Identification of Canopy Gap and Early Successional Habitat Patches on the Nantahala and Pisgah National Forests

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Introduction:

The Nantahala and Pisgah National Forests' (hereafter, the Forests) Plan Revision Assessment (hereafter, the Assessment) highlighted the current condition of under-represented young forest across all ecozones on both NFS and other lands in the planning area. The Assessment states:

> *Over the last fifteen years on the national forests the amount of mature and old forest has increased, while the amount of very young forest – also known as early successional habitat and calculated based on 0-10 year old regenerated stands - has decreased from 3.0% to 0.6% of the national forests, from 31,026 acres to 6,244 acres.*

Under-representation of early successional habitat (ESH) is a conservation concern for the Forests because of implications of this deficit on plant and animal species that rely on early successional habitats for all or part of their life history. Examples of such species include the Golden-winged Warbler, White-tailed Deer, Elk, Ruffed Grouse, and multiple plant species of conservation concern, including mountain catchfly and a host of other sun-loving plant species. Acres of the forest with various canopy cover classes were calculated as part of the Assessment; however, there is a need to take that analysis deeper to identify gaps in the canopy that could represent areas of openings and early successional forest.

This analysis utilizes the existing LiDar-derived vegetation structural data to identify gaps in the canopy, and assesses the composition and spatial configuration of such gaps across the 18-county area used for the assessment. Results from this analysis may be used to support decisions on future restoration and forest management projects by identifying existing gaps that could provide desired habitat, and where those gaps may be maintained, as well as identifying areas where gaps are less prevalent but may need to be created for species restoration.

Questions that can be answered by this data summarization and analysis include, but are not limited to:

- How much of the Forest consists of gaps? How are those gaps characterized, in terms of spatial configuration (e.g. size, shape) and distribution? And how do these gaps contribute to open forest and/or young forest (YF)/ESH conditions on the landscape?

- Is there a difference in the number and/or size of gaps between ecozones? Are some ecozones prone to more gaps than others? Are there ecozones that have fewer gaps than would be expected under natural disturbance regimes?

- Are there areas on the landscape where gaps are more or less prevalent?

- Is there a difference in the number and/or size of gaps in wilderness areas versus the non-wilderness or managed NFS lands? If so, what are the differences?

It is important to note that some of these questions require integration with other analyses such as Potential Natural Vegetation (PNV) modeling, Natural Range of Variation (NRV) estimation and Spectrum analysis of projected change in forest conditions over time.

Methods

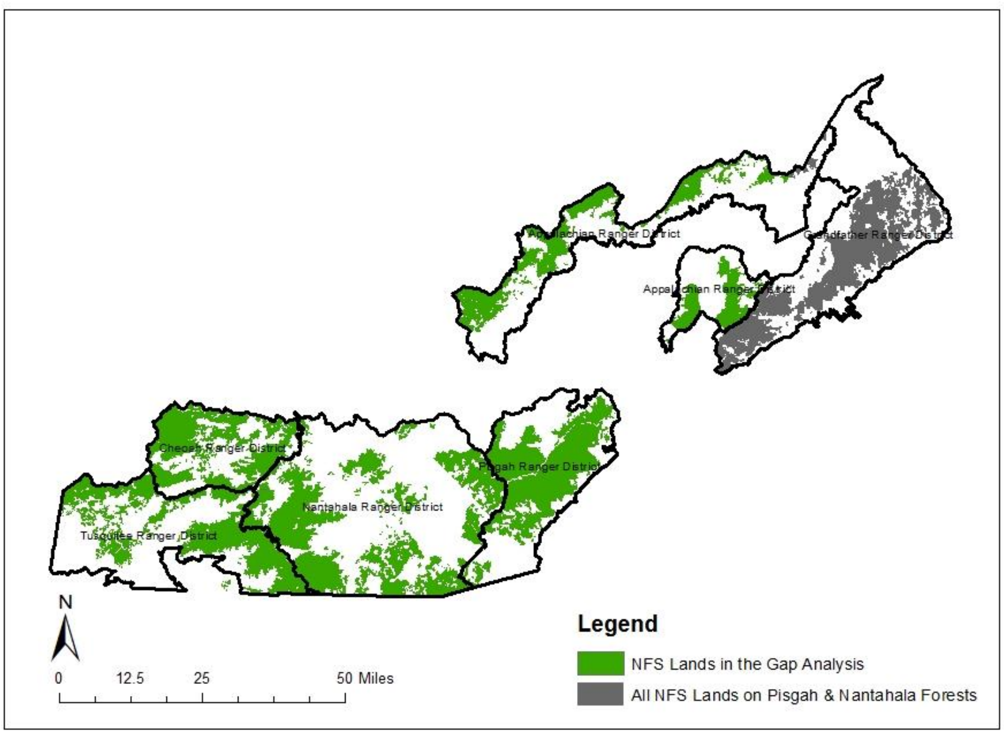
To identify canopy gaps, we used the most precise, full-coverage vegetation data available, which is the LiDar data that was developed in 2005. The dataset has good accuracy with canopy height and cover, and good precision, as the pixel size is 40'x40' (or <0.01 acre). However, the data layer is dated, and thus this analysis should be interpreted as a "snapshot in time" of where canopy gaps occurred on the Forests in 2005. The biggest assumption here is that gap creation and loss/closure have been happening at the same rate since 2005. New LiDar data is expected to be available in 2018, at which time the analysis could be re-run to compare changes in the past decade.

LiDar data does, however, have inherent limitations, and thus should be interpreted with those limitations in mind. For example, it is unable to discern what ground cover composition is from the data. Identified canopy gaps could be grassy, providing grazing habitat for herbivores, or they could be covered in leaf litter or rock or gravel, providing different habitat characteristics or quality. Similarly, tree canopy and shrub layer composition cannot be assessed from LiDar data. Vegetative composition is critical to hard and soft mast-dependent species such as many migratory birds and small mammals, Black Bear, Wild Turkey, and Ruffed Grouse.

Additionally, a portion of the Forests was not included in the 2005 LiDar data collection. Part of the Grandfather Ranger District had LiDar collected in Phase 2 (prior to 2005) and the results are of lower quality, and therefore not comparable with the Phase 3 data. Therefore, the areas without Phase 3 data were eliminated from this analysis. Results will need to be extrapolated to the areas with no data, with an understanding that accuracy will be decreased and not site-specific for those areas, or the analysis re-run with new LiDar data once it is available. However, this is not expected to happen until plan revision is complete, so the 2005 Phase 3 LiDar data is considered to be the best available information at the time of this analysis.

In summary, this analysis included all NFS lands that have Phase 3 LiDar data available, approximately 846,572 acres (Figure 1).

Figure 1. National Forest System (NFS) lands used in the canopy gap analysis for the Nantahala and Pisgah National Forests.



Details of the GIS processing steps that were taken to identify gaps are attached as an appendix to this document. The steps below explain key processes of this analysis:

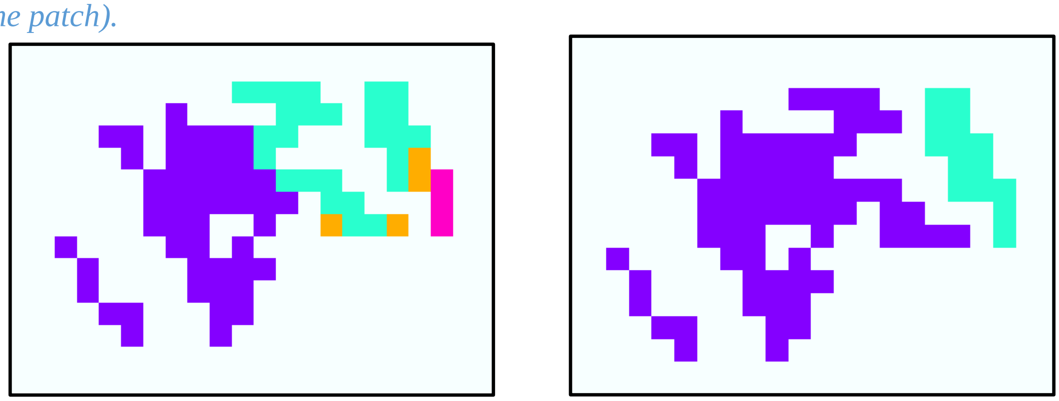
1. Canopy gaps were defined ecologically as *places where the canopy is open and the trees and shrubs are small enough and their density is low such that sunlight is able to reach the forest floor, providing potential habitat for species (plants and animals) that prefer such open conditions*. From the LiDar data, this is identified as pixels exhibiting the following characteristics: *Canopy Cover 0-25% AND Tree Height 0-15 feet AND Shrub Density <50%.*

2. To reduce extreme patchiness of the data, the Aggregate Function was used to create a reduced-resolution raster that took the mean value for an 80'x80' pixel, and then to identify patches based on an 8-pixel neighbor grouping (i.e. if two pixels were touching on any sides or corners, they were considered part of the same patch) (Figure 2).

3. Canopy gap patches were intersected with the Nantahala-Pisgah PNV model to identify ecozone values, based on which ecozone represented the majority of the canopy gap patch (Figure 2).

