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OBJECT-BASED SEGMENTATION AND CLASSIFICATION  
OF ONE METER IMAGERY FOR USE IN  
FOREST MANAGEMENT PLANS

by

W. Kevin Wells

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

in

Geography

(Geographic Information Systems/Remote Sensing)

Approved:

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UTAH STATE UNIVERSITY  
Logan Utah

2010

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## ABSTRACT

Object-based Segmentation and Classification of One-  
Meter Imagery for Use in Forest Management Plans

by

W. Kevin Wells, Master of Science

Utah State University, 2010

Major Professor: Dr. R. Douglas Ramsey  
Department: Wildland Resources

This research developed an ArcGIS Python model that extracts polygons from aerial imagery and assigns each polygon a vegetation type based on a modified set of landcover classes from the Southwest Regional Gap Analysis Project. The model showed an ability to generate polygons that accurately represent vegetation community boundaries across a large landscape. The model is for use by the Utah Division of Forestry, Fire, and State Lands to assist in the preparation of forest management plans. The model was judged useful because it was easy to use, it met a designated 50% threshold of useable polygons, and it met a designated 50% threshold of vegetation class assignment accuracy.

(56 pages)

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I thank my employer, the Utah Division of Forestry, Fire, and State Lands, for allowing me to pursue this degree in conjunction with my work assignments. I thank them for the initial tuition payments that allowed me to pursue this degree. I hope that the knowledge and skills I have obtained will return benefits to the Division exceeding the investment made in me.

I thank my wife, Valerie, for her kindness and patience. The completion of this degree took longer than originally planned. Although my pursuit of this degree increased her burdens, she remained kind and supportive.

W. Kevin Wells

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## BACKGROUND

There is a need for an automated process to develop vegetation landcover maps at a scale appropriate for use in forest management plans within the Utah Division of Forestry, Fire and State Lands (Division). Currently Division foresters use digital aerial photographs and geographic information systems (GIS) to manually digitize polygons around vegetation communities for inclusion in management plans. The polygons are assigned a landcover class by the forester; e.g., aspen, spruce-fir, etc. This workflow can be difficult and time consuming for foresters who use GIS infrequently. This process can be automated and standardized using consistent inputs coupled with digital image processing algorithms, thereby becoming easier to implement, requiring less time, and providing an output that is repeatable and useful in the preparation of forest management plans.

In order to successfully meet the needs of land managers, the model developed here must meet three criteria. First, the model must be easy to use. Second, the model must segment an aerial image into polygons of vegetation types at a scale useable in forest management plans. Third, the vegetation types assigned to the segmented polygons must be accurate. Advancements in image segmentation and GIS tools plus the ready availability of high resolution aerial imagery make the creation of such a model feasible.

Many different digital image segmentation and classification methods have been developed over the years. For reviews of image segmenting algorithms see Pal and Pal (1993), Skarbek and Koschan (1994), Egmont-Petersen et al. (2001), and Zhang et al. (2007). Image segmentation algorithms can be divided into two generic types: 1) pixel-based classification and 2) object-oriented classification. I focus my work on the latter

type. More specifically, I wish to segment imagery into the various contextual components, or objects, that make up a given landscape.

Pixel-based classifications focus primarily on the spectral properties of pixels, often combined with ancillary data to provide geographic context. These classification methods were developed at a time when image spatial resolution was too coarse to detect individual features on a given landscape.

Object-oriented classifications focus on groups of pixels that constitute an “object” in the image. In the context of this study, a meadow or a stand of conifers are two examples of vegetation objects. Object-oriented classification is a relatively new class of algorithms that have been developed to focus not only on the spectral properties of features, but also their shape, orientation, and adjacency to other features. These classifiers are generally termed feature extraction or object-oriented classifiers. Object-based image analysis (OBIA) is an emerging field (Lang and Blaschke 2006) that seeks to extract complex information from remotely sensed images. Hay and Castilla (2006) propose that OBIA be considered a sub-discipline of GIScience. This sub-discipline is referred to as GEOBIA. On August 6-7, 2008 the University of Calgary hosted the first ever conference on this sub-discipline that uses the new name (GEOBIA 2008).

Castilla (2004) and Castilla et al. (2007) describe two very similar object based segmentation workflows that create polygon output around vegetation objects in aerial imagery. The workflows contained these steps.

- Apply a smoothing algorithm to an aerial image to reduce inter-pixel variance thereby increasing homogeneity within vegetation type objects.

- Use Euclidean distance or another distance measure to calculate dissimilarity between vegetation objects creating a raster that is a gradient of the dissimilarity.
- Apply a partitioning algorithm to segment the image into individual objects.
- Vectorize the image to create polygons that represent vegetation objects.

This research seeks to develop a computer model that meets the needs of Division foresters to derive a vegetation data layer from aerial imagery for use in forest management plans. It will use as inputs the readily available one meter 2006 aerial imagery from the National Agricultural Imagery Program (NAIP) and landcover classes from the Southwest Regional Gap Analysis Project (SWReGAP) (USGS National Gap Analysis Program 2004). In essence, the model will extrapolate SWReGAP land cover classes to a finer scale making them useful in Division forest management plans.

## THE RESEARCH PROBLEM

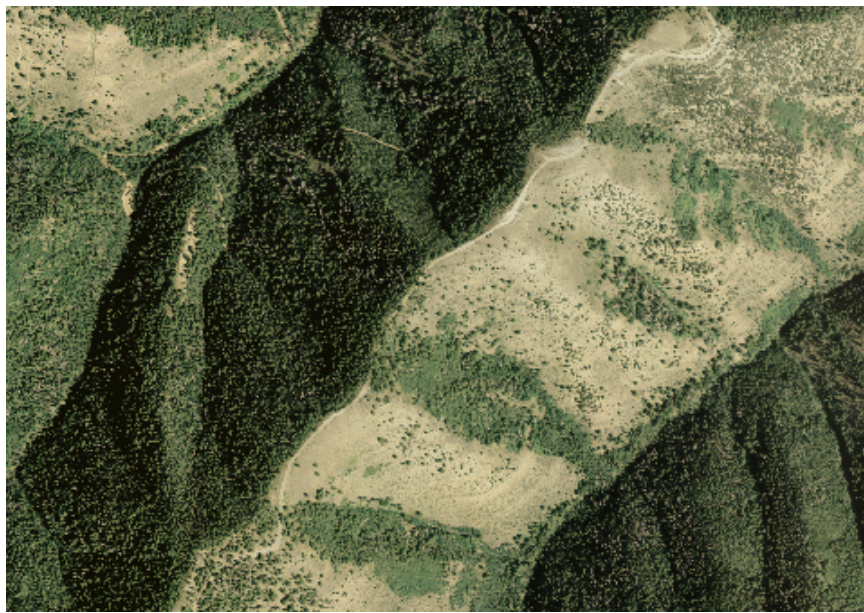
Humans can readily discern vegetation patterns in remotely sensed imagery and can draw polygons around vegetation types. Transferring this ability to a computerized system consisting of statistical and object-oriented classification algorithms has been a major thrust in remote sensing research for many years. Blaschke (2010) reviews pixel-based and object-based efforts to identify objects from remotely sensed data over the last few decades with special emphasis on object-oriented methods of the current decade. Pixel-based classification workflows do not easily partition landscapes into logical forest stands or community types when using fine resolution imagery.

Consider the aerial photograph in Figure 1. A typical human analyst can readily identify and combine the various landscape components into a small set of logical categories. If the mapping objective is to identify areas of similar cover, the human analyst can easily filter out the individual trees or shrubs and place them in the context of a community. Pixel-based classification systems are, by design, focused on individual pixels and cannot innately combine individuals into a larger context.

