SWReGAP Land Cover Mapping Methods Documentation

Functional Unit or Mapping Zone: Arizona 2

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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)
35/35	2000-096	2000-256	1999-317
35/36	2000-128	2000-256	1999-317
36/34	2000-103	2000-167	1999-292
36/35	2000-103	2000-167	1999-292
36/36	2000-103	2000-167	1999-292
37/34	2000-126	2000-158	1999-283
37/35	2000-094	2000-158	1999-283

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

AZ\ARCHIVE\AZ2\MOSAIC\az2_fa.mos
AZ\ARCHIVE\AZ2\MOSAIC\az2_sp.mos
AZ\ARCHIVE\AZ2\MOSAIC\az2_su.mos

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

AZ\ARCHIVE\AZ2\MOSAIC\mosaic/az2_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\AZ2\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\AZ2\IMG_FILES.

All imagery derived predictor layers can be found at:

AZ\ARCHIVE\AZ2\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\AZ2\IMG_FILES\

2) Samples:

a) Sample collection methods:

USGS SBSC 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\AZ2\TRAIN_DATA\az2_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 assigned either 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.

AZ3 or AZ4 in AZ2: These data were collected in the portion of functional unit AZ3 or AZ4 that overlapped with AZ2. The source of these data are various and can be identified by the PLOTNUM structure. See descriptions under field_pts for identification of PLOTNUM structure and description of the source of these data.

AzGF: Data were collected by the Arizona Department of Game and Fish along riparian corridors (example code AZCO096) from 1993 to 2000.

Field_pts: These data come from various sources. The source can be determined from the structure of the PLOTNUM.

AZ<month/day><year><teamcode><idnum><sequence letter, if appl>: Data collected by the U.S. Geological Survey SWReGAP field crew from 2001 to 2003. An example plot code is: AZ091802KM007

<idnum>: NoAzGAP data collected by the U.S. Geological Survey Colorado Plateau Research Station in 1997 for accuracy assessment of the first generation Arizona Gap Analysis land cover map. An example plot code is An example plot code is: 3568..

561.484-173(P1): Data with this plot code structure are from U.S. Forest Service (USFS) Terrestrial Ecosystem Survey conducted in 1994 on the Coconino National Forest. Site locations were determined by the U.S. Geological Survey SWReGAP team using plot locations inscribe on aerial photography as provided by the USFS.

<idletter>: Identifies a sample taken 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.

AZ<month/day>97TU<idnum>: SoAzGAP data 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.

AZ2DQT<idnum>: Some plots were included that should be more properly labeled as Terra_CPRS. See that category below for a description of the PLOTNUM structure and source of the data.

NM<month/day><year><teamcode><idnum>: Samples collected by the New Mexico Cooperative Fish and Wildlife Research Unit SWReGAP field crew.

SUCR<idnum> or SC-<idnum>: Data collected by the U.S. Geological Survey Colorado Plateau Research Station in 1999 as part of a vegetation mapping project at Sunset Crater National Monument.

TB<idnum> or TB-OBS-<idnum>: Data collected by the U.S. Geological Survey Colorado Plateau Research Station in 2003 for vegetation studies in the Tsezhin bii area of the Navajo Nation.

WUPA<idnum>: Some plots were included that should be more properly labeled as WUPA. See that category below for a description of the PLOTNUM structure and source of the data.

GCMRC: Data were collected by the U.S. Geological Survey's Grand Canyon Research and Monitoring in 2003. The identification number for each plot was accidentally stripped from these samples.

Terra_CPRS: These data are from interpretation of aerial photography available on the TerraServer web site, http://terraserver.microsoft.com/. The U.S. Geological Survey SWReGAP team did the interpretation. An example plot code is: AZ2DQT127.

UT: A number of samples were contributed by Utah State University RSGIS lab. The original source for these is distinguished by their PLOTNUM structure

UT043003JD28: Data with an identifier with this sort of structure was collected by the Utah State University RSGIS lab SWReGAP field team.

ut3-doq020904_111: Data with an identifier with this sort of structure is 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.

ut3-mapck-13: Data with an identifier with this sort of structure was collected by the Utah State University RSGIS lab SWReGAP team as augmentation data in modeling misclassification trouble spots.

