Monitoring landscape-scale forest heterogeneity: a protocol

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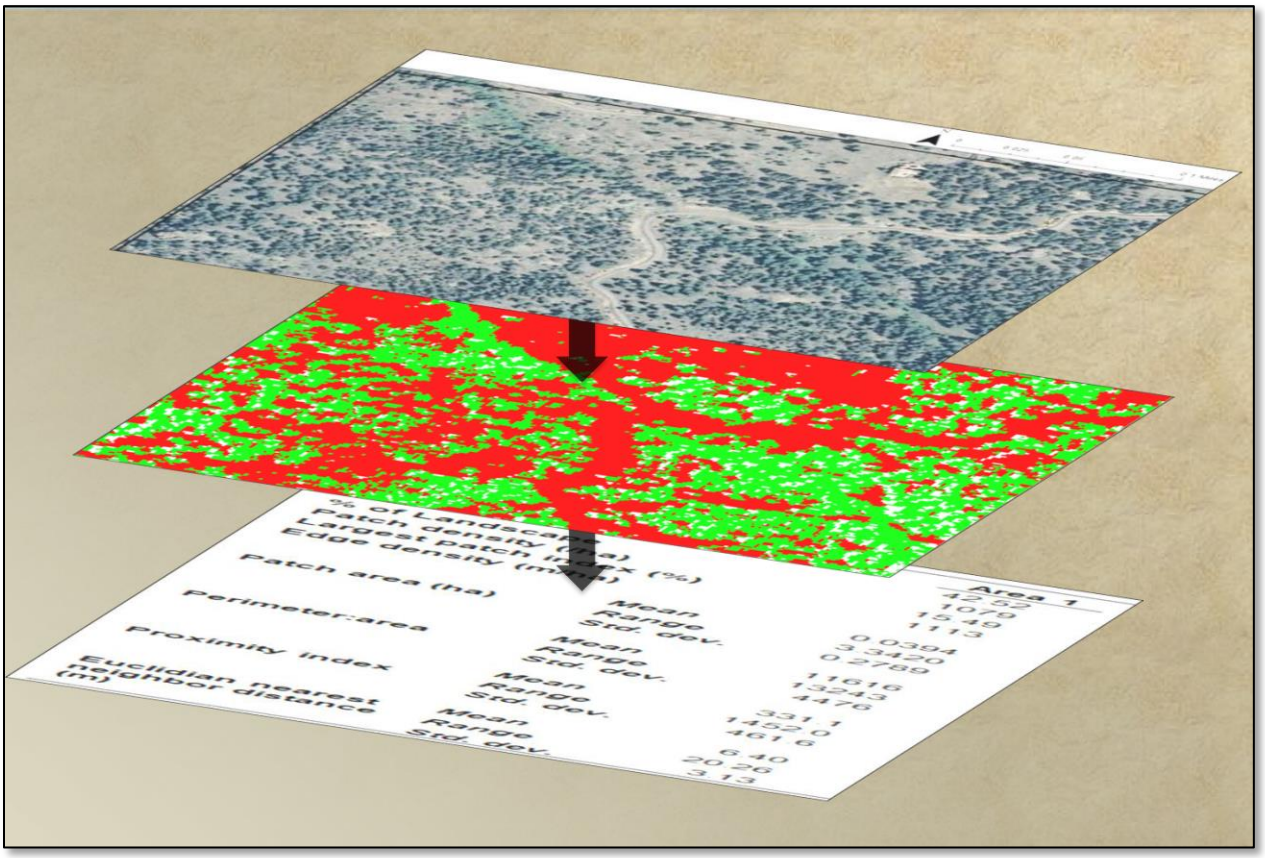

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COLORADO FOREST
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Introduction

The Front Range Collaborate Forest Landscape Restoration Project (FR-CFLRP) aims to "Establish a complex mosaic of forest density, size and age (at landscape scales)" (Clement and Brown 2011). Over the past two years the Spatial Heterogeneity Subgroup has endeavored to refine this aim, define desired future conditions for forest structure, and develop methods to monitor the success of restoration treatments in achieving these desired future conditions. This document outlines the method for monitoring the effectiveness of treatments in creating a structurally diverse forested landscape and presents an example of these analysis methods.

Although these methods were specifically developed for the Front Range Collaborative Forest Landscape Restoration Project (FR-CFLRP), they are applicable to other restoration projects with similar landscape scale restoration goals.

Protocol Overview

The approach presented here uses the Landfire 2010 canopy cover data (30 m resolution) and the canopy cover data derived from NAIP imagery (2.4 m resolution) to measure the landscape-scale patterns of forest cover pre- and post-treatment. Landfire's canopy cover data is a robust dataset derived from USFS Forest Inventory Analysis (FIA) data, National Aerial Imagery Program (NAIP) imagery, Landsat data, and reported disturbances.

The Landfire 2010 canopy cover data is updated using the pre- and post-treatment canopy cover maps (created during the stand-scale analysis of NAIP imagery). This updated canopy cover data is delineated into five categories: non-forest (0%), sparse (1-10%), low (11-40%), moderate (41-70%) and dense (71-100%) canopy cover. The landscape patterns of these five categories are then analyzed using FRAGSTATS. FRAGSTATS breaks the landscape into discrete patches of similar canopy cover. It then calculates a variety of metrics that can be used to describe the patchwork mosaic of canopy cover across the landscape. These metrics include: 1) percentage of the landscape (PLAND), 2) largest patch index (LPI), 3) patch density (PD), 4) edge density (ED), 5) patch area mean, range, and coefficient of variation (AREA), 6) perimeter to area ratio mean, range and coefficient of variation (PARA), and 7) the Euclidean distance to the nearest similar neighboring patch mean, range and coefficient of variation (ENN). Refer to Table 1 for further description of these metrics and their expected trends with successful restoration.

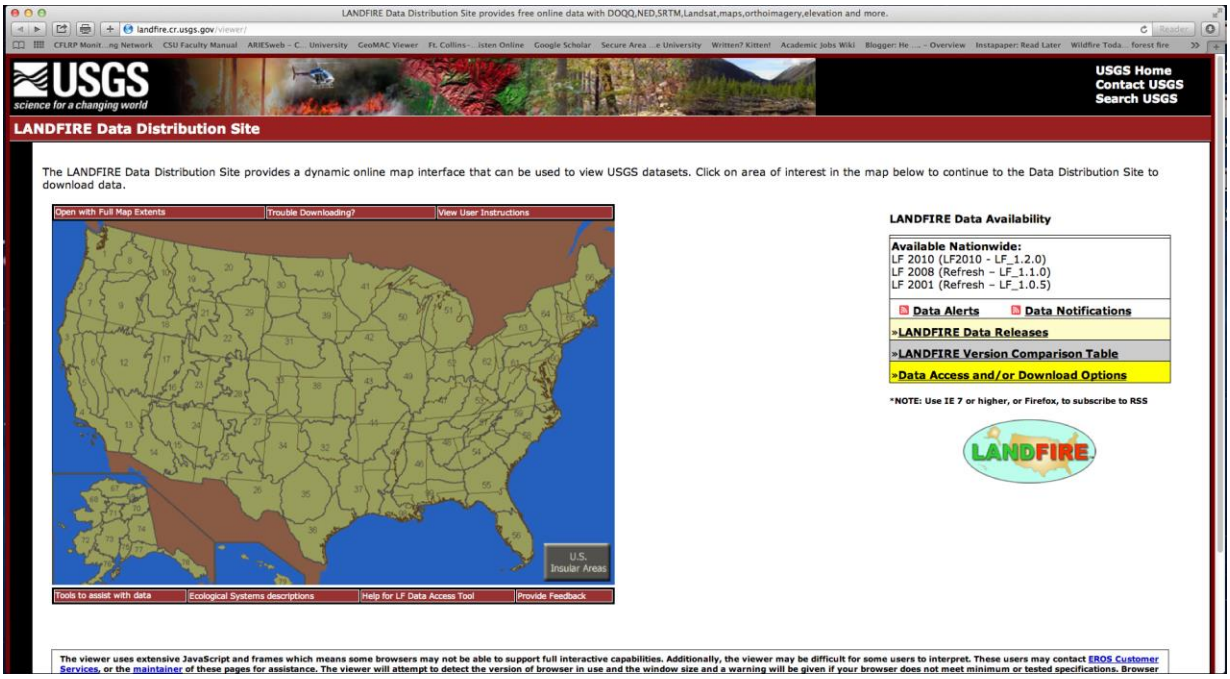
This protocol uses ArcMap 10.1 (http://www.esri.com/software/arcgis) and a freely available extension called FRAGSTATS 4.1 (available for download at http://www.umass.edu/landeco/research/fragstats/fragstats.html). Note that exact procedures will likely differ among software versions. Extensive help is available for ArcMap through the help menus within the software and online at http://resources.arcgis.com/en/help/main/10.1/. These methods may be adapted for other geographic information systems, and we encourage users to adapt these methods to their needs.