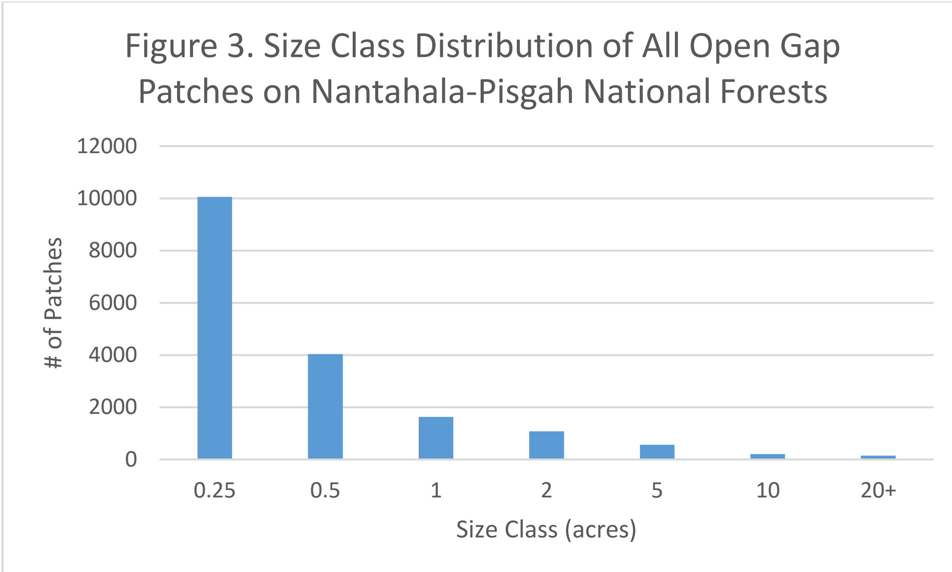
4. Canopy gap patches were converted from rasters to polygons, and associated data was exported to Microsoft Excel for summarization and presentation (however, spatial presentation is still needed for parts of this process).

Figure 2. Example of multiple ecozones within the same patch (left), which were aggregated into patches based on the majority ecozone (right). Three patches total were created, based on the "eight neighbor rule" (i.e. pixels have to be touching on a side or corner to be considered the same patch).

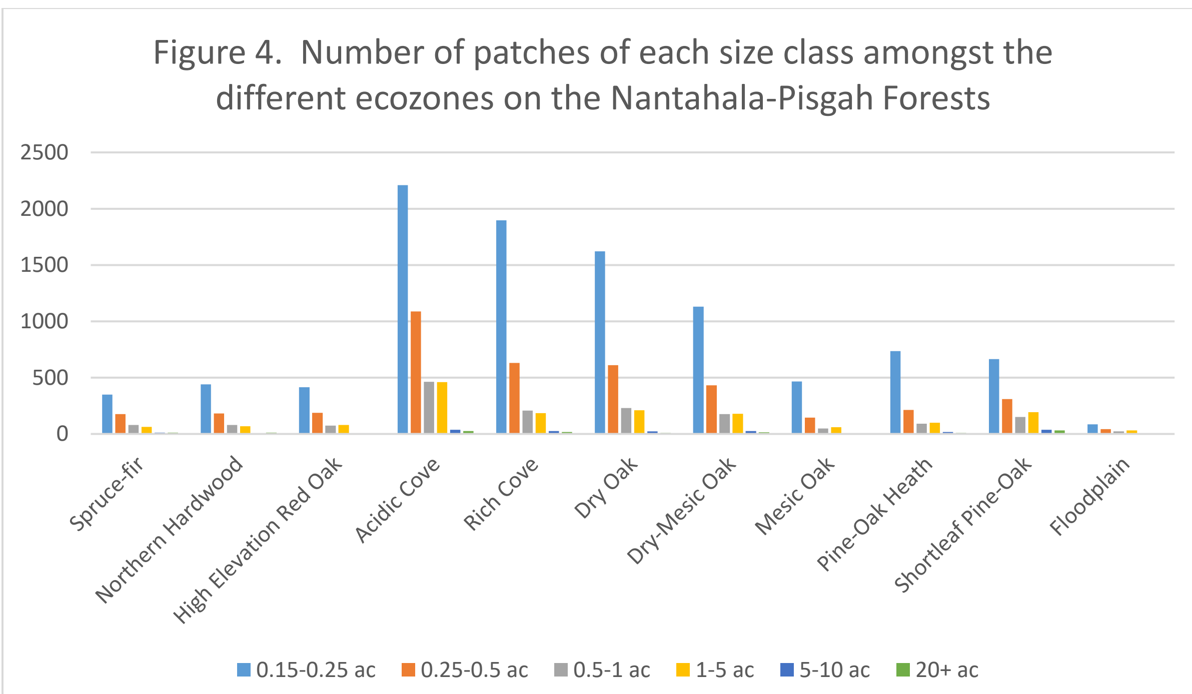


PRELIMINARY RESULTS

Approximately 18,000 canopy gap patches, totaling approximately 13,000 acres, were identified on the Forests (approximately 1.5% of the analysis area, keeping in mind that only Phase III LiDar was used) (Table 1). The majority of canopy gap patches (approximately 80%) were 0.5 acres or less in size, and approximately 5% were 5 acres or larger, with the largest being 747 acres (Black Balsam/Sam's Knob area on the Pisgah Ranger District) (Figure 3).



Canopy gap patches occurred in all ecozones, and the size distribution was similar to that shown above for all gaps (Figure 2). Across ecozones, smallest patches were the most prevalent, and larger patches (1 acre or larger) were rare (Figure 4).



The Acidic Cove ecozone had the greatest number of gaps, as well as the greatest amount of acreage in gaps (Table 1). Ecologically this may seem strange, since coves are usually fairly protected from disturbances that would cause gaps. However, the Acidic Cove is the most prevalent ecozone in the analysis area. To understand the proportion of each ecozone that is a gap, we looked at the acres of gap habitats within each ecozone relative to the amount of that ecozone on the landscape. That gave a different picture, one that is perhaps more expected (Table 1, last column).

Table 1. Gap patches by ecozone on the Nantahala-Pisgah Forests, showing the total number of patches, the total acres of gap patches, average patch size (and standard deviation), and proportion of the ecozone that is a gap.

Ecozone (acres in analysis area)	**# of Gap Patches**	**Total Acres of Gap**	**Avg. Patch Size**	**% of Ecozone that is Gap**
Spruce-fir (15,649)	691	1,288	1.9	8.2
Northern Hardwood (48,304)	787	710	0.9	1.5
High Elevation Red Oak (38,176)	767	417	0.5	1.1
Acidic Cove (182,119)	4,282	2,764	0.6	1.5
Rich Cove (165,630)	2,961	1,631	0.6	1.0
Dry Oak (156,661)	2,704	1,532	0.6	1.0
Dry-Mesic Oak (86,986)	1,956	1,223	0.6	1.4
Mesic Oak (41,216)	730	342	0.5	0.8
Pine-Oak Heath (61,288)	1,215	785	0.6	1.3
Shortleaf Pine-Oak (31,568)	1,391	1,662	1.2	5.3
Floodplain (1,089)	193	273	1.4	25.0
Grassy Bald (517)	28	188	6.7	36.4
All	17,705	12,814	0.7	

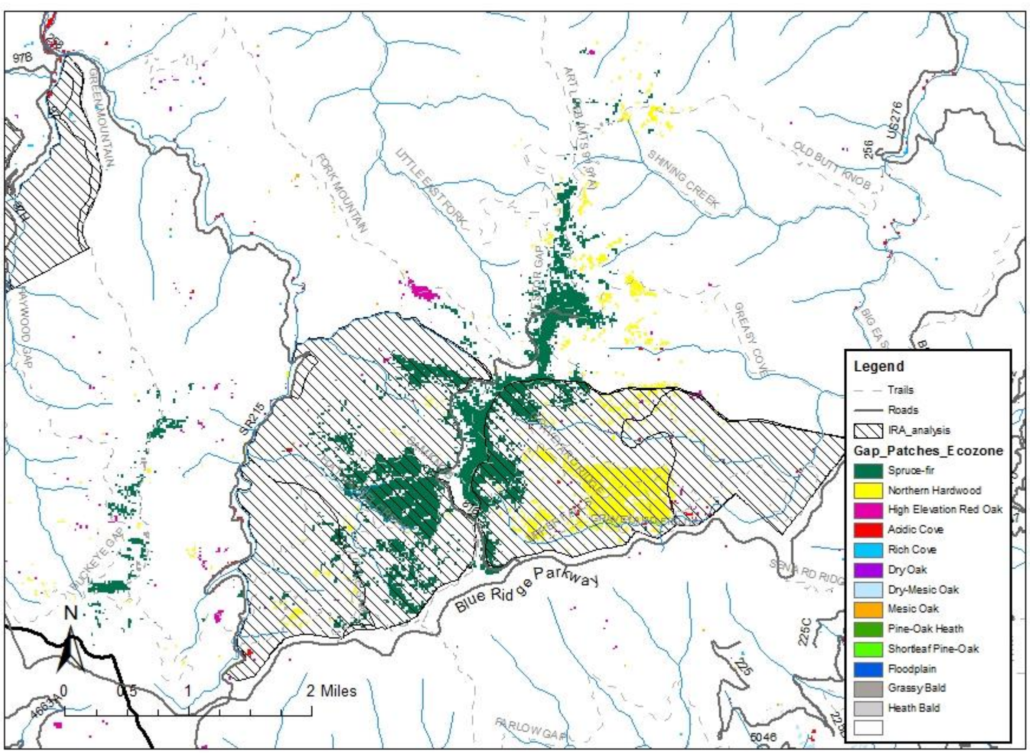
Table 2. Relative ranking of ecozones in relation to the amount of gaps within the ecozone. The first column shows rank by the total number of acres, second column is by the total number of patches, and the third column shows the proportion of the ecozone that is a gap.