1997-27-8: Data with an identifier with this sort of structure is from 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\.

WUPA: Data with the identifier WUPA was collected by the U.S. Geological Survey Colorado Plateau Research Station in 2002 as part of a vegetation mapping project at Wupatki National Monument.

b) Summary of samples:

4319 samples were available to model this mapping area. A polygon coverage containing all samples is located at: AZ/ARCHIVE/AZ2/TRAIN_DATA.

	Ecological System Name	# Samples
D04	INVASIVE SW RIPARIAN WOODLAND AND SHRUBLAND	272
D06	INVASIVE PERENNIAL GRASSLAND	18
D09	INVASIVE ANNUAL FORBLAND	21
N31	BARREN	15

S006	ROCKY MOUNTAIN CLIFF AND CANYON COMPLEX	28
S010	COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND	277
S011	INTER-MOUNTAIN BASINS SHALE BADLANDS	29
S020	NORTH AMERICAN WARM DESERT WASH	179
S023	ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND	44
S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND	33
S036	ROCKY MOUNTAINS PONDEROSA PINE WOODLAND	223
S039	COLORADO PLATEAU PINYON-JUNIPER WOODLAND	664
S046	ROCKY MOUNTAINS GAMBEL OAK - MIXED MONTANE SHRUBLAND	24
S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND	203
S056	COLORADO PLATEAU MIXED LOW SAGEBRUSH SHRUBLAND	23
S059	COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND	112
S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB	246
S075	INTER-MOUNTAIN BASINS JUNIPER SAVANNA	211
S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE	571
S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND	419
S093	ROCKY MOUNTAINS LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND COMPLEX	50
S096	INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX	70
S136	SOUTHERN COLORADO PLATEAU SAND SHRUBLAND	268
	**Total	4319

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:

	Ecological System Name
D04	INVASIVE SW RIPARIAN WOODLAND AND SHRUBLAND
D06	INVASIVE PERENNIAL GRASSLAND
D09	INVASIVE ANNUAL FORBLAND
N31	BARREN
S006	ROCKY MOUNTAIN CLIFF AND CANYON COMPLEX
S010	COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND
S011	INTER-MOUNTAIN BASINS SHALE BADLANDS
S020	NORTH AMERICAN WARM DESERT WASH
S023	ROCKY MOUNTAIN ASPEN 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
S054	INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND
S056	COLORADO PLATEAU MIXED LOW SAGEBRUSH SHRUBLAND
S059	COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND
S065	INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB
S075	INTER-MOUNTAIN BASINS JUNIPER SAVANNA
S079	INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE
S090	INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND
S093	ROCKY MOUNTAINS LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND COMPLEX
S096	INTER-MOUNTAIN BASINS GREASEWOOD FLAT COMPLEX
S136	SOUTHERN COLORADO PLATEAU SAND SHRUBLAND

b) Non CT modeled cover types:

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

Code	Ecological System Name
S012	INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES
S013	INTER-MOUNTAIN BASINS VOLCANIC ROCK AND CINDERLAND
S014	INTER-MOUNTAIN BASINS GREASEWOOD WASH
S015	INTER-MOUNTAIN BASINS PLAYA
S102	ROCKY MOUNTAINS ALPINE/MONTANE WET MEADOW
N11	OPEN WATER
N21	DEVELOPED, LOW INTENSITY
N22	DEVELOPED, MED-HIGH INTENSITY
N82	AGRICULTURE, CULTIVATED CROPS
D02	RECENTLY BURNED
D03	RECENTLY MINED OR QUARRIED

S012 Inter-Mountain Basins Active and Stabilized Dunes

The active and stabilized dunes class was extracted from the ETM+ imagery using an unsupervised classification procedure. The initial unsupervised classification used an input image stack consisting of the raw bands of the fall image. The AOI was selected for identifying dunes based on field knowledge and the DeLorme Atlas (1993). The 6 band image stack was classified into 20 clusters using Erdas Imagine's unsupervised classification module. Dunes were identified by visually inspecting the images for bright areas known to contain dunes. The classified dunes image was recoded to a binary image and then filtered, applying a 5x5 majority filter three times, to reduce speckle and produce an image of contiguous dune fields. For AOIs, see /AOI/dune_aoi folder in the ARCHIVE.

