SWReGAP Land Cover Mapping Methods Documentation

Functional Unit or Mapping Zone: UT3

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1) Predictor layer preparation:

a) Image standardization:

Standardization from DN values to at-sensor reflectance was performed on Landsat 7 ETM+ imagery using methods presented by Huang et. al (2001a), with the addition of a dark object subtraction step to remove atmospheric haze, as suggested by Chavez (1988, 1996). The equation used was as follows:

$$\rho_{BandN} = \frac{\pi((L_{BandN} * Gain_{BandN} + Bias_{BandN}) - (H_{BandN} * Gain_{BandN} + Bias_{BandN})) * D^2}{E_{BandN} * (COS((90 - \theta) * \pi / 180))}$$

Where,

ρ_{BandN} = Reflectance for Band N

L_{bandN} = Digital Number for Band N

H_{bandN} = Digital Number representing Dark Object for Band N

D = Normalized Earth-Sun Distance

E_{bandN} = Solar Irradiance for Band N

b) Image dates and mosaicking:

Images were mosaicked using ERDAS Imagine 8.6 Mosaic Tool with "no cutline" for *type*, and the "Overlay" option for *overlap function*.

Image dates and scenes were as follows:

ETM Scene (path/row)	Spring (yr-Julian date)	Summer (yr-Julian date)	Fall (yr-Julian date)	Spring Overlay Order	Summer Overlay Order	Fall Overlay Order
35/34	2000-144	2000-256	1999-285	4	3	4
36/33	2000-103	2000-167	1999-307	5	2	3
36/34	2000-103	2000-167	1999-292	5	2	2
37/33	2000-126	2000-158	1999-283	3	1	1
37/34	2000-126	2000-158	1999-283	3	1	1
38/34	2000-133	2000-165	1999-306	1	4	5
38/35	2000-117	2000-165	1999-290	2	4	6

Three coverages (one for each season) showing overlap arrangement and date and scene attributed in the SOURCE field can be found:

/ut/archive/ut3/mosaic/ut3_spscn
/ut/archive/ut3/mosaic/ut3_suscn
/ut/archive/ut3/mosaic/ut3_fascn

Six band ETM mosaics for each season can be found at:

/ut/archive/ut3/mosaics/

c) Image derived datasets:

Normalized Difference Vegetation Index (NDVI): Used a modified version of the NDVI model provided by ERDAS Imagine 8.6. This model performs the band ratio (band4-band3)/(band4+band3) then scales the output by 200 to create a continuous unsigned 8-bit image ranging from 0 – 200. For an example of the *.gmd file go to /ut/archive/ut3/img_files/.

Tasseled cap: Brightness, Greenness & Wetness band transformations were created using coefficients derived for the Landsat 7 ETM+ sensor, by Huang, et. al (2001b). An example of the *.gmd file can be found at: /ut/archive/ut3/img_files/.

All imagery derived predictor layers can be found at:

/ut/archive/ut3/img_files/.

d) DEM derived datasets:

Thirty meter digital elevation models were obtained from the Eros Data Center, National Elevation Database (NED). The date for these data was October 1999. DEMs were converted from floating point grids to integer grids and mosaicked for the region, then clipped to the mapping area.

Aspect: A nine class aspect grid was created. Values 1=N, 2=NE, 3=E, 4=SE, 5=S, 6=SW, 7=W, 8=NW, 9=FLAT.

Landform: A 10 class landform grid was created from a topographic relative moisture (values ranging from 0-28) index grid (Manis et. al 2001).

For modeling purposes all arcinfo grids were converted to ERDAS Imagine .img files and can be found at:

/ut/archive/ut3/img_files/

2) Samples:

a) Sample collection methods:

The majority of samples were collected on the ground as polygons delineated over imagery in the field by USU field crews, but others come from other sources. Samples were assigned a label corresponding to either an Ecological System (Comer et. al 2003) or a cover type uniquely defined for the SWReGAP project.

The method and/or source for each sample can be distinguished by the SITEID field in the polygon coverage:

UT070501LL02: Identifies a sample taken by USU RSGIS lab SWReGAP field crew. Indicates it was the second site taken on May 7, 2002 by Lisa Langs.

HELPER-02-0018 (e.g. <quadname>-<date>-<site>): Indicates sample from Utah Department of Natural Resources, Division of Wildlife. East Manti Vegetation Coverage Project(2003).

Ut3doq_167 and doq051204_25: Indicates sites obtained from interpretation of black and white Digital Orthophoto Quads available for the state of Utah from AGRC (date of DOQs is either 1993 or 1997). DOQ interpretation by RSGIS lab personnel.

Ut3_colo: Obtained from Colorado Basin Wide database.

Ref-<idnum> and Val-<idnum>: Indicates data collected by USDA Firelab for the Landfire project reference 2000 or validation 2001 points and plot number.

ZION<num>: Indicates data collected by Zion National Park given to USU by Keith Schultz with Nature Serve. Citation: Comer, P.J., M.S. Reid, R.J. Rondeau, A. Black, J. Stevens, J. Bell, M. Menefee, and D. Cogan. 2002. A working classification of terrestrial ecological systems in the Northern Colorado Plateau: Analysis of their relationship to the National Vegetation Classification System and application to mapping. NatureServe. Report to the National Park Service. 23 pp. + appendices.