Rank	**Total Acres of Gaps**	**Total # Gap Patches**	**Relative Proportion of Ecozone that is Gap**
1	Acidic Cove	Acidic Cove	Grassy Bald
2	Shortleaf Pine-Oak	Rich Cove	Floodplain

3	Rich Cove	Dry Oak-Deciduous Heath	Spruce-Fir
4	Dry Oak	Dry Mesic Oak	Shortleaf Pine-Oak
5	Spruce-Fir	Shortleaf Pine-Oak	Acidic Cove
6	Dry-Mesic Oak	Pine-Oak Heath	N. Hardwood
7	Pine-Oak Heath	N. Hardwood	Dry-Mesic Oak
8	N. Hardwood	High Elev. Red Oak	Pine-Oak Heath
9	High Elev. Red Oak	Mesic Oak	High Elev. Red Oak
10	Mesic Oak	Spruce-fir	Rich Cove
11	Floodplain	Floodplain	Dry Oak
12	Grassy Bald	Grassy Bald	Mesic Oak

The two smallest ecozones, grassy balds and alluvial floodplains, had the highest proportion of the ecozone in a gap structural state (Table 2). These ecozones both are prone to open conditions due, so this is not surprising. Two of the high elevation ecozones (spruce-fir and northern hardwood,) were among the highest in terms of relative proportion of the ecozone in gap states. These ecozones contain the largest canopy gap patch (approximately 747 acres) on the Forests (Figure 3).

Figure 3. Large gap at Black Balsam/Sam's Knob area on the Pisgah Ranger District in spruce-fir ecozone.



Other Early Stand Habitat Patches

Using the same methods as used to identify canopy gap patches, patches of Early Successional Habitat (ESH) were identified similar to canopy gap patches, except that the canopy density was greater than 25%, indicating a stand that is starting to fill back in after a disturbance. We identified two kinds of ESH patches: ESH Moderate (canopy cover 25-60%) and ESH Dense (canopy cover >60%).

There were substantially more patches and more acres of the ESH types than there were the open canopy gap patches (Table 5). Similar to canopy gap patches, these ESH patches were primarily small, isolated patches across the Forest, many of which are likely the result of single-tree falls that are growing back in quickly with vegetation, leading to the higher canopy cover.

Table 5. Size of ESH) patches across the Nantahala and Pisgah National Forests.

Acres	ESH Mod	ESH Dense	Total # Patches	% of all patches
0-0.15	53,188	96,604	149,792	75
0.15-0.3	13,088	14,996	28,084	14
0.3-0.5	5,485	3,845	9,330	5
0.5-1	5,649	2,038	7,687	4
1-2	2,407	274	2,681	1
2-5	881	26	907	<1
5-10	135	4	139	<1
10-20	13	1	14	<1
>20	1	1	2	<1
Total	**80,847**	**117,789**	**198,636**	**100**

Overall there were acres of 46,836 acres of ESH in the analysis area, representing approximately 5.5% of the analysis area. As was the case canopy gap patches, the floodplain and grassy bald ecozones had the greatest proportion of their area in ESH. Overall, the proportion of the ecozones that are ESH is much higher than the proportion that is a Gap (compare Table 1 with Table 6).

Table 6. Total acres of Early Stand Habitat (ESH) by ecozone in the analysis area, and the proportion of each ecozone that was in ESH in 2005.

	ESH Dense	ESH Moderate	Grand Total	% of Ecozone that is ESH
Spruce-fir	399	1,051	1,451	9.3
Northern Hardwood	909	1,271	2,180	4.5
High Elevation Red Oak	837	1,322	2,159	5.7
Acidic Cove	4,951	4,827	9,778	5.4
Rich Cove	4,514	4,057	8,570	5.2
Dry Oak	3,831	4,157	7,988	5.1
Dry-Mesic Oak	2,649	2,772	5,421	6.2
Mesic Oak	928	1,109	2,036	4.9
Pine-Oak Heath	1,678	2,375	4,053	6.6
Shortleaf Pine-Oak	1,214	1,660	2,874	9.1
Floodplain	92	128	221	20.3
Grassy Bald	53	51	104	20.1
All	22,056	24,780	46,836	

ATTACHMENTS:

Appendix 1: Canopy Gap Patch identification steps

Appendix 2: Early Successional Habitat Patch identification steps

****This process should be updated as further analysis and summarization of gap data is completed****

Gap Analysis

Thursday, March 17, 2016
12:45 PM

This document details the GIS processing steps that were taken to identify "Gaps" on Nantahala-Pisgah NFs based on the 2005 Lidar data.

The model steps identified below are developed in Model Builder, and saved in the toolbox called "GapAnalysis_NP.tbx" located here T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis.

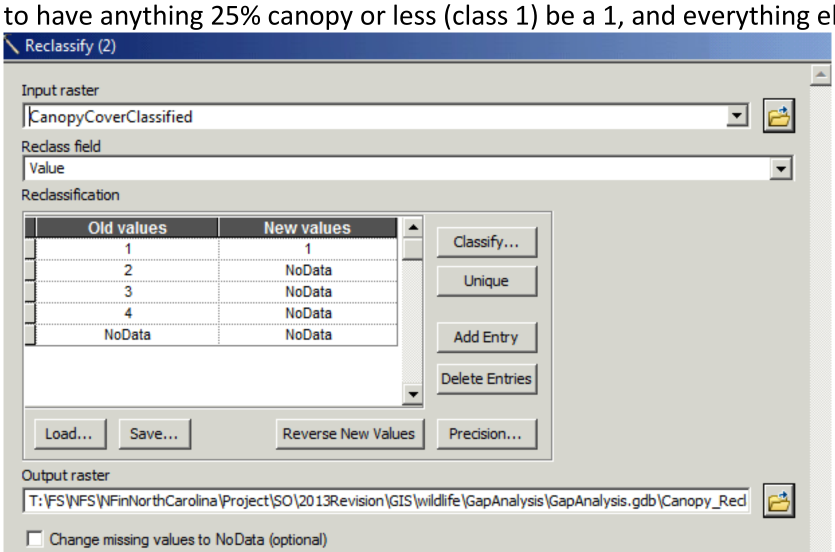
The ArcMap project that includes all of the gap analysis data is called "GapAnalysis.mxd" and is saved here T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis.

The geodatabases that contain the gap analysis layers is called

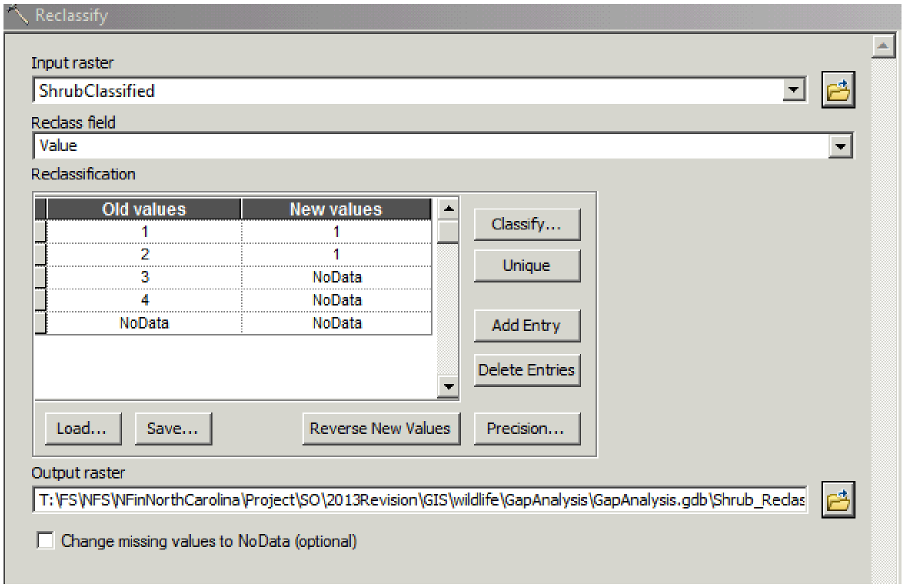
STEP 1: Classify vegetation datasets to select the attributes we want.

