SWReGAP Land Cover Mapping Methods Documentation

Functional Unit or Mapping Zone: NV6 (Sierra Nevada Mapping Unit)

Organization: Lockheed Martin Environmental Services Office in association with the U.S. Environmental Protection Agency – Landscape Ecology Branch

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1) Predictor layer preparation:

a) Image standardization:

Because of the insufficient number and quality of "dark objects" in the Nevada Landsat ETM+ imagery, a simple conversion of digital numbers to at-sensor reflectance was performed via the following equation:

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

Where,

ρ_{BandN} = Reflectance for Band N

L_{bandN} = Digital Number for Band N

D = Normalized Earth-Sun Distance

E_{bandN} = Solar Irradiance for Band N

b) Image dates and mosaicking:

Images were mosiacked using ERDAS Imagine 8.6 Mosiac Tool with "no cutline" for *type*, and the "overlay" option for *overlap function*.

Image dates and scenes were as follows:

ETM+ Scene (path/row)	Summer (yr – Julian date)	Fall (yr – Julian date)
42/33	2000 - 209	1999 – 270
42/34	2000 - 209	1999 - 302
43/32	1999 - 197	1999 – 293
43/33	2000 - 200	2000 - 280

Spring scenes were not used due to the abundance of snow across a significant portion of the scenes. This snow rendered the spring imagery unsuitable for land cover modeling purposes.

Two coverages (summer and fall mosaics) showing overlap arrangement, date, and path/row can be found at:

/nv/archive/nv6/mosaic/mosaics.zip - nv6_summer_mosaic.shp
/nv/archive/nv6/mosaic/mosaics.zip - nv6_fall_mosaic.shp

The six-band ETM+ mosaics can be found in:

/nv/archive/nv6/mosaic/mosaics.zip - nv6_summer.img
/nv/archive/nv6/mosaic/mosaics.zip - nv6_fall.img

c) Image derived datasets:

Landsat 7 ETM+ (Reflectance values): Once the digital numbers of the Landsat mosaic were converted to reflectance values, these "raw" bands were incorporated into land cover models. These images are labeled as *nv6_summer* and *nv6_fall*.

Tasseled Cap: Bright-ness, green-ness, and wet-ness band transformations were created for the summer and fall mosaics using coefficients derived from the Landsat 7 ETM+ sensor, by Huang et al. (2001b). An example of the *.gmd file can be found at: /nv/archive/nv6/img_files/. These images are labeled as *nv6_sum_tcap* and *nv6_fall_tcap*.

Multi-temporal Kauth-Thomas Transformation: "Stable" and "change" components of bright-ness, green-ness, and wet-ness were created from the Tasseled Cap transformations of the summer and fall mosaics by using the transformation coefficients of Collins and Woodcock (1996). The first three bands of this image represent stable elements of bright-ness, green-ness, and wet-ness, while the second three bands represent "change" elements of bright-ness, green-ness, and wet-ness. An example of the *.gmd file can be found at: /nv/archive/nv6/img_files/. This image is labeled as *nv6_mtk*.

Fractional Vegetation: The percent of ground covered by photosynthetic vegetation was estimated by the equation of Carlson and Ripley (1997). Reference values used in the equation were identified by examination of NDVI histograms and locating known sites of bare soil and irrigated agricultural fields. An example of the *.gmd file can be found at: /nv/archive/nv6/img_files/. These images are labeled as *nv6_sum_fr* and *nv6_fall_fr*.

All image-derived datasets and corresponding *.gmd models can be found in:

/nv/archive/nv6/img_files/images1.zip
/nv/archive/nv6/img_files/images2.zip

d) DEM derived datasets:

Aspect: The aspect image was derived from the original elevation grid via the *aspect* algorithm in the *topographic analysis* menu of ERDAS Imagine. Aspect values range from 0 to 361, where 361 indicates flat terrain. This image is labeled as *nv6_asp*.

Southwest-ness: Since tree models are sometimes confounded by circular variables (i.e. aspect), the aspect image was converted to a linear "southwest-ness" image. Values range from –1 (indicating northeast-facing slopes) to +1 (indicating southwest-facing slopes). An example of the *.gmd file can be found at: /nv/archive/nv6/img_files/. This image is labeled as *nv6_swness*.