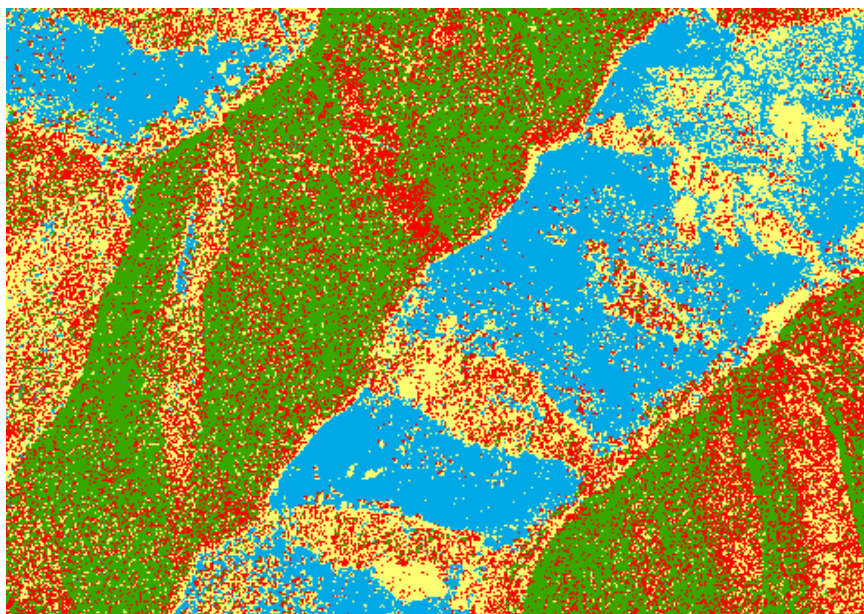
The output for a pixel-based classification algorithm of the same area is shown in Figure 2. In this example, the clustering and classification algorithm generated four clusters which correspond to a simple segmentation of landscape components. The end result has a salt and pepper look to it with each pixel assigned to one of the four classes without considering the relationships between pixels.

The problem for this project then is how to create a relatively simple, automated process that segments high-resolution imagery into vegetation types based not upon

individual pixels but upon the larger vegetation objects within an image, i.e. a stand of trees.



**Figure 1. Aerial photograph of mountain area.**



**Figure 2. Salt and pepper effect of pixel-based classification.**

## **Objective and Thesis Statement**

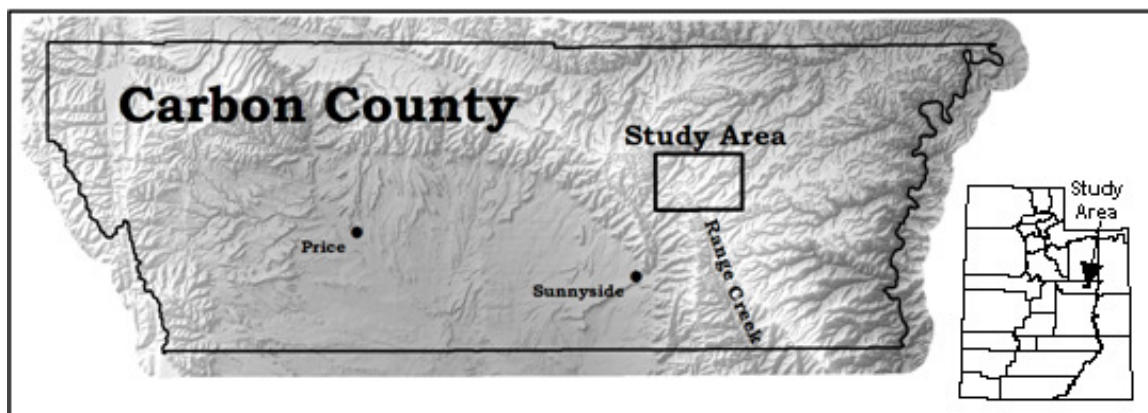
The objective of this research is to develop a model useful to Division foresters in the development of forest management plans that automatically segments 1-meter aerial imagery into polygons representing vegetation types and assigns each polygon a vegetation type. This objective can be stated as a research question: Can a GIS model be created that is easy to use and that automatically and accurately segments aerial imagery into a vegetation data layer that would be useable in forest management plans?

## **The Study Area**

Data covering an 18,000 acre area of state, private, and Bureau of Land Management land near Range Creek on the West Tavaputs Plateau of Carbon County, Utah was used to develop the model. See Figure 3 for a map showing the location of the study area.

This area is delineated by the USGS Bruin Point SE and Bruin Point SW quarter quadrangles (3.75' x 3.75' of latitude and longitude). The area is mountainous, forested and undeveloped. Human alteration within the study area includes dirt roads, fence lines, communication towers, and a few buildings.

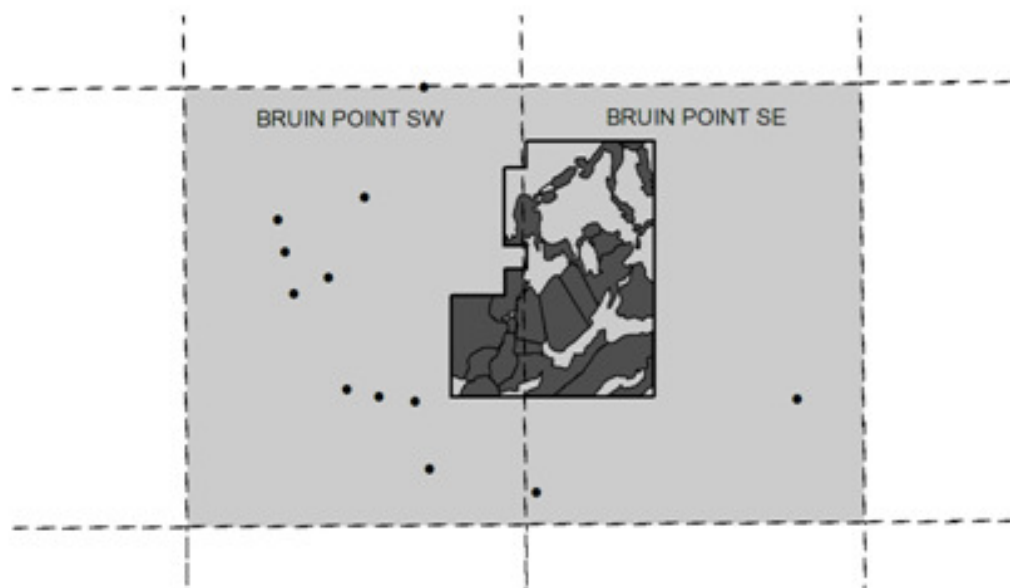
Within the study area is the 2,600 acre Cold Spring Property owned by the Utah Division of Wildlife Resources. During 2007 the Utah Division of Forestry, Fire and State Lands created a Forest Stewardship Plan for the Cold Spring property (Conlin 2007). The Cold Spring property is characteristic of the entire study area. The management plan describes the area as having a diverse topography of deep canyons, ridge lines, and gentle sloping areas, with general vegetation cover of forests and



**Figure 3. Location of study area.**

sagebrush steppe meadows. Tree species include quaking aspen (*Populus tremuloides* Michx.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), subalpine fir (*Abies lasiocarpa* Nutt.), and Engelmann spruce (*Picea engelmannii* Parry ex Engelm.). Shrubland cover primarily consists of sagebrush (*Artemisia tridentata* Nutt. *ssp. vaseyana*). There are several riparian areas adjacent to creeks and springs.

Reference data in the study area are the digitized forest stands of the Cold Spring Forest Stewardship Plan and 14 SWReGAP ground training data points (Figure 4).



