SWReGAP Land Cover Mapping Methods Documentation

Functional Unit or Mapping Zone: Arizona 1

Organization: U.S. Geological Survey, Southwest Biological Science Center

Person Preparing Document: Kathryn Thomas, Cynthia Wallace, Jess Kirby

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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:

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

Where,

P_{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

H_{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 date (yr Julian date)
37/35	2000-94	2000-158	1999-283
38/34	2000-133	2000-165	1999-306
38/35	2000-117	2000-165	1999-290
39/35	2000-92	2000-156	1999-297

The ERDAS Imagine mosaic files showing overlap arrangement can be found at:

AZ\ARCHIVE\AZ1\MOSAIC\az1_fa.mos
AZ\ARCHIVE\AZ1\MOSAIC\az1_sp.mos
AZ\ARCHIVE\AZ1\MOSAIC\az1_su.mos

In addition, a description of the overlap arrangement is presented in:

AZ\ARCHIVE\AZ1\MOSAIC\mosaic\az1_readme.txt

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 AZ\ARCHIVE\AZ1\IMG_FILES.

Tasseled cap: Brightness, Greenness & Wetness band transformations wee 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 AZ\ARCHIVE\AZ1\IMG_FILES.

All imagery derived predictor layers can be found at:

AZ\ARCHIVE\AZ1\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. DEM's were converted from floating point grids to integer grids and mosaicked for the region, then clipped to the mapping area.

Aspect: A nine-class 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 index grid (values ranging from 0-28) (Manis et al 2001).

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

AZ\ARCHIVE\AZ1\IMG_FILES\

2) Samples:

a) Sample collection methods:

U.S. Geological Survey Southwest Biological Science Center field crews collected the majority of samples on the ground, others came from existing data 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 SOURCE field in the \AZ\ARCHIVE\AZ1\TRAIN_DATA\az1_polys_all identifies the source for each sample except where noted. The PLOTNUM field indicates the unique identifier for that record. In the case of samples taken from existing data, the unique identifier was either assigned by the project generating the data or by the SWReGAP field team for the purposes of this project. Following is an explanation of each data source.

Babbitt: Data from an existing database of vegetation relevés obtained by the U.S. Geological Survey on the Babbitt Ranches in northern Arizona in 1997 and 1998.

Field_CPRS: Data collected by the U.S. Geological Survey SWReGAP field crew from 2001 to 2003. Plot code structure is:
AZ<month/day><year><teamcode><idnum><sequence letter, if appl>. An example plot code is: AZ070902KM010.

GRCA_Cole: Data originally reported in work done by Warren et al in 1978-79 within the Grand Canyon corridor. The raw data was subsequently georeferenced and entered into digital format by a team directed by Ken Cole of the U.S. Geological Survey. Although the data is somewhat dated, the resources required to sample below the Grand Canyon rim was prohibitive to this project and no other field survey data existed. Other studies (Bowers et al 1995) have shown that vegetation generally has long persistence within the Grand Canyon. An example plot code is: 923

Landfire: Data from an existing database of vegetation observations developed by the USGS-US Forest Service Landfire project (http://gam.usgs.gov/,/landfire.shtml). Some of these points are identified in the Siteid column as ref-<idnum>, data collected in 2000 as reference data, or val-<idnum>, data collected in 2001 as validation data. An example plot code is: 24005

NoAzGAP: Data from an existing database collected for accuracy assessment of the first generation Arizona Gap Analysis land cover map. The U.S. Geological Survey Colorado Plateau Research Station collected these data in 1997. An example plot code is: 3568.

SoAzGAP: Data from an existing database collected for accuracy assessment of the first generation Arizona Gap Analysis land cover map. Data were collected by the U.S. Geological Survey Sonoran Desert Research Station in 1997. An example plot code is: AZ080997TU03.

Rippts: Data occurring in riparian corridors. Data were collected by the U.S. Geological Survey's Grand Canyon Research and Monitoring (example code GRCA302) in 2003 or by the Arizona Department of Game and Fish along riparian corridors (example code AZCO096) from 1993 to 2000.

UT043003JD25: Data with an identifier with this sort of structure indicated in the SiteID column is from the Utah State University RSGIS lab SWReGAP field team.

doq022004_85: Data with an identifier with this sort of structure indicated in the SiteID column is a from interpretation of black and white Digital Orthophoto Quads available from the state of Utah from AGRC. DOQ interpretation was done by the RSGIS lab personnel.