Ut3-mapck<num>: Indicates data collected by USU RSGIS lab SWReGAP field crew. This data was collected to as augmentation data in modeling misclassification trouble spots.

2000-10-14: Data provided by the Utah Department of Natural Resources, Division of Wildlife Resources, the Utah Big Game Range Trend Studies Annual Reports 1997-2001. Indicates that the most recent year of data collection at the study site was in 2000, in the Wildlife Management Unit number 10, for trend study number 14.

man-800_21-3: (e.g. <NF><roll#><frame#><site#>) Indicates air-photo interpreted site from 'Manti-La Sal' National Forest.

National Forest & Roll numbers	Scale	Type	Date
Dixie (199-2099)	15,840	Color	1999
Fish Lake (all except rolls 101, 201, 301)	15,840	Color	1995
Fish Lake (rolls 101, 201, 301)	15,840	Color	2001
Manti-La Sal (all rolls)	15,840	Color	2000
Uinta (all rolls)	15,840	Color	1998
Wasatch-Cache (all rolls)	15,840	Color	2001

b) Summary of samples:

4,416 samples were available to model this mapping area of which 4,305 samples were used in the final model. Qualifiers for a discarded sample site was sample quality, Ecological System (ES) mapability and sample abundance. Sample quality can be defined as the likelihood that the sample has a correct geospatial location and that the site sample characteristics correspond with site species data. ES mapability can be defined as the sites likelihood to map accurately given the map model conditions. Landuse types, in comparison to landcover types, typically are seen as sites that were discarded for ES mapability problems (example: Recently Burned, Recently Mined or Quarried and Developed areas). Sample abundance can be defined as all Ecological System cover types with roughly less then 20 samples sites collected in the field. Polygon coverage containing all samples is located at: ut/archive/ut3/train_data/.

VALUE	SCODE	Description Ecological System (Name)	Number Of Samples
304	D04	INVASIVE SW RIPARIAN WOODLAND AND SHRUBLAND	52
308	D08	INVASIVE ANNUAL GRASSLAND	56
309	D09	INVASIVE ANNUAL FORBLAND	41
0	S000	IGNORED	111
2	S002	ROCKY MOUNTAIN ALPINE BEDROCK AND SCREE	58
6	S006	ROCKY MOUNTAIN CLIFF AND CANYON COMPLEX	65
10	S010	COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND	290
11	S011	INTER-MOUNTAIN BASINS SHALE BADLANDS	101
12	S012	INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES	84
23	S023	ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND	95
28	S028	ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND	54
32	S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND	37
36	S036	ROCKY MOUNTAINS PONDEROSA PINE WOODLAND	178
39	S039	COLORADO PLATEAU PINYON-JUNIPER WOODLAND	555
40	S040	GREAT BASIN PINYON-JUNIPER WOODLAND	57
42	S042	INTER-MOUNTAIN WEST ASPEN-MIXED CONIFER FOREST AND WOODLAND COMPLEX	67
45	S045	INTER-MOUNTAIN BASINS MAT SALTBUSH SHRUBLAND	140
46	S046	ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND	231
52	S052	COLORADO PLATEAU PINYON-JUNIPER SHRUBLAND	383
54	S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND	471
59	S059	COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND	278
65	S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB	254
71	S071	INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH	104

		STEPPE	
79	S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE	156
83	S083	ROCKY MOUNTAIN SUBALPINE MESIC MEADOW	39
90	S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND	166
93	S093	ROCKY MOUNTAINS LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND COMPLEX	88
96	S096	INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX	134
136	S136	NORTHERN COLORADO PLATEAU SAND SHRUBLAND	71
		Total number of samples	**4416**

3) Cover types:

a) Classification Tree modeled cover types:

The following cover types were modeled using the See5 Classification Tree:

VALUE	SCODE	Description Ecological System (Name)	Number Of Samples
304	D04	INVASIVE SW RIPARIAN WOODLAND AND SHRUBLAND	52
308	D08	INVASIVE ANNUAL GRASSLAND	56
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23	S023	ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND	95
28	S028	ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND	54
32	S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND	37
36	S036	ROCKY MOUNTAINS PONDEROSA PINE WOODLAND	178
39	S039	COLORADO PLATEAU PINYON-JUNIPER WOODLAND	555
40	S040	GREAT BASIN PINYON-JUNIPER WOODLAND	57
42	S042	INTER-MOUNTAIN WEST ASPEN-MIXED CONIFER FOREST AND WOODLAND COMPLEX	67
45	S045	INTER-MOUNTAIN BASINS MAT SALTBUSH SHRUBLAND	140
46	S046	ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND	231
52	S052	COLORADO PLATEAU PINYON-JUNIPER SHRUBLAND	383
54	S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND	471
59	S059	COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND	278
65	S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB	254
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79	S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE	156
83	S083	ROCKY MOUNTAIN SUBALPINE MESIC MEADOW	39
90	S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND	166
93	S093	ROCKY MOUNTAINS LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND COMPLEX	88

96	S096	INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX	134
136	S136	NORTHERN COLORADO PLATEAU SAND SHRUBLAND	71
		Total number of samples	**4305**

b) Non CT modeled cover types:

Screen digitized over ETM imagery at a scale between 1:24,000 and 1:100,000: Updated existing **Land Use | Water Related Use** GIS coverage (screen digitizing over ETM imagery). Source of GIS coverage: Utah Department of Natural Resources, Division of Water Resources, collection period: 1985-2001. FGDC metadata for **Land Use | Water Related Use** coverage is found at: /ut/archive/ut3/non_model/

VALUE	SCODE	Description Ecological System (Name)
13	S013	Inter-Mountain Basins Volcanic Rock and Cinder Land
211	N11	Open Water
221	N21	Developed, Open Space - Low Intensity
222	N22	Developed, Medium - High Intensity
281	N81	Agriculture, Pasture/Hay
282	N82	Agriculture, Cultivated Crops
302	D02	Recently Burned
303	D03	Recently Mined or Quarried
310	D10	Recently Logged Areas
311	D11	Recently Chained Pinyon-Juniper Areas
314	D14	Disturbed, Oil well

Modeled with a post-classification model (see section 5c for details):

VALUE	SCODE	Description Ecological System (Name)
30	S030	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
34	S034	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
57	S057	Mogollon Chaparral
97	S097	North American Warm Desert Riparian Woodland and Shrubland

4) Summary of predictor layers used:

a) Multi band predictors:

ut3_fall_2000.img (ETM bands 1-5 & 7 for fall 2000)
ut3_spr_2000.img (ETM bands 1-5 & 7 for spring 2000)
ut3_sum_2000.img (ETM bands 1-5 & 7 for summer 2000)

All multi-band predictors can be found at:
/ut/archive/ut3/mosaics/

b) Single band predictors:

asp_9cls.img Categorical 9 class aspect
elev.img Continuous (integer) elevation
fabrt.img Fall brightness band
fagrn.img Fall greenness band
spbrt.img Spring brightness band
spgrn.img Spring greenness band
subrt.img Summer brightness band
sugrn.img Summer greenness band
landf.img Categorical 10 class landform (from DEM)

All single-band predictors can be found at:
/ut/archive/ut3/img_files/

5) Modeling Methods:

a) See5 Classification Tree modeling:

Sampling: Pseudo-replication within each sample polygon was conducted in order to increase the number of samples used by the classification algorithm. While this use of non-independent data is not ideal for classification tree modeling, it has been found to improve classification accuracies, particularly when there are limited amounts of training data. 20 random points were placed within each polygons using an Arcview Avenue script. The points were converted to pixels while ensuring that the resulting pixels (the new grid) aligned with the raster predictor layers. The resulting sub-sampled pixels would often be less than 20 per sample polygon, if random points fell within the same pixel. This new grid was converted to an Imagine IMG file (e.g.m4all20ppp.img) and is available at: UT/ARCHIVE/UT2/TRAIN_DATA/

Withholding Validation Sites: 20% of the all sample polygons were withheld for validation. With the remaining 80%, 20 sub-samples were randomly selected for each sample polygon. This was done by first randomly generating points within each polygon and then converting the points to a raster *.img file. Pixels in the *.img (each to be considered a separate observation for the See5 classifier) were 'drilled' through predictor layers using the Sampling tool from CART Module for Imagine (EarthSatellite Corp. 2003), producing two important files for See5: the *.names and *.data files.

See5 Classification Tree: See5 (Release 1.8) data mining software (Rulequest 2004) was used for generating classification trees. Boosting was employed using 15 trials.

The See5 files are located: ut/archive/ut3/output/. The following briefly describes these files (Rulequest 2004).

*.names file: Identifies the dependent variable *.img file and the predictor *.img files created from the CART Module Sampling tool. Required by See5 software.

*.data file: Contains the training cases from which See5 extracts rules. This is also produced from the CART Module Sampling tool, by 'drilling' the dependent variable pixels through the specified predictor images. Required by See5 Software.

*.test file: Produced from the CART Module Sampling tool, but not used by SWReGAP. This file, if populated, would contain a separate 'test' set of cases to evaluate the rules generated from See5. The SWReGAP mapping procedures did not populate this file, and it was not used.

*.names.hst file: Produced from the CART Module Sampling too. Details the distribution of samples available within the dependent input, and those output to the *.data and *.test file. Not required by See5, but produced by CART Module Sampling tool.

*.set file: Produced from See5 software. This file contains the settings for the classification tree run. For example the third value '15' indicates the number of boosts used for boosting.

*.tree file: Produced from the See5 software. This file contains the classification tree in 'tree' format. This along with the *.data and *.names file are required by the CART Module Classifier tool to spatially apply the tree.

*.out file: Output file generated by See5 and displayed when See5 classification tree model has run. This file provides a visual representation of the classification tree that is somewhat easier to interpret than the *.tree file.

As a result of spatially applying the classification tree using the CART Module's Classifier tool, two files are creates: an *.img file, which is the spatial application of the tree's rules, and the *_error.img file which is spatial depiction of confidence in the rules generated by the tree and displayed pixel by pixel.

b) Post-classification, recoding and other modeling steps:

Introduction: This post-classification model was designed to be used as a tool to assist in differentiating between ecological systems that have similar characteristics. Similar characteristics can be defined as one or all of the following: Shared physiognomic structure, shared species composition and/or shared ecological process. This model has also been designed to correct for poor TM image quality. Clouds, fire smoke or dramatic scene lines are example of such quality issues.