S013 Inter-Mountain Basins Volcanic Rock and Cinderland

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.

S014 Inter-Mountain Basins Greasewood Wash

For AZ3, the nested unsupervised classification accomplished for the open water class was used to extract linear features of moderately abundant vegetation associated with drainage patterns. These features were recoded to produce a binary image. 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 as Greasewood Wash based on field knowledge and ancillary data, including digital orthophoto quarter quad data.

S015 Inter-Mountain Basins Playa

This class was captured in two ways: screen digitizing over the ETM+ imagery and unsupervised classification of the ETM+ imagery within local AOIs. Some playas were identified on the fall ETM+ imagery and screen digitized over ETM+ imagery at a scale of 1:24,000 or larger. Other playas were identified on the imagery as distinct, closed, highly reflective patches in topographic lows and verified in the DeLorme Atlas. AOIs were created around these features and an unsupervised classification of the 6 raw bands of the fall image was performed. The classification specified 20 clusters, which were labeled as a binary playa image based on inspection of the image. For AOIs, see /AOI/playa_aoi folder in the ARCHIVE.

S102 Rocky Mountains Alpine/Montane Wet Meadow

An AOI was defined and the class was extracted from the ETM+ imagery using an 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. Wet Meadow was identified by visually inspecting the images for rounded features displaying homogeneous reflectance commonly moderately bright in the infrared spectrum. The classified Wet Meadow image was recoded to a binary image, clumped (allowing 4 neighbors), and eliminated (removing clusters less than 5 pixels in size), to produce a Wet Meadow image that retains only features of 1 acre MMU. The image was converted to a grid and the grid was converted to a polygon coverage.

The Wet Meadow polygons extracted from the imagery were then given to a field mapper, who labeled or deleted polygons based on field knowledge and by comparing them to information in the DeLorme Atlas and ancillary data sources.

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
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.

N82 Agriculture, Cultivated Crops

The agricultural areas were identified on ETM+ imagery and screen digitized at a scale of 1:50,000 or larger (1:24,000) using ArcMAP. Typically, agricultural fields were easily recognized by their rectangular geometries and distinctive patterns of uniform spectral brightness, including extremely bright near-infrared reflectances found in at least one of the seasonal images. Fall, spring and summer images were variously used. When the image pattern was questionable, agricultural areas were verified by referring to ancillary data, including the DeLorme Atlas (1993).

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
S028	ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND
S032	ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND

4) Summary of predictor layers used:

a) Multi band predictors:

Multi band predictors:

AZ2_fa.img	(ETM bands 1-5 & 7 for fall)
AZ2_sp.img	(ETM bands 1-5 & 7 for spring)
AZ2_su.img	(ETM bands 1-5 & 7 for summer)

All multi-band predictors can be found at: AZ\ARCHIVE\AZ2\IMG_FILES

b) Single band predictors:

aspect.img	Categorical 5 class aspect
elev.img	Continuous (integer) elevation
fabrt.img	Fall brightness band
fagrn.img	Fall greenness band
spbrt.img	Spring brightness band
spgrn.img	Spring greenness band
subrt.img	Summer brightness band
sugrn.img	Summer greenness band
landf.img	Categorical 10 class landform (modeled from DEM)

All multi-band predictors can be found at: AZ\ARCHIVE\AZ2\IMG_FILES

<u>5) Modeling Methods:</u>

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/AZ2/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:

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\AZ2\POST_MODEL\swgap_az2.gmd

Step 1: Removing spring snow and clouds from the CT output image.