1997-27-8: Data with an identifier with this sort of structure indicated in the SiteID column is provided by the Utah Department of Natural Resources, Division of Wildlife Resources, the Utah Big Game Range Trend Studies Annual Reports 1997-2001. FGDC metadata is at: \UT\ARCHIVE\UT3\TRAIN_DATA\.

b) Summary of samples:

2402 samples were available to model this mapping area. A polygon coverage containing all samples is located at: AZ\ARCHIVE\AZ1\TRAIN_DATA.

Code	Ecological System Name	a
D04	INVASIVE SW RIPARIAN WOODLAND AND SHRUBLAND	15
D09	INVASIVE ANNUAL FORBLAND	42
S010	COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND	111
S020	NORTH AMERICAN WARM DESERT WASH	15
S023	ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND	30
S028	ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND	30
S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND	109
S036	ROCKY MOUNTAINS PONDEROSA PINE WOODLAND	295
S039	COLORADO PLATEAU PINYON-JUNIPER WOODLAND	676
S046	ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND	23
S057	MOGOLLON CHAPARRAL	23
S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND	273
S060	MOJAVE MID-ELEVATION MIXED DESERT SCRUB	164
S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB	62
S069	SONORA-MOJAVE CREOSOTEBUSH-WHITE BURSAGE DESERT SCRUB	31
S075	INTER-MOUNTAIN BASINS JUNIPER SAVANNA	49
S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE	256
S085	SOUTHERN ROCKY MOUNTAINS MONTANE GRASSLAND	24
S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND	128
S097	NORTH AMERICAN WARM DESERT RIPARIAN WOODLAND AND SHRUBLAND	5
_	**TOTAL	2402

c) Preparing Sample Data for Classification Tree (CT) Modeling:

The point sample data were prepared for decision tree modeling input by the following steps:

1. Create UTM point coverage of all point data with attributes (ArcInfo commands generate, dbaseinfo, additem, tables, joinitem. Note that additional fields are idnum, to accomplish the join, and N4RPTS, which is the number of random points that will be extracted from each sample polygon and is initially set to 20)
2. Project UTM points to Albers
3. Flag points that are within 30 meters of a road and increase their buffer value if they are smaller than 90m (this step is to ensure enough sample points once the roads are erased):
    a. Identity az_pt1 az_tran_b30m az_pt2
    b. Tables

c. Sel az_pt2.pat
d. Resel inside = 100
e. Resel buffer < 90 (smaller)
f. Resel buffer > 15 (not riparian)
g. Calc buffer = 90 (to get enough to sample once roads are erased)
h. Calc num4rpts = 40 (define more samples near roads as some will be erased to eliminate pixels on the roads)

4. Buffer the field points according to the field notes as modified by step 3. Use ArcView extension BufferThemeBuilder, choose attribute 'buffer' as the distance field.
5. Find overlapping polygons and eliminate (either re-label, if appropriate, or delete)
6. Merge all neighboring data (adjacent mapzones and states).
7. Merge with data points identified from imagery. For example, class S010 was digitized as polygons but included in the decision tree modeling by: buffering polygons by 100m (to avoid mixed pixels at edges) and assigning the number of random points to be extracted for these polygons to 5 (N4RPTS). These polygons were added after they were 'erased' by the buffered polygons of field data, so that field data took precedence.
8. Recode the character field containing the Ecosystem Code (ES_code) to a number (ES2NUM) using ArcView extension Recode.
9. Create 80% training and 20% validation polygon sets from the sample polygons. Use ArcView with featureselect extension, select 20 percent for validation set, recorded in field 'ESWH20'.
10. Create random points within each sample polygon. Use ArcView extension Random Point Generator v. 1.27, specify N4RPTS as the field with the number of points desired, convert shapefile to coverage az_rpts_all in ArcInfo.
11. Delete random points within 45m of roads. (In ArcInfo, identity the random points with the 45m road buffer coverage; in ArcEdit, delete points with INSIDE = 100).
12. Attached sample polygon attributes to the random points using Identity in ArcInfo and the azx_polys_all coverage.
13. In ArcInfo, copy the sample polygon set (azx_polys_all) twice to create azx_polys_trn and azx_polys_val. In ArcEdit, delete the polygons with ESWH20 = 1 in azx_polys_trn and delete the polygons with ESWH20 = 0 in azx_polys_val.
14. In ArcInfo, copy the sample point set (azx_rpts_all) twice to create azx_rpts_trn and azx_rpts_val. In ArcEdit, delete the polygons with ESWH20 = 1 in azx_rpts_trn and delete the polygons with ESWH20 = 0 in azx_rpts_val.
15. Convert the three random point coverages (azx_rpts_all, azx_rpts_trn and azx_rpts_val) to grids using the ES2NUM field as the grid value. Use ArcView with Spatial analysis tool, specify extent and grid cells to match the ETM+ imagery.
16. Import the grids azx_rpts_all and azx_rpts_trn into ERDAS Imagine as *.img files for Cart modeling.

