SWReGAP Land Cover Mapping Methods Documentation

Functional Unit or Mapping Zone: NV2 (North Great Basin Mapping Unit)

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

Person Preparing Document: Todd Sajwaj

Date of Preparation: 25 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 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)
40/31	1999 - 192	1999 - 288
40/32	2000 - 195	1999 - 272
41/31	2000 - 202	1999 – 247
41/32	2000 - 202	1999 – 247
42/31	2000 - 209	1999 – 270
42/32	2000 - 209	1999 - 254

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/nv2/mosaic/mosaics.zip – nv2_summer_mosaic.shp
/nv/archive/nv2/mosaic/mosaics.zip – nv2_fall_mosaic.shp

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

/nv/archive/nv2/mosaic/mosaics.zip – nv2_summer.img
/nv/archive/nv2/mosaic/mosaics.zip – nv2_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 *nv2_summer* and *nv2_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/nv1/img_files/. These images are labeled as *nv2_sum_tcap* and *nv2_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/nv2/img_files/. This image is labeled as *nv2_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/nv2/img_files/. These images are labeled as *nv2_sum_fr* and *nv2_fall_fr*.

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

/nv/archive/nv2/img_files/images1.zip
/nv/archive/nv2/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 *nv2_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/nv2/img_files/. This image is labeled as *nv2_swness*.

Elevation: The elevation image was created by importing the original elevation grid to an ERDAS Imagine file format. This image is labeled as *nv2_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 *nv2_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 *nv2_landf*.

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

/nv/archive/nv2/img_files/images1.zip
/nv/archive/nv2/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 2,220 training sites were collected in the NV2 mapping unit. A polygon coverage containing all training site locations and their ecological system labels are found at:

/nv/archive/nv2/train_data/shapefiles.zip – nv2_sites.shp

S Code	# Samples	Ecological System Label
D02	2	Recently Burned
D03	6	Recently Mined/Quarried
D06	25	Invasive Perennial Grassland
D07	1	Invasive Perennial Forbland
D08	81	Invasive Annual Grassland
D09	40	Invasive Annual and Biennial Forbland
N11	30	Open Water
N31	21	Barren
N81	46	Pasture/Hay Irrigated Agriculture
S002	7	Rocky Mountain Alpine Bedrock and Scree
S004	2	Rocky-Mountain Alpine Fell-Field
S009	93	Inter-Mountain Basins Cliff and Canyon
S014	3	Inter-Mountain Basins Greasewood Wash
S015	9	Inter-Mountain Basins Playa
S023	129	Rocky Mountain Aspen Forest and Woodlands
S025	4	Rocky Mountain Subalpine Limber-Bristlecone Pine Woodlands
S026	14	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodlands
S028	21	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodlands
S030	41	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodlands
S039	1	Colorado Plateau Pinyon-Juniper Woodlands
S040	109	Great Basin Pinyon-Juniper Woodlands
S041	5	Columbia Plateau Western Juniper Woodlands
S042	3	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodlands
S050	62	Inter-Mountain Basins Mountain Mahogany Woodland and Shrublands
S053	35	Great Basin Semi-Desert Chaparral
S054	367	Inter-Mountain Basins Big Sagebrush Shrublands
S055	194	Great Basin Xeric Mixed Sagebrush Shrublands
S065	66	Inter-Mountain Basins Mixed Salt Desert Scrub
S071	257	Inter-Mountain Basins Montane Sagebrush Steppe
S078	99	Inter-Mountain Basins Big Sagebrush Steppe
S079	33	Inter-Mountain Basins Semi-Desert Shrub Steppe
S081	9	Rocky Mountain Dry Tundra
S083	24	Rocky Mountain Subalpine Mesic Meadows
S090	149	Inter-Mountain Basins Semi-Desert Grasslands
S091	14	Rocky Mountain Subalpine-Montane Riparian Shrublands
S092	6	Rocky Mountain Subalpine-Montane Riparian Woodlands
S096	68	Inter-Mountain Basins Greasewood Flats
S096L	17	Inter-Mountain Basins Greasewood Flats – *Distichilis spicata* Herbaceous
S100	19	North American Arid West Emergent Marsh
S102	5	Rock Mountain Alpine-Montane Wet Meadow
S118	103	Great Basin Foothill Lower Montane Riparian Woodland and Shrublands
TOTAL	**2220**	