Elevation: The elevation image was created by importing the original elevation grid to an ERDAS Imagine file format. This image is labeled as *nv6_elev*.

Slope: The slope image was produced from the original elevation grid via the *slope* algorithm in the *topographic analysis* menu of ERDAS Imagine. The units of the slope image are degrees and range from 0 to 90. This image is labeled as *nv6_slope*.

Landform: A 10-class landform was created from a topographic relative moisture (values ranging from 0-28) index grid (Manis et al. 2001). This image is labeled as *nv6_landf*.

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

/nv/archive/nv6/img_files/images1.zip
/nv/archive/nv6/img_files/images2.zip

2) Samples:

a) Sample collection methods:

All training site data was collected by Eastern Nevada Landscape Coalition (ENLC) field crews during the summer and fall of 2003 by the protocols described in the "Field Methodologies and Training Manual for Nevada Field Crews" (see http://www.epa.gov/nerlesd1/land-sci/pdf/training-manual.pdf for further details). Based on the floristic composition and ecological setting, each training site was assigned an *Alliance* and *Ecological System* label (Comer et. al. 2003).

NV090403BB02: Identifies a training site collected by an ENLC field crew. The site identification indicates it was sampled on September 4, 2003 by Brian Brost.

No other training data sources were available for the NV6 mapping unit.

b) Summary of samples:

A total of 644 training sites were collected in the NV6 mapping unit. A polygon coverage containing all training site locations and their ecological system labels are found at:

/nv/archive/nv6/train_data/shapefiles.zip - nv6_sites.shp

S Code	# Samples	Ecological System Label
OMIT	18	Omitted Training Sites
D02	2	Recently Burned
D04	2	Invasive Southwest Riparian Woodlands and Shrublands
D06	3	Invasive Perennial Grasslands
D08	23	Invasive Annual Grasslands
D09	20	Invasive Annual and Biennial Forblands
N11	10	Open Water
N31	4	Barren
N81	24	Pasture/Hay Irrigated Agriculture
S003	5	Mediterranean California Alpine Bedrock and Scree
S007	24	Sierra Nevada Cliff and Canyon
S011	1	Inter-Mountain Basins Shale Badlands
S015	4	Inter-Mountain Basins Playas
S023	10	
S026	3	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodlands
S029	26	Northern Pacific Mesic Subalpine Woodlands
S033	7	Mediterranean California Dry-Mesic Mixed Montane Conifer Forest and Woodlands
S040	118	Great Basin Pinyon-Juniper Woodlands
S042	1	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodlands
S050	22	Inter-Mountain Basins Mountain Mahogany Woodlands and Shrublands
S053	27	Great Basin Semi-Desert Chaparral
S054	158	Inter-Mountain Basins Big Sagebrush Shrublands
S055	61	Great Basin Xeric Mixed Sagebrush Shrublands
S065	40	Inter-Mountain Basins Mixed Salt Desert Scrub
S071	80	Inter-Mountain Basins Montane Sagebrush Steppe
S078	2	Inter-Mountain Basins Big Sagebrush Steppe
S079	28	Inter-Mountain Basins Semi-Desert Steppe
S084	2	Mediterranean California Subalpine Meadow
S090	26	Inter-Mountain Basins Grasslands
S091	10	Rocky Mountains Subalpine-Montane Riparian Shrublands
S092	14	Rocky Mountains Subalpine-Montane Riparian Woodlands
S096	17	Inter-Mountain Basins Greasewood Flats
S100	17	North American Arid West Emergent Marsh
S103	7	Temperate Pacific Montane Wet Meadow
S105	4	Mediterranean California Subalpine-Montane Fen
S118	28	Great Basin Foothills Lower Montane Riparian Woodlands and Shrublands
S121	33	Mediterranean California Red Fir Forest and Woodlands
S122	17	Sierra Nevada Subalpine Lodgepole Pine Forest and Woodlands
S123	46	Mediterranean California Ponderosa-Jeffrey Pine Forest and Woodlands
S134	19	Northern Pacific Montane Grasslands
TOTAL	**968**	

3) Cover types:

a) Classification Tree modeled cover types:

