SWReGAP Land Cover Mapping Methods Documentation

Functional Unit or Mapping Zone: UT1

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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 Mosaic:

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
39/31	2000-92	2000-172	1999-297	4	7	8
39/32	2000-124	2000-156	1999-281	3	6	7
39/33	2000-124	2000-172	1999-281	2	1	6
39/34	2000-124	2000-188	1999-281	1	5	5
38/31	2000-117	2000-181	2000-277	7	3	4
38/32	2000-149	1999-230	1999-290	8	2	3
38/33	2000-117	2000-213	1999-306	5	8	2
38/34	2000-133	2000-165	1999-306	6	4	1

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

/ut/archive/ut1/mosaic/ut1_spscn
/ut/archive/ut1/mosaic/ut1_suscn
/ut/archive/ut1/mosaic/ut1_fascn

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

/ut/archive/ut1/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/ut1/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/ut1/img_files/.

All imagery derived predictor layers can be found at:

/ut/archive/ut1/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/ut1/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.

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.

Jhl<date>_<site number>, doq_<site number> and jhl_doq<date>_<site number>: 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.

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

mapchk_<date>_<site number>, ut<date><collector initials><site number>_mapchk_<site number>: Indicates data collected by USU RSGIS lab SWReGAP field crew. This data was collected as augmentation data in modeling misclassification trouble spots.

b) Summary of Samples:

3,680 samples were available to model this mapping area of which 3,612 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.

VALUE	SCODE2	DESCRIPTION (ECOLOGICAL SYSTEM NAME)	Number Of Samples
9	S009	INTER-MOUNTAIN BASINS CLIFF AND CANYON COMPLEX	70
15	S015	INTER-MOUNTAIN BASINS PLAYA	152
23	S023	ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND	22
24	S024	ROCKY MOUNTAIN BIGTOOTH MAPLE RAVINE WOODLAND	41
32	S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND	72
40	S040	GREAT BASIN PINYON-JUNIPER WOODLAND	462
46	S046	ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND	72
54	S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND	502
55	S055	GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLAND	232
65	S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB	539
71	S071	INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE	77
79	S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE	299
85	S085	SOUTHERN ROCKY MOUNTAINS MONTANE GRASSLAND	55
90	S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND	95
96	S096	INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX	313
100	S100	NORTH AMERICAN ARID WEST EMERGENT MARSH	68
50	S050	INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLAND AND SHRUBLAND	32
306	D06	INVASIVE PERENNIAL GRASSLAND	73
308	D08	INVASIVE ANNUAL GRASSLAND	189
309	D09	INVASIVE ANNUAL FORBLAND	113
118	S118	GREAT BASIN FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND	88
0	S000	IGNORED	68
15	A866	IODINE BUSH SHRUBLAND ALLIANCE (synonymous with S015 for modeling)	47
		Total number of samples	**3680**

Polygon coverage containing all samples is located at:
ut/archive/ut1/train_data/

3) Cover Types:

a) Classification Tree Modeled Cover Types:

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

VALUE	SCODE2	DESCRIPTION (ECOLOGICAL SYSTEM NAME)	Number Of Samples
9	S009	INTER-MOUNTAIN BASINS CLIFF AND CANYON COMPLEX	70
15	S015	INTER-MOUNTAIN BASINS PLAYA	199
23	S023	ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND	22
24	S024	ROCKY MOUNTAIN BIGTOOTH MAPLE RAVINE WOODLAND	41
32	S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND	72
40	S040	GREAT BASIN PINYON-JUNIPER WOODLAND	462

46	S046	ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND	72
54	S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND	502
55	S055	GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLAND	232
65	S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB	539
71	S071	INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE	77
79	S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE	299
85	S085	SOUTHERN ROCKY MOUNTAINS MONTANE GRASSLAND	55
90	S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND	95
96	S096	INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX	313
100	S100	NORTH AMERICAN ARID WEST EMERGENT MARSH	68
50	S050	INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLAND AND SHRUBLAND	32
306	D06	INVASIVE PERENNIAL GRASSLAND	73
308	D08	INVASIVE ANNUAL GRASSLAND	189
309	D09	INVASIVE ANNUAL FORBLAND	113
118	S118	GREAT BASIN FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND	88
		Total number of samples	**3612**