Required Data Inputs

The following datasets are required for this protocol:

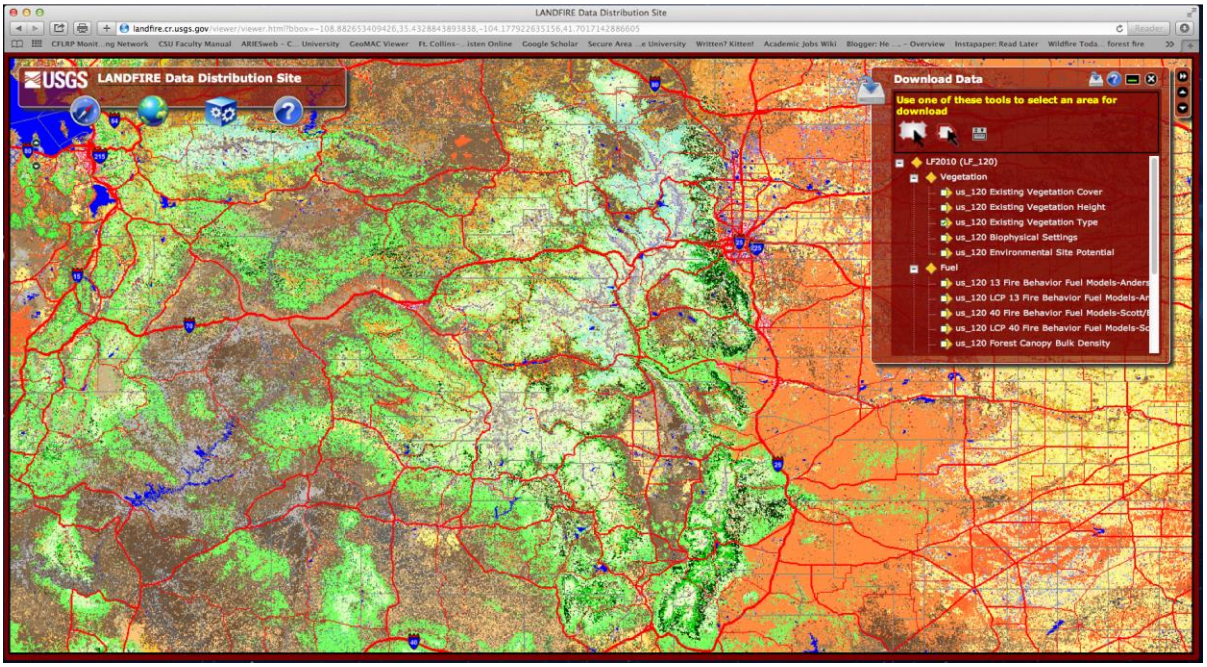
1. Landfire 2010 canopy cover

All Landfire data is freely and publically available online. Browse to the LANDFIRE Data Distribution Site (http://landfire.cr.usgs.gov/viewer/) to download the Landfire 2010 canopy cover data.



Click on the region of interest in the map. Another (more detailed) map will automatically open.

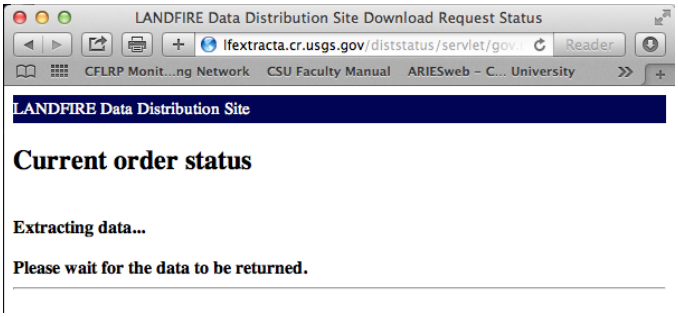
Click on the globe icon in the top left corner of the map. Select 'Download Data' from the menu. The Download Data menu will appear in the top right corner of the map.



In the directory, check the box next to the Landfire 2010 canopy cover data (LF2010 (LF_120) > Fuel > us_120 Forest Canopy Cover). Ensure that no other boxes are checked.

Click on the 'Define rectangular area for seamless data' icon. It is the first icon above the directory on the left in the Download Data menu (the white box with a red outline and a black arrow). Click and drag over the map to select the area of interest.

A new window will open titled 'LANDFIRE Data Distribution Site Request Summary Page'. Click the 'Modify data request' button and scroll down to 'us_120 Forest Canopy Cover'. Ensure that the selected data format is "ArcGRID" and click the 'Save changes & return to summary' button. This will return you to the previous page. Finally, click 'Download'. A small window will appear while the server is collating the data to be downloaded. The download will begin automatically.

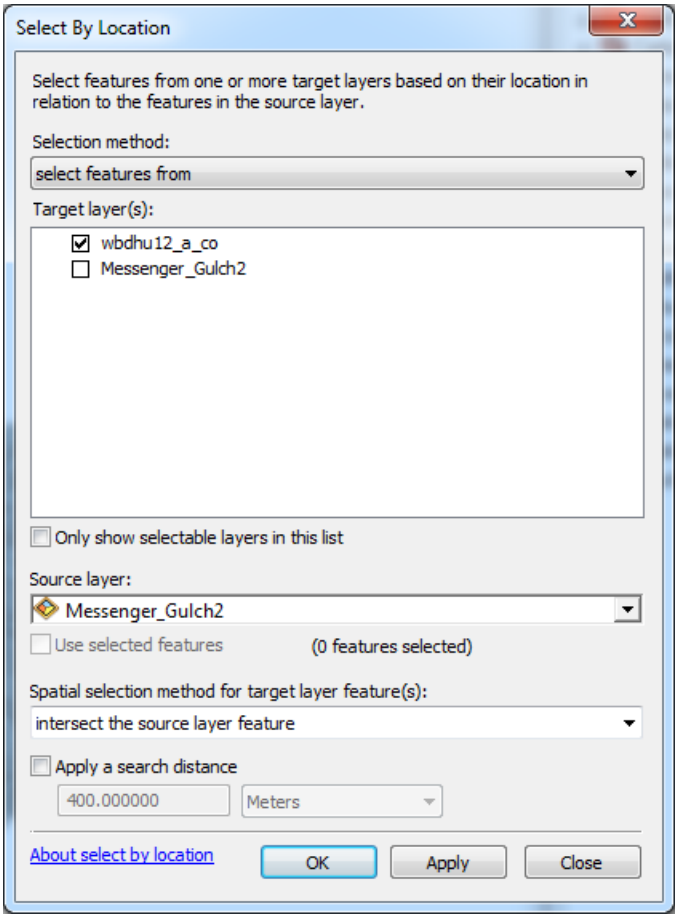


2. Polygon shapefile of the landscape boundary

In this protocol, the landscape will be defined by the HUC12 watershed(s) surrounding the treatment unit. The boundaries of these watersheds are available for download from the USDA NRCS Geospatial Data Gateway (http://datagateway.nrcs.usda.gov). Locate the 'I Want To…' box on the right-hand side of the home screen. Select a downloading method of your choice from this menu. Follow the instructions in the first column to download the data.

The map layer of interest is '12 Digit Watershed Boundary Dataset in HUC8 NRCS Version' under the 'Hydrologic Units' subheading.

After downloading the HUC12 watershed shapefile, extract the watershed(s) of interest to create a shapefile that includes the boundary of your treatment of interest. To do this, open the downloaded shapefile in ArcMap. Select the watershed(s) of interest either interactively or by using the **Select by Location** tool. Click on the 'Selection' menu on the top toolbar and, within this menu, choose 'Select By Location…'. The Select By Location window should open. Specify "select features from" in the 'Selection method' field. The 'Target layer' will be the downloaded HUC12 watershed shapefile and the 'Source layer' will be the treatment boundary. Select "intersect the source layer feature" in the 'Spatial selection method for target layer feature(s)' field. Click 'OK'.



To export the selected watersheds to a new shapefile, right click on the watershed layer in the Table of Contents and select 'Data > Export Data…'. Export the selected features only. Specify an output directory and file name. Click 'OK'. If the process completes successfully, the shapefile will be added to the Table of Contents and map.