3) Cover types:

a) Classification Tree modeled cover types:

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

Code	Ecological System Name
D04	INVASIVE SW RIPARIAN WOODLAND AND SHRUBLAND
D09	INVASIVE ANNUAL FORBLAND
S010	COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND
S020	NORTH AMERICAN WARM DESERT WASH
S023	ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND
S028	ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND
S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND
S036	ROCKY MOUNTAINS PONDEROSA PINE WOODLAND
S039	COLORADO PLATEAU PINYON-JUNIPER WOODLAND
S046	ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND
S057	MOGOLLON CHAPARRAL
S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND
S060	MOJAVE MID-ELEVATION MIXED DESERT SCRUB
S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB
S069	SONORA-MOJAVE CREOSOTEBUSH-WHITE BURSAGE DESERT SCRUB
S075	INTER-MOUNTAIN BASINS JUNIPER SAVANNA
S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE
S085	SOUTHERN ROCKY MOUNTAINS MONTANE GRASSLAND
S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND
S097	NORTH AMERICAN WARM DESERT RIPARIAN WOODLAND AND SHRUBLAND

b) Non CT modeled cover types:

The following types were included as non-modeled cover types:

Code	Ecological System Name
S013	INTER-MOUNTAIN BASINS VOLCANIC ROCK AND CINDERLAND
N11	OPEN WATER
N22	DEVELOPED, MED-HIGH INTENSITY
D02	RECENTLY BURNED
D03	RECENTLY MINED OR QUARRIED

S013 INTER-MOUNTAIN BASINS VOLCANIC ROCK AND CINDER LAND

The volcanic rock and cinder land class was extracted from the ETM+ imagery using an unsupervised classification procedure. The unsupervised classification used an input image stack consisting of the 6 non-thermal raw bands of the summer image. Several distinct AOIs were selected for identifying volcanics based on field knowledge and inspection of the imagery. Volcanics were identified by visually inspecting the images for dark areas known to contain volcanics, commonly with distinctive crater or flow textures. Areas thought to contain volcanics based on inspection of the imagery were confirmed by referring to the Roadside Geology of Arizona (Chronic 1983) and/or the Delorme Atlas (1993). The 6 band image stack was classified into 20 or 30 clusters using ERDAS Imagine's unsupervised classification module. The classified volcanics image was recoded to a binary image, clumped (allowing 4 neighbors), and eliminated (removing clusters less than 5 pixels in size), to produce a volcanics image that retains only features of 1 acre MMU. For AOIs, see AZ\ARCHIVE\AOI\LAVA_AOI folder in the ARCHIVE.

N11 OPEN WATER

The majority of the open water class was extracted from the ETM+ imagery using a nested unsupervised classification procedure. The initial unsupervised classification used an input image stack consisting of the following 13 images:

- 12 pca bands resulting from a PCA analysis of the 12 band stack of the fall image and the summer image. This pca was calculated to enhance the seasonal differences between the two dates.
- Slope image, derived from the 30 meter DEM.

The 13 image stack was classified into 40 clusters using ERDAS Imagine's unsupervised classification module. Water was identified by visually inspecting the images for open water visible in either season. Several of the original 40 clusters were isolated and re-classified into 20 clusters. The classified water image was recoded to a binary image, clumped (allowing 8 neighbors), and eliminated (removing clusters less than 5 pixels in size), to produce a water image that retains only water bodies of 1 acre MMU. The image was converted to a grid and the grid was converted to a polygon coverage.

The polygons extracted from the imagery were then given to a field mapper, who labeled or deleted polygons by comparing them to information in the DeLorme Atlas (1993) and ancillary data sources. Areas where the image classification incorrectly identified pixels as water (e.g., areas of shadow) were captured via screen digitizing as a polygon coverage that was used to erase the water coverage. Additional areas of open water visible in either the fall or summer image (but missed by the nested unsupervised classification) were screen digitized over ETM+ imagery at a scale of 1:24,000 or larger using ArcMap.