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/ut1/non_model/

VALUE	CODE	DESCRIPTION (ECOLOGICAL SYSTEM NAME)
12	S012	INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES
13	S013	INTER-MOUNTAIN BASINS VOLCANIC ROCK AND CINDER LAND
118	S118	GREAT BASIN FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND
211	N11	OPEN WATER
221	N21	DEVELOPED, LOW INTENSITY
222	N22	DEVELOPED, MED-HIGH INTENSITY
231	N31	BARREN LANDS (NON-SPECIFIC)
281	N81	AGRICULTURE, PASTURE/HAY
282	N82	AGRICULTURE, CULTIVATED CROPS
301	D01	NON-SPECIFIC DISTURBED
302	D02	RECENTLY BURNED
303	D03	RECENTLY MINED OR QUARIED

***c)* Cover Types Modeled with a Post-Classification model:**
(see section 5c for details)

CODE	DESCRIPTION (ECOLOGICAL SYSTEM NAME)
S028	Rocky Mountain Subalpine Dry- Mesic Spruce-Fir Forest and Woodland
S030	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
S034	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland

S039	Colorado Plateau Pinyon-Juniper Woodland
S093	Rocky Mountain Lower Montane Riparian Woodland and Shrubland

4) Summary of Predictor Layers Used:

a) Multi band predictors:

ut1_fall_2000.img (ETM bands 1-5 & 7 for fall, 2000 meter buffer)
ut1_spr_2000.img (ETM bands 1-5 & 7 for spring, 2000 meter buffer)
ut1_sum_2000.img (ETM bands 1-5 & 7 for summer, 2000 meter buffer)

All multi-band predictors can be found at:
/ut/archive/ut1/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
fandvi.img	Fall Normalized Difference Vegetation Index
spbrt.img	Spring brightness band
spgrn.img	Spring greenness band
spndvi.img	Spring Normalized Difference Vegetation Index
subrt.img	Summer brightness band
sugrn.img	Summer greenness band
sundvi.img	Summer Normalized Difference Vegetation Index
landf.img	Categorical 10 class landform (from DEM)

All single-band predictors can be found at:
/ut/archive/ut1/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/ut1/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/ut1/post_model/ut1.gmd

Note: The original CT output image referred to in the following text can be found at /archive/ut1/post_model/post_model/images/ m6all1_rec.img. The final image output of this post-modeled can be found at /archive/ut1/Final_Map/ ut1_final.img.

Step 1: Correcting Scene line, Cloud and Smoke Error
A conditional statement was written for the purpose of correcting misclassified landcover Ecological System output pixels. The presence

of mosaic scene lines, seasonal clouds and smoke emitted by fires that was captured on the Landsat 7 ETM+ imagery can be attributed for the errors. Errors were identified by visually inspecting Landsat imagery and ct model output images.

The details of the conditional statement follow:

1A:EITHER m6all1_nosum_rec IF (sceneline_clouds_rec == 1) OR m6all1_rec OTHERWISE

1B: EITHER m6all1_nosum_rec IF (sceneline2_rec ==1) OR memory OTHERWISE

Where:

m6all1_nosum_rec	UT1 output image which integrated NO SUMMER brightness, greenness or Landsat raw band imagery as independent variables. Recoded to standard integer code.
sceneline_clouds_rec	Scene line, cloud and smoke mask image. Indicates area where error occurred. 1 = error 0 = all other area
sceneline2_rec	Scene line mask image. Indicates area where error occurred. 1 = error 0 = all other area
m6all1_rec or memory	UT1 standard CT output image. Recoded to standard integer code. Note: This output is also represented as a temporary memory file that has been modified by previous steps in the post classification model.