The .gmd file used for this post-classification model is:

/archive/ut3/post_model/ut3.gmd

Step 1: Discriminating S093-Rocky Mountain Lower Montane Riparian Woodland and Shrubland* and *S097-North American Warm Desert Riparian Woodland and Shrubland.

A small but significant portion of the Northern Colorado Plateau canyon bottoms is home to several riparian woodland and shrubland ecological systems. This post-classification model was designed to assist in identifying one such riparian system, S097-*North American Warm Desert Riparian Woodland and Shrubland,* and separating it from a upper elevation counterpart, S093- *Rocky Mountain Lower Montane Riparian Woodland and Shrubland.* S093 is found in canyon bottom riparian areas typically below 1200 meters in elevation. Within the extent of the UT3 functional mapping unit, S097 is constrained to a small biogeographical region located in the vicinity of the Virgin River corridor. A post-classification model was used to map S097. The logic and parameters for the model are as follows:

Model methods: A standard map model was created withholding S097, while allowing S093 to be mapped exclusively. A condition statement was then created to extract S097 based known elevation parameters. The detail of the conditional statement follows:

```
EITHER 97 IF ($n2_m12all1_rec == 93 AND $n1_elev < 1200) OR
$n2_m12all1_rec OTHERWISE
```

Where:

97	*North American Warm Desert Riparian Woodland and Shrubland*
93	*Rocky Mountain Lower Montane Riparian Woodland and Shrubland*
$n2_m12all1_rec	UT3 standard CT output image. Recoded to standard integer code.

***Step 2*: Discriminating Mesic Conifer from Non-Mesic Conifer Forests Types:**

The National Vegetation Classification Standard (NVCS) legend used for the Southwest Regional Gap Analysis Project divided Rocky Mountain conifer forest types into two distinct moisture classes; Mesic Forest types and Dry-Mesic Forest types (Comer et. al 2003). Early indications revealed that these types would be difficult to accurately discriminate using standard CT modeling methods due to site composition and spectral similarities. As a result, these types have been post modeled using their Ecological System conceptual description as a basis for modeling.

Step 2A: Discriminating Between Rocky Mountain Montane Dry-Mesic and Rocky Mountain Montane Mesic Conifer Types

Model methods: The original CT output modeled *S032 Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland* as the only montane conifer type. This post model was designed to discriminating between*S032* and, its moister ecologic counterpart, *S034 Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland*. The logic and parameters for the model were as follows:

This post-classification model was designed to extract *S034 Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland* from the standard CT modeled conifer system, *S032 Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland*.

NatureServe's NVCS concept describes S032 montane mesic system as;

> "occurring predominantly in cool ravines and on north-facing slopes. Elevations range from 1200 to 3300 m. Occurrences of this system are found on cooler and more mesic sites than the Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland. Such sites include lower and middle slopes of ravines, along stream terraces, moist, concave topographic positions and north and east-facing slopes which burn somewhat infrequently." (Comer et. al 2003)

Using the output of step 1, a conditional statement was created to extract *S034 Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland*. The conditional statement was created by using the aspect and landform characteristics described above. Affected pixels were then recoded to represent montane mesic mixed conifer system S034. The details of the conditional statement follow:

```
EITHER 34 IF (($n7_landf == 2 OR $n7_landf == 5 OR $n7_landf==6 OR
$n7_landf == 9) AND ($n6_asp9cls == 1 OR $n6_asp9cls == 2 OR $n6_asp9cls
== 0) AND ($n4_memory == 32)) OR $n4_memory OTHERWISE
```

Where:

34	*S034 Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland*.
32	*S032 Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland*
Landform	10 class landform 2= toe slopes, bottoms, and swales, 5= very moist steep slopes, 6= moderately moist steep slopes, 9= cool aspect scarps, cliffs, canyons,
asp9cls	Nine class aspect image 1=North facing slope

	2=Northeast facing slope 0=slope less than 3 degrees
Memory	UT3 standard CT output image. Recoded to standard integer code. Note: This output is a temporary memory file that has been modified by previous steps in the post classification model.

Step 2B: Discriminating Between Rocky Mountain Subalpine Dry-Mesic Spruce-Fir and Rocky Mountain Subalpine Mesic Spruce-Fir Types.

Using the output of step 2b, S030 *Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland* was extracted from its Dry-Mesic counterpart S028 following similar parameters as step 2A.

NatureServe NVCS concept (Comer et. al 2003) describes the subalpine mesic system to be;

> "typically found in locations with cold air drainage or ponding, or where snowpacks linger late into the summer, such as north-facing slopes and high elevation ravines. They can extend down in elevation below the subalpine zone in places where cold air ponding occurs; northerly and easterly aspects predominate. These forests are found on gentle to very steep mountain slopes, high elevation ridgetops and upper slopes, plateaulike surfaces, basins, alluvial terraces, well-drained benches, and inactive stream terraces."