**Figure 4. Reference data in study area.**



## METHODS

### **Data Inputs**

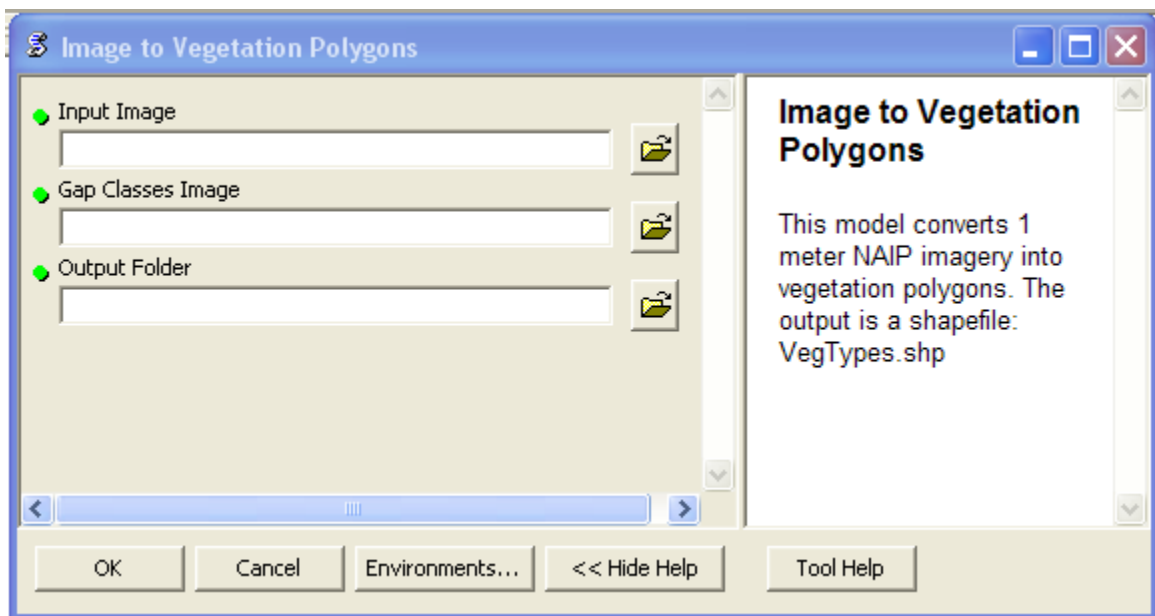
The primary inputs were two spatial data layers. The first was one meter resolution NAIP aerial imagery collected in 2006 and obtained from the Utah Automated Geographic Reference Center. The images were used as delivered with no additional processing applied. The second primary data layer was the statewide, general land cover map produced by the Southwestern Gap Analysis project (SWReGAP) (Lowry et al. 2006 and Lowery et al. 2007). The SWReGAP land cover map identified 80 individual natural land cover classes within Utah. These 80 classes were combined into 18 general classes to better represent the level of detail used in forest management plans. The 18 land cover classes for this study are 1) Mixed Conifer, 2) Spruce-Fir, 3) Lodgepole Pine, 4) Ponderosa Pine, 5) Limber-Bristlecone Pine, 6) Pinyon-Juniper, 7) Aspen, 8) Aspen-Mixed Conifer, 9) Bigtooth Maple, 10) Gambel Oak, 11) Mountain Mahogany, 12) Riparian Woodland, 13) Brush-Shrubs, 14) Grass-Forbs, 15) Agriculture, 16) Developed, 17) Water, and 18) Non-vegetated. Appendix A lists the 18 land cover classes with the SWReGAP classes they were derived from.

### **Model Development**

The model was created as a Python script compatible with ArcGIS™ software which is used by the state of Utah. The model uses several ArcGIS spatial data processing tools as well as image processing subroutines of the Python Imaging Library (PIL). The Python code of the model is given in Appendix B. The model consists of 9 steps.

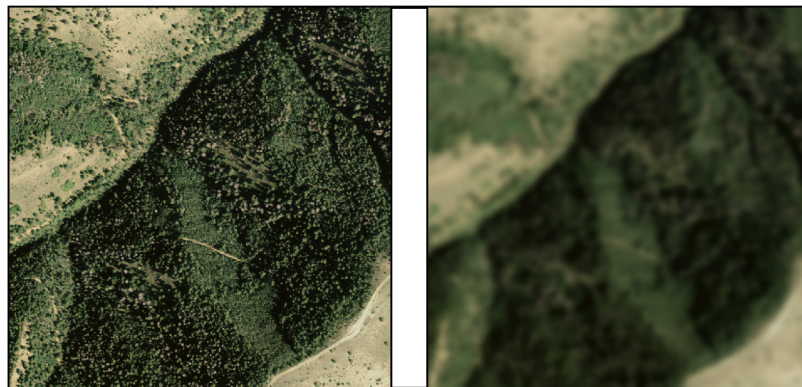
Step 1 establishes access to the input data. This is accomplished through ArcGIS's model interface that prompts the user to identify model inputs. Three inputs are required: the location of the input image (e.g. NAIP image), the location of the vegetation class layer (e.g. SWReGap), and the location of an output folder (Figure 5).

Step 2 extracts the equivalent geographic area of the input image to be segmented from the existing, coarser resolution vegetation layer and identifies the individual land cover classes contained in the subset land cover map. The number of vegetation classes is the number of segmentation types the model will use in the subsequent step. This subset of the statewide vegetation map will also be used to label polygons extracted from the high-resolution image.

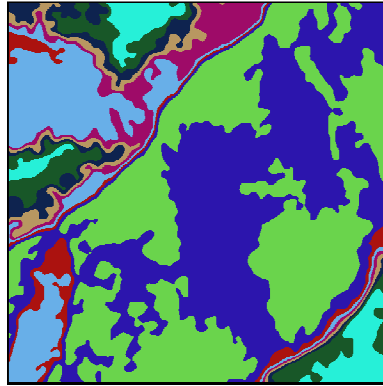


**Figure 5. Input dialog.**

Step 3 processes the image to accentuate the objects in the image. This is one of the most important steps of the model. It is this step that focuses the model on the objects within the image rather than on individual pixels. The model uses a blur filter to repeatedly blur the image in 20 different iterations. The effect is greater uniformity within vegetation objects and an increase in the contrast between vegetation object boundaries (Figure 6). The final operation of step three uses the “slice” tool in the ArcGIS tools library to segment the image into preliminary classes defined by the clipped SWReGap land cover map and uses natural breaks in the data (Figure 7). During development it was determined that this initial segmentation was best if the same number of SWReGap classes was used instead of more classes with the idea of merging later because it proved to be a shorter route to the same results.



**Figure 6. Repeated blur effect.**



**Figure 7. Slice tool effect.**

Step 4 merges objects of less than 10 acres into adjacent objects. Ten acres was chosen because areas less than this are not commonly delineated for forest management plans. Future editions of the model will have this as a parameter that the user can specify. This merging is accomplished in three intermediate steps of increasing minimum sizes. The intermediate approach allows smaller areas to merge and become an object larger than the minimum threshold without being eliminated in a single merge step. This procedure protects unique and possibly important areas within the image. Input units use the English system in order to relate to the target user. All units are converted to metric to correspond to measurement units used by the geospatial data.

Step 5 creates polygons by converting the segmented raster data into a vector shapefile. The polygons are preliminary polygons needing further refinement.

Step 6 reduces the number of exceedingly large polygons that consist of several areas connected by long, thin corridors not suited for use in forest management plans (Figure 8). This is accomplished by creating a three-meter buffer on both sides of the preliminary polygons' boundary lines, using the buffer as a mask to extract from the



**Figure 8. Example of exceedingly large polygon.**

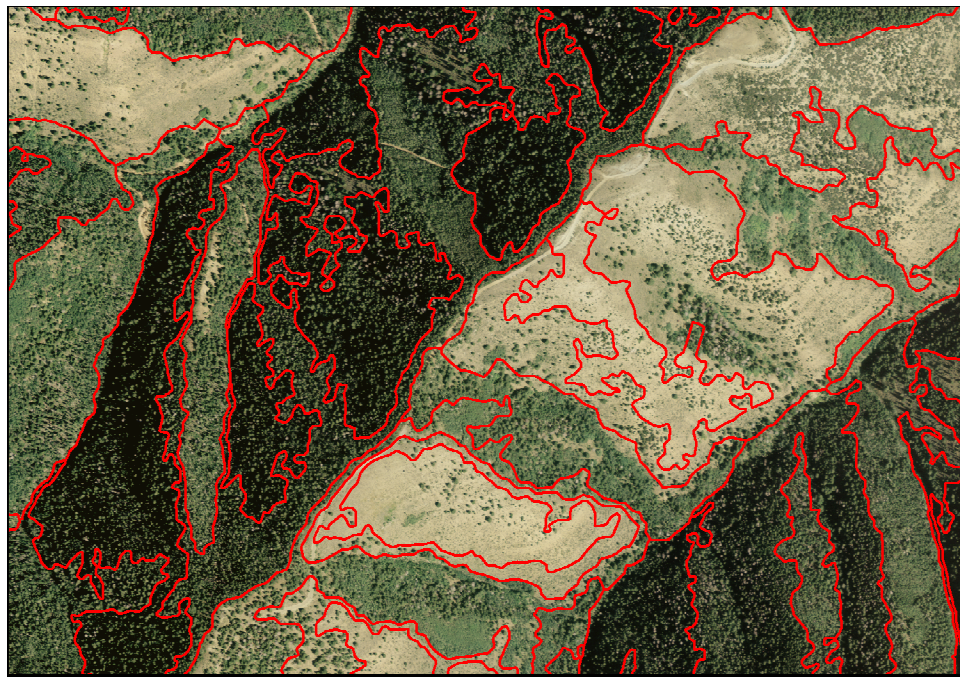
raster everything not within the buffer, then expanding all the classes to fill in the blank areas created by the buffer. This step also creates distinct boundaries between classes.