Clouds and reminisce of seasonal snow on TM imagery inhibits the ability to accurately classify the land cover beneath the obstructions resulting in misrepresentation of the true cover. A post-classification model was used to remove clouds and snow from AZ2. The logic and parameters for the model follow:

Clouds and snow were identified by visually inspecting three seasons of TM imagery (spring, summer and fall). Spring imagery was found to contain the majority of problematic clouds and snow areas. Problematic areas were identified as areas where the output CT vegetation was effected by the presence of clouds and seasonal snow. Effected vegetation areas usually mimic the shape of the cloud or snow patch and/or were classified as the wrong cover type. These areas were captured using an area of interest (AOI). A cloud mask and a snow mask were then generated using the AOI (see output images AZ\ARCHIVE\AZ2\POST_MODEL\POST_MODEL_IMAGES\snow*_all.img* and *cld_mask_spr.img*). A standard CT output model was run which excluded spring imagery and spring imagery derived variables (see AZ\ARCHIVE\AZ2\POST_MODEL\POST_MODEL_IMAGES*az2all_m9_j1_nospr_rec.img*). A condition statement was then created to extract cloud and snow influenced vegetation pixels and replaced them with non-influenced pixels.

The conditional statement for cloud removal is:

Cloud Removal:
EITHER $n25_az2all_m9_j1_nospr_rec IF ($n23_snow_all==1) OR $n2_az2all_m9_j1_rec OTHERWISE

Where:

$n25_az2all_m9_j1_nospr_rec	AZ2 CT output image containing no spring brightness, spring greenness or spring raw TM imagery as independent variables. Recoded to standard integer code.
$n23_snow_all	Binary image cloud mask image 1 = clouds 0 = all other areas
$n2_az2all_m9_j1_rec	AZ2 standard CT output image. Recoded to standard integer code.

The conditional statement for snow removal is:

EITHER $n25_az2all_m9_j1_nospr_rec IF ($n37_cld_mask_spr==1) OR $n22_memory OTHERWISE

Where:

$n25_az2all_m9_j1_nospr_rec	AZ2 CT output image containing no spring brightness, spring greenness or spring raw TM imagery as independent variables. Recoded to standard integer code.
snow_all.img	Binary image snow mask image 1 = snow cover 0 = all other areas
$n22_memory	AZ2 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 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). It was determined early in the modeling process that these types are difficult to discriminate using standard CT modeling methods alone due to composition similarities. As a result, it was decided that these types would be post modeled based strictly on conceptual meaning rather than spectral and ancillary differences. The logic and parameters for the model follows:

Step 2a: Field data collection revealed that subalpine forest communities, *SO28 ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND* and *S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND*, are present on the landscape in mapping functional unit AZ2. Collections also revealed that these mesic systems are present but not abundant among the conifer forest types in this sampling path, collecting only five training sites. Recognizing the ecological importance of these subalpine forest types, it was decided to post process this system rather then model them. Low sampling numbers can be credited for this decision. The five training site where drilled through a digital elevation layer to collect average site elevations at occurrence locations. This elevation data (average > 2500m), along with NVCS concepts for subalpine forests, was used as the determining point of separation for identifying subalpine forest types.

A standard CT model was run withholding all subalpine conifer types S028/S030 and mesic montane conifer type *S034* consequently allowing *S032* to be mapped as the only montane conifer system. Step 2a was designed to extract subalpine conifer types S028/S030 using the above elevation characteristic and mapped all pixels temporarily as S028.

The conditional statement is:

EITHER 28 IF ($n36_memory==32 AND $n31_elev > 2500) OR $n36_memory OTHERWISE

Where:

28	S028 *ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND*
32	*S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND*
$n31_elev	Thirty meter digital elevation model

$n36_memory AZ2 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: Discriminating S028 *ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND* and *S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND.* A post-classification model was used to discriminate S028 from S030.

The post-classification model was designed to extract *S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND* from S028 *ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND*. NatureServe's NVCS concept describes *S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND* 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." (Comer et al 2003).

Using the output of step 2a a conditional statement was created to extract *S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLAND* using the above aspect and landform characteristics in order to identify this subalpine mesic conifer system.