Model methods: A conditional statement was created to extract *S030 Mountain Subalpine Mesic Spruce-Fir Forest and Woodland* using the above aspect and landform characteristics in order to identify this subalpine mesic conifer system. The details of the conditional statement follow:

```
EITHER 30 IF (($n7_landf== 2 OR $n7_landf == 5 OR $n7_landf==6
OR $n7_landf== 9) AND ($n6_asp9cls== 1 OR $n6_asp9cls == 2 OR
$n6_asp9cls == 0) AND ($n4_memory == 28)) OR $n4_memory
OTHERWISE
```

Where:

30	*S030 Mountain Subalpine Mesic Spruce-Fir Forest and Woodland*
28	S028 *Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland*
landf	10 class landform 2= toe slopes, bottoms, and swales 5= very moist steep slopes 6= moderately moist steep slopes 9= cool aspect scarps, cliffs, canyons
aspect_9cls	Nine class aspect image 1=North facing slope 2=Northeast facing slope 0=slope less than 3 degrees
memory	UT3 standard CT output image. Recoded to standard integer code. Note that this output is a temporary memory that has been modified by previous steps in the post classification model.

Step 3: *Discriminating S046-Rocky Mountain Gambel Oak Mixed-Montane Shrubland and S057-Mogollon Chaparral*: A post-classification model was used to map S057. The logic and parameters for the model were as follows:

S057-Mogollon Chaparral Ecological System was post-classified to allow for the account of an otherwise anomalous land cover vegetation type within the Northern Colorado Plateau UT3 functional mapping unit. The composition of species that define this Ecological System (i.e. *Quercus turbinella, Arctostaphylos pungens and A. pringlei)* are infrequent within this mapping zone. The extent of the chaparral has been identified by using ground true points. As a result of this systems' unique species composition and geographically restricted presence on the landscape, it was decided that post-classification would be the best method to accurately represent it on the landscape.

Model methods: A standard CT model was run which excluded the S057 training data while allowing the model to assign *S046 Rocky Mountain Gambel Oak-Mixed Montane Shrubland* pixels to the chaparral area. This post-classification model was designed to recode S046 pixel values to S057. The detail of the conditional statement follows:

EITHER 57 IF ($n8_memory==46 AND $n21_s046_to_s057==1) OR $n8_memory OTHERWISE

Where:

57	S057-*Mogollon Chaparral*
46	*S046-Rocky Mountain Gambel Oak Mixed-Montane Shrubland*
s046_to_s057	Mask image indicating where error occurred
memory	UT3 standard CT output image. Recoded to standard integer code. Note that this output is a temporary memory that has been modified by previous steps in the post classification model

Step 4: *Discriminating S040-Great Basin Pinyon-Juniper Woodland* and *S039-Colorado Plateau Pinyon-Juniper Woodland*. A post-classification model was used to restrict S040. The logic and parameters for the model were as follows:

The *S040-Great Basin Pinyon-Juniper Woodland* ecological system requires the presence of *Pinus monophylla,* among other characteristic, to be considered for this ecological system nomenclature. *S040-Great Basin Pinyon-Juniper Woodland*, typically found in the Great Basin ecoregion, was discovered to inhabit a small portion of the landscape in the northwest section of UT3 functional mapping unit. This system differs from its widespread Northern Colorado Plateau counterpart S039 by the presence of *Pinus monophylla* opposed to *Pinus edulis*. Differentiating between these two covertypes can be problematic using standard modeling methods and utimately leads to misclassification by allowing a Great Basin system to occur far from its accepted natural distribution. In order to restrict S040 to its biogeographic range it was necessary to post-classify this type.

Model methods: A standard model was run using all cover types. An area of interest (AOI) was then created and used as a mask to restrict S040 to its known range. The detail of the conditional statement follows:

```
EITHER 39 IF ($n22_memory == 40 AND $n26_s040_to_s039 == 1)
OR $n22_memory OTHERWISE
```

Where:

39	*Colorado Plateau Pinyon-Juniper Woodland*
40	*Great Basin Pinyon-Juniper Woodland*
s040_to_s039	Binary mask image indicating where S040 should be mapped on the landscape.
memory	UT3 standard CT output image. Recoded to standard integer code. Note: This output is a temporary memory file that has been modified by previous steps in the post classification model.

c) Generalizing to MMU and map completion:

Once the CT model and the post-classification steps were employed, the map was generalized using the Clump tool in ERDAS Imagine 8.6. The parameter of 4 connected neighbors (or "rook's move") was used in the clumping process. Isolated pixels that fell under the specified 1-acre minimum mapping unit (MMU) were removed using the Eliminate tool.

Following the Clump & Eliminate step, the non-CT modeled classes were then "burned in" to the final map using the Overlay function. The final map can be found at: /ut/archive/ut3/final_map/.

6) Validation:

a) CT model validation: 20% of sample polygons were randomly selected and withheld from CT modeling using the featureselect.avx as reference data. The CT model was run as described in section 5a using the remaining 80% of the samples. The 20% withheld samples were used to assess the predictive capability of the CT modeled map using the 80% training data. The CT-modeled classes were assessed using kappa.avx, which works by intersecting the validation sample polygons through the CT modeled land cover map, and considers the site correctly mapped when the majority of pixels within the sample polygon agree with the sample label. Output from kappa.avx consists of a *.txt, *.dbf and *.shp file. The *.txt file presents the kappa statistic, the *.dbf file is an error matrix indicating errors of commission and omission and the *.shp file indicates for each reference sample site whether the sample location was considered correctly mapped, or incorrectly mapped and what it was mapped as. These files can be found at: /ut/archive/ut3/validation/.

b) Final map: After CT model validation, a final map was generated using the methods described in section 5a this time using 100% of the sample data. Similarly to the steps involved with the 80% CT model, post-classification modeling, inclusion of the non-modeled cover types, and generalization to the MMU were completed to create **the final map product**, which can be found at /ut/archive/ut3/final_map/.

c) Discussion of mapped cover types: The following narrative provides qualitative assessments by the mapping team for each cover type mapped in this mapping area. It is intended to elaborate on the quantitative results of the CT model validation from the perspective of those most familiar with the map and the mapping process and is hoped to be of value to potential map users.