Step 7 tests for and removes tiny artifact polygons that sometimes are created during step six. These are minute polygons likely formed from a line that looped itself. They are removed by eliminating any polygon with an area of less than one square meter.

Step 8 assigns vegetation types and names to each polygon by intersecting the vector output of Step 7 with the raster layer extracted from the SWReGap land cover map. The model assigns to a polygon the land cover class having the largest association with the polygon based upon a simple overlay. This means that polygons in the same

preliminary segmented class of Step 3 may be assigned to different vegetation classes in this step based upon the overlay. This also allows for adjacent polygons, initially identified as different, to be assigned the same land cover class.

Step 9 creates an output shapefile named “VegTypes” which can be further modified if needed (Figure 9).

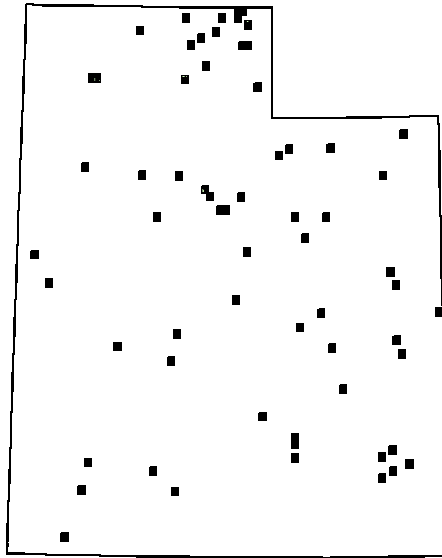


**Figure 9. Example of model’s polygon output.**

## Testing the Model

Three questions need to be answered to determine if the model is useful for its intended purpose. First, is the model easy to use? Second, do the model-generated polygons represent vegetation types in a manner useable in a forest management plan? Third, are the vegetation class assignments accurate?

To generate data to answer these questions 64 individual quarter quadrangles tiles of 2006 NAIP imagery were selected across the state (Figure 10). Each image needed at least one SWReGAP ground reference site within the area covered by the image to be selected. The model was run for each of the 64 images.



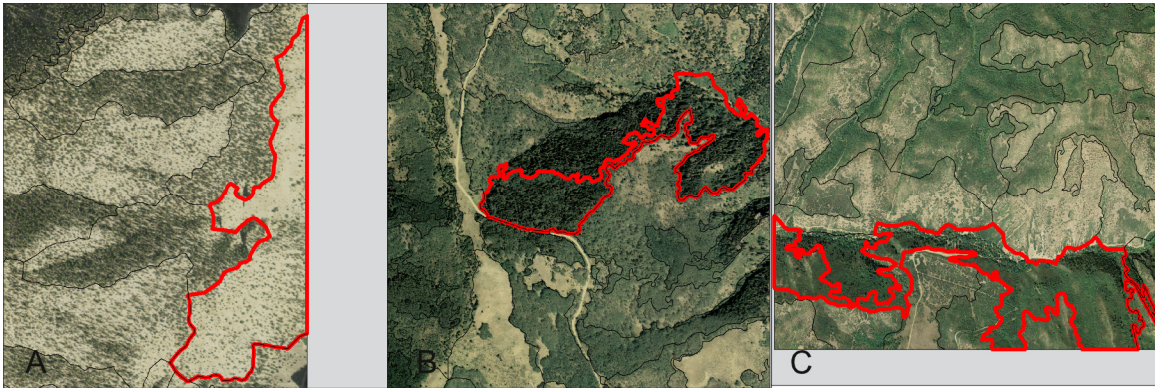
**Figure 10. Location of testing images.**

## Testing Polygon Representation of Vegetation Objects

To get a statistical idea of how well output polygons represent vegetation objects I needed a sample size of at least 100 polygons. This was based upon a population size of at least several thousands vegetation objects across the state, a confidence level of 95%, and a precision of plus or minus 10%. The first 29 image tiles run in the model were selected at random for testing. Polygons within these tiles that contained a SWReGAP ground reference site were chosen to use in the sample. This process identified 115 polygons.

Two visual subjective judgments of the polygons were made with the polygons overlaid on their corresponding image. The first judgment assumed that a polygon would be useful if it accurately represented the vegetation type and was not too radically different from what a forester would hand digitize. The polygon was judged to be useable as is, useable after simple modifications, or useable only after complex modifications. A polygon that required simple modification was defined as needing only some clipping and/or merging to become useable. A polygon that required complex modifications was defined as needing excessive clipping, merging, or vertex manipulation to reshape the polygon to make it useable. Figure 11 shows examples of these three types of polygons.





**Figure 11. Polygon judging (A) Use as is, (B) Easy to modify, (C) Difficult to modify.**

The second subjective judgment of the polygon considered only how well the polygon's shape represented the vegetation object. It did not consider how it might or might not be similar to a forester's hand digitizing. This time the polygons were judged as good, fair, or poor. Good means the polygon represents the vegetation type. Fair means the polygon represents the vegetation type but has some inaccuracies, i.e., a small inclusion of an adjacent vegetation type. Poor means the polygon does not represent the vegetation type.

For both of these subjective judgments a threshold of 50% was applied to determine if the model was useful. In the first case the model was considered useful if more than 50% of the polygons were judged useable as is or only needing simple modifications. In the second case the model was considered useful if 50% of the polygons were judged as good or fair. The 50% threshold was chosen because if foresters have to modify more than 50% of the polygons it would probably be easier to just hand digitize from the beginning and not use the model.

### **Testing Vegetation Class Assignment**

Assigned vegetation classes were compared to SWReGAP ground reference sites. Three classes, agriculture, developed, and water did not have ground control points and photo interpretive points were used.

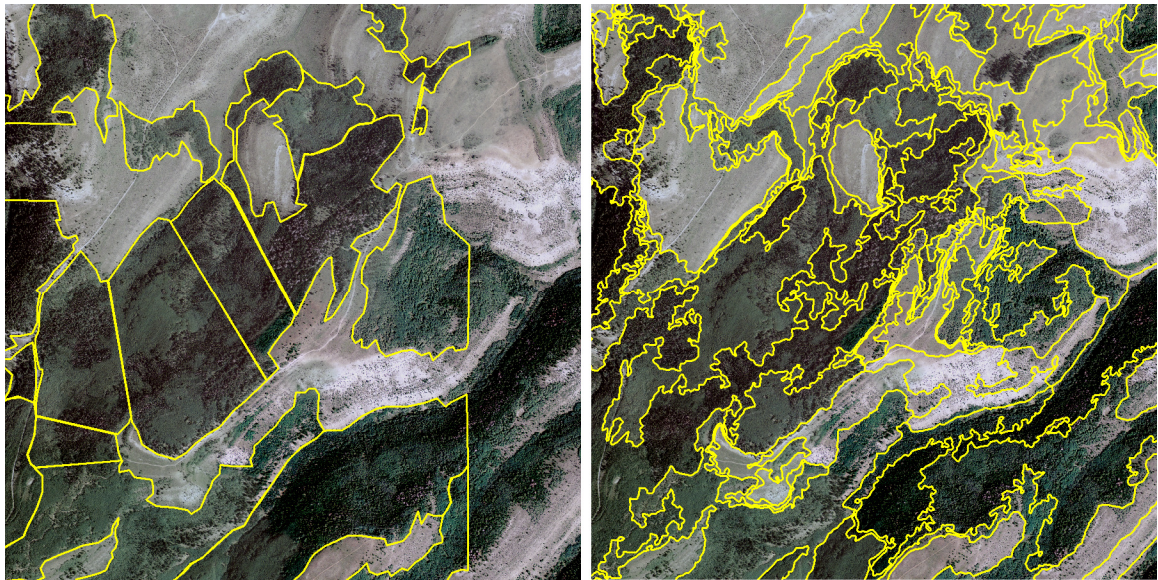
At least 15 points within each class were desired to assess the accuracy of vegetation class assignments. The original 29 randomly selected images did not provide enough reference sites in each vegetation class so an additional 35 images were selected that contained the needed reference sites. All reference sites within a selected image were used.

The threshold of 50% was applied to this test as well. If 50% or more of the vegetation class assignments were correct then the model would be judged useful.

## RESULTS AND DISCUSSION

The three questions that determine if the model will be useful for its intended purpose will be discussed. These are: ease of using the model, polygon representation of vegetation objects, and accuracy of vegetation class assignments. Forester responses on the likelihood of using the model and other potential uses of the model will also be discussed. But first, the visual differences between human-digitized polygons and the model's outputted polygons are considered (Figure 12).