The conditional statement is:

EITHER 30 IF (($n3_landf==2 OR $n3_landf==5 OR $n3_landf==6 OR $n3_landf==9) AND ($n4_aspaz2==1 OR $n4_aspaz2==2 OR $n4_aspaz2==0) AND ($n34_memory==28)) OR $n34_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*
$n3_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

$n4_aspaz2	Nine class aspect image 1=North facing slope 2=Northeast facing slope 0=slope less than 3 degrees
$n32_memory	AZ2 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 *S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND* and *S034 ROCKY MOUNTAINS MONTANE MESIC MIXED CONIFER FOREST AND WOODLAND.* A post-classification model was used to discriminate S032 from S034.

The post-classification model was designed to extract *S034 ROCKY MOUNTAINS MONTANE MESIC MIXED CONIFER FOREST AND WOODLAND* from the standard CT modeled *S032 ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND* ecological system cover type. NatureServe's NVCS concept (Comer et al 2003) describes this 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."

Using the output of step 2b 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 details of the conditional statement follow:

EITHER 34 IF (($n3_landf==2 OR $n3_landf==5 OR $n3_landf==6 OR $n3_landf==9) AND ($n4_aspaz2==1 OR $n4_aspaz2==2 OR $n4_aspaz2==0) AND ($n34_memory==32)) OR $n34_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*
$n3_landf	10 class landform grid

	2= toe slopes, bottoms, and swales 5= very moist steep slopes 6= moderately moist steep slopes 9= cool aspect scarps, cliffs, canyons
$n4_aspaz2	Nine class aspect image 1=North facing slope 2=Northeast facing slope 0=slope less than 3 degrees
$n34_memory	AZ2 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\AZ2\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 az2_final.img, which can be found at \AZ\ARCHIVE\AZ2\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\AZ2\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.

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, such as the Rodeo-Chedisky 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 42% (producers) based on 19 independent validation samples. This type was confused with S011 INTER-MOUNTAIN BASINS SHALE BADLAND (1 of 19), S020 NORTH AMERICAN WARM DESERT WASH (5 of 19), S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (2 of 19), S056 COLORADO PLATEAU MIXED LOW SAGEBRUSH SHRUBLAND (1 of 19), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (1 of 19), and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (1 of 19). D04 was largely confused with another riparian system and with upland systems that may have occurred adjacent to riparian corridors.

D06: INVASIVE PERENNIAL GRASSLAND: Quantitatively assessed, validation 100% (users) and 50% (producers) based on 4 independent validation samples. This type was confused with S036 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (2 of 4). This system is disturbance driven and was not expected to model well. Despite being quantitatively assessed with reasonable results, there are too few validation points to adequately assess the modeling.

D09: INVASIVE ANNUAL FORBLAND: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 3 independent validation samples. This type was confused with S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (2 of 5), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (1 of 5), and INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (2 of 5). This system is disturbance driven and was not expected to model well. There are too few validation points to adequately assess the modeling.

N11: 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.

N21: DEVELOPED, LOW INTENSITY: Not quantitatively assessed. Qualitative assessment indicates that most low-density developed areas contemporary with the date of the imagery are included.

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.

N31: BARREN: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 3 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 3), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (1 of 3), and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (1 of 3). This system did not model well.

N81: PASTURE/HAY: Quantitatively assessed, validation 80% (users) and 67% (producers) based on 6 independent validation samples. This type was confused with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (1 of 6) and S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 6).

N82: AGRICULTURE, CULTIVATED CROPS: Not quantitatively assessed. Qualitative assessment indicates that most agricultural areas contemporary with the date of the imagery are included; however, distinction between cultivated crops and pasturelands may not be consistent.

S006: ROCKY MOUNTAIN CLIFF AND CANYON COMPLEX: Not quantitatively assessed.

S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND: Quantitatively assessed, validation 84% (users) and 73% (producers) based on 49 independent validation samples. This type was confused with S036 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (1 of 49), S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (6 of 49), S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (1 of 49), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (1 OF 49), S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (3 OF 49), and S136 SOUTHERN COLORADO PLATEAU SAND SHRUBLAND (1 of 49). This system was mainly confused with S039, with which it can intergrade, and S090, which can be spectrally similar when at low cover. The system is generally well modeled.