N21 DEVELOPED, LOW INTENSITY-OPEN SPACE
N22 DEVELOPED, MED-HIGH INTENSITY

The urban areas were identified on ETM+ imagery and screen digitized at a scale of 1:50,000 or larger (1:24,000) using ArcMAP. Urban areas were recognized by their distinctive rectilinear patterns of intersecting road networks and variable patterns of spectral brightness, including extremely bright visible reflectance associated with roofing materials and concrete. Fall, spring and summer images were variously used. When the image pattern was questionable, urban areas were verified by referring to ancillary data, including the DeLorme Atlas (1993) and the ALRIS urban area coverage (based on census tract data). The shapefile created using the fall image was then overlain on the spring and summer images and additional urban areas visible on these images were captured. Two classes of urban areas were recognized: N21 (open space - low intensity developed) and N22 (medium - high intensity developed). These were differentiated on the basis of the density of 'green space' included, i.e. yards, parks, golf courses, etc.

D02 RECENTLY BURNED

Recently burned areas were identified on ETM+ imagery as dark patches, typically angular, commonly bordered by roads. These were captured by: defining an AOI around each burn identified in each season, performing an unsupervised classification within the AOI specifying 20 clusters, and recoding the clusters corresponding to the burned area. For AOIs, see AZ\ARCHIVE\AZ1\AOI\FIRE_AOI folder in the ARCHIVE.

D03 RECENTLY MINED OR QUARRIED

Recently mined areas were identified on the fall ETM+ imagery and screen digitized over ETM+ imagery at a scale of 1:24,000 or larger. The image was overlaid with locations of surface mining activities extracted from the USGS Minerals point coverage found at: http://mrdata.usgs.gov/. Areas of apparent disturbance (anomalous reflectance on the image) that were collocated with known surface mining activity were identified and digitized as land cover type D01. A few larger mined areas were digitized with the Urban Areas and extracted from that shapefile to include in this coverage.

The following cover types were modeled with a post-classification model (see section 5b for details):

Code	Ecological System Name
S030	ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND
S034	ROCKY MOUNTAINS MONTANE MESIC MIXED CONIFER FOREST AND WOODLAND
S059	COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND
S040	GREAT BASIN PINYON-JUNIPER

4) Summary of predictor layers used:

a) Multi band predictors:

Multi band predictors:

AZ1_fa.img	(ETM bands 1-5 & 7 for fall)
AZ1_sp.img	(ETM bands 1-5 & 7 for spring)
AZ1_su.img	(ETM bands 1-5 & 7 for summer)

All multi-band predictors can be found at: AZ\ARCHIVE\AZ1\IMG_FILES

b) Single band predictors:

asp_az1_9cls.img	Aspect in 9 categorical classes
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 (modeled from DEM)

All multi-band predictors can be found at: AZ\ARCHIVE\AZ1\IMG_FILES

5) Modeling Methods:

a) See5 Classification Tree modeling:

Samples: 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: AZ\ARCHIVE\AZ1\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 created: 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. These files can be found at AZ\ARCHIVE\AZ1\OUTPUT.

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

The post-classification model described below was created to assist in differentiating between ecological system cover types that possess similar characteristics. In these cases species composition, species presents and/or ecoregional location was not enough to distinguish between the two types especially when the types share similar physiognomic and hydrologic characteristics. The following model is a tool for discriminating between these ecological system cover types.

The .gmd file used for this post-classification model is:
AZ\ARCHIVE\AZ1\POST_MODEL\swgap_az1.gmd

Step1: Removing spring snow from the output image

Remnants of seasonal snow on TM imagery confound accurate classification of land cover beneath the snow. A post-classification model was used to remove snow from AZ1. The logic and parameters for the model follow:

Snow was identified by visually inspecting three seasons of imagery (spring, summer and fall). Spring imagery was found to contain the majority of problematic snow areas. Problematic snow areas were identified as areas where the output CT vegetation was affected by the presence of seasonal snow on the TM imagery. These vegetation areas usually mimic the shape of the snow patch and/or are classified as the wrong cover type. These areas were captured using an area of interest (AOI). A snow mask was then generated using the snow AOI (see AZ\ARCHIVE\AZ1\POST_MODEL\ POST_MODEL_IMAGES\ *az1_snow_spr_sub.img*). A standard CT output model was run which excluded spring imagery and spring imagery derived variables (see AZ\ARCHIVE\AZ1\POST_MODEL\POST_MODEL_IMAGES\ *az1all_m1_j2_nospr_rec.img*). A condition statement was then created to extract snow influenced vegetation pixels and replaced them with non-snow influenced pixels.