The human-digitized polygons are block-like. It is easier and less tedious to digitize straight lines rather than lines full of curves. The model-generated polygons are sinuous following the natural boundaries of vegetation types. The human generated



**Figure 12. Human-digitized polygons (left) and model-generated polygons (right).**

polygons do not cover the entire landscape. Humans may tend to digitize the least amount possible, even if full coverage is desirable. The model-generated polygons do cover the entire landscape. The human generated polygons have straight edges at property boundaries. The model-generated polygons transcend property boundaries but have straight edges at the image's edge.

### **Ease of Using the Model**

Division employees have access to ArcGIS and the spatial analyst extension needed to run the program. The required inputs are readily available and the model's interface is intuitive and user friendly. The approximately 30 minutes of model run time is quicker than it would take a human to hand digitize the same area with a comparable level of detail. Users will probably need some initial training to install and run the model, but it does not require advanced and intensive training. Therefore, the model meets the ease of use criteria.

### **Polygon Representation of Vegetation Objects**

The two subjective judging methods used to determine that output polygons accurately represented vegetation objects led to the conclusion that the model met the second criteria of usefulness. Also, comments from potential users of the model reveal the model's outputted polygons would likely be used.

The first subjective judgment was made by answering the question, "Could this polygon substitute for a hand digitized polygon and be used in a forest stewardship plan?" This considered not only how well the polygon represented the vegetation object

in the photograph but whether or not the overall shape of the polygon was too radically different to fit into the current norm of a forest management plan. Table 1 shows the results of this analysis, revealing that 107 of the 115 polygons were judged as either being useful as is or needing only simple modification to be useful. This is 93%, well above the 50% threshold for the model to be useful. Even though the shapes of the outputted polygons were judged useful 74 of the 115 or 64% require some modification. This requires additional processing time to modify polygons for the final output.

The second subjective judgment only considered how well the polygon's shape represented the vegetation type in the aerial photograph. Table 2 shows the results, revealing that 96 of the 115 polygons were judged as being useful because they had good or fair representation of the vegetation type. This is 83%, well above the 50% threshold for the model to be useful.

**Table 1. Polygon usefulness, considering vegetation representation and polygon shape.**

|          | Useful Polygons |                              | Non-useful Polygons             | Total |
|----------|-----------------|------------------------------|---------------------------------|-------|
|          | Use As Is       | Use with Simple Modification | Use With Difficult Modification |       |
| Polygons | 33              | 74                           | 8                               | 115   |

**Table 2. Polygon usefulness, considering only vegetation representation.**

|          | Useful Polygons |      | Non-useful Polygons | Total |
|----------|-----------------|------|---------------------|-------|
|          | Good            | Fair | Poor                |       |
| Polygons | 52              | 44   | 19                  | 115   |

### Accuracy of Vegetation Class Assignments

Table 3 is the error matrix of vegetation class assignment compared with reference points. It reveals that 346 of the 534 points were within correctly assigned polygons giving an overall accuracy of 65%. This is above the 50% threshold and lends support to the thesis statement. Let's consider what this overall accuracy means.

Errors in class assignment could come from two sources, the model's assignment algorithm itself or error passed along from SWReGAP data, since the model assigns vegetation classes using a data layer derived from SWReGAP data. The final report on land cover mapping methods for the SWReGAP states an overall correct classification of 61% for that project (p. 22, Lowry et al. 2005). Since the model's overall accuracy of 65% is slightly above the 61% accuracy of SWReGAP it appears that the model successfully transfers the SWReGAP data to the refined polygons.

However, not all classes meet the 50% threshold and a closer look at the data is warranted. Five classes are below the threshold. They are Class 5 Limber/Bristlecone Pine, Class 7 Aspen, Class 12 Riparian Woodland, Class 14 Grass/Forbs, and Class 16 Developed. Their importance in forest management plans will be considered next.

**Table 3. Error matrix of vegetation class assignments to polygons.**

| Classes                                | Assigned Vegetation Class |           |     |           |          |           |           |           |           |           |     |          |           |           |           |          |           |           | Total | %   |     |
|--|---------------------------|-----------|-----|-----------|----------|-----------|-----------|-----------|-----------|-----------|-----|----------|-----------|-----------|-----------|----------|-----------|-----------|-------|-----|-----|
|  | 1                         | 2         | 3   | 4         | 5        | 6         | 7         | 8         | 9         | 10        | 11  | 12       | 13        | 14        | 15        | 16       | 17        | 18        |       |     |     |
| Class 1<br>Mixed Conifer               | <b>21</b>                 | 1         | 2   | 2         |          | 2         |           | 1         | 1         | 5         |     |          |           |           |           |          |           |           | 35    | 60% |     |
| Class 2<br>Spruce/Fir                  | 3                         | <b>26</b> | 1   |           |          |           | 5         |           |           | 1         |     |          | 1         |           |           |          |           | 1         | 38    | 68% |     |
| Class 3<br>Lodgepole Pine              |                           |           | 1   | <b>19</b> |          |           |           |           |           |           |     |          | 2         |           |           |          |           |           | 22    | 86% |     |
| Class 4<br>Ponderosa Pine              | 2                         |           |     | <b>14</b> |          | 1         |           |           |           | 3         |     |          |           |           |           |          |           |           | 20    | 70% |     |
| Class 5<br>Limber/<br>Bristlecone Pine | 1                         | 2         |     |           | <b>2</b> |           |           | 2         |           |           |     |          | 1         |           |           |          |           | 2         | 10    | 20% |     |
| Class 6<br>Pinyon/Juniper              |                           |           |     |           |          | <b>28</b> |           |           |           | 1         |     |          | 2         | 1         |           |          |           | 1         | 33    | 85% |     |
| Class 7<br>Aspen                       | 3                         |           | 1   | 1         |          |           | <b>13</b> | 1         | 1         | 3         | 1   |          | 4         |           |           |          |           |           | 28    | 46% |     |
| Class 8<br>Aspen/<br>Mixed Conifer     | 1                         | 2         |     |           |          |           | 3         | <b>14</b> |           | 1         |     |          | 2         |           |           |          |           |           | 23    | 61% |     |
| Class 9<br>Bigtooth Maple              | 4                         |           |     |           |          |           | 2         |           | <b>10</b> | 1         |     |          |           |           |           |          |           |           | 17    | 59% |     |
| Class 10<br>Gambel Oak                 |                           |           |     | 2         |          |           | 5         | 1         |           | <b>17</b> |     |          | 1         |           |           |          |           |           | 26    | 65% |     |
| Class 11<br>Mountain Mahogany          |                           |           |     |           |          |           | 1         |           |           | 1         |     | <b>9</b> |           | 4         |           |          |           |           | 15    | 60% |     |
| Class 12<br>Riparian Woodland          |                           | 1         |     |           |          |           | 1         | 1         |           | 1         |     |          | <b>5</b>  | 5         | 1         |          |           | 1         | 1     | 17  | 29% |
| Class 13<br>Brush/Shrubs               | 1                         | 1         |     |           |          | 10        | 1         |           |           |           | 1   |          | <b>99</b> | 5         |           |          |           | 3         | 121   | 82% |     |
| Class 14<br>Grass/Forbs                |                           | 5         |     | 1         |          | 2         |           |           | 1         | 2         |     | 1        | 14        | <b>17</b> |           |          |           | 1         | 7     | 51  | 33% |
| Class 15<br>Agriculture                |                           |           |     |           |          |           |           |           |           |           |     |          | 1         |           | <b>15</b> |          |           |           |       | 16  | 94% |
| Class 16<br>Developed                  |                           |           |     |           |          |           |           |           |           |           |     |          | 2         |           | 6         | <b>6</b> | 1         |           |       | 15  | 40% |
| Class 17<br>Water                      |                           |           |     |           |          |           |           |           |           |           |     | 1        | 1         | 1         | 1         | 1        | <b>11</b> |           |       | 16  | 69% |
| Class 18<br>Non-vegetated              |                           | 1         |     |           |          | 1         |           |           |           | 1         |     |          | 5         | 3         |           |          |           | <b>20</b> | 31    | 65% |     |
| Totals                                 | 36                        | 40        | 23  | 20        | 2        | 46        | 30        | 19        | 15        | 35        | 11  | 7        | 144       | 28        | 22        | 7        | 14        | 35        | 534   |     |     |
| Percentage                             | 58%                       | 65%       | 83% | 70%       | 100%     | 61%       | 43%       | 74%       | 67%       | 49%       | 82% | 71%      | 69%       | 61%       | 68%       | 86%      | 79%       | 57%       |       |     |     |

Boldface shows correctly assigned polygons.