N11 OPEN WATER:

Not quantitatively assessed. Qualitative assessment indicates that most perennial open water has been mapped well. Ephemeral water bodies were not a focus of the effort and may be missing.

N21 DEVELOPED, OPEN SPACE-LOW INTENSITY:
Not quantitatively assessed. Qualitative assessment indicates that most low density developed areas contemporary with the date of the imagery are included. Some confusion may occur with the N22 DEVELOPED, MEDIUM-HIGH INTENSITY class.

N22 DEVELOPED, MEDIUM-HIGH ITENSITY:
Not quantitatively assessed. Qualitative assessment indicates that most low density developed areas contemporary with the date of the imagery are included. Some confusion may occur with the N21 DEVELOPED, OPEN SPACE-LOW INTENSITY class.

N81 PASTURE/HAY:
Not quantitatively assessed. Qualitative assessment indicates that most pasture/hay agricultural areas contemporary with the date of the imagery are included. This class included alfalfa and other non-irrigated agricultural types, which may be confused with N82 CULTIVATED CROPS.

N82 CULTIVATED CROPS:
Not quantitatively assessed. Qualitative assessment indicates that most cultivated agricultural areas contemporary with the date of the imagery are included. This class may be confused with N81 PASTURE/HAY, where crops were harvested prior to the date of the imagery or where crops were out of rotation for the season producing spectral signatures similar to that of N81.

D02 RECENTLY BURNED:
Not quantitatively assessed. Qualitative assessment indicates that most recently burned areas contemporary with the date of the imagery are included. This class may be confused with areas that have had fires in the past, but where the site has become somewhat revegetated since the time of the burn.

D04 INVASIVE SOUTHWEST RIPARIAN WOODLAND AND SHRUBLAND:
Quantitatively assessed, validation 27% (producers) and 38% (users) based on 11 independent validation samples. Confusion is primarily with S093 ROCKY MOUNTAINS LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND COMPLEX (6 of 11 samples). Confusion can be explained by similarities between these two cover types and by possible discrepancies between the date of the imagery and sample data. Where training data was available D04 mapped very well.

D08 INVASIVE ANNUAL GRASSLAND:
Quantitatively assessed, validation 8% (producers) and 14% (users) based on 12 independent validation samples. Confusion is primarily with S045 INTERMOUNTAIN BASINS MAT SALTBUSH SHRUBLAND (3 of 12 samples) AND D09 INVASIVE ANNUAL FORBLAND (2 of 12 samples). The majority of the training and validation data were collected in Grand County, Utah on disturbed shale substrates and among the salt desert shrub communities of Kane County, Utah and Mojave County, Arizona. Confusion can be explained by similarities between these cover types and by possible discrepancies between the date of the imager and sample data. While validation numbers are low, D08 was included in the map because field recognizance indicated it was mapped reasonably well and because of the importance of this cover type for land management activities. Where training data was available D08 mapped very well.

D09 INVASIVE ANNUAL FORBLAND:

Quantitatively assessed, validation 22% (producers) and 40% (users) based on 9 independent validation samples. This ecological system, like all invasive systems, is driven by disturbance rather than ecological process. Where training data available D09 is mapping well. Where data is absent the cover type is confusing with a variety of ecological systems which would be expected. The immense variability of possible species compositions and landscape variation allowed within this class explains this expectation.

D10 RECENTLY LOGGED AREAS:
Not quantitatively assessed. Qualitative assessment indicates that most recently logged areas contemporary with the date of the imagery are included. This class may be confused with areas that have been logged in the past, but where the site has become somewhat revegetated since the time of the logging.

D11 RECENTLY CHAINED PINYON-JUNIPER AREAS:
Not quantitatively assessed. Qualitative assessment indicates that most recently chained pinyon-juniper areas contemporary with the date of the imagery are included. This class may be confused with areas that have been chained in the past, but where the site has become somewhat revegetated since the time of the chaining.

D14 DISTURBED – OIL WELL:
Not quantitatively assessed. Qualitative assessment indicates that most disturbed areas due to oil well development contemporary with the date of the imagery are included. There are areas known to have oil well development but were not mapped due to minimum mapping unit constraints. Some confusion may occur with the N21 DEVELOPED, OPEN SPACE-LOW INTENSITY class.

S002 ROCKY MOUNTAIN ALPINE BEDROCK AND SCREE:
Quantitatively assessed, validation 75% (producers) and 100% (users) based on 12 independent validation samples. S002 is mapping extremely well within anticipated alpine areas. Expect to observe S004 ROCKY MOUNTAINS ALPINE FELL-FIELD, a rare large patch alpine system, amongst the La Sal and Hennery mountain ranges of Southern Utah being mapped as S002. Insufficient representation of S004 on the landscape and similarities between the two systems supported the joining of these two cover types.