The following cover type were modeled via the EROS Data Center's CART Module for ERDAS Imagine:

S Code	Ecological System Name
D06	Invasive Perennial Grasslands
D08	Invasive Annual Grasslands
D09	Invasive Annual and Biennial Forblands
N31	Barren
S003	Mediterranean California Alpine Bedrock and Scree
S007	Sierra Nevada Cliff and Canyons
S015	Inter-Mountain Basins Playa
S023	Rocky Mountain Aspen Forest and Woodlands
S026	Inter-Mountain Basins Subalpine Limber-Bristlecone Forest and Woodlands
S029	Northern Pacific Mesic Subalpine Woodlands
S033	Mediterranean California Dry-Mesic Mixed Montane Conifer Forest and Woodlands
S040	Great Basin Pinyon-Juniper Woodlands
S050	Inter-Mountain Basins Mountain Mahogany Woodland and Shrublands
S053	Great Basin Semi-Desert Chaparral
S054	Inter-Mountain Basins Big Sagebrush Shrublands
S055	Great Basin Xeric Mixed Sagebrush Shrublands
S065	Inter-Mountain Basins Mixed Salt Desert Scrub
S071	Inter-Mountain Basins Montane Sagebrush Steppe
S079	Inter-Mountain Basins Semi-Desert Steppe
S090	Inter-Mountain Basins Grasslands
S091	Rocky Mountains Subalpine-Montane Riparian Shrublands
S092	Rocky Mountains Subalpine-Montane Riparian Woodlands
S096	Inter-Mountain Basins Greasewood Flats
S100	North American Arid West Emergent Marsh
S103	Temperate Pacific Montane Wet Meadow
S105	Mediterranean California Subalpine-Montane Fen
S118	Great Basin Foothills Lower Montane Riparian Woodlands and Shrublands
S121	Mediterranean California Red Fir Forest and Woodlands
S122	Sierra Nevada Subalpine Lodgepole Pine Forest and Woodlands
S123	Mediterranean California Ponderosa-Jeffrey Pine Forest and Woodlands
S134	Northern Pacific Montane Grasslands

INTER-MOUNTAIN BASINS SHALE BADLANDS (S011), INTER-MOUNTAIN BASINS ASPEN-MIXED CONIFER FOREST AND WOODLANDS (S042), INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE (S078), and MEDITERRANEAN CALIFORNIA SUBALPINE MEADOW (S084) cover types were withheld from the modeling process due to insufficient sample size.

b) Non CT modeled cover types:

The PASTURE/HAY IRRIGATED AGRICULTURE (S Code – N81) was screen digitized using Landsat ETM+ imagery at a scale of 1:24,000 and 1:100,000. PASTURE/HAY IRRIGATED AGRICULTURE is given the value "2" in this image.

The OPEN WATER (S Code - N11) cover type was mapped by a presence/absence model in which Open Water training sites were labeled as "1" while all other training sites were labeled as "0." A model was executed with the Image CART Module using the reflectance and topographic variables. The output was compared against the summer

Landsat imagery to remove minor errors. OPEN WATER is given the value "2" in this image.

The RECENTLY BURNED (S Code - D02) cover type was mapped by performing an unsupervised classification of Landsat imagery that was subsequently subjected to a density slice to identify those areas scarred by fire. RECENTLY BURNED is given the value "2" in this image.

The DEVELOPED, LOW INTENSITY (S code – N21) and DEVELOPED, MED-HIGH INTENSITY (S code – N22) was developed by sub-setting the urbanized regions from a fractional vegetation layer, and performing a density slice of the fractional vegetation values to differentiate the two urban classes from natural vegetation. Within the nv2_urban.img file, DEVELOPED, LOW INTENSITY was labeled as "1" and DEVELOPED, MED-HIGH INTENSITY was labeled as"2."

