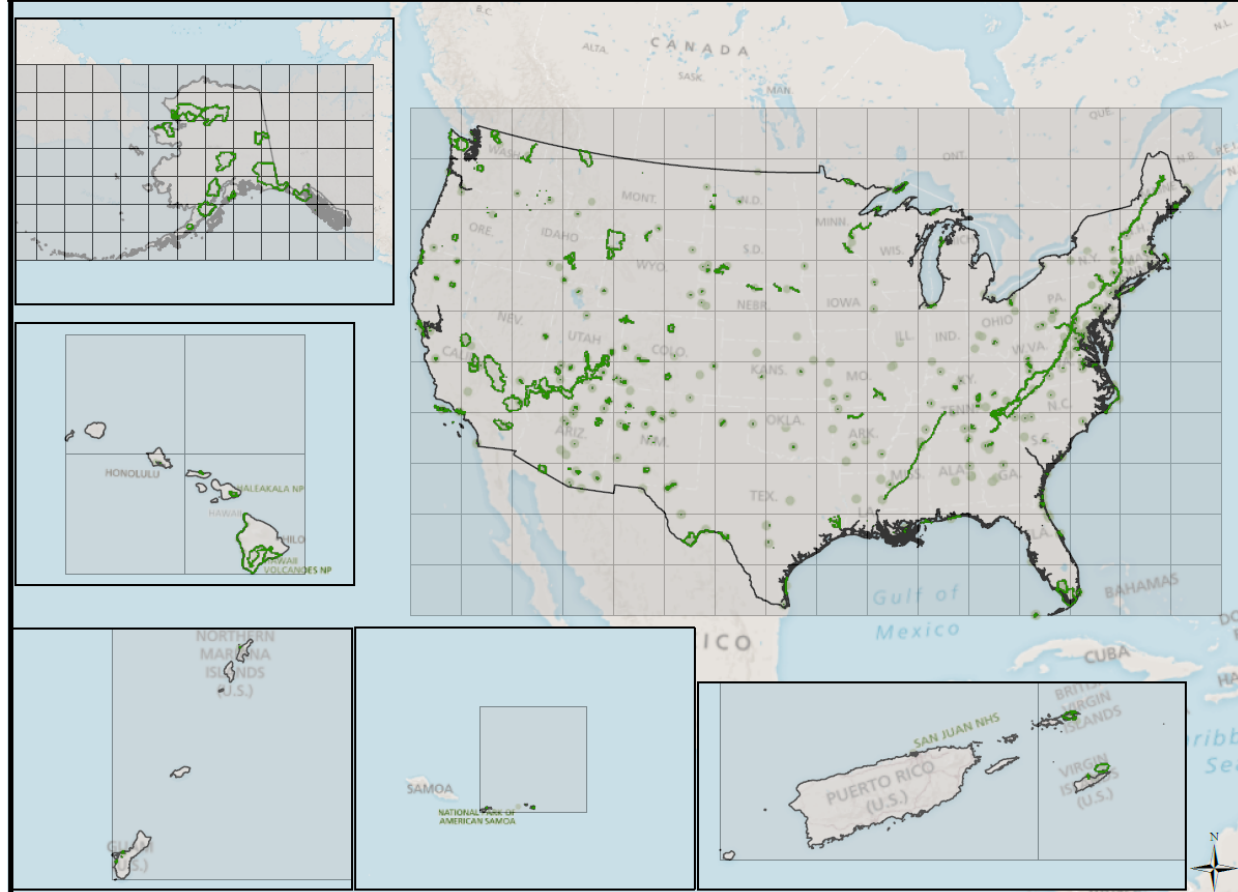


**Figure 10.** Processing extents

## Appendix 4: Processing Parameters

For indicator raster processing, see the table below for processing parameters by geographic area.

**Table 2.** Indicator raster processing parameters by geographic extent

| Geographic Area | Source land cover raster<br>( <i>snap raster also</i> ) | Data Year | Target Type | Output File                          |
|-----------------|---------------------------------------------------------|-----------|-------------|--------------------------------------|
| CONUS           | Landcover_Level2_NLCD2011v11.tif                        | 2011      | Forest      | Forest_Indicator_NLCD_2011v11.tif    |
|                 | Landcover_Level2_NLCD2011v11.tif                        | 2011      | Grassland   | Grassland_Indicator_NLCD_2011v11.tif |
|                 | Landcover_Level2_NLCD2011v11.tif                        | 2011      | Shrubland   | Shrubland_Indicator_NLCD_2011v11.tif |
|                 | Landcover_Level2_NLCD2011v11.tif                        | 2011      | Wetland     | Wetland_Indicator_NLCD_2011v11.tif   |
|                 | Landcover_Level2_NLCD2006v11.tif                        | 2006      | Forest      | Forest_Indicator_NLCD_2006v11.tif    |
|                 | Landcover_Level2_NLCD2006v11.tif                        | 2006      | Grassland   | Grassland_Indicator_NLCD_2006v11.tif |
|                 | Landcover_Level2_NLCD2006v11.tif                        | 2006      | Shrubland   | Shrubland_Indicator_NLCD_2006v11.tif |
|                 | Landcover_Level2_NLCD2006v11.tif                        | 2006      | Wetland     | Wetland_Indicator_NLCD_2006v11.tif   |
|                 | Landcover_Level2_NLCD2001v11.tif                        | 2001      | Forest      | Forest_Indicator_NLCD_2001v11.tif    |
|                 | Landcover_Level2_NLCD2001v11.tif                        | 2001      | Grassland   | Grassland_Indicator_NLCD_2001v11.tif |
|                 | Landcover_Level2_NLCD2001v11.tif                        | 2001      | Shrubland   | Shrubland_Indicator_NLCD_2001v11.tif |
|                 | Landcover_Level2_NLCD2001v11.tif                        | 2001      | Wetland     | Wetland_Indicator_NLCD_2001v11.tif   |
| Alaska          | NLCD2011_Alaska.tif                                     | 2011      | TBD         | TBD                                  |