3. Polygon shapefile of the treatment boundary

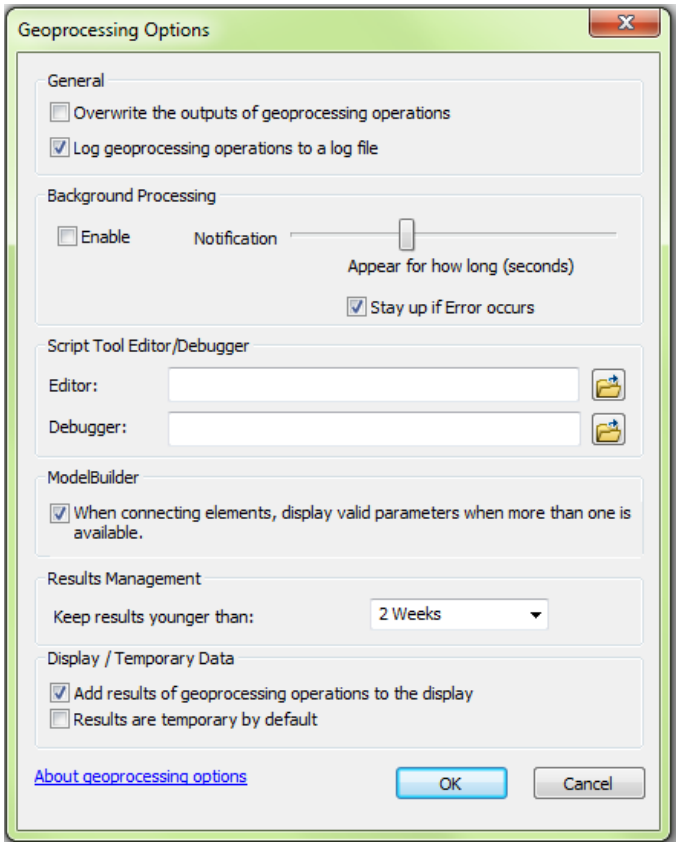
4. Extracted classified aerial image for the treatment area for both pre-treatment and post-treatment (2.4 m resolution)

This is a product from the stand-scale analysis of canopy cover. See Pelz and Dickinson (2014) for instructions on how to derive this data from aerial imagery.

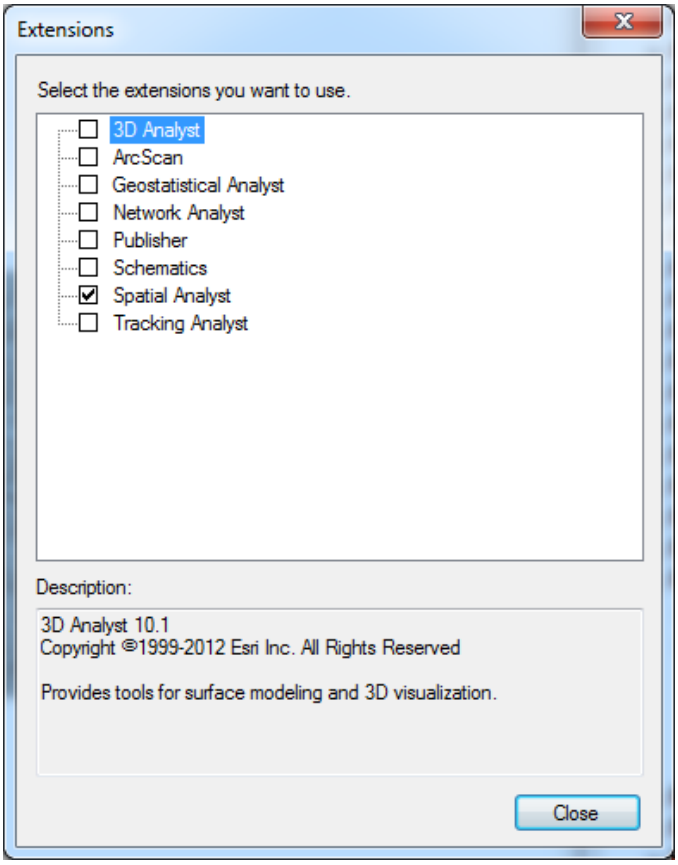
Make sure all projections are defined and projected into the same projection (for monitoring of treatments on Colorado's Front Range, we recommend using NAD_1983_UTM_Zone13N). Right-click on a layer in the Table of Contents and select 'Properties…'. The layer's projection is documented in the 'Data Source' box under the 'Source' tab. Tools to manipulate layer projections are located in the 'Projections and Transformations' toolbox (ArcToolbox > Data Management > Projections and Transformations).

Data Analysis

Due to well-known conflicts in the ArcGIS software, we recommend that you turn off background geoprocessing when following this protocol. Click on 'Geoprocessing' in the main toolbar and select 'Geoprocessing options…' from the menu. The Geoprocessing Options window will open. Make sure the 'Enable' check box is empty under 'Background Processing'. Click 'OK' to close the window.



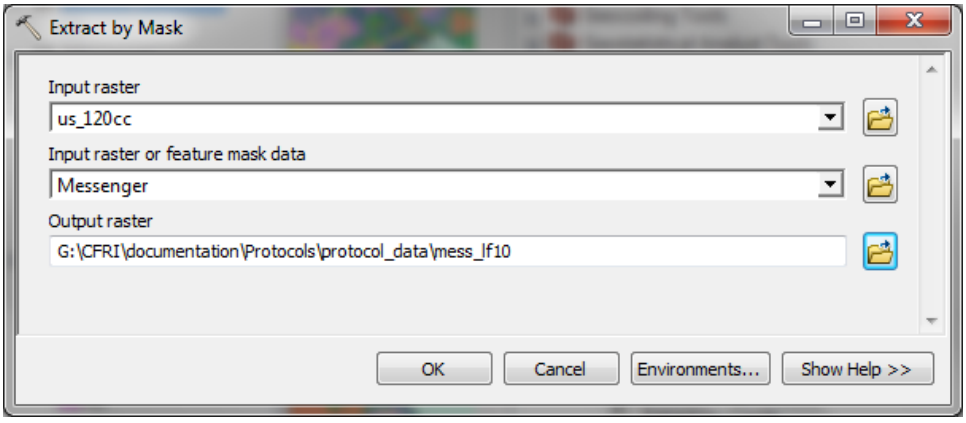
This protocol uses tools in the 'Spatial Analyst' toolbox. Ensure that this extension is enabled. Click on 'Customize' in the main toolbar and select 'Extensions…' from the menu. Check the box next to 'Spatial Analyst'. Click 'Close' to close the window.



Load all of the required data described above.

Constructing the pre-treatment Landfire 2010 canopy cover dataset

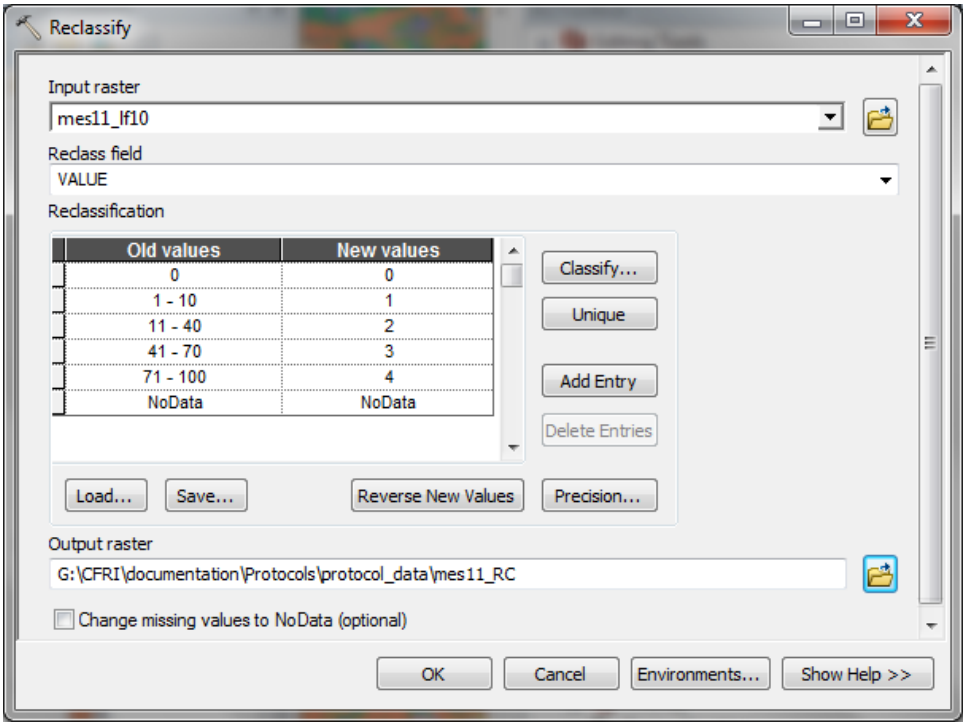
Extract the Landfire 2010 canopy cover data for the landscape of interest using the **Extract by Mask** tool. Open the **Extract by Mask** tool (ArcToolbox > Spatial Analyst Tools > Extraction > Extract by Mask). The 'Input raster' will be the downloaded Landfire 2010 canopy cover data. The 'Input raster or feature mask data' will be the landscape boundary. Specify a directory and filename for the resulting raster file in the 'Output raster' field. Click 'OK' and wait for the process to complete. If the process completes successfully, the raster will be added to the Table of Contents and map.