The conditional statement is:

EITHER $n56_az1all_m1_j2_nospr_rec IF ($n58_az1_snow_spr_sub==1) OR $n55_az1all_m1_j2_rec OTHERWISE

$n56_az1all_m1_j2_nospr_rec	AZ1 output image which integrated NO spring brightness, spring greenness or spring raw TM imagery as independent variables. Recoded to standard integer code.
$n58_az1_snow_spr_sub	Binary snow mask image 1 = snow 0 = all other area
$n55_az1all_m1_j2_rec	AZ1 standard CT output image integrated all spring, fall and summer derived imagery. Recoded to standard integer code.

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

The Southwest Regional GAP-National Vegetation Classification Standard (NVCS) legend has divided Rocky Mountain montane and subalpine forest types into two distinct classes; mesic forest types and dry-mesic forest types (Comer et al 2003). We determined early in the modeling process that these types would be difficult to discriminate using standard CT modeling methods alone due to vegetation composition similarities. As a result, we post modeled these types using topographic position as criteria.

Step 2a: The original CT output modeled S028 *ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND* as the only subalpine conifer type. In Step 2a we discriminated S028 *ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND* and *S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND*.

NatureServe NVCS concept (Comer et al 2003) describes the subalpine mesic system (S030) 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."

A conditional statement was created to extract *S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND* using the above described aspect and landform characteristics to identify this subalpine mesic conifer system.

The conditional statement is:

EITHER 30 IF (($n11_landf==2 OR $n11_landf==5 OR $n11_landf==6 OR $n11_landf==9) AND ($n20_aspaz1==1 OR $n20_aspaz1==2 OR $n20_aspaz1==0) AND ($n5_memory ==28)) OR $n5_memory OTHERWISE

Where:

30	*S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND*
28	S028 *ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND*
$n11_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
$n20_aspaz1	Nine class aspect image 1=North facing slope 2=Northeast facing slope 0=slope less than 3 degrees
$n5_memory	AZ1 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 2b: The original CT output modeled *S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND* as the only montane conifer

type. In Step 2b we discriminated *S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND* and *S034 ROCKY MOUNTAINS MONTANE MESIC MIXED CONIFER FOREST AND WOODLAND.*

NatureServe NVCS concept describes this montane mesic system (S032) 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 (S34). 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 2a, a conditional statement was created to extract *S034 ROCKY MOUNTAINS MONTANE MESIC MIXED CONIFER FOREST AND WOODLAND* using the above aspect and landform characteristics in order to identify this montane mesic mixed conifer system.

The conditional statement is:

EITHER 34 IF (($n11_landf==2 OR $n11_landf==5 OR $n11_landf==6 OR $n11_landf==9) AND ($n20_aspaz1==1 OR $n20_aspaz1==2 OR $n20_aspaz1==0) AND ($n13_memory==32)) OR $n13_memory OTHERWISE

Where:

34	*S034 ROCKY MOUNTAINS MONTANE MESIC MIXED CONIFER FOREST AND WOODLAND*
32	*S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND*
$n11_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,
$n20_aspaz1	Nine class aspect image 1=North facing slope 2=Northeast facing slope 0=slope less than 3 degrees
$n13_memory	AZ23 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 S020 North American Warm Desert Wash to compatible terrain.

A post-classification model was used to limit the mappable area of S020 by restricting it to landforms supporting washes. S020 North American Warm Desert Wash was mapped in locations uncharacteristic of wash environments. A conditional statement was used to restrict washes to characteristic landforms. First, a standard CT model was run ignoring cover class S020 (see AZ\ARCHIVE\AZ1\ POST_MODEL\POST_MODEL_IMAGES\az1all_m1_j2_nos020.img). This output provided replacement vegetation types for areas mapped as S020 but identified as unsuitable terrain for S020. NVCS cover type descriptions were used to identify landforms considered suitable terrain.