***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 ((landform==2 OR landform==5 OR landform==6 OR landform==9) AND (aspect==1 OR aspect==2 OR aspect==0) AND (memory==32)) OR 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,
Aspect	Nine class aspect image 1=North facing slope 2=Northeast facing slope 0=slope less than 3 degrees
Memory	UT1 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: Mapping *Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland.*

The original CT output was unsuccessful when modeling *S028 Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland* due to a lack in significant training data sample numbers. As a result the original CT model image mapped all S028 sample sites as S032 *Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland.* Step 2b was designed to discriminate between S028 *Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland* and *S032 Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland* using elevation as the differentiating factor. The logic and parameters for the model were as follows:

EITHER 28 IF (memory == 32 AND elev >= 2600) OR memory OTHERWISE

Where:

28	*Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland*
32	*S032 Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland*
Elev	Thirty meter digital elevation model
Memory	UT1 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 2c: 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 ((landf==2 OR landf==5 OR landf==6 OR landf==9) AND (aspect_9cls ==1 OR aspect_9cls ==2 OR aspect_9cls ==0) AND (memory ==28)) OR 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	UT1 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: Restrict *S118 Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland* to riparian corridors

A post-classification model was used to limit the mappable area of S118 by restricting it to riparian corridors.

During the visual inspection of the standard CT output image output, S118 Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland was found to be mapping in undesirable and non-riparian locations. This conditional statement restricts S118 to riparian areas using a stream corridor mask that has been buffered to 250meters.

Model Methods: Two standard output CT model output were created one that ignored Ecological System class S118 and the other that mapped Ecological System class S118. The map that withheld S118 was reserved as replacement vegetation pixel values for areas within the map that contained Ecological System class S118 that were identified as unsuitable terrain for S118. Suitable terrain was identified by the 250meter buffered stream corridor mask image.

The detail of the conditional statement follows:

EITHER m6all1_norip_rec IF (memory==118 AND ut_nhd < 99) OR memory OTHERWISE

Where:

118	*S118 Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland*
m6all1_norip_rec	UT1 output image ignoring riparian Ecological System class S118. Recoded to standard integer code.
Ut_nhd	250m buffered stream corridor 1-99= all other terrain 1000= suitable riparian terrain
memory	UT1 standard 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: Correcting for Regional Ecological System Name Changes

This conditional statement was designed to correct for areas were regional names change due to transition zones between ecoregions. A mask was created to identify were *S118 Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland* pixels needed to be recoded to *S093 Rocky Mountain Lower Montane Riparian Woodland and Shrubland*. The same mask was used to identify areas were *S040 Great Basin Pinyon-Juniper Woodland* pixels were recoded to *S039 Colorado Plateau Pinyon-Juniper Woodland*. This model corrected an otherwise abrupt edge and allowed for a smooth transition between the Rocky Mountain/ Great Basin/ Colorado Plateau which better represents the ecotone.

The detail of the conditional statement follows:

4A: EITHER 39 IF (memory== 40 AND transitionzone==1) OR memory OTHERWISE

4B: EITHER 93 IF (memory==118 AND transitionzone==1) OR memory OTHERWISE

Where:

39	*S039 Colorado Plateau Pinyon-Juniper Woodland*
40	*S040 Great Basin Pinyon-Juniper Woodland*
93	*S093 Rocky Mountain Lower Montane Riparian Woodland and Shrubland*.
118	*S118 Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland*
Memory	UT1 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.
Transitionzone	Transition Zone Mask that where identifies ecotone/ regional name change occurred

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/ut1/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/ut1/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/ut1/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.

DO3 RECENTLY MINED OR QUARRIED:
Not quantitatively assessed. Qualitative assessment indicates that most recently mined or quarried areas contemporary with the date of the imagery are included. Some confusion may occur with the N21 DEVELOPED, OPEN SPACE-LOW INTENSITY class.

D06 INVASIVE PERENNIAL GRASSLANDS:
Quantitatively assessed, validation 40% (producers) and 75% (users) based on 15 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (5 of 15 samples). This ecological system, like all invasive systems, can be difficult to map. Post fire reseeding and rangeland treatments pervade dated imagery (3years old) and can account for some of the confusion. Where training data was available D08 mapped very well.