The extracted Landfire 2010 canopy cover data is presented in 10% canopy cover classes. However, for this analysis we will be using just 5 classes of canopy cover (non-forest, sparse, low, moderate and high canopy cover). Therefore, the data needs to be reclassified into these new classes. Open the **Reclassify** tool (ArcToolbox > Spatial Analyst Tools > Reclass > Reclassify). The 'Input raster' will be the Landfire 2010 canopy cover data extracted to the landscape of interest. The 'Reclass field' will be "VALUE". Specify the required changes to the classes in the 'Reclassification' field by changing the "Old values" and "New values" following the table below:

Old values	New values	Class name
0	0	Non-forest
1 – 10	1	Sparse canopy cover (1- 10%)
11 – 40	2	Low canopy cover (11-40%)
41 – 70	3	Moderate canopy cover (41-70%)
71 – 100	4	Dense canopy cover (71-100%)

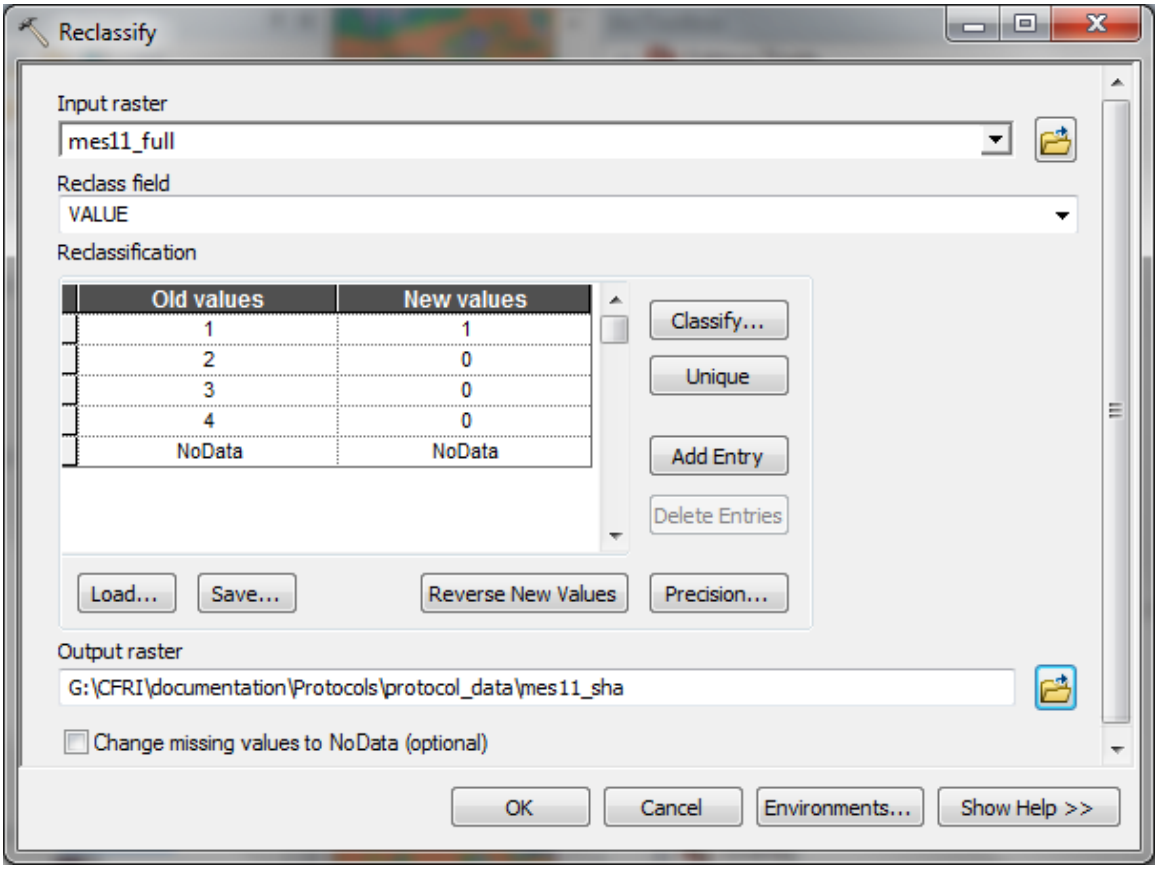
Make sure you have the correct spacing and number of digits when specifying these changes in the 'Reclassification' field as ArcMap has very specific requirements. Specifically, ArcMap will produce an error and make automatic corrections if it detects overlap between the values of the classes. Specify the directory and filename of the output in 'Output raster' field. Click 'OK' and wait for the process to complete. If the process completes successfully, the raster will be added to the Table of Contents and map.



Constructing the pre-treatment landscape canopy cover dataset

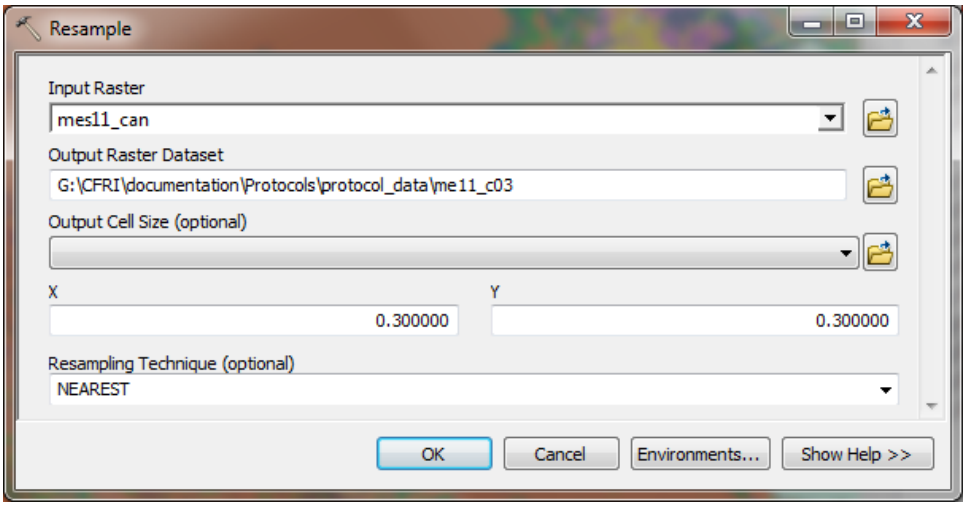
Now construct the pre-treatment landscape canopy cover dataset by updating the Landfire 2010 canopy cover data using the classified image from the stand-scale analysis. First, the classified image from the pre-treatment stand-scale analysis will need to be converted from presence/absence data of canopy cover at a 2.4m resolution to percent cover values at a 30m resolution.

To do this first create two separate raster files - one for the canopy cover data and one for the shadow cover data. Open the **Reclassify** tool (ArcToolbox > Spatial Analyst Tools > Reclass > Reclassify). The 'Input raster' will be the extracted classified image for the pre-treatment area from the stand-scale analysis. The 'Reclass field' will be "VALUE". Specify the required changes to the classes in the "Reclassification" field by changing the "Old values" and "New values" so that the canopy cover class is assigned a value of "1" and all other classes are assigned a value of "0". Specify the directory and filename of the output in the 'Output raster' field. Click 'OK' and wait for the process to complete. If the process completes successfully, the raster will be added to the Table of Contents and map. Repeat this process for the shadow cover data. The shadow cover class will be assigned a value of "1" and all other classes will be assigned a value of "0".

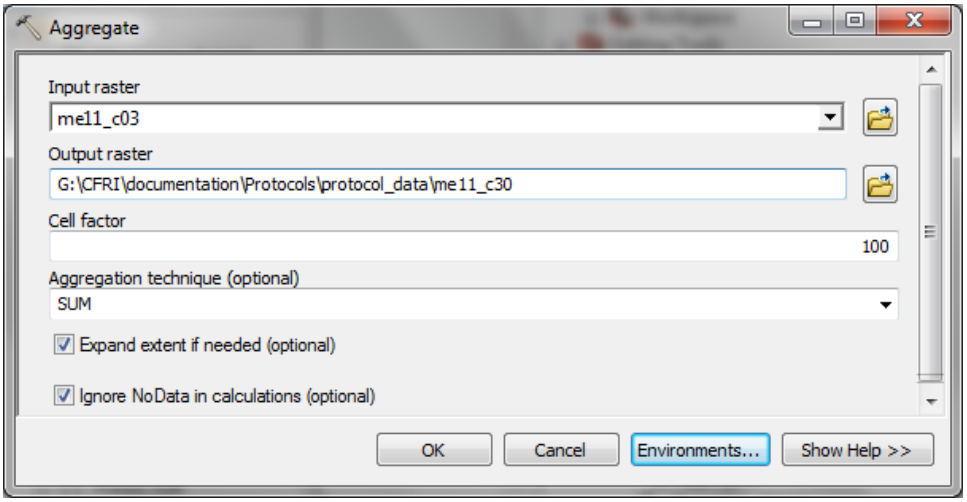


Next, resample both the canopy and shadow rasters to a 30m resolution. This process is comprised of two steps. The rasters are first resampled to a 0.3m resolution and then are aggregated up to a 30m resolution. Open the **Resample** tool (ArcToolbox > Data Management

Tools > Raster > Raster Processing > Resample). The 'Input Raster' will be the canopy cover raster we have just created. Specify a directory and file name for the output in the 'Output Raster Dataset' field. Specify 0.3 in the 'Output Cell Size' and accept the remaining defaults. Click 'OK' and wait for the process to complete. If the process completes successfully, the raster will be added to the Table of Contents and map.