We're defining gaps as anything having Canopy Cover $\leq$25% AND Canopy Height $\leq$15' AND Shrub Density $\leq$50%. Here's how to do that

1. "Canopy Cover Phase 3 Classified" raster (from Mark E's data) , add field 'reclass' and reclassified to have anything 25% canopy or less (class 1) be a 1, and everything else "nodata"



2. "Canopy Height Classified" raster , add field 'reclass' and reclassified to have anything 15' height or less (class 1, 2, 3) be a 1, and everything else "nodata"
3. "Shrub Cover Classified" raster , add field 'reclass' and reclassified to have anything 50% canopy or less (value=1 or 2) be a 1, everything else "nodata"

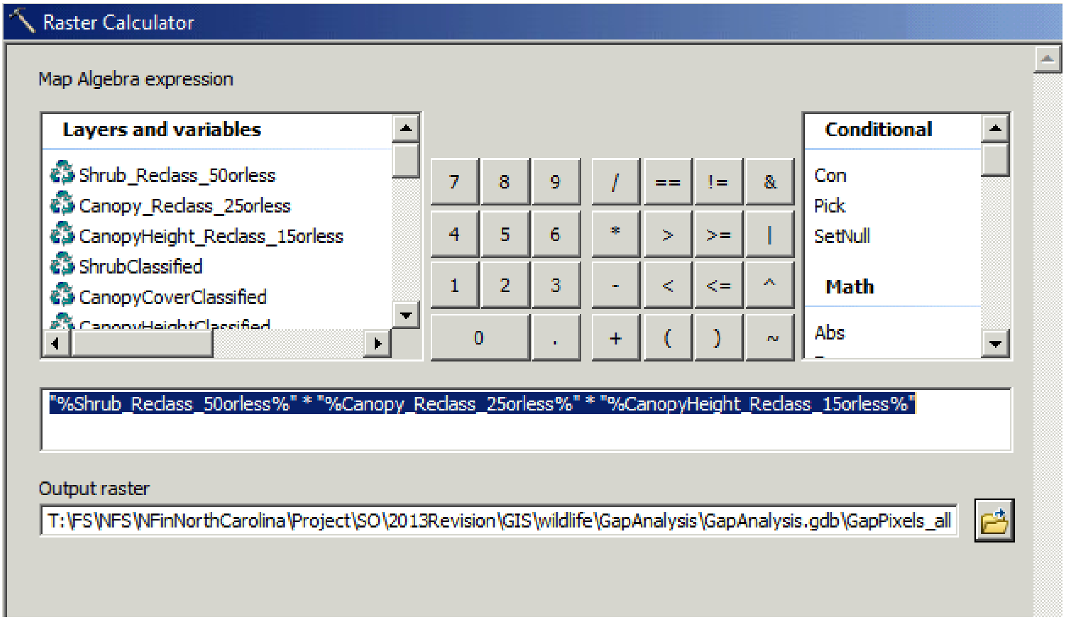


4. Also while reclassifying the base datasets, we went ahead and reclassified the Ecozones ("Ecozones_lumped_rs" from Mark E's original data) to have the following values (this comes in handy down in Step 5):

100	Spruce-fir
200	Northern Hardwood Slope
300	High Elevation Red Oak
400	Acidic Cove
500	Rich Cove
600	Montane Oak-Hickory Slope
700	Dry Mesic Oak
800	Dry Oak Evergreen and Deciduous Heath
900	Pine-Oak Heath
1000	Low Elevation Pine Shrub
1100	Montane Alluvial and Large Floodplain
1200	Grassy Bald
1300	Health Bald
1400	Reservoirs and Lakes and Ponds

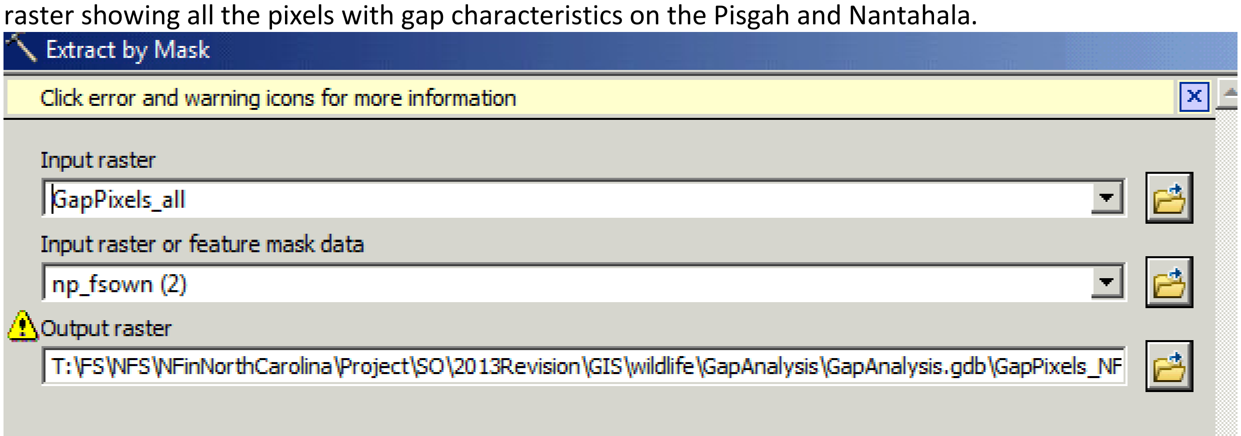
STEP 2: Create a new raster that combined height, canopy cover, and shrub density to identify every pixel on the landscape that has characteristics of a gap.

To do that, I combined these three layers using Raster Calculator, which multiplied the values together so that all gaps received a value of either 1 or NoData. This output is called "GapPixels_all"



Step 3: Clipped the gap pixels to NFS lands.

Used "Extract By Mask" command to do this (can use a polygon to clip a raster!) So the result was a raster showing all the pixels with gap characteristics on the Pisgah and Nantahala.

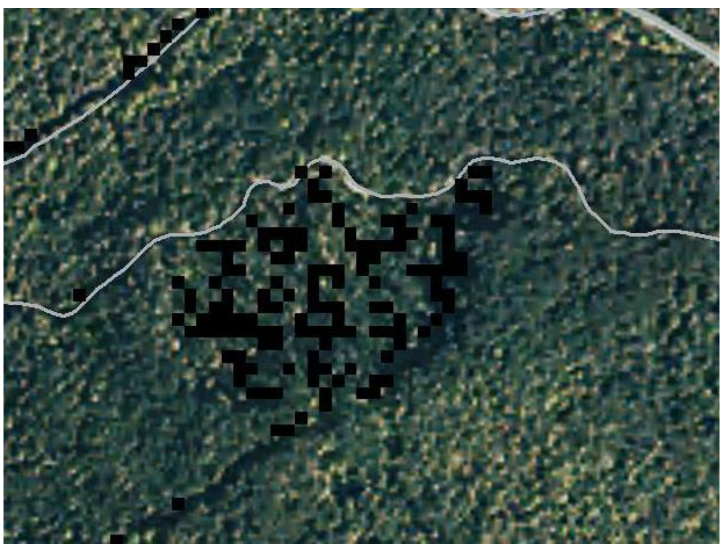


Step 4: Aggregate the gap pixels to allow for better identification of ecologically functional patches.

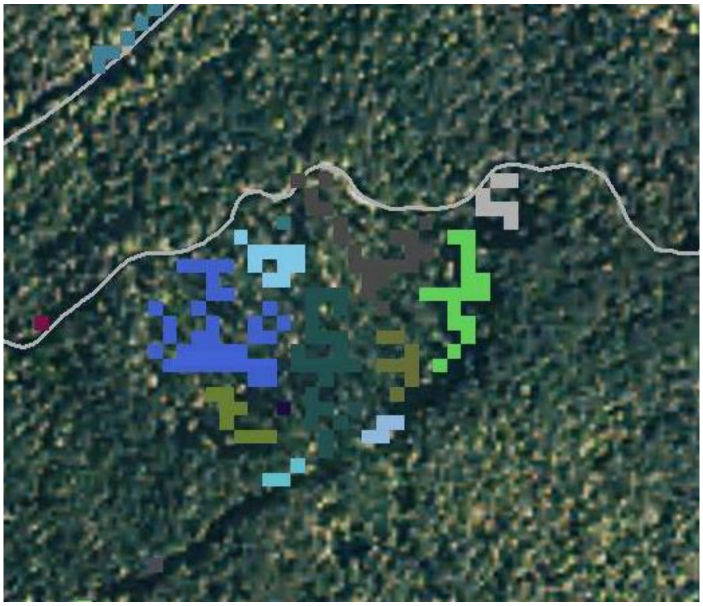
This step got added in after we looked at what happened without it, and saw that there were a lot of patches being identified as separate, that really functionally were all one patch. For example:

Look at this sample area-- a harvest unit that looks like one unit.