Aspen is a common vegetation type on the landscape and often is very important in forest management plans. The fact that it does not quite (46%) meet the 50% threshold is a concern. Still, users should be aware that with aspen the model will likely be wrong a little over 50% of the time. The Grass/Forbs (33%) class may be a prominent vegetation type in some landscapes and may be very important in forest management plans when grazing by domestic or wild animals is a concern. The model often assigned this type to the Brush/Shrub class, a similar class in that trees are not present. Riparian Woodlands (29%) were often incorrectly assigned. They are important in management plans because of the woodland's functions in riparian areas. Users should understand that even though this type is found near riparian areas the model usually does not assign it correctly. Limber/Bristlecone Pine (20%) is a rare vegetation type and not normally of great importance in forest management plans. Developed areas (40%) were often assigned as agricultural areas. The model, while often incorrectly assigning it, is at least keeping it separate from the natural vegetation classes which are of more importance in forest management plans.

The model's strengths and weaknesses can be further understood by considering errors of commission and omission. Errors of commission are considered from the reference point of the polygon. They are errors of assigning (committing) the polygon to the wrong class. Errors of omission are considered from the reference point of a vegetation type on the landscape. These are errors of being omitted from the correct class.

Table 4 shows errors of commission, the incorrect assignment of polygons. The table also contains an estimate, based upon the errors, of the likelihood that the model



**Table 4. Errors of Commission, polygons assigned to incorrect vegetation class.**

|                                  | All Polygons<br>Assigned to<br>Class | Polygons<br>Committed<br>to Correct<br>Class | <b>Errors of<br/>Commission</b><br>Polygons<br>Committed<br>to Incorrect<br>Class | Estimated<br>Likelihood<br>of Model<br>Committing<br>polygon to<br>Incorrect Class |
|----------------------------------|--------------------------------------|--|---|--|
| Class 1, Mixed Conifer           | 36                                   | 21   | 15  | 42%  |
| Class 2, Spruce/Fir              | 40                                   | 26   | 14  | 35%  |
| Class 3, Lodgepole Pine          | 23                                   | 19   | 4   | 17%  |
| Class 4, Ponderosa Pine          | 20                                   | 14   | 6   | 30%  |
| Class 5, Limber/Bristlecone Pine | 2                                    | 2  | 0   | 0%   |
| Class 6, Pinyon/Juniper          | 46                                   | 28   | 18  | 39%  |
| Class 7, Aspen                   | 30                                   | 13   | 17  | 57%  |
| Class 8, Aspen/Mixed Conifer     | 19                                   | 14   | 5   | 26%  |
| Class 9, Bigtooth Maple          | 15                                   | 10   | 5   | 33%  |
| Class 10, Gambel Oak             | 35                                   | 17   | 18  | 51%  |
| Class 11, Mountain Mahogany      | 11                                   | 9  | 2   | 18%  |
| Class 12, Riparian Woodland      | 7                                    | 5  | 2   | 29%  |
| Class 13, Brush/Shrubs           | 144                                  | 99   | 45  | 31%  |
| Class 14, Grass/Forbs            | 28                                   | 17   | 11  | 39%  |
| Class 15, Agriculture            | 22                                   | 15   | 7   | 32%  |
| Class 16, Developed              | 7                                    | 6  | 1   | 14%  |
| Class 17, Water                  | 14                                   | 11   | 3   | 21%  |
| Class 18, Non-vegetated          | 35                                   | 20   | 15  | 43%  |
| <b>Totals</b>                    | <b>534</b>                           | <b>346 (65%)</b>                             | <b>118 (35%)</b>  |  |

will make an incorrect assignment when it assigns a polygon to a particular class.

Clearly, Class 7 Aspen is of the most concern, followed by Class 10 Gambel Oak, Class 18 Non-vegetated, and Class 1 Mixed Conifer.

Table 5 shows errors of omission, the omitting of a vegetation type from the correct class. The table also contains an estimate, based upon the errors, of the likelihood that the model will omit a vegetation type from its correct class. Class 5 Limber/Bristlecone Pine and Class 12 Riparian Woodland are both very likely to be omitted from the correct class.

Table 6 shows both estimates of the likelihood of errors side by side. The table shows that, except for aspen, the model is most likely to have errors of omission for those classes that did not meet the threshold of usefulness. For aspen the model is just as likely to have errors of commission as errors of omission.

Users should note the five classes for which the model does not perform in a manner to meet the threshold of usefulness. Additional manipulation of the output will be needed for these classes. However, overall the model does meet the threshold of usefulness.

**Table 5. Errors of Omission, ground points omitted from correct vegetation class.**

|                                  | All Ground<br>Points in<br>Class | Ground<br>Points<br>Included in<br>Correct Class | <b>Errors of<br/>Omission</b><br>Ground<br>Points<br>Omitted from<br>Correct Class | Estimated<br>Likelihood<br>of Model<br>Omitting Ground<br>Point from<br>Correct Class |
|----------------------------------|----------------------------------|--|--|---|
| Class 1, Mixed Conifer           | 35                               | 21   | 14   | 40%   |
| Class 2, Spruce/Fir              | 38                               | 26   | 12   | 32%   |
| Class 3, Lodgepole Pine          | 22                               | 19   | 3  | 14%   |
| Class 4, Ponderosa Pine          | 20                               | 14   | 6  | 30%   |
| Class 5, Limber/Bristlecone Pine | 10                               | 2  | 8  | 80%   |
| Class 6, Pinyon/Juniper          | 33                               | 28   | 5  | 15%   |
| Class 7, Aspen                   | 28                               | 13   | 15   | 54%   |
| Class 8, Aspen/Mixed Conifer     | 23                               | 14   | 9  | 39%   |
| Class 9, Bigtooth Maple          | 17                               | 10   | 7  | 41%   |
| Class 10, Gambel Oak             | 26                               | 17   | 9  | 35%   |
| Class 11, Mountain Mahogany      | 15                               | 9  | 6  | 40%   |
| Class 12, Riparian Woodland      | 17                               | 5  | 12   | 71%   |
| Class 13, Brush/Shrubs           | 121                              | 99   | 22   | 18%   |
| Class 14, Grass/Forbs            | 51                               | 17   | 34   | 66%   |
| Class 15, Agriculture            | 16                               | 15   | 1  | 6%  |
| Class 16, Developed              | 15                               | 6  | 9  | 60%   |
| Class 17, Water                  | 16                               | 11   | 5  | 31%   |
| Class 18, Non-vegetated          | 31                               | 20   | 11   | 35%   |
| <b>Totals</b>                    | <b>534</b>                       | <b>346 (65%)</b>                                 | <b>188 (35%)</b>   |   |

**Table 6. Estimated likelihood of committing and omitting errors of the model.**

|                                  | Estimated Likelihood<br>of Model Committing<br>Polygon to<br>Incorrect Class | Estimated Likelihood<br>of Model Omitting<br>Ground Point from<br>Correct Class |
|----------------------------------|--|---|
| <b>Classes Below Threshold</b>   |  |   |
| Class 5, Limber/Bristlecone Pine | 0%   | 80%   |
| Class 7, Aspen                   | 57%  | 54%   |
| Class 12, Riparian Woodland      | 29%  | 71%   |
| Class 14, Grass/Forbs            | 39%  | 66%   |
| Class 16, Developed              | 14%  | 60%   |
| <b>Classes Above Threshold</b>   |  |   |
| Class 1, Mixed Conifer           | 42%  | 40%   |
| Class 2, Spruce/Fir              | 35%  | 32%   |
| Class 3, Lodgepole Pine          | 17%  | 14%   |
| Class 4, Ponderosa Pine          | 30%  | 30%   |
| Class 6, Pinyon/Juniper          | 39%  | 15%   |
| Class 8, Aspen/Mixed Conifer     | 26%  | 39%   |
| Class 9, Bigtooth Maple          | 33%  | 41%   |
| Class 10, Gambel Oak             | 51%  | 35%   |
| Class 11, Mountain Mahogany      | 18%  | 40%   |
| Class 13, Brush/Shrubs           | 31%  | 18%   |
| Class 15, Agriculture            | 32%  | 6%  |
| Class 17, Water                  | 21%  | 31%   |
| Class 18, Non-vegetated          | 43%  | 35%   |

### **Likelihood of the Model Being Used**

The results of the model were presented to five staff foresters at the Utah Division of Forestry, Fire and State Lands. All five indicated they would try the model and three indicated that they likely would use it during the preparation of forest stewardship plans. Reasons given for using the model included: eliminates need for digitizing, faster, and perhaps better accuracy. Two foresters mentioned the need for ground truthing when using the model.