The conditional statement is:

EITHER $n47_az1all_m1_j2_nos020_rec IF ($n30_landf_RC==0 AND $n18_memory== 20) OR $n18_memory OTHERWISE

Where:

$n47_az1all_m1_j2_nos020_rec	AZ1 output image ignoring ecological system class S020. ; recoded to standard integer code.
$n30_landf_RC	Landform image recoded to a binary "wash" indicator area. 1= suitable wash terrain 0= all other terrain
$n18_memory	AZ1 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: Discriminate between *S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB* and *S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND*.

A standard CT output model was run mapping *MOJAVE MID-ELEVATION MIXED DESERT SCRUB* while ignoring *S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND* as an option for classification. Upon further investigation, it was discovered that this Mojave Desert type S060 was mapping out of its intended suitable range, on the Colorado Plateau. We restricted S060 in the output and selected a more suitable system for the misclassified area, *S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND*. A post classification model was designed to recode S060 pixels mapped on the Colorado Plateau to S059, thus restricting S060 to the Mojave Desert. The recode criterion was based on a simple elevation break derived from NatureServes NVCS ecological system descriptions (Comer et al 2003):

S059 restricted to elevations >1400 meters
S060 restricted to elevations <1400 meters

The conditional statement is:

EITHER 59 IF ($n48_elev >1400 AND $n35_memory== 60) OR $n35_memory
OTHERWISE

Where:

59	*S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND*
$n48_elev	Thirty meter digital elevation model
$n35_memory	AZ1 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 5: Discriminating *S040 GREAT BASIN PINYON-JUNIPER WOODLAND* and *S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND*.

A post-classification model was used to map S040. The *S040 GREAT BASIN PINYON-JUNIPER WOODLAND* ecological system requires the presence of *Pinus monophylla*, among other characteristic, to be eligible for this ecological system nomenclaure. *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 AZ1 functional mapping unit. This system differs from its widespread Northern Colorado Plateau counterpart *S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND* by the absence of dominating *Pinus edulis*. Differentiating between these two covertypes can be proplematic using standard CT modeling methods as similarities between the two result in the Great Basin system being mapped far from its biogeographic range. In order to restrict S040 to the northwest section of AZ1, it was necessary to post-classify this type.

A standard CT model was run mapping all Pinyon-Juniper types as *S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND*. An area of interest (AOI) was created to identify S040 known area and the AOI was then converted to a mask image. This mask image (az1_s040.img) allows the model to restrict *S040 GREAT BASIN PINYON-JUNIPER WOODLAND* to its known range. Information on the known range for S040 was gathered from on-site Arizona field crew observations.

The conditional statement is:

EITHER 40 IF ($n43_az1_s040_RC==1 AND $n40_memory==39) OR $n40_memory OTHERWISE

Where:

40	*S040 GREAT BASIN PINYON-JUNIPER WOODLAND*
39	*S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND*
$n43_az1_s040_RC	Binary AOI image indicating S040 range 1 = area identified by AOI to be known range 0 = all other area
$n40_memory	AZ1 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.

c) Generalizing to MMU and map completion:

After the spatial application of the CT model to create an *.img file, and post classification steps were taken, the map was generalized using ERDAS Imagine 8.6 GIS Analysis, Clump tool using 4 connected neighbors (rooks move), and then using Eliminate with a setting of a minimum of 1 acre.

After the Clump & Eliminate step, the non CT modeled classes were 'burned in' to the final map using an overlay function. The final map can be found at: AZ\ARCHIVE\AZ1\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 az1_final.img, which can be found at AZ\ARCHIVE\AZ1\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: AZ\ARCHIVE\AZ1\VALIDATION\.

b) 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. User's accuracy indicates how well the model predicts a withheld sample point; producer's accuracy indicates how well a withheld sample was predicted by the model. When quantitatively evaluated, the error tendency can be described as confusion between types indicated by the producer's accuracy and the tendency of the mapped types to actually represent some other type as indicated by the user's error. Accuracy of 65% of above indicates good model performance. It is important to note that this is not a complete accuracy assessment of map performance, but is rather a preliminary measure of map performance. Also, the total number of withheld samples may differ from the total number of samples reported in 2b above. Overlapping training sites create duplicate ID fields and replicates site information; these training sites were ignored in the validation totals.

N10: OPEN WATER: Not quantitatively assessed. Qualitative assessment indicates that most perennial open water mapped well. Ephemeral water bodies were not a focus of the effort and may be missing.

