SWReGAP Land Cover Mapping Methods Documentation

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Functional Unit or Mapping Zone: NV3 (Lahontan Mapping Unit)

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

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Date of Preparation: 29 August, 2004

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 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)	Summer (yr – Julian date)	Fall (yr – Julian date)
P39/R34	2000 - 188	IMAGE NOT AVAILABLE
P40/R33	2000 – 227	1999 – 288
P40/R34	2000 - 163	1999 – 288
P41/R33	2000 - 202	2000 – 282
P41/R34	2000 - 202	2000 - 282
P42/R31	2000 – 209	1999 – 270
P42/R32	2000 - 209	1999 – 254
P42/R33	2000 - 209	1999 – 270
P43/R31	1999 - 181	2000 – 280
P43/R32	1999 - 197	1999 – 293
P43/R33	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/nv3/mosaic/mosaics.zip – nv3_summer_mosaic.shp
/nv/archive/nv3/mosaic/mosaics.zip – nv3_fall_mosaic.shp

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

/nv/archive/nv3/mosaic/mosaics.zip – nv3_summer.img
/nv/archive/nv3/mosaic/mosaics.zip – nv3_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 *nv3_summer* and *nv3_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/nv3/img_files/. These images are labeled as *nv3_sum_tcap* and *nv3_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/nv3/img_files/. This image is labeled as *nv3_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/nv3/img_files/. These images are labeled as *nv3_sum_fr* and *nv3_fall_fr*.

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

/nv/archive/nv3/img_files/images1.zip
/nv/archive/nv3/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 *nv3_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/nv3/img_files/. This image is labeled as *nv3_swness*.

Elevation: The elevation image was created by importing the original elevation grid to an ERDAS Imagine file format. This image is labeled as *nv3_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 *nv3_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 *nv3_landf*.

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

/nv/archive/nv3/img_files/images1.zip
/nv/archive/nv3/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 NV1 mapping unit.

b) Summary of samples:

A total of 5723 training sites were collected in the NV3 mapping unit. A polygon coverage containing all training site locations and their ecological system labels are found at:

/nv/archive/nv3/train_data/shapefiles.zip - nv3_sites.shp

S Code	**# Samples**	**Ecological System Label**
OMIT	24	Omitted Training Sites
D02	2	Recently Burned
D03	8	Recently Mined/Quarried
D04	29	Invasive Riparian Woodlands and Shrublands
D08	186	Invasive Annual Grassland
D09	113	Invasive Annual and Biennial Forbland
N11	24	Open Water
N31	57	Barren
N81	150	Pasture/Hay Irrigated Agriculture
S009	99	Inter-Mountain Basins Cliff and Canyon
S011	7	Inter-Mountain Basins Shale Badlands
S012	31	Inter-Mountain Basins Active and Stabilized Dunes
S013	5	Inter-Mountain Basins Volcanic Rock and Cinder Lands
S015	161	Inter-Mountain Basins Playa
S018	1	North American Warm Desert Active and Stabilized Dunes
S020	17	North American Warm Desert Wash
S023	1	Rocky Mountain Aspen Forest and Woodlands
S040	228	Great Basin Pinyon-Juniper Woodlands
S050	2	Inter-Mountain Basins Mountain Mahogany Woodland and Shrublands
S054	802	Inter-Mountain Basins Big Sagebrush Shrublands
S055	399	Great Basin Xeric Mixed Sagebrush Shrublands
S060	128	Mojave Mid-Elevation Mixed Desert Scrub
S065	1734	Inter-Mountain Basins Mixed Salt Desert Scrub
S069	52	Sonora-Mojave Creosote-White Bursage Desert Scrub
S070	15	Sonora-Mojave Desert Mixed Desert Scrub
S071	40	Inter-Mountain Basins Montane Sagebrush Steppe
S078	46	Inter-Mountain Basins Big Sagebrush Steppe
S079	601	Inter-Mountain Basins Semi-Desert Shrub Steppe
S090	146	Inter-Mountain Basins Semi-Desert Grasslands
S096	486	Inter-Mountain Basins Greasewood Flats
S100	51	North American Arid West Emergent Marsh
S118	78	Great Basin Foothill Lower Montane Riparian Woodland and Shrublands
TOTAL	**5723**	