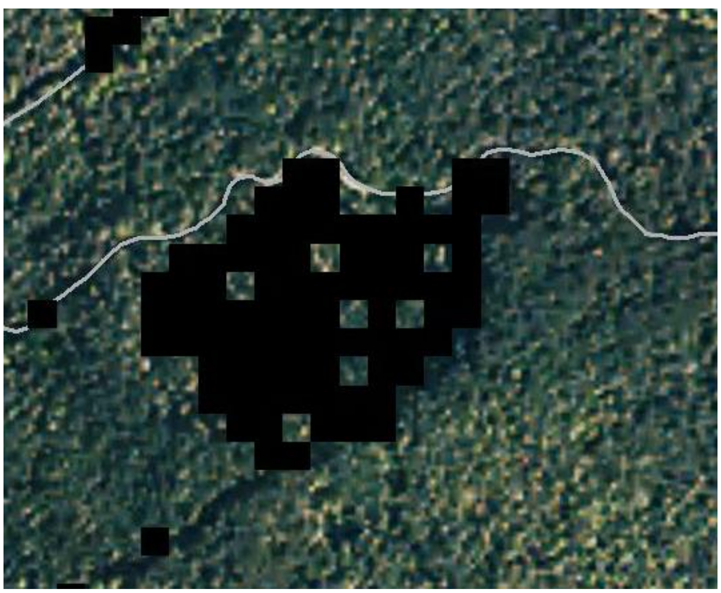
Our first cut at identifying gap pixels showed us the reality, which is that there is some variation in the unit:



But under this scenario, when we identify patches, this would result in several different patches, broken apart where pixels aren't touching one another (each color below is a separate patch).

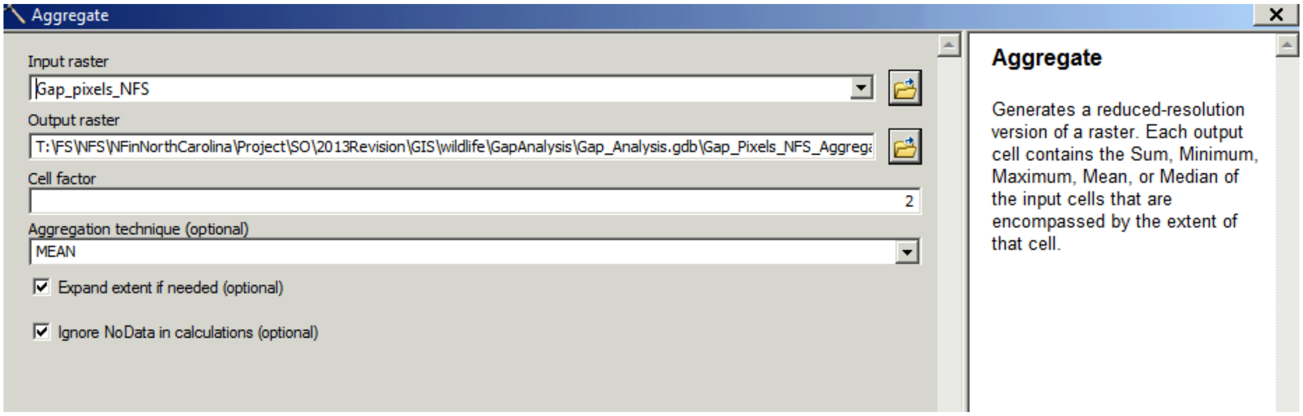


By using the aggregate tool, we were able to reduce the resolution of the pixels by a factor of 2, and then look to see if the majority of new pixel was previously identified as a gap or not. If so, the new pixel was considered gap, and if not, it wasn't.

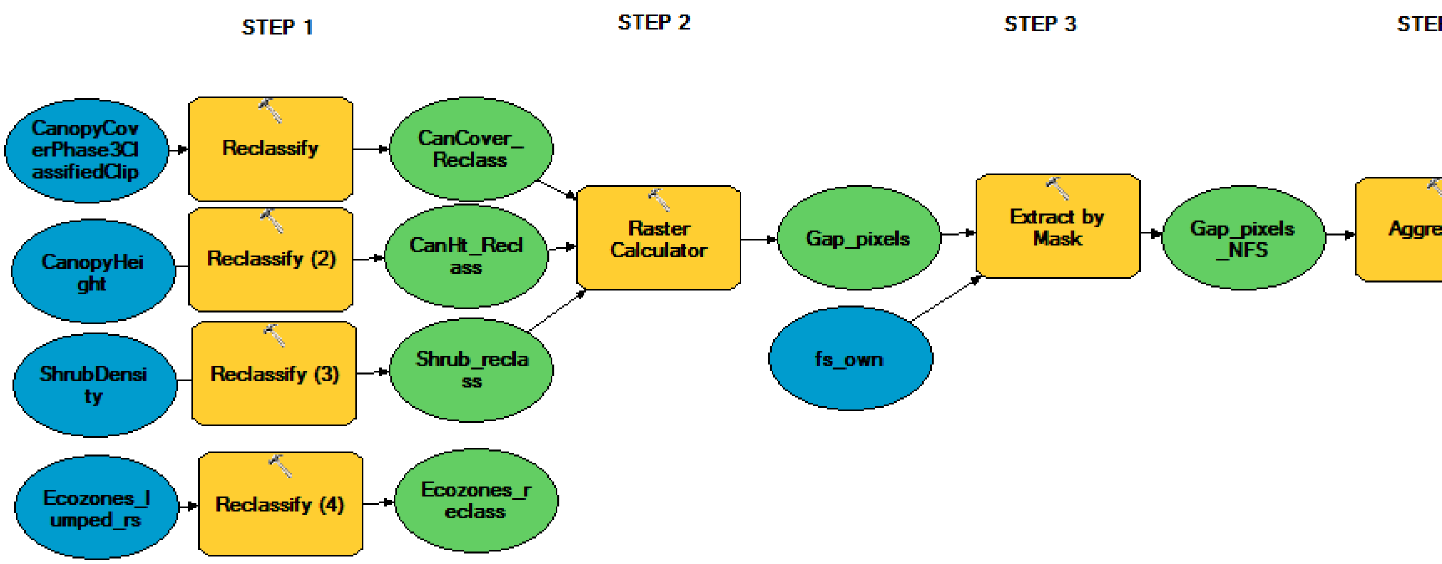


Now this big blob will show up as one large patch in step 5 below, and will allow for more meaningful ecological identification of the gap patches.

The following shows the model input to perform the aggregation. The cell factor of 2 changes our pixel size from a 40'x40' pixel to an 80'x80' pixel.

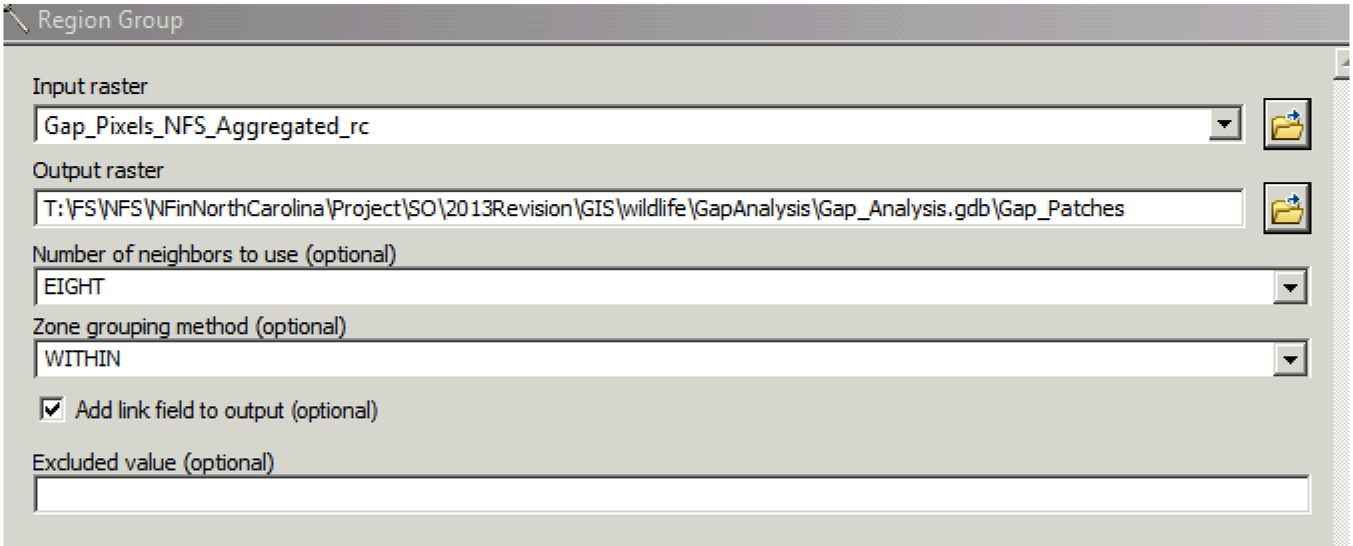


Steps 1-4 are represented in the following model (called "Step_1_2_3_4" in GapAnalysis_NP.tbx (Toolbox) located here: T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis)



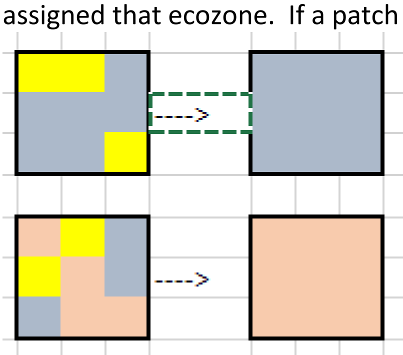
Step 5: Identify patches from the pixels.