S011 INTER-MOUNTAIN BASINS SHALE BADLAND: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 6 independent validation samples. This type was confused with S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (1 of 6), S065 INTER-MOUNTAIN BASINSMIXED SALT DESERT SCRUB (2 of 6), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (1 of 6), and S096 INTER-MOUNTAIN BASINS GREASEWOOD FLAT (2 of 6). This system did not model well.

S012: INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES: Not quantitatively assessed. Qualitative assessment shows that larger dunes have been adequately captured in the mapping.

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

S014: INTER-MOUNTAIN BASINS GREASEWOOD WASH: Not quantitatively assessed.

S015: INTER-MOUNTAIN BASINS PLAYA: Not quantitatively assessed. Qualitative assessment shows that major playa systems have been adequately captured in the mapping.

S020: NORTH AMERICAN WARM DESERT WASH: Quantitatively assessed, validation 58% (users) and 64% (producers) based on 11 independent validation samples. This type was confused with D04 INVASIVE SOUTHWEST RIPARIAN WOODLAND AND SHRUBLAND (4 of 11). D04 and S020 occur in similar habitats and can have similar structure when D04 is dominated by shrubs.

S023: ROCKY MOUNTAIN ASPEN FOREST AND WOODLAND: Quantitatively assessed, validation 100% (users) and 78% (producers) based on 9 independent validation samples. This type was confused with SO36 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (1 of 9) and S046 ROCKY MOUNTAIN GAMBEL OAK-MIXED MONTANE SHRUBLAND (1 of 9). This system is generally well modeled.

S028: ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLAND: This system was not quantitatively assessed.

S032: ROCKY MOUNTAINS MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLAND: Quantitatively assessed, validation 100% (users) and 29% (producers) based on 7 independent validation samples. This type was confused with SO36 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (4 of 7) and S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 7). S032 was confused with systems with similar structure.

S036: ROCKY MOUNTAINS PONDEROSA PINE WOODLAND: Quantitatively assessed, validation 70% (users) and 93% (producers) based on 45 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (3 of 45). S036 is generally well modeled.

S039: COLORADO PLATEAU PINYON-JUNIPER WOODLAND: Quantitatively assessed, validation 69% (users) and 82% (producers) based on 133 independent validation samples. This type was confused with N81 PASTURE/HAY (1 of 133), S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (1 of 133), SO36 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (4 of 133), S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (5 of 133), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (5 of 133), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (3 of 133), S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (3 of 133), and S136 SOUTHERN COLORADO PLATEAU SAND SHRUBLAND (2 of 133). This widespread system is generally well modeled. It is sometimes confused with systems with which it intergrades.

S046: ROCKY MOUNTAINS GAMBEL OAK-MIXED MONTANE SHRUBLAND: Quantitatively assessed, validation 67% (users) and 40% (producers) based on 5 independent validation samples. This type was confused with SO36 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (2 of 5) and S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 5). S046 is sometimes confused with systems with which it can intergrade.

S054: INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND: Quantitatively assessed, validation 67% (users) and 71% (producers) based on 41 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (5 of 41), S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (1 of 41), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (1 of 41), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (1 of 41), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (3 of 41), and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (1 of 41). Although S054 is sometimes confused with other shrublands that occur in this functional unit (S059, S065 or S079) or with systems with which it intergrades (S039 or S075), it is generally well modele.

S056: COLORADO PLATEAU MIXED LOW SAGEBRUSH SHRUBLAND: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 5 independent validation samples. This type was confused with S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (1 of 5), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (1 of 5), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (2 of 5), and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (1 of 5). This system is not well modeled.

S059: COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND: Quantitatively assessed, validation 52% (users) and 23% (producers) based on 23 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 23), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (4 of 23), S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (1 of 23), and S136 SOUTHERN COLORADO PLATEAU SAND SHRUBLAND (1 of 23). S059 is generally confused with other shrublands and steppes that occur in the region.