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
D04	Invasive Southwest Riparian Woodlands and Shrublands
D06	Invasive Perennial Grasslands
D08	Invasive Annual Grasslands
D09	Invasive Annual and Biennial Forblands
N31	Barren
S009	Inter-Mountain Basins Cliff and Canyons
S012	Inter-Mountain Basins Active and Stabilized Dunes
S015	Inter-Mountain Basins Playa
S016	North American Warm Desert Bedrock Cliff and Canyon
S022	North American Warm Desert Playa
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
S060	Mojave Mid-Elevation Mixed Desert Scrub
S065	Inter-Mountain Basins Mixed Salt Desert Scrub
S069	Sonora-Mojave Creosote-White Bursage Desert Scrub
S070	Sonora-Mojave Desert Mixed Salt Desert Scrub
S071	Inter-Mountain Basins Montane Sagebrush Steppe
S078	Inter-Mountain Basins Big Sagebrush Steppe
S079	Inter-Mountain Basins Semi-Desert Shrub Steppe
S090	Inter-Mountain Basins Semi-Desert Grasslands
S094	North American Warm Desert Lower Montane Riparian Woodlands and Shrublands
S096	Inter-Mountain Basins Greasewood Flats
S100	North American Arid West Emergent Marsh
S118	Great Basin Foothill Lower Montane Riparian Woodland and Shrublands

ROCKY MOUNTAINS ASPEN FOREST AND WOODLANDS (S023), INTER-MOUNTAIN BASINS SHALE BADLANDS (S011), INTER-MOUNTAIN BASINS VOLCANIC ROCK AND CINDERLANDS (S013), and NORTH AMERICAN WARM DESERTS ACTIVE AND STABILIZED DUNES (S018) 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 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 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 RECENTLY MINED OR QUARRIED (S Code – D03) was screen digitized using Landsat ETM+ imagery at a scale of 1:24,000 and 1:100,000. RECENTLY MINED OR QUARRIED is given the value "2" in this image.

The INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES (S code – S012) cover type was supplemented to improve the accuracy of the Cresent Dunes south of the Slumbering Hills of northern Nevada. This supplement was developed by sub-setting the Cresent Dunes region and performing an unsupervised classification on the Landsat imagery. Each spectral cluster was assigned to a "dune" or "non-dune" class via visual inspection. INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES was labeled as "2" while all other non-dune pixels were labeled as "1" or "0."

The image files depicting these non-modeled classes are found in:
/nv/archive/nv3/non_model/non_model.zip – agriculture.img
/nv/archive/nv3/non_model/non_model.zip – burns.img
/nv/archive/nv3/non_model/non_model.zip – water.img
/nv/archive/nv3/non_model/non_model.zip – urban.img
/nv/archive/nv3/non_model/non_model.zip – mines.img
/nv/archive/nv3/non_model/non_model.zip – dunes.img

4) Summary of predictor layers used:

a) Multi band predictors:

nv3_summer.img	(ETM+ bands 1-5 & 7 – mixed 1999 & 2000 images)
nv3_fall.img	(ETM+ bands 1-5 & 7 – mixed 1999 & 2000 images)
nv3_mtk.img	(bands 1-3 = stable brightness, greenness, wetness; bands 4-6 = change brightness, greenness, wetness)
nv3_sum_tcap.img	(summer brightness, greenness, wetness)
nv3_fall_tcap.img	(fall brightness, greenness, wetness)

All multi-band predictors can be found at:
/nv/archive/nv3/img_files/images1.zip
/nv/archive/nv3/img_files/images2.zip

b) Single band predictors:

nv3_slope.img	Continuous slope (units = degrees)
nv3_swness.img	Linear, continuous transformation of aspect
nv3_elev.img	Continuous elevation (units = meters)
nv3_sum_fr.img	Continuous fractional vegetation
nv3_fall_fr.img	Continuous fractional vegetation
nv3_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 4,462 training site polygons that were converted by the process described above into 52,075 pixels for use in creating the "preliminary" land cover map via the CART modeling process. The *total data set* contained 5,538 training site polygons that were converted into 65,022 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, 15 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 using the *80% data set* developed the NV3 mapping unit are described below:

Model #	**Model Name**	**# of Variables**	**Variable Labels**
1	Sum	6	Summer
2	Fall	6	Fall
3	Sffr_topo	5	Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation
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	Mtk_landf_sffr	9	Multi-temporal Kauth-Thomas, Summer and Fall Fractional Vegetation, Landform
11	Sum_ftcap_se	11	Summer, Fall Tasseled Cap, Slope, Elevation
12	Fall_stcap_se	11	Fall, Summer Tasseled Cap, Slope, Elevation
13	Sum_fall_topo	15	Summer, Fall, Slope, Southwest-ness, Elevation
14	Fall_mtk_topo	15	Fall, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
15	Full	29	Summer, Fall, Multi-temporal Kauth-Thomas, Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation

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

/nv/archive/nv3/output/80percent/see5_files.zip

A different set of models were used with the *total data set* to create the final land cover map for NV2:

Model #	Model Name	# of Variables	Variable Labels
1	Sum	6	Summer
2	Fall	6	Fall
3	Mtk	6	Multi-temporal Kauth-Thomas
4	Sffr_topo	5	Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation
5	Topo	4	Slope, Southwest-ness, Elevation, Landform
6	Sftcap	6	Summer and Fall Tasseled Cap
7	Sum_topo	9	Summer, Slope, Southwest-ness, Elevation
8	Fall_topo	9	Fall, Slope, Southwest-ness, Elevation
9	Mtk_topo	9	Multi-temporal Kauth-Thomas, Fall, Slope, Southwest-ness, Elevation
10	Sftcap_topo	9	Summer and Fall Tasseled Cap, Fall, Slope, Southwest-ness, Elevation
11	Mtk_landf_sffr	9	Multi-temporal Kauth-Thomas, Summer and Fall Fractional Vegetation, Landform
12	Sum_ftcap_se	11	Summer, Fall Tasseled Cap, Slope, Elevation
13	Fall_stcap_se	11	Fall, Summer Tasseled Cap, Slope, Elevation
14	Sum_fall_topo	15	Summer, Fall, Slope, Southwest-ness, Elevation
15	Fall_mtk_topo	15	Fall, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
16	Full	29	Summer, Fall, Multi-temporal Kauth-Thomas, Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation

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

/nv/archive/nv3/output/alldata/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/nv3/output/80percent/see5_files.zip
/nv/archive/nv3/output/alldata/see5_files.zip

CART Classifier 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 15 land cover images were produced for the *80% data set*:

1) sum.img
2) fall.img
3) sffr_topo.img
4) topo.img

5) sftcap.img
6) sum_topo.img
7) fall_topo.img
8) mtk_topo.img
9) sftcap_topo.img
10) mtk_landf_sffr.img
11) sum_ftcap_se.img
12) fall_stcap_se.img
13) sum_fall_topo.img
14) fall_mtk_topo.img
15) full.img

The 16 output land cover maps are found at:

/nv/archive/nv3/output/80percent/nv3_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 to 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 (prf_preliminary.gmd) and "preliminary" map resulting from this process (prf15_v2.img) can be found at:

/nv/archive/nv3/output/80percent/nv3_maps.zip

This land cover classification, following the addition of non-modeled classes, was subjected to an accuracy assessment using the withheld data (1,118 reference sites).

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

Upon inspection of the eco-regional transition between mapping units NV3 Lahontan region) and NV5 (Mojave Desert region), it was decided that transition overly abrupt and did not reflect the gradual transition of vegetation types between these eco-regions. It was decided to smooth this abrupt transition through the use of a Great Basin-Mojave transition model.

While the training data set for the NV3 mapping unit included a small number of training sites from the north limit of the Mojave eco-region, it was insufficient to produce a gradual transition between the eco-regions. Therefore, a broad overlap region was delineated to include adequate sample numbers of both Great Basin and Mojave vegetation types. The overlap region polygon can be found at:

/nv/archive/gb_mjav_transition/trans_region.aoi

The overlap region included approximately 3600 training sites. The abbreviated database containing the training site attributes can be found at:

/nv/archive/gb_mjav_transition/transition_sites.mdb

The shapefile containing the training sites used to classify the Great Basin-Mojave transition is located at:

/nv/archive/gb_mjav_transition/transition_sites.shp

The overlap region polygon was also used to subset a number of predictor variables including summer and fall reflectance data, summer and fall Tasseled Cap variables, slope and elevation.