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
D02	Recently Burned
D03	Recently Mined/Quarried
D08	Invasive Annual Grasslands
D06	Invasive Perennial Grasslands
D09	Invasive Annual and Biennial Forblands
N11	Open Water
N21	Developed, Low Intensity
N22	Developed, Med. – High Intensity
N31	Barren
N81	Pasture/Hay Irrigated Agriculture
S002	Rocky Mountain Alpine Bedrock and Scree
S009	Inter-Mountain Basins Cliff and Canyons
S015	Inter-Mountain Basins Playa
S023	Rocky Mountain Aspen Forest and Woodlands
S025	Inter-Mountain Basins Subalpine-Montane Limber-Bristlecone Forest and Woodlands
S026	Inter-Mountain Basins Subalpine Limber-Bristlecone Forest and Woodlands
S028	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodlands
S030	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodlands
S040	Great Basin Pinyon-Juniper Woodlands
S042	Inter-Mountain Basins Aspen-mixed Conifer Forest and 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
S078	Inter-Mountain Basins Big Sagebrush Steppe
S079	Inter-Mountain Basins Semi-Desert Shrub Steppe
S081	Rocky Mountains Dry Tundra
S083	Rock Mountains Subalpine Mesic Meadows
S090	Inter-Mountain Basins Semi-Desert Grasslands
S092	Rocky Mountains Subalpine/Montane Riparian Woodlands and Shrublands
S096	Inter-Mountain Basins Greasewood Flats
S100	North American Arid West Emergent Marsh
S102	Rocky Mountain Alpine-Montane Wet Meadow
S118	Great Basin Foothill Lower Montane Riparian Woodland and Shrublands

Pixels originally modeled as ROCKY MOUNTAINS SUBALPINE/MONTANE RIPARIAN SHRUBLANDS (S091) were combined ROCKY MOUNTAINS SUBALPINE/MONTANE RIPARIAN (S092) via a simple recode. Pixels originally modeled at INTER-MOUNTAIN BASINS GREASEWOOD WASH (S014) were recoded as INTER-MOUNTAIN BASINS GREASEWOOD FLATS (S096). Pixels Originally modeled as INTER-MOUNTAIN BASINS GREASEWOOD FLATS – *Distichilis spicata* (S096L) were recoded as INTER-MOUNTAIN BASINS PLAYA (S015) according to instructions from NatureServe collaborators.

The ecological systems of COLORADO PLATEAU PINYON-JUNIPER WOODLANDS (S039) and COLUMBIA PLATEAU WESTERN JUNIPER WOODLANDS (S041) were not included in the training data set due to insufficient sample sizes.

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 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 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 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 image files depicting these non-modeled classes are found in:
/nv/archive/nv2/non_model/non_model.zip – nv2_agriculture.img
/nv/archive/nv2/non_model/non_model.zip – nv2_burns.img
/nv/archive/nv2/non_model/non_model.zip – nv2_water.img
/nv/archive/nv2/non_model/non_model.zip – nv2_mines.img
/nv/archive/nv2/non_model/non_model.zip – nv2_urban.img

4) Summary of predictor layers used:

a) Multi band predictors:

nv2_summer.img	(ETM+ bands 1-5 & 7 – mixed 1999 & 2000 images)
nv2_fall.img	(ETM+ bands 1-5 & 7 – 1999 images)
nv2_mtk.img	(bands 1-3 = stable brightness, greenness, wetness; bands 4-6 = change brightness, greenness, wetness)
nv2_sum_tcap.img	(summer brightness, greenness, wetness)
nv2_fall_tcap.img	(fall brightness, greenness, wetness)

All multi-band predictors can be found at:
/nv/archive/nv2/img_files/images1.zip
/nv/archive/nv2/img_files/images2.zip

b) Single band predictors:

nv2_slope.img	Continuous slope (units = degrees)
nv2_swness.img	Linear, continuous transformation of aspect
nv2_elev.img	Continuous elevation (units = meters)
nv2_sum_fr.img	Continuous fractional vegetation
nv2_fall_fr.img	Continuous fractional vegetation
nv2_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 1772 training site polygons that were converted by the process described above into 21,175 pixels for use in creating the "preliminary" land cover map via the CART modeling process. The *total data set* contained 2220 training site polygons that were converted into 26,396 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 using the *80% data set* developed the NV2 mapping unit are described below:

Model #	Model Name	# of Variables	Variable Labels
1	Topo	4	Slope, Southwest-ness, Elevation, Landform
2	Stcap_se	5	Summer Tasseled Cap, Slope, Elevation,
3	Ftcap_se	5	Fall Tasseled Cap, Slope, Elevation,
4	Summer	6	Summer
5	Fall	6	Fall
6	Mtk	6	Multi-temporal Kauth-Thomas
7	Sum_ffr_e	8	Summer, Fall Fractional Vegetation, Elevation
8	Fall_sfr_s	8	Fall, Summer Fractional Vegetation, Slope
9	Sftcap_sffr	8	Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation
10	Mtk_se_sfr	9	Multi-temporal Kauth-Thomas, Slope, Elevation, Summer Fractional Vegetation
11	Ftcap_sum	9	Summer, Fall Tasseled Cap
12	Stcap_fall	9	Fall, Summer Tasseled Cap
13	Sum_topo	10	Summer, Slope, Southwest-ness, Elevation, Landform
14	Fall_topo	10	Fall, Slope, Southwest-ness, Elevation, Landform
15	Mtk_topo	10	Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation, Landform
16	Topo_mtk_sum	16	Summer, Multi-temporal Kauth-

			Thomas, Slope, Southwest-ness, Elevation, Landform

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

/nv/archive/nv2/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	Topo	4	Slope, Southwest-ness, Elevation, Landform
2	Stcap_se	5	Summer Tasseled Cap, Slope, Elevation,
3	Ftcap_se	5	Fall Tasseled Cap, Slope, Elevation,
4	Summer	6	Summer
5	Fall	6	Fall
6	Mtk	6	Multi-temporal Kauth-Thomas
7	Sum_ffr_e	8	Summer, Fall Fractional Vegetation, Elevation
8	Fall_sfr_s	8	Fall, Summer Fractional Vegetation, Slope
9	Sftcap_sffr	8	Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation
10	Mtk_se_sfr	9	Multi-temporal Kauth-Thomas, Slope, Elevation, Summer Fractional Vegetation
11	Ftcap_sum	9	Summer, Fall Tasseled Cap
12	Stcap_fall	9	Fall, Summer Tasseled Cap
13	Sum_topo	9	Summer, Slope, Southwest-ness, Elevation
14	Mtk_topo	9	Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
15	Sum_mtk_topo	15	Summer, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
16	full	21	Summer, Fall, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation

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

/nv/archive/nv2/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/nv2/output/80percent/see5_files.zip
/nv/archive/nv2/output/alldata/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) topo.img
2) stcap_se.img
3) ftcap_se.img
4) summer.img
5) fall.img
6) mtk.img
7) sum_ffr_e.img
8) fall_sfr_s.img
9) sftcap_sffr.img
10) mtk_se_sfr.img
11) ftcap_sum.img
12) stcap_fall.img
13) sum_topo.img
14) fall_topo.img
15) mtk_topo.img
16) topo_mtk_sum.img

The 16 output land cover maps are found at:

/nv/archive/nv2/output/80percent/nv2_prelim_maps.zip
/nv/archive/nv2/output/80percent/nv2_prelim_maps2.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 (prf_pixel.gmd) and "preliminary" map resulting from this process (nv2_pseudo_rf.img) can be found at:

/nv/archive/nv2/output/80percent/nv2_prelim_maps2.zip

This land cover classification, following the addition of non-modeled classes, was subjected to an accuracy assessment using the withheld data (448 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/nv2/post_model/s028_to_S030.gmd
/nv/archive/nv2/post_model/s030_to_S028.gmd

Step 1: Discriminating S028-Rocky Mountains Subalpine Dry-Mesic Spruce-Fir Forests and Woodlands and S030-Rocky Mountains Subalpine Mesic Spruce-Fir Forests and Woodlands. The logic and parameters are as follows:

This model was used to differentiate S028-Rocky Mountains Subalpine Dry-Mesic Spruce-Fir Forests and Woodlands and S030-Rocky Mountains Subalpine Mesic Spruce-Fir Forests and Woodlands. NatureServe describes

S030 to be "*typically found in location with cold air drainage or ponding, or where snow pack lingers late into the summer, such as noth-facing slopes and higher elevation ravines. They can extend down in elevation below the subalpine zone in places where cold air ponging occurs; northerly and easterly aspects predominate. These forest are found on gentle to very steep mountain slopes, high elevation ridgetops and upper-slopes, plateau-like surfaces, basins, alluvial terraces, well-drained benches, and inactive stream terraces*."