D08 INVASIVE ANNUAL GRASSLAND:
Quantitatively assessed, validation 32% (producers) and 50% (users) based on 35 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (7 of 35 samples) and S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (5 of 35 samples). This ecological system, like most invasive systems, is driven by disturbance rather than ecological process and can be difficult to map. Fire, rangeland treatments and disturbance allows for the rapid advancement and establishment of cheat grass. These disturbances can pervade dated imagery (3 years old) and can account for some of the confusion. Where training data was available D08 mapped very well.

D09 INVASIVE ANNUAL FORBLAND:
Quantitatively assessed, validation 30% (producers) and 54% (users) based on 23 independent validation samples. This ecological system, like most 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 S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (9 of 23 samples). *Atriplex confertifolia* is commonly found in these disturbed sites and in some cases was the preexisting dominating system. Where training data was available D09 mapped well.

S009 INTER-MOUNTAIN BASINS CLIFF AND CANYON COMPLEX:
Quantitatively assessed, validation 57% (producers) and 89% (users) based on 14 independent validation samples. Confusion is randomly distributed among a number of cover types. Where training data was available S006 mapped very well.

S015 INTER-MOUNTAIN BASINS PLAYA:
Quantitatively assessed, validation 73% (producers) and 94% (users) based on 41 independent validation samples. Confusion is primarily with S096 INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX (8 of 41 samples). S096 commonly occurs adjacent to and/or co-dominating with S015. Overall this cover type is mapping well.

S023 ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND: Quantitatively assessed, validation 80% (producers) and 67% (users) based on 5 independent validation samples. This cover type is mapping extremely well.

S024 ROCY MOUNTAIN BIGTOOTH MAPLE RAVINE WOODLAND:
Quantitatively assessed, validation 67% (producers) and 75% (users) based on 9 independent validation samples. Confusion is primarily with S118 GREAT BASINS FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND S096 (2 of 9 samples). This confusion can be attributed to the similarities in environmental settings and spectral signature among S024 and S118. Where training data was available S024 mapped very well.

S028 ROCKY MOUNTAINS SUBALPINE DRY-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 2B* for a detailed explanation. Post-classification mapped S028 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 2C* for a detailed explanation. Post-classification mapped S030 well.

S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND: Quantitatively assessed, validation 100% (producers) and 83% (users) based on 15 independent validation samples. This cover type is mapping extremely well. This degree of accuracy can be carried over to S028, S030, and S034 see specific cover types for details.

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 2A* for a detailed explanation. Post-classification mapped S034 well.

S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND:
Not quantitatively assessed. This ecological system represents the transition zones from the Great Basin pinyon-juniper cover type into the Northern Colorado Plateau ecoregion. It was necessary to limit the distribution of this cover type and map it using a post processing modeler. Please see *Post-classification and recoding Step 4* for a detailed explanation.

S040 GREAT BASIN PINYON-JUNIPER WOODLAND: Quantitatively assessed, validation 78% (producers) and 70% (users) based on 93 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (13 of 93 samples). This confusion can be understood when the presence of *Artemisia tridentata*, a common understory shrub species of S040 system, is considered as a co-dominate. Otherwise, S040 is mapping extremely well.

S046 ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND:
Quantitatively assessed, validation 33% (producers) and 50% (users) based on 15 independent validation samples. Confusion is primarily with S040 GREAT BASIN PINYON-JUNIPER WOODLAND ROCKY (4 of 15 samples). This confusion can be attributed to the sometime abundant presence of *Quercus gambelii* in the understory of Pinyon Juniper Woodlands. Other confusion is with S024 ROCY MOUNTAIN BIGTOOTH MAPLE RAVINE WOODLAND (2 of 15 samples) and S118 GREAT BASINS FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND (2 of 15 samples). This confusion can be partially explained by examining environmental setting and spectral signatures characteristics which mimics that of Gambeled Oak.

S050 INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLAND AND SHRUBLAND:
Quantitatively assessed, validation 0% (producers) and 0% (users) based on 7 independent validation samples. Confusion is primarily with S040 GREAT BASIN PINYON-JUNIPER WOODLAND (4 of 7 samples). With only 7 samples, this is a complex and difficult type to map accurately. Clearly sufficient training data was not obtained to produce satisfactory results and in response this system is not mapping well. Where training data was available S055 mapped well all be it limited in distribution.