The image files depicting these non-modeled classes are found in:
/nv/archive/nv6/non_model/non_model.zip – nv6_agriculture.img
/nv/archive/nv6/non_model/non_model.zip – nv6_burns.img
/nv/archive/nv6/non_model/non_model.zip – nv6_water.img
/nv/archive/nv6/non_model/non_model.zip – nv6_urban.img

4) Summary of predictor layers used:

a) Multi band predictors:

nv6_summer.img	(ETM+ bands 1-5 & 7 – mixed 1999 & 2000 images)
nv6_fall.img	(ETM+ bands 1-5 & 7 – mixed 1999 & 2000 images)
nv6_mtk.img	(bands 1-3 = stable brightness, greenness, wetness; bands 4-6 = change brightness, greenness, wetness)
nv6_sum_tcap.img	(summer brightness, greenness, wetness)
nv6_fall_tcap.img	(fall brightness, greenness, wetness)

All multi-band predictors can be found at:
/nv/archive/nv6/img_files/images1.zip
/nv/archive/nv6/img_files/images2.zip

b) Single band predictors:

nv6_slope.img	Continuous slope (units = degrees)
nv6_swness.img	Linear, continuous transformation of aspect
nv6_elev.img	Continuous elevation (units = meters)
nv6_sum_fr.img	Continuous fractional vegetation
nv6_fall_fr.img	Continuous fractional vegetation
nv6_landf.img	Categorical 10 class landform (from DEM)

5) Modeling Methods:

a) See5 Classification Tree modeling:

Training Data Sets: Once training site polygons were attributed with an ecological system label, 20% of the training sites for each land cover class were withheld for an accuracy assessment. Thus, two training data sets were produced:

1) An *80% training data set* used to produce a "preliminary" land cover maps (and subjected to an accuracy assessment)
2) A *total data set* used to create a "final" land cover map.

Data Set Generation: Twenty points were randomly located within each of the training site polygons of the *80%* and *total data sets* using the Random Points extension for ArcView. The two sets of random points were converted to ARCINFO grids and then to Imagine *.img files. Each Imagine pixel was attributed with the appropriate ecological system code. The

80% data set contained 756 training site polygons that were converted by the process described above into 8,842 pixels for use in creating the "preliminary" land cover map via the CART modeling process. The *total data set* contained 948 training site polygons that were converted into 10,609 pixels for production of the "final" land cover map via the CART modeling process.

Sample pixels were "drilled" through each of the predictor data layers to produce a data set containing both predictor (imagery and DEM-derived) variables and the response variable (ecological system label code) using the *CART Sampling Tool* of the CART Module (EarthSatellite Corporation 2003). For both the *80%* and *total* data sets, 16 CART training data sets were prepared by the methodology described above where each CART training data set was composed of different numbers and sets of predictor variables. The training data sets developed the NV6 mapping unit are described below:

Model #	Model Name	# of Variables	Variable Labels
1	Sum	6	Summer
2	Fall	6	Fall
3	Mtk	6	Multi-temporal Kauth-Thomas
4	Topo	4	Slope, Southwest-ness, Elevation, Landform
5	Sftcap	6	Summer and Fall Tasseled Cap
6	Sum_topo	9	Summer, Slope, Southwest-ness, Elevation
7	Fall_topo	9	Fall, Slope, Southwest-ness, Elevation
8	Mtk_topo	9	Multi-temporal Kauth-Thomas, Fall, Slope, Southwest-ness, Elevation
9	Sftcap_topo	9	Summer and Fall Tasseled Cap, Fall, Slope, Southwest-ness, Elevation
10	Sftcap_sffr	8	Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation
11	Sffr_topo	5	Summer and Fall Fractional Vegetation, Elevation, Slope, Southwest-ness
12	Sum_ftcap	9	Summer, Fall Tasseled Cap
13	Fall_stcap	9	Fall, Summer Tasseled Cap
14	Sum_mtk_topo	15	Summer, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
15	Fall_mtk_topo	15	Fall, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
16	Full	30	Summer, Fall, Multi-temporal Kauth-Thomas, Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation, Landform

The output files from the CART Sampling Tool (*.names, *.data, *.test) are located in:

/nv/archive/nv6/output/see5_files.zip

Classification Tree Construction: See5 data mining software (Release 1.8, http://www.rulequest.com) was used to construct 16 tree classifiers for both the *80%* and *total* data sets. Boosting was employed using 15 trials for the construction of each tree classifier. The output files (*.out, *.names.hst, *.set) from tree classifier construction are found at:

/nv/archive/nv6/output/80pnt/see5_files.zip
/nv/archive/nv6/output/80percent/see5_files.zip

CART Classifer and Land Cover Map Creation: The *CART Classifier* of Imagine CART module was used to implement the tree classifier produced by the See5 software package and thus create a land cover map. A total of 16 land cover images were produced for the *80% data set*:

1) sum.img
2) fall.img
3) mtk.img
4) topo.img
5) sftcap.img
6) sum_topo.img
7) fall_topo.img
8) mtk_topo.img
9) sftcap_topo.img
10) sftcap_sffr.img
11) sffr_topo.img
12) sum_ftcap.img
13) fall_stcap.img
14) sum_mtk_topo.img
15) fall_mtk_topo.img
16) full.img

The 16 output land cover maps are found at:

/nv/archive/nv6/output/80pnt/nv6_input_maps.zip

These 16 images were stacked in a single .img file with 16 bands, each corresponding to one of the 16 land cover maps. The STACK MAJORITY function was then used allow each land cover map to "vote" for the best ecological system label for every pixel. In other words, the 16 ecological system labels (one from each land cover map) for each pixel location are tallied, and the ecological system with the highest number of "votes" is entered into the output "preliminary" land cover map. The "pseudo-random forest" model (nv6_prf_pixel.gmd) and "preliminary" map resulting from this process (prf16_v1.img) can be found at:

/nv/archive/nv6/output/80pnt/nv6_input_maps.zip

This land cover classification, following the addition of non-modeled classes, was subjected to an accuracy assessment using the withheld data (192 reference sites).

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

Introduction: The post-classification models described below were used to differentiate ecological systems that possessed similar ecological and spectral characteristics. In these cases, species composition, and eco-regional location was not enough to distinguish between certain ecological systems especially when the systems share phenological and hydrological characteristics.

The models used are located at:

/nv/archive/nv6/post_model/s033_to_S134.gmd
/nv/archive/nv6/post_model/s134_to_S033.gmd

Step 1: Discriminating S033-Mediterranean California Dry-Mesic Mixed Montane Conifer Forest and Woodlands and S124-Mediterranean California Mesic Mixed Montane Conifer Forest and Woodlands. The logic and parameters are as follows:

This model was used to differentiate S033-Mediterranean California Dry-Mesic Mixed Montane Conifer Forest and Woodlands and S124-Mediterranean California Mesic Mixed Montane Conifer Forest and Woodlands. NatureServe describes S033 to be "in a variety of topo-edaphic positions, such as upper slopes at higher elevations, canyon sideslopes, ridgetops, and south- and west-facing slopes."

Model Methods: The preliminary models were run to include both ecological systems. A conditional statement was then applied to re-classify S033 pixels on drier, southerly facing slopes to S124, and a second conditional statement was used to re-classify S124 pixels on wetter, northerly-facing slopes to S033.

Model 1a: Either S134 (IF *Modeled Vegetation* = S033 AND ((ASPECT GT 45) AND (ASPECT LT 275)) OR *Modeled Vegetation* OTHERWISE

Model 1b: Either S033 (IF *Modeled Vegetation* = S134 AND ((ASPECT LE 45) OR (ASPECT GE 275)) OR *Modeled Vegetation* OTHERWISE

c) Generalizing to MMU and map completion:

This final land cover map had non-modeled classes incorporated into it. This image was then subjected to the CLUMP function with 4 *connected neighbors*. This image then had the ELIMINATE algorithm run upon it to yield a land cover map generalized to the 2 hectare minimum mapping unit.

6) Validation:

a) CT model validation:

Twenty percent of the sample polygons were randomly selected and withheld from CT modeling. The preliminary CT models were run as described in section 5a using the remaining 80% of the training site data. The 20% withheld samples were used to ass the predictive capability of the CT modeled map via the kappa.avx extension for ArcView by intersecting the reference polygons through the CT modeled land cover map. This extension considers the site correctly mapped when the majority of pixels within the reference polygon agree with the reference label. Output from kappa.avx includes a *.txt, *.dbf, and *.shp file. The *.txt file contains the kappa statistic. The *.dbf file contains an error matrix indicating errors of omission and commission. The *.shp file contains the locations of the reference polygons whether the reference polygon was correct or incorrect, and the actual ecological systems label for the site. These files can be found at:

/nv/archive/nv6/validation

b) Final map:

A second set of 16 land cover images were produced for the *total data set*:

1) sum.img
2) fall.img
3) mtk.img
4) topo.img
5) sftcap.img
6) sum_topo.img

7) fall_topo.img
8) mtk_topo.img
9) sftcap_topo.img
10) sftcap_sffr.img
11) sffr_topo.img
12) sum_ftcap.img
13) fall_stcap.img
14) sum_mtk_topo.img
15) fall_mtk_topo.img
16) full.img

The 16 output land cover maps are found at:

/nv/archive/nv6/output/allpnt/input_maps.zip

These 16 images were processed by the methods described above. The "pseudo-random forest" model (prf_final.gmd) and "final" map resulting from this process (prf16_v1.img) can be found at:

/nv/archive/nv6/output/allpnt/input_maps.zip

c) Discussion of mapped cover types: The following narrative provides qualitative assessments for each cover type mapped in the NV6 mapping unit. It is intended to elaborate on the quantitative results of the CT model validation from the perspective of those most familiar with the map and the mapping process and is hoped to be of value to potential map users.

N11 OPEN WATER: Quantitatively assessed, validation 100% (producers) and 67% (users) based on 2 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. A qualitative assessment suggests that water has been mapped well, however the error matrix indicates some confusion between OPEN WATER and ephemeral water bodies and emergent wetlands.

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

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

N31 BARREN: Quantitatively assessed, validation 100% (producers) and 0% (users) based on 1 independent sample. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy.

N81 PASTURE HAY-IRRIGATED AGRICULTURE: Quantitatively assessed, validation 100% (producers) and 50% (users) based on 5 independent samples. In general, this system was mapped well though it might have been over-represented at the expense of INVASIVE PERENNIAL GRASSLANDS in some instances. There is also the possibility that some riparian grasslands have been mistaken for irrigated agriculture.

D02 RECENTLY BURNED: Not quantitatively assessed. This system was modeled separately. The confusion of the land cover class is

likely due to differences between the dates of imagery and training data collection.

D06 INVASIVE PERENNIAL GRASSLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. Even qualitatively, this accuracy of this system is difficult to establish. Because this system is largely composed of seeded grasses (e.g. *Agropyron cristatum* Semi-Natural Herbaceous alliance) in areas formerly occupied by sagebrush-grass mosaics, this type of confusion is to be expected.

D08 INVASIVE ANNUAL GRASSLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 3 independent samples. This system was confused with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (1 of 3 reference sites), INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (1 of 3 reference sites), and INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS (1 of 3 reference sites) that might be attributed to differences between the dates of imagery and sample data collection.

D09 INVASIVE ANNUAL AND BIENNIAL FORBLANDS: Quantitatively assessed, validation 25% (producers) and 0% (users) based on 4 independent samples. This disturbance system is with PASTURE HAY-IRRIGATED AGRICULTURE (1 of 4 reference sites), INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (1 of 4 reference sites), and GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (1 of 4 reference sites). This is another ecological system that is associated with disturbance, and is thus difficult to map.

S003 MEDITERRANEAN CALIFORNIA ALPINE BEDROCK AND SCREE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. This system was confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (1 of 1 reference sites).

S007 SIERRA NEVADA CLIFF AND CANYONS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 5 independent samples. This system was confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (4 of 5 reference sites) and INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (1 of 5 reference sites) that occurred on steep slopes and with relatively sparse vegetative cover.

S015 INTER-MOUNTAIN BASINS PLAYAS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This system was confused with GREAT BASIN PINYON_JUNIPER WOODLANDS (1 of 1 reference sites) in a small region due to similarities of soil brightness and sparse vegetative cover.

S023 ROCKY MOUNTAINS ASPEN FOREST AND WOODLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 2 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was most commonly confused with GREAT BASIN PINYON-JUNIPER WOODLANDS (1 of 2 reference sites), and INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH SHRUBLANDS (1 of 2 reference sites).