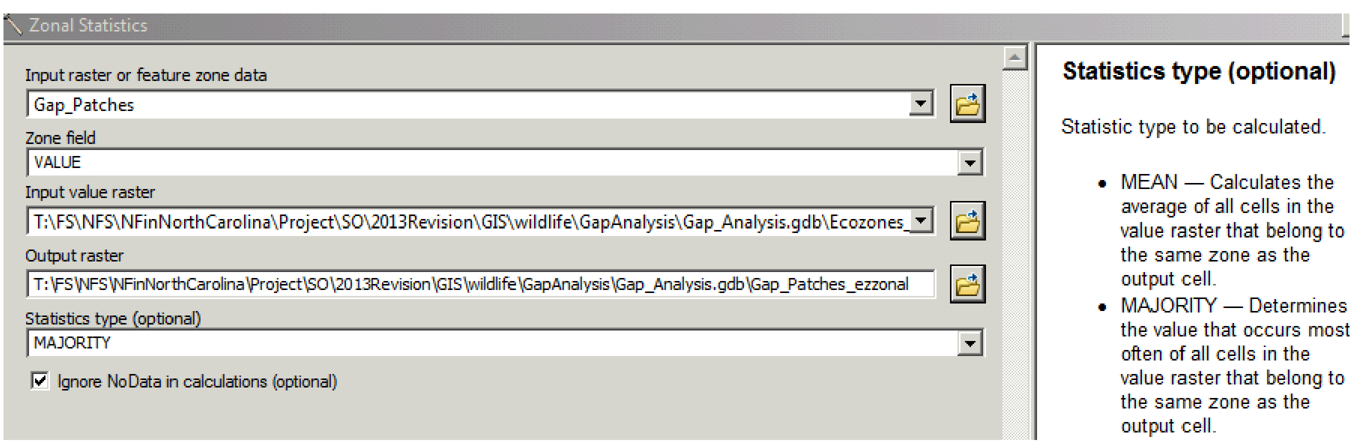
Group all gap pixels together into patches, based on whether they were touching on at least one side or corner



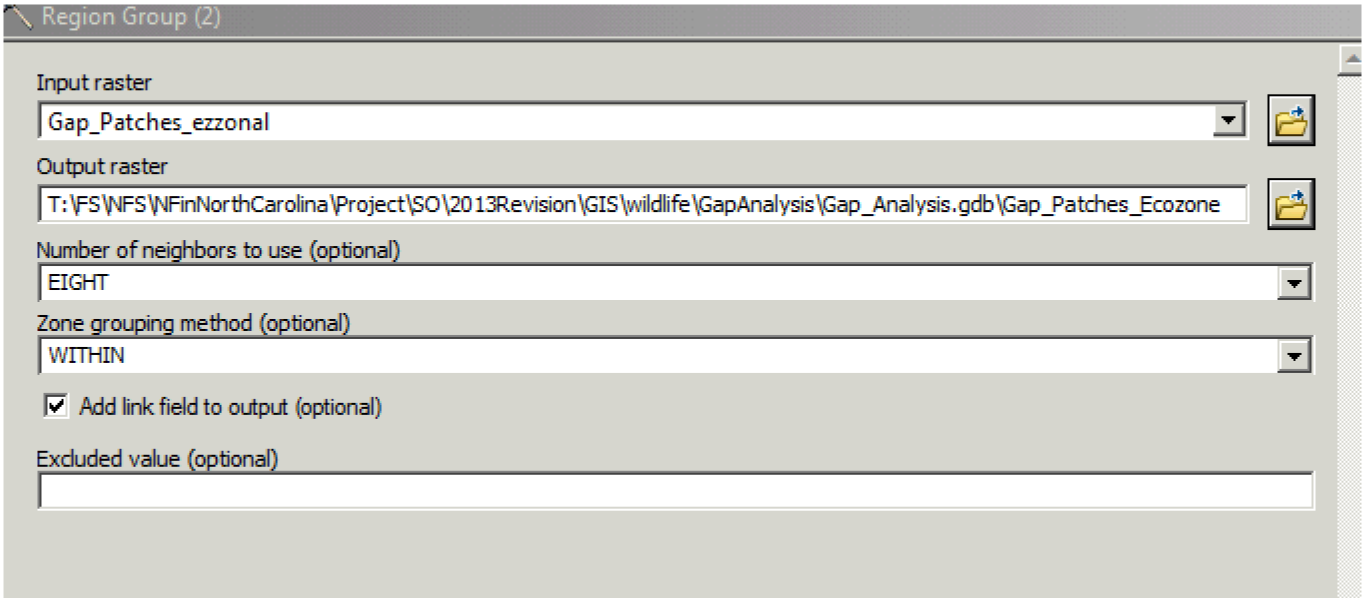
Step 6: Identify which ecozone the patch is primarily in.

Then we had to break out patches based on what ecozone the majority of pixels in that patch were. To do this, we used a tool called "Zonal Statistics." This step used the Gap Patches that we created in Step 5, and looked to see which Ecozone(s) those patches were in. If a patch was all in one ecozone, it was assigned that ecozone. If a patch overlapped two or more ecozones, we chose the MAJORITY ecozone.

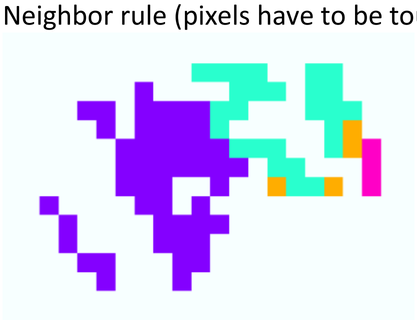


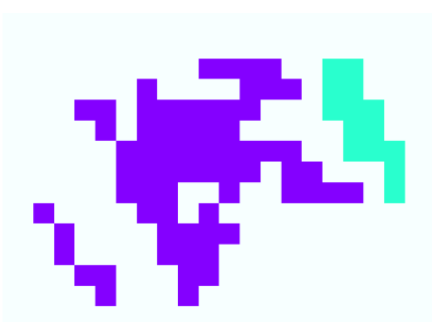


Step 7: Group patches of similar ecozone together as one.

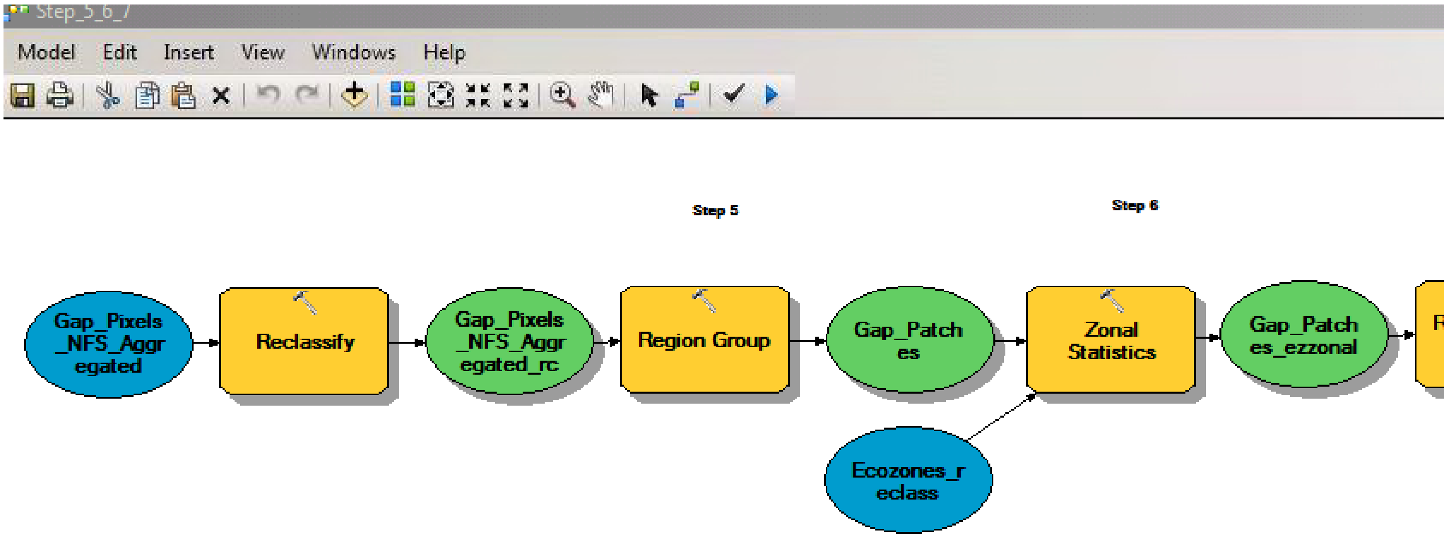


Example: This shows multiple ecozones within the same patch (above), which were aggregated into patches based on the majority ecozone. Three patches total were created, based on the Eight Neighbor rule (pixels have to be touching on a side or corner to be considered the same patch).