One forester, while willing to try, was not likely to use the model in the preparation of forest stewardship plans because of the inability to control number of polygons, size of polygons, and the sinuosity of boundaries — features not part of the model but may be added in the future. This forester also expressed that he/she enjoyed hand digitizing stand boundaries.

Another forester responded that he would most likely use the model to suggest boundary lines for forest stands but hand digitize the actual boundaries. This forester thinks that the model delineates between vegetation types too finely creating too many polygons, and that the boundaries are too sinuous.

### **Other Uses of the Model**

Three of the foresters indicated that the model might be useful for work tasks other than in the preparation of forest management plans. Those mentioned were: fire and fuel projects, prescribed burns, rangeland management, evaluation of tamarisk in riparian forests, and mapping cheat grass to plan fuel breaks. Because the model's output is

useable in a GIS, any project that requires spatial information about vegetation types is a likely candidate to benefit from use of the model.

The model could be used in the creation of a statewide vegetation data layer at a resolution that currently doesn't exist. This would negate the need for individuals to run the model on a case by case basis. The model would need to be run for over 6,000 aerial images that cover the state of Utah and the output shapefiles combined. This is not a trivial task but very doable. One option to reduce the workload is to first combine quarter quadrangle images before applying the model. This would also reduce the number of boundaries between images which is a common area for errors to occur. It seems that a statewide vegetation layer produced from one meter aerial imagery would be useful and thus valuable.

The model could be changed, modified and/or improved to be used for other tasks. The ability to control the minimum and maximum size of polygons could be added. One forester mentioned that it would be nice if the shapefile's attributes table included acreage, aspect, and slope. These calculations could be added to the model. Other changes could also be made.

An intriguing idea is to use the model to create a series of vegetation objects of varying sizes that lie upon each other to see how smaller vegetation groups combine into larger groups. This could be accomplished by changing the number of vegetation types possible within the model. For instance, a researcher could designate 10, 15, and 20 possible vegetation types for a given input image and overlay the outputs. Another option is to assign all possible SWReGap types from the beginning and then dissolve common boundaries between types as desired.

Because the model's output simulates natural boundaries between vegetation types with sinuous lines in more detail than a human would digitize, the model could be helpful to those studying the environmental factors that impact vegetation and the establishment of natural boundaries between vegetation. The sinuous lines of the polygons reveal in greater detail the interlocking connections between vegetation types and may provide valuable insight to possible effects of management actions.

In summary, the model has many other possible uses besides what it was created for initially. It provides a means to explore and gain greater understanding of vegetation types and the natural boundaries between them.

The model will be distributed to Division foresters. They will be trained in its use. The model will then be a tool to help foresters accomplish their work tasks, especially in the creation of forest stewardship plans. Improvements and additions will be made as use of the model identifies problem areas. Also, it is likely that the Division will pursue other uses of the model.

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APPENDICES

## Appendix A. Vegetation Classes

The reduction of 80 SWReGAP classes to 18 classes.

Following are the land cover classes used in this study and the SWReGAP land cover types within each class.

Class 1 Mixed Conifer

Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland

Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland

Class 2 Spruce-Fir

Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland

Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland

Class 3 Lodgepole Pine

Rocky Mountain Lodgepole Pine Forest

Class 4 Ponderosa Pine

Rocky Mountain Ponderosa Pine Woodland

Class 5 Limber-Bristlecone Pine

Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland

Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland

Class 6 Pinyon-Juniper

Colorado Plateau Pinyon-Juniper Woodland

Great Basin Pinyon-Juniper Woodland

Colorado Plateau Pinyon-Juniper Shrubland

Class 7 Aspen

Rocky Mountain Aspen Forest and Woodland

Class 8 Aspen-Mixed Conifer

Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex

Class 9 Bigtooth Maple

Rocky Mountain Bigtooth Maple Ravine Woodland

Class 10 Gambel Oak

Rocky Mountain Gambel Oak-Mixed Montane Shrubland

Rocky Mountain Lower Montane-Foothill Shrubland

Class 11 Mountain Mahogany

Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland

Class 12 Riparian Woodland

Rocky Mountain Subalpine-Montane Riparian Woodland

Rocky Mountain Lower Montane Riparian Woodland and Shrubland

North American Warm Desert Lower Montane Riparian Woodland and Shrubland

North American Warm Desert Riparian Woodland and Shrubland

North American Warm Desert Riparian Mesquite Bosque

Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland

Invasive Southwest Riparian Woodland and Shrubland

### Class 13 Brush-Shrubs

Rocky Mountain Alpine Dwarf-Shrubland

Inter-Mountain Basins Mat Saltbush Shrubland

Great Basin Semi-Desert Chaparral

Inter-Mountain Basins Big Sagebrush Shrubland

Great Basin Xeric Mixed Sagebrush Shrubland

Colorado Plateau Mixed Low Sagebrush Shrubland

Mogollon Chaparral

Colorado Plateau Blackbrush-Mormon-tea Shrubland

Mojave Mid-Elevation Mixed Desert Scrub

Inter-Mountain Basins Mixed Salt Desert Scrub

Sonora-Mojave Creosotebush-White Bursage Desert Scrub

Sonora-Mojave Mixed Salt Desert Scrub

Inter-Mountain Basins Montane Sagebrush Steppe

Inter-Mountain Basins Big Sagebrush Steppe

Inter-Mountain Basins Semi-Desert Shrub Steppe

Rocky Mountain Subalpine-Montane Riparian Shrubland

Inter-Mountain Basins Greasewood Flat

Sonora-Mojave-Baja Semi-Desert Chaparral

Wyoming Basins Low Sagebrush Shrubland

Southern Colorado Plateau Sand Shrubland

#### Class 14 Grass-Forbs

Inter-Mountain Basins Juniper Savanna

Rocky Mountain Dry Tundra

Rocky Mountain Subalpine Mesic Meadow

Southern Rocky Mountain Montane-Subalpine Grassland

Inter-Mountain Basins Semi-Desert Grassland

North American Arid West Emergent Marsh

Rocky Mountain Alpine-Montane Wet Meadow

Recently Burned

Invasive Perennial Grassland

Invasive Annual Grassland

Invasive Annual and Biennial Forbland

Recently Logged Areas

Recently Chained Pinyon-Juniper Areas

#### Class 15 Agriculture

Agriculture

#### Class 16 Developed



Developed, Open Space - Low Intensity

Developed, Medium - High Intensity

Class 17 Water

Open Water

Class 18 Non-vegetated

North American Alpine Ice Field

Rocky Mountain Alpine Bedrock and Scree

Rocky Mountain Alpine Fell-Field

Rocky Mountain Cliff and Canyon

Inter-Mountain Basins Cliff and Canyon

Colorado Plateau Mixed Bedrock Canyon and Tableland

Inter-Mountain Basins Shale Badland

Inter-Mountain Basins Active and Stabilized Dune

Inter-Mountain Basins Volcanic Rock and Cinder Land

Inter-Mountain Basins Wash

Inter-Mountain Basins Playa

North American Warm Desert Bedrock Cliff and Outcrop

North American Warm Desert Volcanic Rockland

North American Warm Desert Wash

North American Warm Desert Playa

Barren Lands, Non-specific

Disturbed, Non-specific

Recently Mined or Quarried

Disturbed, Oil well

## Appendix B. Model Code

The Python code that constitutes the model.

```

# Img2VegPolygons.py
# (c) W. Kevin Wells, 2009
#
# This Python script is for use in ArcMap. It creates polygons representing
# vegetation objects from a 1 meter aerial photograph and assigns a vegetation
# type to each polygon from data derived from 2004 ReGAP data. The resulting
# polygons are at a scale suitable for use in Forest Management Plans.
#
# The script was created during research pursuit to a Masters of Science Degree
# from Utah State University. It was specifically designed for use by the Utah
# Division of Forestry, Fire, and State Lands.
#
# The model uses Python Image Library and ArcGIS tools.

# Import libraries
import sys, string, os, shutil
sys.path.append("c:/Program Files/ArcGIS/Bin")
import arcgisscripting
from PIL import Image, ImageFilter

# ArcGIS settings
gp = arcgisscripting.create()
gp.overwriteoutput = 1
coorsysPart1 = "Coordinate Systems\Projected Coordinate Systems\Utm"
coorsys = coorsysPart1 + "\Nad 1983\NAD 1983 UTM Zone 12N.prj"
gp.OutputCoordinateSystem = coorsys
tempworkspace = str(sys.argv[3]) + "/TempFolderImg2Veg"
os.mkdir(tempworkspace)
gp.workspace = tempworkspace
gp.CheckOutExtension("spatial")

# ***** Functions, listed in the order used in the model *****

def getNumGAPvegTypes(toClipImg):
    """
    This function calculates the number of vegetation classes.

    The function first clips the ReGAP data by the extent of the input image.
    Then it calculates the number of vegetation classes in the clip.
    """
    # Get the GapClasses.tif file
    gapClassesToClip = sys.argv[2]

    # Describe the inImage to have access to the extent
    descToClipImg = gp.Describe(toClipImg)