The predictor variables are located at:

/nv/archive/gb_mjav_transition/images/images1.zip

The 3600 transition training sites were then used to classify the vegetation of the transition via the EDC CART module. A single model was constructed using the predictor variables listed above. The See5 output files generated during the modeling process are found at:

/nv/archive/gb_mjav_transition/images/output.zip

The resulting preliminary land cover map for the Great Basin-Mojave Transition (gb_mjav_transition.img) is located at:

/nv/archive/gb_mjav_transition/images/images1.zip

The resulting land cover map for the transition region was used in conjunction with the preliminary land cover map for the NV3 mapping unit (prf15_v2.img) to generate an "agreement" map. This map depicts only those pixels that share the same ecological systems label in both the original NV3 preliminary map and transition maps. As expected, most of the pixels that were not retained ("disagreement" pixels that had conflicting ecological systems labels) were distributed along the southern border of the NV3 mapping unit.

To complete the process, a second model was created to retain the "agreement" pixel labels, and to then assign labels to "disagreement" pixels. A polygon was delineated that captured the highest density of "disagreement" pixels in the transition region between the Great Basin and the Mojave Desert eco-regions. This polygon is located at:

/nv/archive/gb_mjav_transition/transition_fill.aoi

It was decided the "disagreement" pixels to the north of the transition_fill.aoi polygon would be filled with labels from the original NV3 preliminary land cover map, "disagreement" pixels south of the transition_fill.aoi polygon would be filled with labels from the original NV5 (Mojave) land cover map, and "disagreement" pixels in the transition_fill.aoi polygon would receive labels from the Great Basin-Mojave Transition land cover map. The rationale was that pixels outside the area of disagreement would have a higher probability of being correctly modeled by the NV3 or NV5 land cover models since they are further away from the transition region. The region with the high density of "disagreement" pixels was filled with labels from the transition map since the transition land cover map was created with data from both eco-region's vegetation types, it should have a higher probability of being "correct" than the NV3 land cover map (whose training data contained very little Mojave vegetation types).

The resulting preliminary map (nv3_prelimnary_pixel.img) for the NV3 mapping unit is the result of this process.

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/nv3/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) sffr_topo.img
5) topo.img
6) sftcap.img
7) sum_topo.img
8) fall_topo.img
9) mtk_topo.img
10) sftcap_topo.img
11) mtk_landf_sffr.img
12) sum_ftcap_se.img
13) fall_stcap_se.img
14) sum_fall_topo.img
15) fall_mtk_topo.img
16) full.img

The 16 output land cover maps are found at:

/nv/archive/nv3/output/alldata/nv3_maps.zip

These 15 images were processed by the methods described above. The "pseudo-random forest" model (nv3_prf16.gmd) and "final" map resulting from this process (prf15_v1.img) can be found at:

/nv/archive/nv3/output/alldata/nv3_maps.zip

c) Discussion of mapped cover types: The following narrative provides qualitative assessments for each cover type mapped in the NV3 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 60% (producers) and 75% (users) based on 5 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.

<u>N21 DEVELOPED, OPEN SPACE-LOW INTENSITY:</u> Not qualitatively 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.

<u>N22 DEVELOPED, MEDIUM-HIGH INTENSITY:</u> Not qualitatively 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.

<u>N31 BARREN:</u> Quantitatively assessed, validation 0% (producers) and 0% (users) based on 14 independent samples. This system was most often confused with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (8 of 14 reference sites) and INTER-MOUNTAIN BASINS GREASEWOOD FLATS (2 of 14 reference sites).

<u>N81 PASTURE HAY–IRRIGATED AGRICULTURE:</u> Quantitatively assessed, validation 83% (producers) and 93% (users) based on 30 independent samples. In general, this system was mapped well though it might have been over-represented at the expense of INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS and INVASIVE ANNUAL GRASSLANDS in some instances. There is also the possibility that some riparian grasslands have been mistaken for irrigated agriculture.