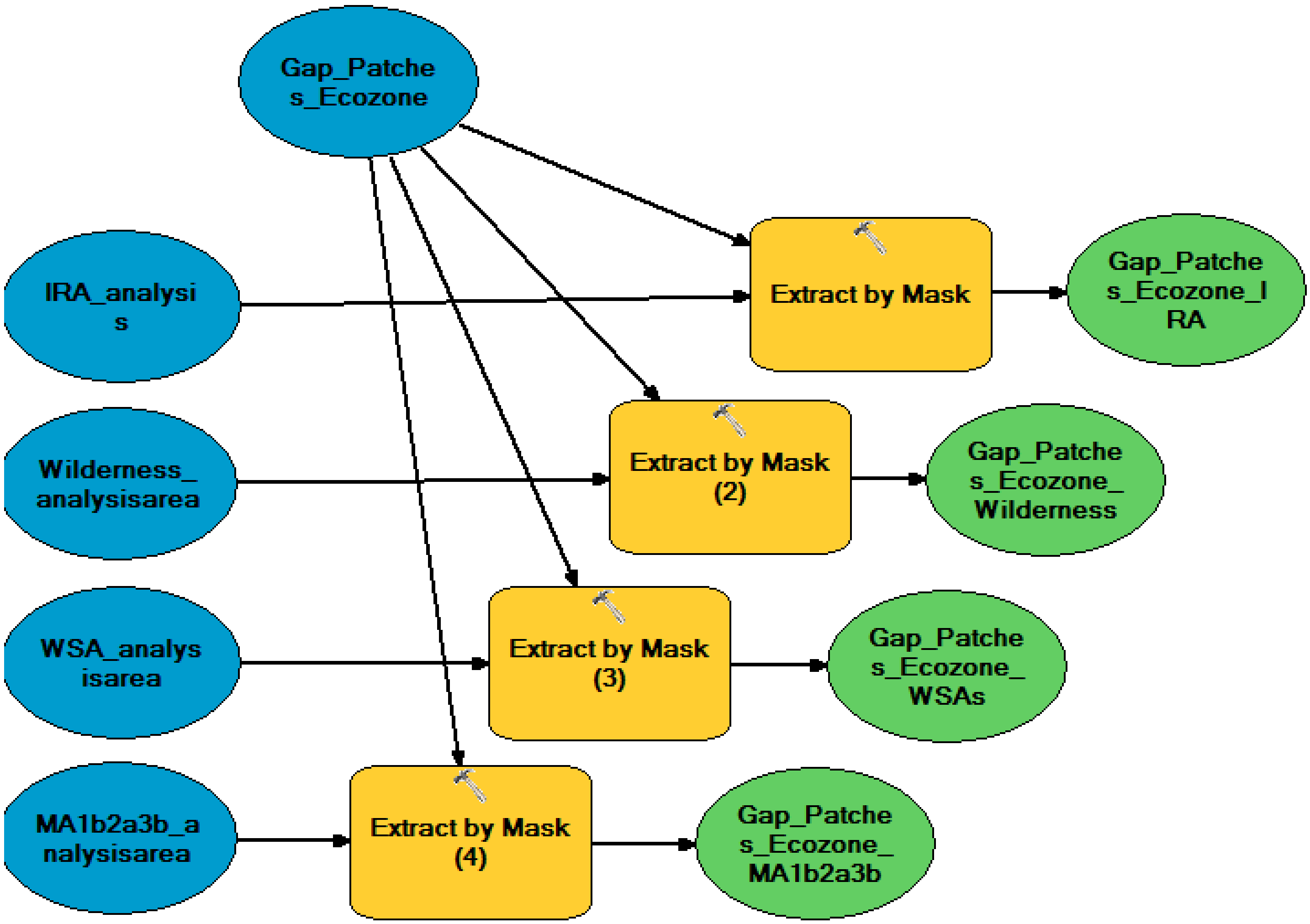


The model for steps 5-7 looks like this and is saved in the same toolbox referenced above.



Step 9-- Clip the gap patches to different management areas (wilderness, WSAs, IRAs, MA1 only, and MA 1-3).

After doing this, export all the attribute tables to .dbf files, then open in Excel to start calculating totals, frequency, etc



STEP 9. Calculated Acres, Exported to Excel for further analysis.

Opened the attribute tables and added a column called "Acres" (which the type was 'float') and then right-clicked to do a Field Calculator where Acres= Count * (6400/42560). Rationale for this equation:

Which is derived from the cell size (80'x80' or 6400 sq ft) divided by the square feet in an acre (43560 sq ft).

Acres= xx pixels x 80’x80’ (6400 sq ft)/pixel x 1 ac/42,560 sq ft

STEP 10. Convert to Polygon

** Need help figuring out how to do this, because when I do, it creates more polygons than I want, splitting out anything that's touching on a corner, whereas the raster will keep those together as a patch.

ESH Analysis

Thursday, March 17, 2016 12:45 PM

STEP 1: Classify vegetation datasets to select the attributes we want.

We're defining ESH in two classes:

ESH Moderate= Tree Height <15' and Canopy 25-60%

ESH Dense= Tree Height <15' and Canopy 60%+

1. "Canopy Cover Phase 3 Classified" raster (from Mark E's data) , add field 'reclass' and reclassified to have anything 25-60% canopy be a 1, 60-100% is a 2, and <25% is a "No Data"

2. "Canopy Height " raster , add field 'reclass' and reclassified to have anything 15' height or less be a 1, and everything else "nodata"

3. Also while reclassifying the base datasets, we went ahead and reclassified the Ecozones ("Ecozones_lumped_rs" from Mark E's original data) to have the following values (this comes in handy down in Step 5):

100	Spruce-fir
200	Northern Hardwood Slope
300	High Elevation Red Oak
400	Acidic Cove
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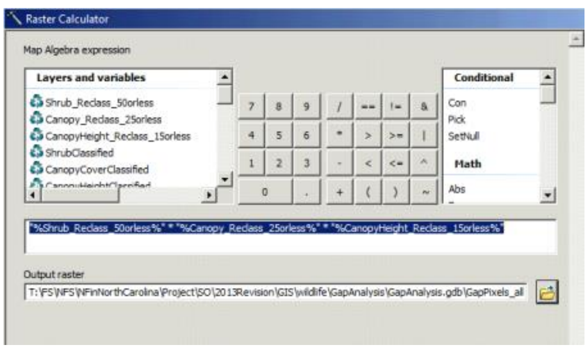
700	Dry Mesic Oak
800	Dry Oak Evergreen and Deciduous Heath
900	Pine-Oak Heath
1000	Low Elevation Pine Shrub
1100	Montane Alluvial and Large Floodplain
1200	Grassy Bald
1300	Health Bald
1400	Reservoirs and Lakes and Ponds

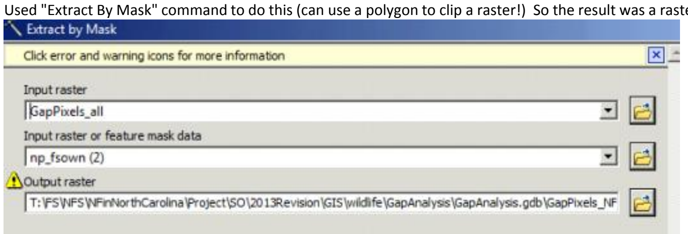
STEP 2: Create a new raster that combined height & canopy cover to identify every pixel on the landscape that has characteristics of ESH.

To do that, I combined the layers using Raster Calculator, which multiplied the values together so that all gaps received a value of either 1,2 or NoData. This output is called "esh_pixels"



Step 3: Clipped the gap pixels to NFS lands.

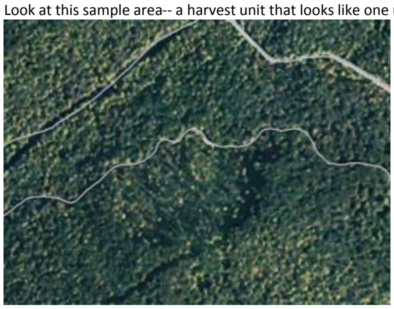
Used "Extract By Mask" command to do this (can use a polygon to clip a raster!) So the result was a raster showing all the pixels with gap characteristics on the Pisgah and Nantahala.



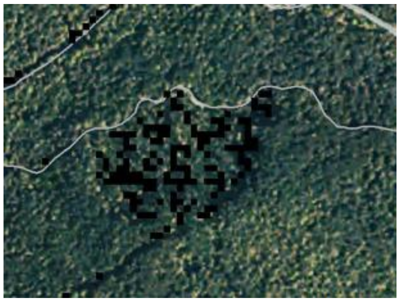
Step 4: Aggregate the gap pixels to allow for better identification of ecologically functional patches.

This step got added in after we looked at what happened without it, and saw that there were a lot of patches being idetnified as separate, that really functionally were all one patch. For example:

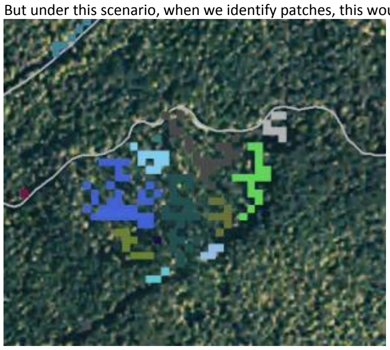
Look at this sample area-- a harvest unit that looks like one unit.