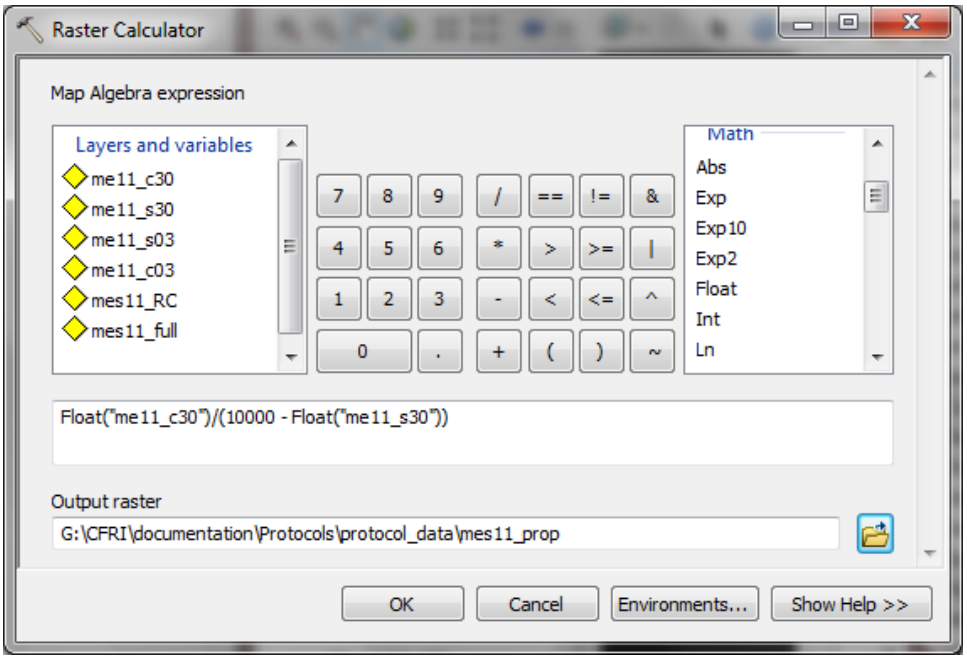
To aggregate the 0.3 m raster to 30 m, open the **Aggregate** tool (ArcToolbox > Spatial Analyst Tools > Generalization > Aggregate). The 'Input Raster' will be the 0.3 m resolution canopy cover raster. Specify a directory and file name for the output in the 'Output Raster' field. The 'Cell factor' will be "100". Select "SUM" for the 'Aggregation technique'. To align the outputs with the pre-treatment Landfire 2010 canopy cover dataset, click on the 'Environments…' button at the bottom of the window. The Environment Settings window will open. Expand 'Output coordinates' by clicking on the down arrow and select the pre-treatment Landfire 2010 canopy cover dataset in the 'Output coordinate system' field. In addition, expand 'Processing Extent' and select the pre-treatment Landfire 2010 canopy cover dataset in the 'Snap Raster' field. Click 'OK' in both the Environment Settings window and the Aggregate Tool window. Wait for the process to complete. If the process completes successfully, the raster will be added to the Table of Contents and map. Repeat the above two steps for the shadow cover raster.



Next, we will calculate the proportion of the non-shadow area in each 30 m cell that is covered by canopy. Open the **Raster Calculator** (ArcToolbox > Spatial Analyst Tools > Map Algebra > Raster Calculator). In the 'Map Algebra expression' field, type:

Float(*x*) / (10000 - Float(*y*))

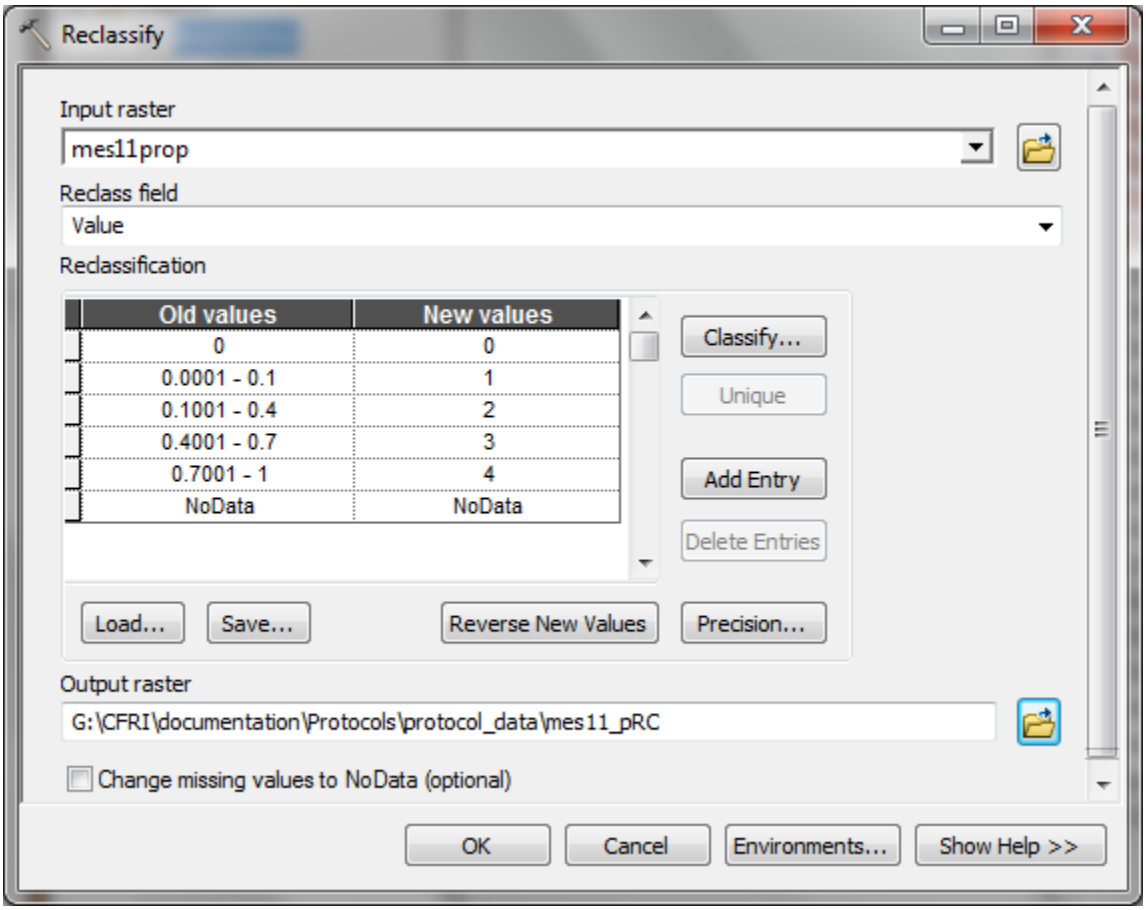
where *x* is the 30m resolution aggregated canopy cover raster and *y* is the 30m resolution aggregated shadow cover raster. You may use the buttons and pick-list on the right hand side of the window to help enter this expression. Specify a directory and file name for the output in the 'Output raster' field. Click 'OK'. If the process completes successfully, the raster will be added to the Table of Contents and map.



These proportions need to be converted to the same 5 classes as the pre-treatment Landfire 2010 canopy cover dataset using the **Reclassify** tool. Open the **Reclassify** tool (ArcToolbox > Spatial Analyst Tools > Reclass > Reclassify). The 'Input raster' will be the proportion of the non-shadow area in each 30 m cell that is covered by canopy. The 'Reclass field' will be "VALUE". Specify the required changes to the classes in the 'Reclassification' field by changing the "Old values" and "New values" following the table below:

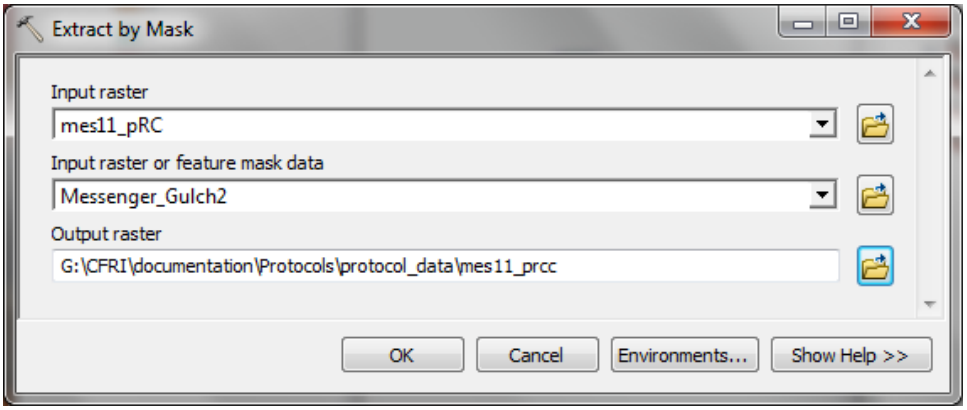
Old values	New values	Class name
0	0	Non-forest
0.0001 – 0.1	1	Sparse canopy cover (1- 10%)
0.1001 – 0.4	2	Low canopy cover (11-40%)
0.4001 – 0.7	3	Moderate canopy cover (41-70%)
0.7001 – 1	4	Dense canopy cover (71-100%)

Also specify the directory and filename of the output in 'Output raster'. Click 'OK' and wait for the process to complete. If the process completes successfully, the raster will be added to the Table of Contents and map.