S006 ROCKY MOUNTAIN CLIFF AND CANYON COMPLEX:
Quantitatively assessed, validation 31% (producers) and 80% (users) based on 13 independent validation samples. Confusion is primarily with COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (6 of 13 samples). Confusion can be explained by similarities between these two barren substrate systems. Where training data was available S006 mapped very well.

S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND:
Quantitatively assessed, validation 79% (producers) and 61% (users) based on 58 independent validation samples. This system comprises a large portion of the mapping area. S010 is mapping very well as expected.

S011 INTER-MOUNTAIN BASINS SHALE BADLANDS: Quantitatively assessed, validation 57% (producers) and 52% (users) based on 21 independent validation samples. Confusion is primarily with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (4 of 21 samples) and S045 INTER-MOUNTAIN BASINS MAT SALTBUSH SHRUBLAND (4 of 21 samples). Confusion can be explained by similarities between these three cover types.

S012 INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES:
Quantitatively assessed, validation 53% (producers) and 82% (users) based on 17 independent validation samples. Confusion is primarily with S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (5 of 17 samples). Confusion can be understood by recognizing that moderately vegetated sandy substrates are associated with both systems and that species occupying these moderately vegetated sandy environments are common to both types.

S013 INTER-MOUNTAIN BASINS ROCK AND CINDERLAND:
Not quantitatively assessed. Qualitative assessment indicates that areas where volcanic rock and cinderland were relatively void of vegetation are included. This class may be confused with areas known to have underlying volcanic rock substrata, but are covered by a greater proportion of vegetation than this relatively unvegetated land cover type.

S023 ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND: Quantitatively assessed, validation 53% (producers) and 63% (users) based on 19 independent validation samples. Confusion is primarily with S046 ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND (6 of 19 samples). Confusion can be understood when similarities in the deciduous nature of these two cover types is considered. S023 is mapping consistently within its expected montane to subalpine lifezone boundary. Where training data was available S023 mapped very well.

S028 ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND: Quantitatively assessed, validation 82% (producers) and 90% (users) based on 11 independent validation samples. Confusion is primarily with S042 INTER-MOUNTAIN WEST ASPEN-MIXED CONIFER FOREST AND WOODLAND COMPLEX (2 of 11 samples). Confusion can be explained by similarities between these two cover types. This system comprises a very small portion of the mapping area yet is mapping extremely well.

S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND: Not quantitatively assessed. This cover type was attained using a post processing modeler. Please reference methods section entitled *Post-classification and recoding Step 2a* for a detailed explanation. Post-classification mapped S030 very well.

S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND: Quantitatively assessed, validation 30% (producers) and 60% (users) based on 8 independent validation samples. Confusion is primarily with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (3 0f 8 samples) and S036 ROCKY MOUNTAINS PONDEROSA PINE WOODLAND (1 of 8 samples). Confusion can be explained by similarities between these three cover types.

S034 ROCKY MOUNTAINS MONTANE MESIC MIXED CONIFER FOREST AND WOODLAND: Not quantitatively assessed. This cover type was attained using a post processing modeler. Please reference methods section entitled *Post-classification and recoding Step 2b* for a detailed explanation. Post-classification mapped S034 very well.

S036 ROCKY MOUNTAINS PONDEROSA PINE WOODLAND: Quantitatively assessed, validation 72% (producers) and 65% (users) based on 36 independent validation samples. Confusion is primarily with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (6 0f 36 samples) and S046 ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND (3 of 36 samples). Confusion can be attributed to the sometime abundant presence of *Quercus gambelii* and *Juniperus osteosperma* in the Ponderosa Pine Woodland understory.

S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND: Quantitatively assessed, validation 77% (producers) and 69% (users) based on 111 independent validation samples. This widespread cover type is most commonly confused with S052 COLORADO PLATEAU PINYON-JUNIPER SHRUBLAND (12 of 111 samples). Confusion can be explained by similarities between these cover types. Overall, this upper pinyon-junper belt woodland is mapping very well.

S040 GREAT BASIN PINYON-JUNIPER WOODLAND: Quantitatively assessed, validation 83% (producers) and 59% (users) based on 12 independent validation samples. This ecological system represents an extension of the Great Basin pinyon-juniper cover type into the Northern Colorado Plateau ecoregion. It was necessary to limit the distribution of this Great Basin extension cover type, see *Post-classification and recoding Step 4* for a detailed explanation. Otherwise, S040 is mapping extremely well.

S042 INTER-MOUNTAIN WEST ASPEN-MIXED CONIFER FOREST AND WOODLAND COMPLEX: Quantitatively assessed, validation 64% (producers) and 69% (users) based on 14 independent validation samples. Confusion is primarily with S036 ROCKY MOUNTAINS PONDEROSA PINE WOODLAND (3 of 14 samples), S023 ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND (1 of 14 samples) and S028 ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND (1 of 14 samples). Confusion can be explained by similarities between these three cover types.