<u>D04 INVASIVE SOUTHWEST RIPARIAN WOODLANDS AND SHRUBLANDS:</u> Quantitatively assessed, validation 17% (producers) and 50% (users) based on 6 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was difficult to distinguish from GREAT BASIN FOOTHILLS LOWER MONTANE RIPARIAN WOODLANDS AND SHRUBLANDS.

<u>D06 INVASIVE PERENNIAL GRASSLANDS:</u> This system was not quantitatively assessed. 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.

<u>D08 INVASIVE ANNUAL GRASSLANDS:</u> Quantitatively assessed, validation 24% (producers) and 38% (users) based on 37 independent samples. This system was most commonly confused with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (12 of 37 reference sites), INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (7 of 37 reference sites), and GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (5 of 37 reference sites) that might be attributed to differences between the dates of imagery and sample data collection.

<u>D09 INVASIVE ANNUAL AND BIENNIAL FORBLANDS:</u> Quantitatively assessed, validation 9% (producers) and 33% (users) based on 22 independent samples. This disturbance system is with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (13 of 22 reference sites). This is another ecological system that is associated with disturbance, and is thus difficult to map.

<u>S009 INTER-MOUNTAIN BASINS CLIFF AND CANYONS:</u> Quantitatively assessed, validation 50% (producers) and 59% (users) based on 20 independent samples. This system was confused with INTER-MOUNTAIN

BASINS MIXED SALT DESERT SCRUB (5 of 20 reference sites) that occurred on steep slopes and with relatively sparse vegetative cover.

S012 INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES: Quantitatively assessed, validation 17% (producers) and 100% (users) based on 6 independent samples. This system was confused with INTER-MOUNTAIN BASINS GREASEWOOD FLATS (3 of 6 reference sites). This system is readily confused since it is difficult to distinguish the qualities of the soil substrate. Some of the errors within this class could be attributed to labeling errors.

S015 INTER-MOUNTAIN BASINS PLAYAS: Quantitatively assessed, validation 79% (producers) and 76% (users) based on 28 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This system was confused with INTER-MOUNTAIN BASINS GREASEWOOD FLATS (2 of 28 reference sites) and INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (3 of 28 reference sites) due to similarities of soil brightness and sparse vegetative cover.

S016 NORTH AMERICAN WARM DESERT BEDROCK, CLIFF, AND OUTCROP: This system was not qualitatively assessed. This ecological system is only distributed in the southern-most regions of the NV3 mapping unit near the transition region between the Great Basin and Mojave Desert eco-regions.

S020 NORTH AMERICAN WARM DESERT WASH: This system was not qualitatively assessed. This system was not mapped effectively due in large part to the subtle hydrological differences between it and adjacent upland ecological systems.

S022 NORTH AMERICAN WARM DESERT PLAYA: This system was not qualitatively assessed. This system was mapped only in the southern reaches of the NV3 mapping unit, and appears to be mapping reasonably well. Given its spectral and ecological similarity to the INTER-MOUNTAIN BASINS PLAYA system, it is expected there will be confusion between these systems in the southern extent of the NV3 mapping unit.

S040 GREAT BASIN PINYON-JUNIPER WOODLANDS: Quantitatively assessed, validation 93% (producers) and 78% (users) based on 46 independent samples. This system was mapped very well in this mapping unit. This system does not appear to be over-mapped to a significant degree, though there is some confusion with INTER-MOUNTAIN BASINS CLIFF AND CANYONS and INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS.

S050 INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS: This system was not qualitatively assessed. This system was sparsely mapped in the NV3 mapping unit as is fitting since it was based on only two training sites. As its distribution was modeled on such sparse data, it is improbable that it’s thematic accuracy is high.

S053 GREAT BASIN SEMI-DESERT CHAPARRAL: This system was not qualitatively assessed. This system is included in the NV3 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV3 mapping unit as is fitting since it only occurs in the southern extent of the NV3 mapping unit. As its distribution was modeled on sparse data, it is improbable that it’s thematic accuracy is high.

S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 68% (producers) and 58% (users) based on 158 independent samples. This system was most commonly confused with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (29 of 158 reference sites) at lower elevations, and also GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (6 of 158 reference sites) along lake terraces, alluvial fans, and bajadas. This matrix system was over-mapped largely at the expense of INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE (13 reference sites) and GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (14 reference sites).