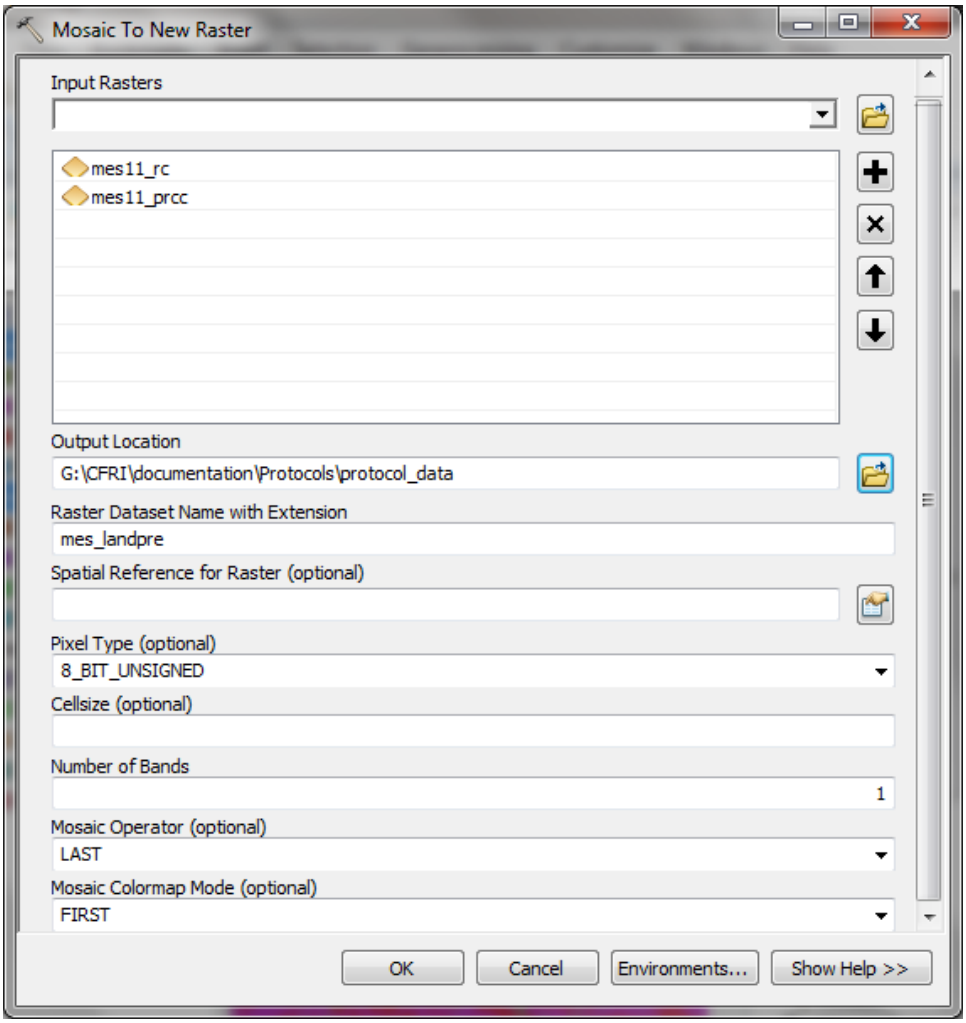


Finally, create the pre-treatment landscape canopy cover dataset by merging this reclassified 30m resolution proportional canopy cover raster with the pre-treatment Landfire 2010 canopy cover dataset.

Open the **Extract by Mask** tool (ArcToolbox > Spatial Analyst Tools > Extraction > Extract by Mask). The 'Input raster' will be the 30m resolution proportional canopy cover raster. The 'Input raster or feature mask data' will be the treatment boundary. Specify a directory and filename for the resulting raster file in the 'Output raster' field. Click 'OK' and wait for the process to complete. If the process completes successfully, the raster will be added to the Table of Contents and map.



Open the **Mosaic To New Raster** tool (ArcToolbox > Data ManagementTools > Raster > Raster Dataset > Mosaic To New Raster). Add both the extracted reclassified 30m resolution proportional canopy cover raster and the pre-treatment Landfire 2010 canopy cover dataset in the 'Input Rasters' field. Specify a directory in the 'Output location' field and a file name for the output in the 'Raster dataset name with extension' field. Make sure that the order of the rasters in the 'Input Rasters' field matches the 'Mosaic Operator'. "LAST" indicates that the output cell value of the overlapping areas will be the value from the last raster dataset in the list. "FIRST" indicates that the overlapping areas will be given the value from the first raster dataset in the list. Ensure that the value from the 30m resolution proportional canopy cover raster is retained in these overlapping areas.



Constructing the post-treatment landscape canopy cover dataset

Repeat the process described above in "Construct the pre-treatment landscape canopy cover dataset" using the post-treatment stand-scale canopy cover data.

Calculating and interpreting the FRAGSTATS metrics

FRAGSTATS is capable of computing a variety of patch, class and landscape metrics. The mean, median, and standard deviation of class metrics may be used to describe (and therefore monitor changes in) the pattern of canopy across the landscape. Specifically, we recommend calculating percentage of landscape (PLAND), largest patch index (LPI), edge density (ED), patch area (PA), perimeter area ratio (PARA), patch density (PD), and Euclidean nearest neighbor distance (ENN) for each canopy cover class. Table 1 describes these metrics and the expected trends associated with successful restoration of ponderosa pine forests on Colorado's Front Range.

For instructions on how to calculate the required FRAGSTATS metrics, refer to "Analyzing Spatial Patterns with FRAGSTATS" in Pelz and Dickinson (2014).

You may find that you need to use ASCII files in FRAGSTATS. Use the **Raster to ASCII** tool to create ASCII type files (ArcToolbox > Conversion Tools > From Raster > Raster to ASCII).

Select the raster file in the 'Input raster' field. Specify a directory and name in the second box. Click 'OK'.

Table 1. Information about selected FRAGSTATS metrics.

Metric	Definition, interpretation and units	Expected trend under successful restoration
Percentage of Landscape (PLAND)	Area of each patch type as a percent of total landscape area (%).	Decrease in dense canopy cover. Increase in sparse canopy cover and non-forest.
Largest Patch Index (LPI)	The percentage of total landscape area comprised by the largest patch (%). It is a measure of the dominance of the largest patch of each patch type.	Decrease in dense canopy cover. Increase in sparse canopy cover and non-forest.
Edge Density (ED)	The length of patch edge per unit area (m/ha) for each patch type. Edges (where adjacent patches influence each other) are important drivers of ecological processes in complex landscapes.	Increase.
Patch Area (PA)	The size of a patch by type (ha). Mean, range, and standard deviation reported. Frequency distribution graphs of patch area may also be plotted using patch-level metrics.	Decrease in mean for dense canopy cover. Increase in sparse canopy cover and non-forest. Increase in range and standard deviation for all patch types.
Perimeter Area Ratio (PARA)	A ratio of the perimeter of a patch to its area (unitless). Large perimeter-to-area ratios indicate convoluted or complex edges with greater proportions of the area influenced by neighboring patches. Mean, range, and standard deviation reported. Frequency distribution graphs may also be plotted using patch-level metrics.	Increase.
Patch Density (PD)	Simple measure of the density of patches per 100 hectares. Patch density is an indication of the prevalence of patch types (i.e. canopy or opening) and is strongly influenced by the size of patches.	Increase.

Euclidean Nearest Neighbor Distance (ENN)	The shortest straight-line distance between the focal patch (m) and its nearest neighbor of the same type. This simple measure of patch context is used to quantify patch isolation. Mean, range and standard deviation reported. Frequency distribution graphs may also be plotted using patch-level metrics.	Increase in mean for dense canopy. Decrease for sparse canopy and non-forest. Increase in range and standard deviation for all patch types.

Example: The impact of the Ryan Quinlan treatment on landscape-scale forest structural diversity

The Ryan Quinlan restoration treatment on the Pike National Forest was completed in early 2013. To monitor the effectiveness of these restoration treatments, the aerial images pre- and post-treatment were analyzed following the protocol described in Pelz and Dickinson (2014) and described above. The results of the landscape-scale analysis are discussed below.