```

```

# Clip the ReGAP raster to the extent
gp.Clip_management(gapClassesToClip, descToClipImg.Extent, "clip", \
                  toClipImg, "", "NONE")

# Count and return the number of classes
classcnt = gp.GetRasterProperties_management("clip", "UNIQUEVALUECOUNT")
return int(classcnt)

def accentuateObjectsInImage(nextImage, outImage, numVegTypes):
    """
    This functions accentuates the vegetation objects in the image by
    reducing the variability of pixel colors.
    """
    # Blur the image with PIL
    im = Image.open(nextImage)
    outBlur = gp.workspace + "/outBlur.png"
    loops = 0
    while loops < 20:
        im = im.filter(ImageFilter.BLUR)
        loops = loops + 1
    im.save(outBlur)

    # Georectify the blurred image
    georectifyImage(nextImage, outBlur, "shiftBlur")

    # Segment the image into the number of vegetation types
    gp.Slice_sa("shiftBlur", outImage, numVegTypes, "NATURAL_BREAKS")

def georectifyImage(baseImage, shiftImage, newImage):
    """
    Creates a copy of the shiftImage at the location of the baseImage.
    """
    # Georectify the processed image.
    leftBase = gp.GetRasterProperties(baseImage, "LEFT")
    topBase = gp.GetRasterProperties(baseImage, "Top")
    leftShift = gp.GetRasterProperties(shiftImage, "LEFT")
    topShift = gp.GetRasterProperties(shiftImage, "Top")

    shiftX = leftBase - leftShift
    shiftY = topBase - topShift
    gp.Shift_management(shiftImage, newImage, shiftX, shiftY)

```

```

def replaceSmallAreas(inRaster, outRaster, acres, pixelSize):
    """
    Replaces regions in a raster with nearby pixel for regions smaller than the
    given acreage.
    """
    # Region group to get a count (size) of each region
    gp.RegionGroup_sa(inRaster, "regions")

    # Create a mask based upon the small areas
    # A count of 4046.87 one meter pixels is approximately 1 acre
    pixelsPerAcre = 4046.87 / (pixelSize * pixelSize)
    msq = int(acres * pixelsPerAcre)
    exp = "0 " + str(msq) + " NoData;" + str(msq + 1) + " 999999999 1"
    gp.Reclassify_sa("regions", "COUNT", exp, "mask", "NODATA")

    # Fill in small areas with nearest pixels
    gp.Nibble_sa(inRaster, "mask", outRaster)

def assignGAPvegType(polygonLayer):
    """
    This function assigns the GAP vegetation type.
    """
    # Add attribute fields
    gp.addfield(polygonLayer, "VegCode", "SHORT")

    # Use search cursor to work with each polygon
    cur = gp.UpdateCursor(polygonLayer)
    row = cur.Next()
    while row:
        # Create a virtual layer of the polygon
        gp.FeatureToPolygon(row.shape, "tempPoly.shp")
        gp.MakeFeatureLayer("tempPoly.shp", "tempPolyLyr")

        # Extract area of interest from Clip of GAP classes
        gp.ExtractByMask_sa("clip", "tempPolyLyr", "tempclip.img")

        # Determine and assign the largest vegetation type to the polygon
        cur2 = gp.SearchCursor("tempclip.img")
        row2 = cur2.Next()
        count = 0
        highCount = 0
        value = 0
        while row2:

```

```

        count = row2.count
        if highCount < count:
            highCount = count
            value = row2.value
            row2 = cur2.Next()

    row.VegCode = value
    cur.UpdateRow(row)
    try:
        gp.deletefeatures("tempclip.img")
        gp.deletefeatures("tempPolyLyr")
    except:
        pass
    row = cur.Next()

def addVegName(inShp):
    """
    This function adds the vegetation type name.
    """
    gp.addfield(inShp, "VegName", "text", 25)

    vegDict = { 1:"Mixed Conifer", 2:"Spruce-Fir", 3:"Lodgepole Pine", \
                4:"Ponderosa Pine", 5:"Limber-Bristlecone Pine", \
                6:"Pinyon-Juniper", 7:"Aspen", 8:"Aspen-Mixed Conifer", \
                9:"Bigtooth Maple", 10:"Gambel Oak", 11:"Mountain Mahogany", \
                12:"Riparian Woodland", 13:"Brush-Shrubs", 14:"Grass-Forbs", \
                15:"Agriculture", 16:"Developed", 17:"Water", 18:"Non-vegetated" }

    cur = gp.UpdateCursor(inShp)
    row = cur.Next()
    while row:
        try:
            row.VegName = vegDict[row.VegCode]
            cur.UpdateRow(row)
            row = cur.Next()
        except:
            row = cur.Next()

    # Release the data layer by deleting cursors
    del row, cur

# **** Steps of the Model ****

```

```

# Step 1
# Get the input image.
inImage = sys.argv[1]

# Step 2
# Determine number of ReGAP vegetation groups within the extent of the image.
numVegTypes = getNumGAPvegTypes(inImage)

# Step 3
# Process the image to accentuate vegetation objects in the image.
accentuateObjectsInImage(inImage, "objects", numVegTypes)

# Step 4
# Merge objects less than 10 acres with adjacent objects.
smallacres = 10
firstacres = smallacres / 3
secondacres = firstacres + firstacres
replaceSmallAreas("objects", "processed", firstacres, 1)
replaceSmallAreas("processed", "processed2", secondacres, 1)
replaceSmallAreas("processed2", "processed3", smallacres, 1)

# Step 5
# Vectorize to polygons.
gp.RasterToPolygon_conversion("processed3", "vectors.shp", "SIMPLIFY", "VALUE")

# Step 6
# Reduce thin connections between vegetation objects that create one
# exceedingly large polygon.
gp.featuretoline("vectors.shp", "lines.shp")
gp.buffer("lines.shp", "buffer.shp", 3, "FULL", "ROUND", "NONE")
gp.PolygonToRaster_conversion("buffer.shp", "ID", "mask1", "CELL_CENTER", \
    "NONE", "1")
reclassValues = "0 999999999 NoData;NoData 1"
gp.Reclassify_sa("mask1", "Value", reclassValues, "mask2", "NODATA")
gp.ExtractByMask("processed3", "mask2", "extract")
gp.Expand_sa("extract", "expanded", "50", \
    "1;2;3;4;5;6;7;8;9;10;11;12;13;14;15;16;17;18")
mergeSmallAreas("expanded", "expanded2", smallacres, 1)
gp.RasterToPolygon_conversion("expanded2", "vectors2.shp", "SIMPLIFY", "VALUE")

# Step 7
# Test for and remove tiny artifact polygons.
gp.addfield("vectors2.shp", "Acres", "DOUBLE", 10, 1)
gp.CalculateField_management("vectors2.shp", "Acres", "!shape.area@acres!", \
    "PYTHON")

```



```
gp.MakeFeatureLayer("vectors2.shp", "tempvectors")
gp.SelectLayerByAttribute("tempvectors", "NEW_SELECTION", "\"Acres\" < 1")
gp.deleterows("tempvectors")
gp.CopyFeatures("tempvectors", "vectors3.shp")
```

```
# Step 8
# Assign vegetation types and names.
assignGAPvegType("vectors3.shp")
addVegName("vectors3.shp")
```

```
# Step 9
# Create the output shapefile and delete the temporary working folder.
gp.CopyFeatures("vectors3.shp", sys.argv[3] + "/VegTypes.shp")
shutil.rmtree(tempworkspace)
```

```
# End of Model
```