S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND: Quantitatively assessed, validation 71% (producers) and 55% (users) based on 101 independent validation samples. Confusion is primarily with S040 GREAT BASIN PINYON-JUNIPER WOODLAND (9 of 101 samples). This confusion can be understood when the presence of *Artemisia tridentata*, a common understory shrub species of S040 systems, is considered as a co-dominate. There is also some confusion with other sagebrush and desert shrub types which is expected. Otherwise, S054 is mapping well.

S055 GREAT BASINS XERIC MIXED SAGEBRUSH SHRUBLAND:
Quantitatively assessed, validation 53% (producers) and 63% (users) based on 47 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (9 of 47 samples) AND S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (9 of 47 samples). Confusion can be partially explained by the presence of *Atriplex confertifolia* and the similar alluvial slopes associated with all three systems. Where training data was available S055 mapped well.

S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB:
Quantitatively assessed, validation 56% (producers) and 49% (users) based on 108 independent validation samples. Confusion is primarily with S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (19 of 108 samples). Confusion can be partially explained by the presence of *Atriplex confertifolia* in both ecological communities and the similar saline subtrates associated with both systems. Confusion also occurs with S096 INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX. This confusion can be explained by acknowledging the common presence of *Atriplex confertifolia* in the understory of Greasewood communities and their physiognomic and spectral commonalities. Where training data was available S065 mapped very well.

S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE:
Quantitatively assessed, validation 38% (producers) and 55% (users) based on 16 independent validation samples. Confusion is primarily with S040 GREAT BASIN PINYON-JUNIPER WOODLAND (4 of 16 samples). It is unclear why this system is mapping poorly. Where training data was available S079 mapped very well.

S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE:
Quantitatively assessed, validation 55% (producers) and 43% (users) based on 60 independent validation samples. Confusion is primarily with S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (15 of 60 samples). Confusion can be partially explained by the presence of *Atriplex confertifolia* in the both systems and the similarities in environmental setting each system can be found occupying. Where training data was available S079 mapped very well.

S085 SOUTHERN ROCKY MOUNTAIN MONTANE GRASSLAND:
Quantitatively assessed, validation 18% (producers) and 40% (users) based on 11 independent validation samples. Confusion is primarily with S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (3 of 11 samples). Confusion can be explained when recognizing the common play of S085 as a patchwork community within the matrix system of S071. Where training data was available S085 mapped very well.

S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND:
Quantitatively assessed, validation 21% (producers) and 44% (users) based on 19 independent validation samples. Confusion is primarily with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (5 of 19 samples), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (3 of 19 samples) and S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (3 of 19 samples). 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: Not quantitatively assessed. This cover type was attained using a post processing modeler. Please reference methods

section entitled *Post-classification and recoding Step 4* for a detailed explanation. Post-classification mapped S093 well.

S096 INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX: Quantitatively assessed, validation 57% (producers) and 56% (users) based on 63 independent validation samples. Confusion is primarily with S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (10 of 63 samples). Confusion can be partially explained by the sometimes dense presence of *Atriplex confertifolia* in the understory and the similar saline subtrates associated with both systems. Confusion also occurs with S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (8 of 63 samples). This confusion can be explained by acknowledging the common co-dominance of Black Greasewood and Big Basin Sagebrush and their physiognomic structure and spectral commonalities. Where training data was available S096 mapped very well.

S100 NORTH AMERICAN ARID WEST EMERGENT MARSH:
Quantitatively assessed, validation 93% (producers) and 100% (users) based on 14 independent validation samples. Confusing only with S118 GREAT BASINS FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND (1 of 14 samples). S100 mapped extremely well.

S118 GREAT BASINS FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND:
Quantitatively assessed, validation 67% (producers) and 57% (users) based on 18 independent validation samples. Please note that the final mapping results will vary because this cover type was attained using a combination of a CT standard modeler, post processing modeler and screen digitizing non-modeling. Please reference methods section entitled *Post-classification and recoding Step 2A* for post classification detailed explanation. Please reference *Cover types* section 3b for non-modeled cover type explanation. Post-classification mapped S118 very well.

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