Generally, the analysis found a 10-fold increase in sparse canopy cover following treatment (Figures 1, 2 and 3, and Table 2); however, the proportion of the entire landscape with sparse canopy cover remains low (increase from 0.025% to 0.38%). This increase in sparse canopy cover is also reflected by increases in the largest patch index, (the proportion of the landscape covered by the single largest patch, increase from 0.005% to 0.05%), patch density (increase from 0.17 to 0.50 patches per 100 ha) and mean patch area (increase from 0.15 to 0.77 ha). The range and coefficient of variation of sparse patch sizes also rose considerably (from 0.45 to 5.76 ha, and 74.7 to 168.3 ha respectively) indicating that these patches of sparse canopy cover had greater size variation. The distance between patches (Euclidean distance to nearest neighbor) decreased (from 132.3 to 68.4) indicating greater connectivity between patches of sparse canopy. There was also a small increase in low canopy cover (from 22.4% to 22.9%), with increases in the largest patch index (from 4.8 to 5.5%), mean patch area (from 1.52 to 1.59 ha), and range in patch sizes (from 546.3 to 621.3 ha). *These changes in sparse and low canopy cover are all consistent with the success of restoration in increasing the complexity of the landscape-scale forest mosaic.*

However, while changes in the sparse and low canopy cover metrics were detected, *only small changes were measured in the cover and pattern of moderate and dense forest cover.* While restoration aims to decrease and break-up moderate and dense canopy cover, it is not unexpected that these treatments did not have a large effect. The majority of the landscape is composed of large, contiguous patches of moderate and dense canopy cover (~67% of the landscape) and the treatments encompass a relatively small proportion of the landscape. Therefore, it may take several treatments within a watershed to significantly impact the level of moderate to dense forest cover within the landscape.

Figure 1: Landfire 2010 canopy cover in the Ryan Quinlan HUC-12 watershed

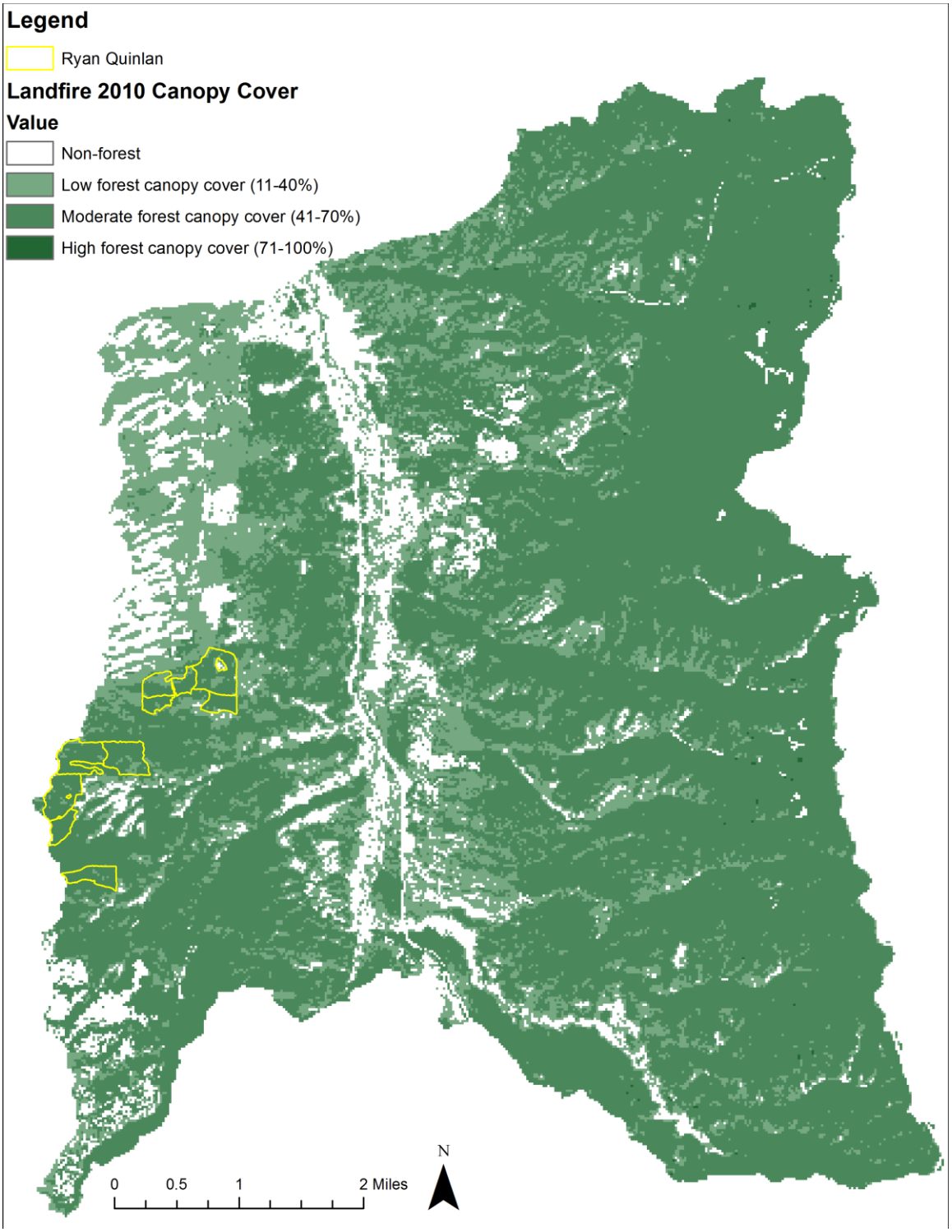


Figure 2: Landfire 2010 canopy cover in the Ryan Quinlan HUC-12 watershed updated using the pre-treatment NAIP-derived canopy cover within the treatment area

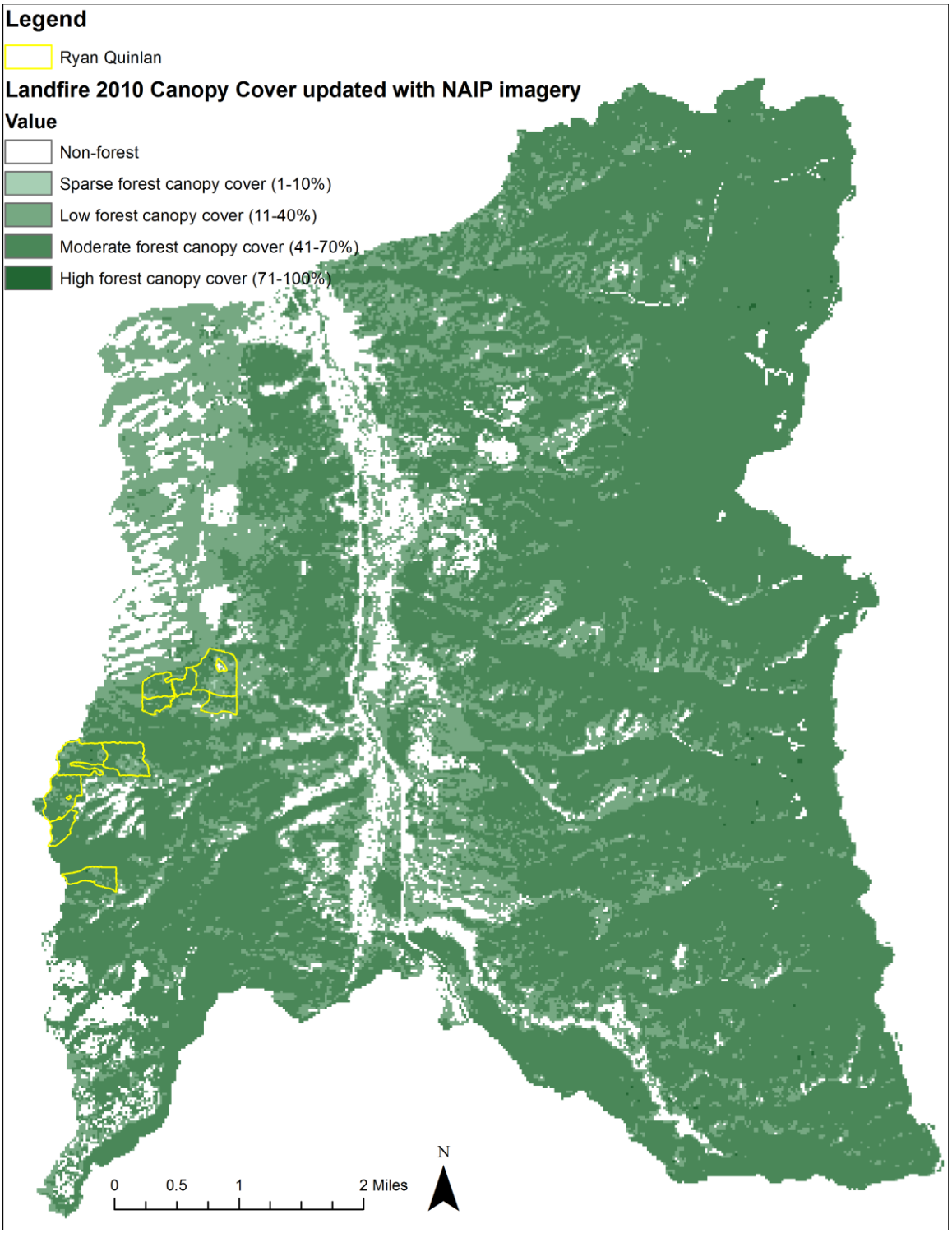


Figure 3: Landfire 2010 canopy cover in the Ryan Quinlan HUC-12 watershed updated using the post-treatment NAIP-derived canopy cover within the treatment area