S026 INTER-MOUNTAIN BASINS SUBALPINE-MONTANE LIMBER-BRISTLECONE PINE WOODLANDS: Quantitatively assessed, validation 100% (producers) and 100% (users) based on 1 independent sample. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. Qualitatively, this system

appears to be under-mapped due the abundance of GREAT BASIN PINYON-JUNIPER WOODLANDS and INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS sites in the training data set.

S029 NORTHERN PACIFIC MESIC SUBALPINE WOODLANDS: Quantitatively assessed, validation 40% (producers) and 50% (users) based on 5 independent samples. This system was confused with GREAT BASIN PINYON-JUNIPER WOODLANDS (1 OF 3 reference sites), INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (1 of 3 reference sites), and MEDITERRANEAN CALIFORNIA RED FIR FOREST AND WOODLANDS (1 of 3 reference sites).

S033 MEDITERRANEAN CALIFORNIA DRY-MESIC MIXED MONTANE CONIFER FOREST AND WOODLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy.

S040 GREAT BASIN PINYON-JUNIPER WOODLANDS: Quantitatively assessed, validation 83% (producers) and 50% (users) based on 24 independent samples. This system was over-mapped at the expense of other woodland and forested communities. It was confused predominantly with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 24 reference sites), INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS (1 of 24 reference sites), MEDITERRANEAN CALIFORNIA PONDEROSA-JEFFREY PINE FOREST AND WOODLANDS (1 of 24 reference sites). and It was over-mapped at the expense of the higher elevation shrubland communities such as INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE, INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS, AND INTER-MOUNTAIN BASINS MOUTNAIN MAHOGANY WOODLANDS AND SHRUBLANDS.

S050 INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 3 independent samples. This system was confused with GREAT BASIN PINYON-JUNIPER WOODLANDS (3 of 3 reference sites). These sources of confusion are reasonable since *Cercocarpus ledifolius* is often found in a gradient with *Juniperus osteosperma* and *Pinus monophylla*.

S053 GREAT BASIN SEMI-DESERT CHAPARRAL: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 5 independent samples. This system was confused with MEDITERRANEAN CALIFORNIA RED FIR FOREST AND WOODLANDS (2 of 5 reference sites), MEDITERRANEAN CALIFORNIA PONDEROSA-JEFFREY PINE FOREST AND WOODLANDS (1 of 5 reference sites), and GREAT BASIN PINYON-JUNIPER WOODLANDS (1 of 5 reference sites). This system does not appear to have been over-mapped, but is likely under-mapped.

S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 66% (producers) and 53% (users) based on 32 independent samples. This system was confused at higher elevations with GREAT BASIN PINYON-JUNIPER WOODLANDS (4 of 32 reference sites), and GREAT BASIN XERIC MIXED SAGEBRUSH (3 of 32 reference sites), and at lower elevations with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (3 of 32 reference sites). This matrix system was over-mapped at the expense of GREAT BASIN XERIC MIXED SAGEBRUSH (5 reference sites) and INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH SHRUBLANDS (3 reference sites).

S055 GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 33% (producers) and 40% (users) based on 12 independent samples. This system was confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (5 of 12 reference sites) and

INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (2 of 12 reference sites).

S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 25% (producers) and 25% (users) based on 8 independent samples. This system was confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 8 reference sites), GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (1 of 8 reference sites), and INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB.

S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE: Quantitatively assessed, validation 38% (producers) and 26% (users) based on 16 independent samples. This system was confused with GREAT BASIN PINYON-JUNIPER WOODLANDS (5 of 16 reference sites), INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (3 of 16 reference sites), and GREAT BASIN SEMI-DESERT CHAPARRAL. Qualitatively, this system was adequately mapped, though it was somewhat over-mapped at the expense of SIERRA NEVADA CLIFF AND CANYON and NORTHERN PACIFIC MONTANE GRASSLANDS.

S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 6 independent samples. This system was confused with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (2 of 6 reference sites), and also with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 6 reference sites). This is likely due to the overlap of ecological setting these systems occur in, and the association of this system with disturbance of the INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS system.

S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 4 independent samples. This system has not mapped well, and was confused with PASTURE/HAY (3 of 4 reference sites). This often occurs in abandoned agriculture fields and pastures.