N22: DEVELOPED, MED-HIGH INTENSITY: Not quantitatively assessed. Qualitative assessment indicates that most medium and high density developed areas contemporary with the date of the imagery are included. Some N21 DEVELOPED, LOW DENSITY class may have been excluded.

D02: RECENTLY BURNED: Not quantitatively assessed. Qualitative assessment indicates that many recently burned areas contemporary with the date of the imagery are included. Recently burned areas were identified on ETM+ imagery as dark patches, typically angular, commonly bordered by roads. Burned areas, however, can be confused with recently logged and regenerating areas or shadows. Since the date of the imagery some substantial fires have occurred. The perimeters of these recent fires may be obtained through Geomac (geomac.usgs.gov) at ftp://ftp.geomac.gov/outgoing.

D03: 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.

D04: INVASIVE SOUTHWEST RIPARIAN WOODLAND AND SHRUBLAND: Quantitatively assessed, validation 67% (users) and 100% (producers) based on 2 independent validation samples. It was confused with S020 NORTH AMERICAN WARM DESERT WASH. It is expected that D04 often occurs in S020 so the confusion may reflect poor registration of a training sample. In general this type mapped well.

D09: INVASIVE ANNUAL FORBLAND: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 9 independent validation samples. It was confused with S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE AND S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND. While this type may exist as patches within S079 and S090, it is not well mapped. Disturbance is more of a driver of this ecological system rather than ecological process.

S010: COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND: Quantitatively assessed, validation 50% (users) and 35% (producers) based on 17 independent validation samples. It was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (7 or 17) and S060 MOJAVE MID-ELEVATION MIXED DESERT SHRUBLAND (3 of 17). In northern Arizona S010 often occurs intermixed with S039 and, within the Grand Canyon, with S060.

S013: INTER-MOUNTAIN BASINS VOLCANIC ROCK AND CINDERLAND: Not quantitatively assessed.

S020: NORTH AMERICAN WARM DESERT WASH: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 3 independent validation samples. It was confused with D04 INVASIVE SOUTHWEST RIPARIAN WOODLAND AND SHRUBLAND (1 of 3) and S060 MOJAVE MID-ELEVATION MIXED DESERT SHRUB (2 of 3). In this mapping zone S020 occurs at lower elevations where it frequently in close contact with S060. In addition, D04 frequently occurs in desert washes. The error may reflect misregistration of initial training points. This type was modeled to be constrained to appropriate landform, see Step 3 of Post-*classification, recoding and other modeling steps* above for details.

S023: ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND: Quantitatively assessed, validation 100% (users) and 17% (producers) based on 6 independent validation samples. This type was confused with S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND (3 of 6) and with S036 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (2 of 6). This type often intergrades with S032 and to some extent S036. There is also structural similarity between the types.

S028: ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND: Quantitatively assessed, validation 60% (users) and 50% (producers) based on 6 independent validation samples. This type was confused with S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST

AND WOODLAND (2 of 6). These two types are very similar in structure and may very well intergrade.

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

S032: ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND: Quantitatively assessed, validation 25% (users) and 18% (producers) based on 22 independent validation samples. This type was confused with S036: ROCKY MOUNTAINS PONDEROSA PINE WOODLAND (14 of 22) and to a lesser extent with S028: ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND (2 of 22) and S039: COLORADO PLATEAU PINYON-JUNIPER WOODLAND (2 of 22). All are coniferous types, and S032 can intergrade with S036 and S028 in particular.

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

S036: ROCKY MOUNTAINS PONDEROSA PINE WOODLAND: Quantitatively assessed, validation 66% (users) and 80% (producers) based on 59 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (7 of 59) or S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND (4 of 59). These types intergrade at the lower elevation (S039) and upper elevations (S032). S039 in particular can intergrade significantly with ponderosa pine making the ecological system call problematic in these ecotones. In general this type was modeled well.

S039: COLORADO PLATEAU PINYON-JUNIPER WOODLAND: Quantitatively assessed, validation 64% (users) and 87% (producers) based on 136 independent validation samples. This type was confused with S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB (7 of 59), S036 ROCKY MOUNTAINS PONDEROSA PINE WOODLAND (5 of 59) or S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (3 of 59). It was generally over predicted. The type intergrades with S036 and S054 frequently. Confusion with S060 most often happened where training data was taken from the Grand Canyon below the rim where the data was not as reliable as other training data. It is expected that juniper does intergrade with the intra-rim shrubs to some extent. In general, this type was modeled well.