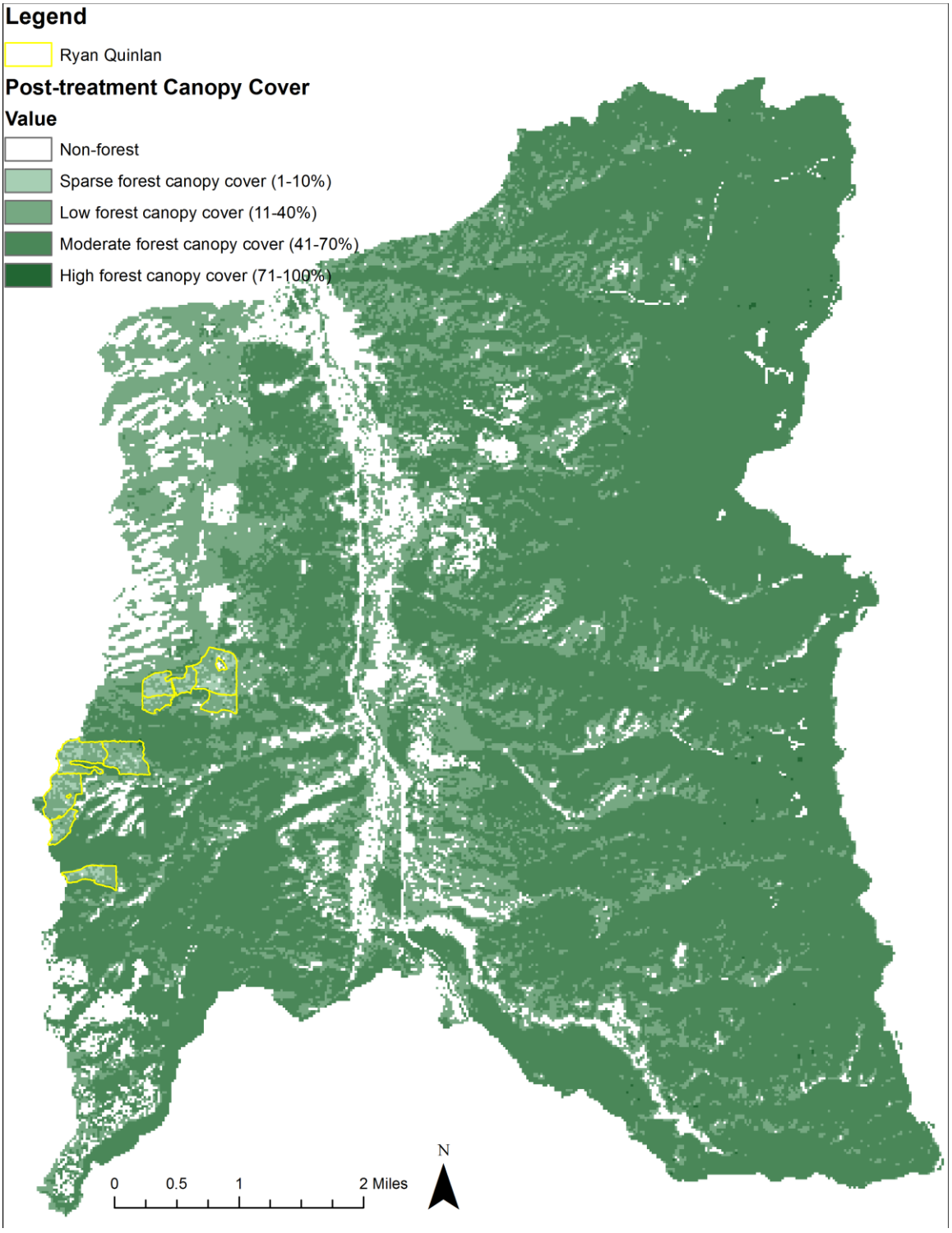


Table 2: Summary of FRAGSTATS output for the Ryan Quinlan HUC-12 watershed

Forest canopy cover		Percent of watershed (PLAND)	Largest patch index (LPI)	Patch density (PD)	Edge density (ED)	Mean patch area (AREA_MN)	Patch area range (AREA_RA)	Patch area coefficient of variation (AREA_CV)
None	**Landfire 2010**	10.7514	3.6612	7.4509	46.9668	1.443	415.62	1018.2923
	Pre-treatment	10.7438	3.661	7.4417	46.917	1.4437	415.62	1018.3528
	Post-treatment	10.7541	3.661	7.5386	47.0412	1.4265	415.62	1024.0321
Sparse	**Landfire 2010**	0.0000	NA	NA	NA	NA	NA	NA
	Pre-treatment	0.0254	0.0048	0.1673	0.2668	0.1516	0.45	74.7391
	Post-treatment	0.3844	0.0515	0.502	2.7239	0.7658	5.76	168.3235
Low	**Landfire 2010**	22.2836	4.8589	14.6375	111.4881	1.5224	551.61	987.4445
	Pre-treatment	22.453	4.8119	14.7601	112.632	1.5212	546.3	977.9434
	Post-treatment	22.9079	5.4722	14.4078	113.7338	1.59	621.27	1055.5643
Moderate	**Landfire 2010**	66.9206	49.8534	3.9808	87.9254	16.8107	5660.46	1651.552
	Pre-treatment	66.7248	49.851	4.0599	89.0414	16.4351	5660.46	1670.7646
	Post-treatment	65.8997	49.851	4.236	87.9952	15.5569	5660.46	1719.0603
High	**Landfire 2010**	0.0444	0.0048	0.3523	0.502	0.126	0.45	67.3856
	Pre-treatment	0.0531	0.0048	0.4315	0.6182	0.1231	0.45	63.8834
	Post-treatment	0.0539	0.0048	0.4139	0.5971	0.1302	0.45	71.0159

Table 2 (cont)

Forest canopy cover		Mean perimeter area ratio (PARA_MN)	Perimeter area ratio range (PARA_RA)	Perimeter area ratio coefficient of variation (PARA_CV)	Mean Euclidean distance to nearest similar neighbor (ENN_MN)	Range of Euclidean distance to nearest similar neighbor (ENN_RA)	Coefficient of variation of Euclidean distance to nearest similar neighbor (ENN_CV)
None	**Landfire 2010**	1050.2186	1139.6825	29.3541	102.5753	698.9466	74.0384
	Pre-treatment	1049.4699	1139.6825	29.3584	102.6167	698.9466	74.2279
	Post-treatment	1052.3388	1139.6825	29.2204	103.0822	698.9466	74.2221
Sparse	**Landfire 2010**	NA	NA	NA	NA	NA	NA
	Pre-treatment	1198.8304	555.5556	16.8981	132.2921	216.5863	56.1604
	Post-treatment	1066.6681	817.2043	27.2144	68.3695	109.7056	29.0338
Low	**Landfire 2010**	1040.5476	1099.8369	28.1623	78.9699	614.1662	53.1131
	Pre-treatment	1043.2131	1100.5326	28.0315	78.8509	614.1662	53.198
	Post-treatment	1040.9599	1082.3677	28.1387	78.9024	614.1662	53.3024
Moderate	**Landfire 2010**	1098.5437	1228.2799	25.6781	81.7927	357.8516	52.1598
	Pre-treatment	1097.2924	1228.2799	25.632	81.4751	357.8516	51.9533
	Post-treatment	1096.878	1228.2799	25.8367	82.3023	357.8516	51.6257
High	**Landfire 2010**	1241.6667	666.6667	14.6886	409.1706	1380.6249	94.6717
	Pre-treatment	1258.5034	666.6667	13.3941	404.0021	1380.6249	90.3544
	Post-treatment	1234.0426	666.6667	15.6761	419.0057	1380.6249	90.019

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About the Colorado Forest Restoration Institute

The Colorado Forest Restoration Institute (CFRI) was established in 2005 as an application-oriented program of the Department of Forest & Rangeland Stewardship in the Warner College of Natural Resources at Colorado State University. CFRI's purpose is to develop, synthesize, and apply locally-relevant science-based knowledge to achieve forest restoration and wildfire hazard reduction goals in Colorado and the Interior West. We do this through collaborative partnerships involving researchers, forest land managers, interested and affected stakeholders, and communities. Authorized by Congress through the Southwest Forest Health and Wildfire Prevention Act of 2004, CFRI is one of three Institutes comprising the Southwest Ecological Restoration Institutes, along with centers at Northern Arizona University and New Mexico Highlands University.

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