S055 GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 63% (producers) and 60% (users) based on 79 independent samples. This system was confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (14 of 39 reference sites) along the lake terraces, alluvial fans, and bajadas of the Great Basin. This system was over-mapped at the expense of INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE (13 reference sites), which shares similar ecological settings but is composed of significantly higher amounts of herbaceous vegetation.

S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB: Quantitatively assessed, validation 86% (producers) and 92% (users) based on 14 independent samples. The mapped extent of this ecological system is based on the procedures used to model the Great Basin-Mojave transition in the southern region of the NV3 mapping unit. Though it appears to be well mapped from a qualitative perspective, so confusion may exist between this system and its Great Basin counter-parts: INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS and GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS.

S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 82% (producers) and 60% (users) based on 341 independent samples. This system was confused at higher elevations with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (21 of 341 reference sites) and INTER-MOUNTAIN BASINS GREASEWOOD FLATS (22 of 341 reference sites) near the upper fringes of lake bottoms. This dominant matrix ecological system was over mapped at the expense of INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE (47 reference sites) and INVASIVE ANNUAL AND BIENNIAL FORBLANDS (13 reference sites).

S069 SONORA-MOJAVE CREOSOTE-WHITE BURSAGE DESERT SCRUB: Quantitatively assessed, validation 67% (producers) and 80% (users) based on 6 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. Qualitatively, this system is mapping well and is restricted to the lower basins of the NV3 mapping unit's southern region.

S070 SONORA-MOJAVE DESERT MIXED SALT DESERT SCRUB: 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 was confused with INTER-MOUNTAIN BASINS GREASEWOOD FLATS (3 of 3 reference sites).

S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE: Quantitatively assessed, validation 25% (producers) and 50% (users) based on 8 independent samples. This system was confused with GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (3 of 8 reference sites) and GREAT BASIN PINYON-JUNIPER WOODLANDS 2 of 8 reference sites). Qualitatively, this system was adequately mapped, however it is likely under-mapped to a degree.

S078 INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 9 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This system was confused predominantly with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (5 of 9 reference sites) due to the similarity of these systems.

S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE: Quantitatively assessed, validation 35% (producers) and 81% (users) based on 113 independent samples. This system was confused with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (47 of 113 reference sites), and also with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (13 of 113 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 21% (producers) and 60% (users) based on 29 independent samples. This system has not mapped well, and is confused most commonly with the matrix communities of INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (5 of 29 reference sites) and INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (5 of 29 reference sites). This community tends to occur in patches among the matrix sagebrush and saltbush systems.

S094 NORTH AMERICAN WARM DESERT LOWER MONTANE RIPARIAN WOODLANDS AND SHRUBLANDS: This system was not quantitatively assessed. Qualitatively, it appears in appropriate locations adjacent to OPEN WATER and in drainage bottoms in the southern region of the NV3 mapping unit..

S096 INTER-MOUNTAIN BASINS GREASEWOOD FLATS: Quantitatively assessed, validation 39% (producers) and 44% (users) based on 97 independent samples. This ecological system is confused with INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (44 of 97 reference sites) along the fringes of lake terraces.

S100 NORTH AMERICAN ARID WEST EMERGENT MARSH: Quantitatively assessed, validation 30% (producers) and 43% (users) based on 10 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 INTER-MOUNTAIN BASINS GREASEWOOD FLATS (3 of 10 reference sites) and with INVASIVE SOUTHWEST RIPARIAN WOODLANDS AND SHRUBLANDS. Confusion with the Greasewood communities can be attributed to differences between the dates of imagery and training data acquisition. Confusion with the Invasive Riparian system is likely due to the similarity in spectral signatures and ecological settings of these systems.

S118 GREAT BASIN FOOTHILL LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS: Quantitatively assessed, validation 69% (producers) and 54% (users) based on 16 independent sample. Qualitatively, this system appears to be mapped well, and was not consistently confused with any particular ecological system. Its geographic distribution is consistent with expectations, except at higher elevations where it may be confused with upland, non-riparian ecological systems.

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