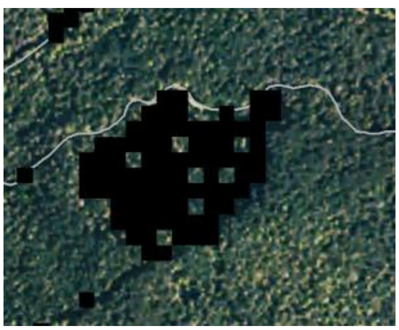
Our first cut at identifying gap pixels showed us the reality, which is that there is some variation in the unit:



But under this scenario, when we identify patches, this would result in several different patches, broken apart where pixelsaren't touching one another (each color below is a separate patch).

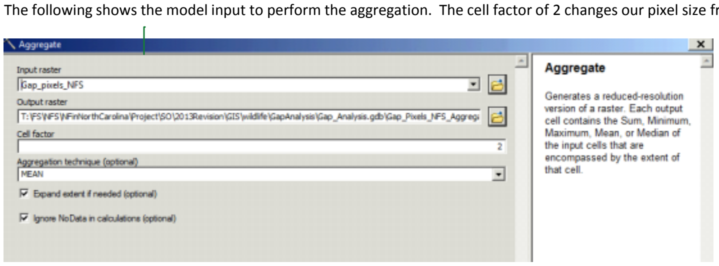


By using the aggregate tool, we were able to reduce the resolution of the pixels by a factor of 2, and then look to see if the majority of new pixel was previously identified as a gap or not. If so, the new pixel was considered gap, and if not, it wasn't.

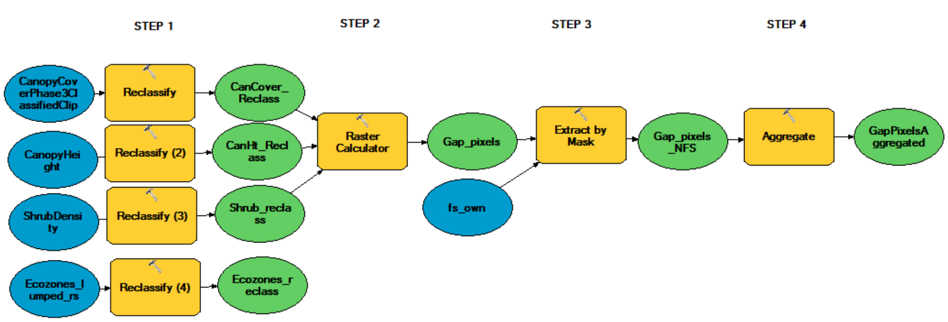


Now this big blob will show up as one large patch in step 5 below, and will allow for more meaningful ecological identification of the gap patches.

The following shows the model input to perform the aggregation. The cell factor of 2 changes our pixel size from a 40'x40' pixel to an 80'x80' pixel.

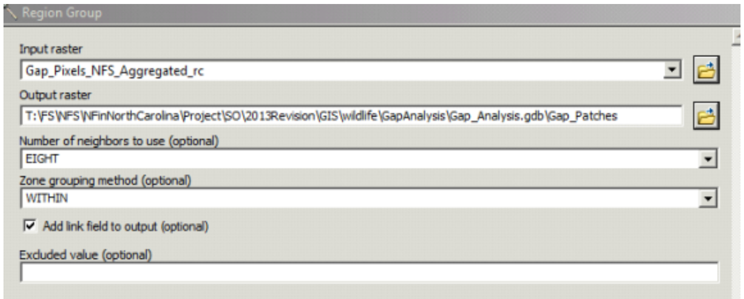


Steps 1-4 are represented in the following model (called "Step_1_2_3_4" in ESH_Analysis.tbx (Toolbox) located here: T:\FS\NFS\NFinNorthCarolina\Project\SO\2013Revision\GIS\wildlife\GapAnalysis)



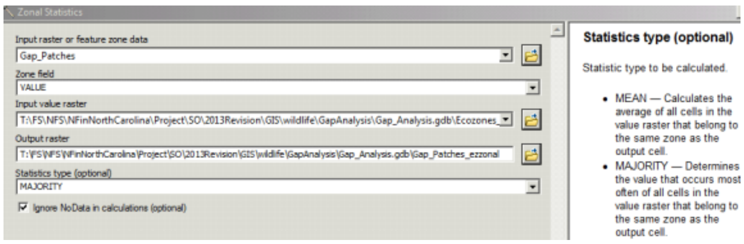
Step 5: Identify patches from the pixels.

Group all gap pixels together into patches, based on whether they were touching on at least one side or corner

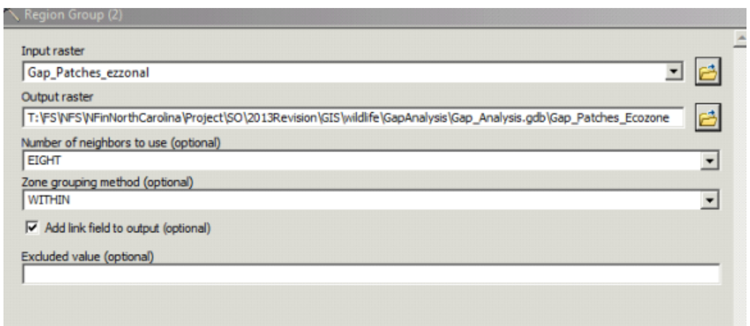


Step 6: Identify which ecozone the patch is primarily in.

Then we had to break out patches based on what ecozone the majority of pixels in that patch were. To do this, we used a toolcalled "Zonal Statistics"

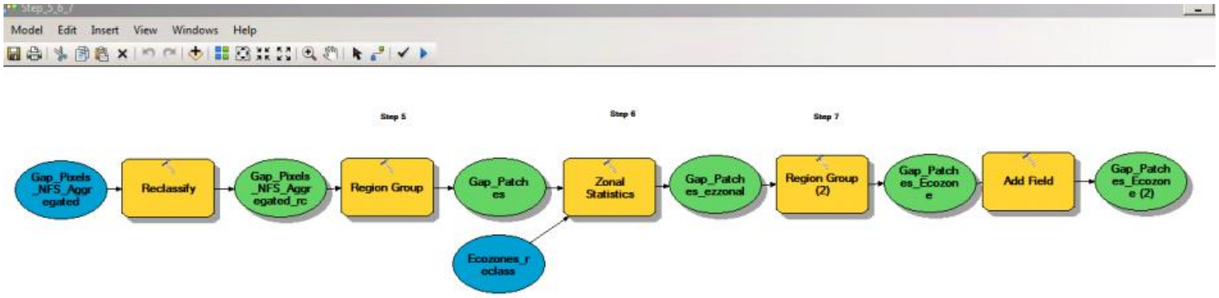


Step 7: Group patches of similar ecozone together as one.



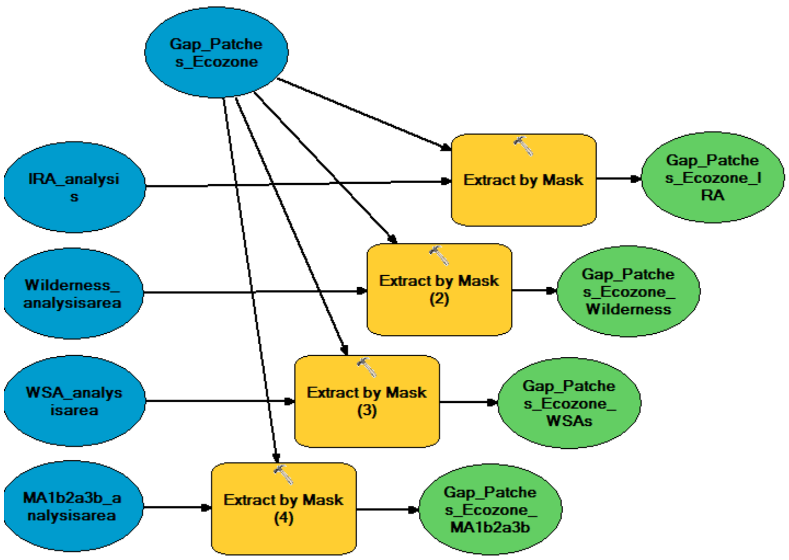
Example: This shows multiple ecozones within the same patch (above), which were aggregated into patches based on the majority ecozone. Three patches total were created, based on the Eight Neighbor rule (pixels have to be touching on a side or corner to be considered the same patch).

The model for steps 5-7 looks like this and is saved in the same toolbox referenced above.



Step 9-- Clip the gap patches to different management areas (wilderness, WSAs, IRAs, MA1 only, and MA 1-3).

After doing this, export all the attribute tables to .dbf files, then open in Excel to start calculating totals, frequency, etc



STEP 9. Calculated Acres, Exported to Excel for further analysis.

Opened the attribute tables and added a column called "Acres" (which the type was 'float') and then right-clicked to do a Field Calculator where Acres= Count * (6400/42560). Rationale for this equation:

Which is derived from the cell size (80'x80' or 6400 sq ft) divided by the square feet in an acre (43560 sq ft).

Acres= xx pixels x 80'x80' (6400 sq ft)/pixel x 1 ac/42,560 sq ft

Results

A total of 30