S045 INTER-MOUNTAIN BASINS MAT SALTBUSH SHRUBLAND: Quantitatively assessed, validation 61% (producers) and 47% (users) based on 28 independent validation samples. Confusion is primarily with S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (3 of 28 samples) and
S011 INTER-MOUNTAIN BASINS SHALE BADLANDS (2 of 28 samples). Confusion can be explained by similarities between these cover types especial when soil substrate and species commonality is considered.

S046 ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND: Quantitatively assessed, validation 64% (producers) and 63% (users) based on 47 independent validation samples. Confusion is primarily with S036 ROCKY MOUNTAINS PONDEROSA PINE WOODLAND (6 of 47 samples) and S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (5 of 47 samples). Confusion can be attributed to the sometime abundant presence of *Quercus gambelii* in the understory of Pinyon Juniper and Ponderosa Woodlands.

S052 COLORADO PLATEAU PINYON-JUNIPER SHRUBLAND: Quantitatively assessed, validation 51% (producers) and 57% (users) based on 77 independent validation samples. Confusion is primarily with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (19 of 77 samples) and S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (7 of 77 samples). Confusion with S039 can be explained by similarities between the cover types. Confusion with S010 can be explained by recognizing that this system is characterized by sparsely dominated dwarfed (usually <3 m tall) pygmy shrublands found most often on exposed rocky mesa tops, rocky slopes and sandstone plateaus. Overall, this lower pinyon-junper belt shrubland is mapping well.

S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND: Quantitatively assessed, validation 77% (producers) and 66% (users) based on 95 independent validation samples. Confusion is primarily with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (5 of 95 samples) and S052 COLORADO PLATEAU PINYON-JUNIPER SHRUBLAND (4 of 95 samples).

Confusion can be explained when the presence of *Artemisia tridentata*, which is a a common understory shrub species in both S039 and S052 systems, is considered. There is also some confusion with other sagebrush and desert shrub types which is expected. Otherwise, S054 is mapping well.

S057 MOGOLLON CHAPARRAL: Not quantitatively assessed. This cover type was attained using a post processing modeler. Please reference methods section entitled *Post-classification and recoding Step 3* for a detailed explanation. Post-classification mapped S047 very well.

S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND: Quantitatively assessed, validation 80% (producers) and 54% (users) based on 56 independent validation samples. Confusion is primarily with S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (4 of 56 samples). These cover types tend to cohabitate adjacent areas within the map zone which can help to explain the confusion. Overall, S059 is mapping extremly well.

S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 33% (producers) and 47% (users) based on 51 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (8 of 51 samples). Other confusion is distributed among S010, S011, S045, S052, S079 and S096. Confusion can be partially attributed to the pure diversity of habitats in which *Atriplex confertifolia* will reside. Where training data was available S065 mapped very well.

S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE: Quantitatively assessed, validation 62% (producers) and 72% (users) based on 21 independent validation samples. Confusion is randomly distributed among a number of cover types. S071 is mapping well in the upper montane to subalpine zones where expected. Some attention, however, should be given to areas where S071 is mapping well into the lower-montane zone which is misrepresenting the cover type. These areas may have been more appropriately mapped as S054 and could likely be attributed to sagebrush sub-species misidentification.

S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE: Quantitatively assessed, validation 28% (producers) and 38% (users) based on 32 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (4 of 32 samples), S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (4 of 32 samples), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (3 of 32 samples) and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (3 of 32 samples). Confusion can be partially explained by the internal variability of accepted species composition within S079. Let it also be noted that all of the systems being confused with S079 have dominating species that when combined make up the S079 ecological system. Where training data was available S079 mapped very well.

S083 ROCKY MOUNTAIN SUBALPINE MESIC MEADOW: Quantitatively assessed, validation 75% (producers) and 60% (users) based on 8 independent validation samples. Confusion is primarily with S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (1 of 8 samples) and S046 ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND (1 of 8 samples). This cover type is mapping very well within the subalpine life zone.

S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND: Quantitatively assessed, validation 24% (producers) and 42% (users) based on 34 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (9 of 34 samples) and S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (5 of sample). It is unclear why this system is mapping poorly. Where training data was available S090 mapped very well.

S093 ROCKY MOUNTAINS LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND COMPLEX: Quantitatively assessed, validation 56% (producers) and 56% (users) based on 18 independent validation samples. Confusion is primarily with D04 INVASIVE SOUTHWEST RIPARIAN WOODLAND AND SHRUBLAND (4 of 18 samples). Confusion can be explained by similarities between these two cover types. Where training data was available S093 mapped very well.

S096 INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX: Quantitatively assessed, validation 44% (producers) and 55% (users) based on 27 independent validation samples. Confusion is primarily with S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (3 of 27 samples). Confusion can be partially explained by the sometimes dense presence of *Atriplex confertifolia* in the understory and the common subtrates associated with both systems. Where training data was available S096 mapped very well.

S097 NORTH AMERICAN WARM DESERT RIPARIAN WOODLAND AND SHRUBLAND: Not quantitatively assessed. This cover type was attained using a post processing modeler. Please reference methods section entitled *Post-classification and recoding Step 1* for a detailed explanation. Post-classification mapped S097 very well.

S126 NORTHERN COLORADO PLATEAU SAND SHRUBLAND: Quantitatively assessed, validation 47% (producers) and 70% (users) based on 15 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (3 of 15 samples) and S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (2 of 15 samples). Where training data was available S126 mapped very well.

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