S065: INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 45% (users) and 50% (producers) based on 50 independent validation samples. This type was confused with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (1 of 50), S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (2 of 50), S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (1 of 50), S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (2 of 50), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (3 of 50), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (8 of 50), S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (5 of 50), S096 INTER-MOUNTAIN BASINS GREASEWOOD FLAT (1 of 50), and S136 SOUTHERN COLORADO PLATEAU SAND SHRUBLAND (2 of 50). S065 is generally confused with other shrubland, steppes and grasslands that occur in the functional unit.

S075: INTER-MOUNTAIN BASINS JUNIPER SAVANNA: Quantitatively assessed, validation 45% (users) and 42% (producers) based on 43 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (14 of 43), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (3 of 43), S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (7 of 43), and S136 SOUTHERN COLORADO PLATEAU SAND SHRUBLAND (1 of 43). S075 is mainly confused with S039 and S090 with which it intergrades.

S079: INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE: Quantitatively assessed, validation 49% (users) and 45% (producers) based on 114 independent validation samples. This type was confused with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (1 of 114), S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (5 of 114), S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (6 of 114), S056 COLORADO PLATEAU MIXED LOW

SAGEBRUSH SHRUBLAND (1 of 114), S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (5 of 114), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (10 of 114), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (6 of 114), S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (19 of 114), and S136 SOUTHERN COLORADO PLATEAU SAND SHRUBLAND (10 of 114). S079 is mainly confused with other shrublands (S054, S056, S059, S065 or S136) or with systems with which it intergrades (S039 or S090).

S090: INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND: Quantitatively assessed, validation 46% (users) and 48% (producers) based on 83 independent validation samples. This type was confused with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (2 of 83), S036 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (1 OF 83), S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (3 of 83), S056 COLORADO PLATEAU MIXED LOW SAGEBRUSH SHRUBLAND (1 of 83), S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (2 of 83), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (5 of 83), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (4 of 83), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (19 of 83), S096 INTER-MOUNTAIN BASINS GREASEWOOD FLAT (1 of 83), and S136 SOUTHERN COLORADO PLATEAU SAND SHRUBLAND (5 of 83). S090 is mainly confused with S079 with which it intergrades, with shrublands such as S056, S059, S065, S096 or S136 which often have a steppe-like structure.

S093: ROCKY MOUNTAIN LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND: Quantitatively assessed, validation 0% (users) and 0% (producers) based on 5 independent validation samples. This type was confused with S010 COLORADO PLATEAU MIXED BEDROCK CANYON AND TABLELAND (1 of 5), S036 ROCKY MOUNTAIN PONDEROSA PINE WOODLAND (3 OF 5), and S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 5). This system was confused with upland types, which may be a function of poor registration of training data. It is not well modeled.

S096: INTER-MOUNTAIN BASINS GREASEWOOD FLAT: Quantitatively assessed, validation 64% (users) and 50% (producers) based on 14 independent validation samples. This type was confused with S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 14), S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (1 OF 14), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (4 of 14), and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (1 of 14). S096 is most often confused with S065 which has similar composition and also occurs in more alkaline habitats.

S102: ROCKY MOUNTAINS ALPINE/MONTANE WET MEADOW: Not quantitatively assessed.

S136: SOUTHERN COLORADO PLATEAU SAND SHRUBLAND: Quantitatively assessed, validation 60% (users) and 61% (producers) based on 54 independent validation samples. This type was confused with S011 INTER-MOUNTAIN BASINS SHALE BADLAND (1 of 54), S039 COLORADO PLATEAU PINYON-JUNIPER WOODLAND (1 of 54), S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND (1 OF 54), S059 COLORADO PLATEAU BLACKBRUSH-MORMON TEA SHRUBLAND (3 of 54), S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (4 of 54), S075 INTER-MOUNTAIN BASINS JUNIPER SAVANNA (1 of 54), S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (8 of 54), and S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLAND (2 of 54). S136 is most often confused with other shrublands.

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