S091 ROCKY MOUNTAINS SUBALPINE-MONTANE RIPARIAN SHRUBLANDS: Quantitatively assessed, validation 50% (producers) and 50% (users) based on 2 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH SHRUBLANDS (1 of 2 reference sites) that can occur in upland positions adjacent to riparian corridors.

S092 ROCKY MOUNTAINS SUBALPINE-MONTANE RIPARIAN WOODLANDS: Quantitatively assessed, validation 33% (producers) and 100% (users) based on 3 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was confused with MEDITERRANEAN CALIFORNIA PONDEROSA-JEFFREY PINE FOREST AND WOODLANDS (1 of 3 reference sites) and NORTHERN PACIFIC MESIC SUBALPINE WOODLANDS (1 of 3 reference sites) that can occur in upland positions adjacent to riparian corridors.

S096 INTER-MOUNTAIN BASINS GREASEWOOD FLATS: Quantitatively assessed, validation 33% (producers) and 50% (users) based on 3 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This ecological system is confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (1 of 3 reference sites) and GREAT BASIN FOOTHILLS LOWER MONTANE RIPARIAN WOODLANDS AND SHRUBLANDS (1 of 3 reference sites) that occur in upland positions adjacent to riparian corridors.

S100 NORTH AMERICAN ARID WEST EMERGENT MARSH: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 3 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This system appears to be mapped well despite confusion with GREAT BASIN FOOTHILL LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS (2 of 3 reference sites) and with PASTURE/HAY (1 of 3 reference sites). Confusion with both of these communities is likely due to the heavy abundance of herbaceous vegetation in all of these systems. The confusion might also be related to differences in the dates of imagery and data acquisition.

S103 TEMPERATE PACIFIC MONTANE WET MEADOW: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was confused with NORTHERN PACIFIC MONTANE GRASSLANDS (1 of 1 reference sites) due to the similar cover of herbaceous vegetation. The low accuracy of this system is likely due to the small number of training sites for this small patch system.

S105 MEDITERRANEAN CALIFORNIA SUBALPINE-MONTANE FEN: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. This ecological system was confused with ROCKY MOUNTAINS SUBALPINE-MONTANE RIPARIAN SHRUBLANDS (1 of 1 reference sites). The low accuracy of this system is likely due to the small number of training sites for this small patch system.

S118 GREAT BASIN FOOTHILL LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS: Quantitatively assessed, validation 67% (producers) and 57% (users) based on 6 independent sample. Qualitatively, this system appears to be mapped well, but was confused with OPEN WATER (1 of 6 reference sites) and GREAT BASIN PINYON-JUNIPER WOODLANDS (1 of 6 reference sites). Its geographic distribution is consistent with expectations, except at higher elevations where it may be confused with upland, non-riparian ecological systems.

S121 MEDITERRANEAN CALIFORNIA RED FIR FOREST AND WOODLANDS: Quantitatively assessed, validation 86% (producers) and 46% (users) based on 7 independent samples. This ecological system was over-mapped at the expense of MEDITERRANEAN CALIFORNIA PONDEROSA-JEFFREY PINE FOREST AND WOODLANDS (3 reference sites) and GREAT BASIN SEMI-DESERT CHAPARRAL (2 reference sites).

S122 SIERRA NEVADA SUBALPINE LODGEPOLE PINE FOREST AND WOODLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 3 independent samples. This system was confused with MEDITERRANEAN CALIFORNIA SUBALPINE-MONTANE FEN (2 of 3 reference sites) and MEDITERRANEAN CALIFORNIA RED FIR FOREST AND WOODLANDS (1 of 3 reference sites).

S123 MEDITERRANEAN CALIFORNIA PONDEROSA-JEFFREY PINE FOREST AND WOODLANDS: Quantitatively assessed, validation 44% (producers) and 44% (users) based on 9 independent samples. This system was confused with MEDITERRANEAN CALIFORNIA RED FIR FOREST AND WOODLANDS (3 of 9 reference sites) and GREAT BASIN PINYON-JUNIPER WOODLANDS (1 of 9 reference sites).

S134 NORTHERN PACIFIC MONTANE GRASSLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 4 independent samples. This ecological system was confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (4 of 4 reference sites).

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