S040: GREAT BASIN PINYON-JUNIPER WOODLAND: Not quantitatively assessed. This ecological type represents an extension of the Great Basin pinyon-juniper cover type into the Northern Colorado Plateau ecoregion. It was necessary to describe the

distribution of this type using a post processing modeler. See *Post-classification, recoding and other modeling steps* Step 5 for a detailed explanation.

S046: ROCKY MOUNTAINS GAMBEL OAK-MIXED MONTANE SHRUBLAND: Quantitatively assessed, validation 50% (users) and 20% (producers) based on 5 independent validation samples. This type was confused with S036 ROCKY MOUNTAINS PONDEROSA PINE WOODLAND (2 of 5) and S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (2 of 5). The ecological system can intergrade with both S036 and S039.

S053: GREAT BASIN SEMI-DESERT CHAPARRAL: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 5 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (3 of 5), with which it frequently intergrades. As mapped it could be S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB, a shrub type with similar structure but which is generally restricted to below the rim of the Grand Canyon.

S054: INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND: Quantitatively assessed, validation 78% (users) and 71% (producers) based on 55 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (3 of 55), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (3 of 55) and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (3 of 55). S054 can intergrade with S039 and S090. It has similar structure as S079. In general the ecological system was well mapped.

S057: MOGOLLON CHAPARRAL: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 5 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (3 of 5) with which it frequently intergrades. As mapped it could be S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB; a shrub type with similar structure but which is generally restricted to below the rim of the Grand Canyon.

S059: COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND: Not quantitatively assessed. This cover type was mapped using a post processing modeler. Please reference methods section entitled *Post-classification, recoding and other modeling* step 4 for a detailed explanation.

S060: MOJAVE MID-ELEVATION MIXED DESERT SCRUB: Quantitatively assessed, validation 52% (users) and 52% (producers) based on 33 independent validation samples. This type was confused with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (2 of 33) and S057 MOGOLLON CHAPARRAL (2 of 33) for producer's accuracy. It is found below the rim of the Grand Canyon where it intergrades with S010 and it shares a similar structure as with S057. User's accuracy shows that where mapped this type in some cases may actually be S010 (3 of 33) or S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (7 of 33).

S065: INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 13 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (6 of 13), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (3 of 13), and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (3 of 13). *Atriplex confertifolia* may commonly occur within S079 or S090, both of which intergrade with S039.

S069: SONORA-MOJAVE CREOSTOEBUSH-WHITE BURSAGE DESERT SCRUB: Quantitatively assessed, validation 50% (users) and 29% (producers) based on 7 independent validation samples. This type was confused with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (2 of 7) and S020 NORTH AMERICAN WARM DESERT WASH (2 of 7). As mapped it may be S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB (2 of 4). Below the Grand Canyon Rim, where S069 occurs, it intergrades with S060.

S075: INTER-MOUNTAIN BASINS JUNIPER SAVANNA: Quantitatively assessed, validation 50% (users) and 10% (producers) based on 10 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (4 of 10) and S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (4 of 10). This type has fewer conifers than S039 and intergrades with S079. This ecological system may be under mapped.

S079: INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE: Quantitatively assessed, validation 51% (users) and 58% (producers) based on 51 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (9 of 51) and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (9 of 51) and to a lesser extent S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (3 of 51), S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB (2 of 51), and S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (2 of 51).

S085: SOUTHERN ROCKY MOUNTAINS MONTANE GRASSLAND: Quantitatively assessed, validation 75% (users) and 60% (producers) based on 5 independent validation samples. This type was confused with S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND (2 of 5). S085 often occurs as inclusions within S032. The ecological system appears to be well mapped.

S090: INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND: Quantitatively assessed, validation 41% (users) and 46% (producers) based on 26 independent validation samples. This type was confused with S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (7 of 26), S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (3 of 26) and S065 INTER-MOUNTAIN BASINS

MIXED SALT DESERT SCRUB (2 of 26) for producer's accuracy. All of the types with which S090 is confused may contain significant grasses or patches of S090, which could cause confusion in signature differentiation.

S097: NORTH AMERICAN WARM DESERT RIPARIAN WOODLAND AND SHRUBLAND: Quantitatively assessed, validation 100% (users) and 100% (producers) based on 1 independent validation samples. While the accuracy is high, the number of independent validation samples is too small to provide a full assessment of the modeling of this ecological system.

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