Model Methods: The preliminary models were run to include both ecological systems. A conditional statement was then applied to re-classify S030 pixels on drier, southerly facing slopes to S028, and a second conditional statement was used to re-classify S028 pixels on wetter, northerly-facing slopes to S030.

Model 1a: Either S028 (IF *Modeled Vegetation* = S030 AND ((ASPECT GT 45) AND (ASPECT LT 275)) OR *Modeled Vegetation* OTHERWISE

Model 1b: Either S030 (IF *Modeled Vegetation* = S028 AND ((ASPECT LE 45) OR (ASPECT GE 275)) OR *Modeled Vegetation* OTHERWISE

Step 2: Recoding S096L-Inter-Mountain Basins Greasewood Flats - *Distichilis spicata* Herbaceous pixels to S015-Inter-Mountain Basins Playa.

This was a simple operation that used the Raster-Recode function of ERDAS Imagine to recode those S096L-Inter-Mountain Basins Greasewood Flats - *Distichilis spicata* Herbaceous pixels to S015-Inter-Mountain Basins Playa.

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 aree 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 polyogn was correct or incorrect, and the actual ecological systems label for the site. These files can be found at: /nv/archive/nv2/validation

b) Final map:

A second set of 16 land cover images were produced for the *total data set* that was produced by using 100% of the training site data through the following models:

1) topo.img
2) ftcap_se.img
3) stcap_se.img
4) sum.img
5) fall.img
6) mtk.img
7) sum_ffr_e.img
8) fall_sfr_e.img
9) sftcap_sffr.img
10) ftcap_sum.img
11) stcap_fall.img
12) mtk_sfr_se.img
13) sum_topo.img
14) mtk_topo.img
15) sum_mtk_topo.img
16) full.img

The 16 output land cover maps are found at:

/nv/archive/nv2/output/alldata/nv2_final_maps.zip

These 15 images were processed by the methods described above. The "pseudo-random forest" model (prf_alldata.gmd) and "final" map resulting from this process (nv1_all_prf16_v1.img) can be found at:

/nv/archive/nv1/output/alldata/nv2_final_maps.zip

c) Discussion of mapped cover types: The following narrative provides qualitative assessments for each cover type mapped in the NV2 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 83% (producers) and 71% (users) based on 6 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 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.

N22 DEVELOPED, MEDIUM-HIGH INTENSITY: 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.

N31 BARREN: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 2 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy.

N81 PASTURE HAY-IRRIGATED AGRICULTURE: Quantitatively assessed, validation 89% (producers) and 89% (users) based on 9 independent sample. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. A qualitative assessment suggests that agricultural lands have been mapped well, though they map have been over represented at the expense of INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS and INVASIVE ANNUAL GRASSLANDS. There is also the possibility that some riparian grasslands have been mistaken for irrigated agriculture.

D06 INVASIVE PERENNIAL GRASSLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 5 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 BIG SAGEBRUSH SHRUBLANDS (3 of 5 reference sites) and INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE (2 of 5 reference sites). 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 7% (producers) and 17% (users) based on 15 independent samples. This system was most commonly confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (6 of 15 reference sites) and INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (4 of 15 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 13% (producers) and 33% (users) based on 13 independent samples. This disturbance system is with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 8 reference sites) and INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS (2 of 8 reference sites). This is another ecological system that is associated with disturbance, and is thus difficult to map.

S002 ROCKY MOUNTAINS ALPINE BEDROCK AND SCREE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 2 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This system is likely confused with INTER-MOUNTAIN BASINS CLIFF AND CANYONS.

S009 INTER-MOUNTAIN BASINS CLIFF AND CANYONS: Quantitatively assessed, validation 42% (producers) and 67% (users) based on 19 independent samples. This system was confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (5 of 19 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 2 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 due to similarities of soil brightness and sparse vegetative cover.

S023 ROCKY MOUNTAIN ASPEN FORST AND WOODLANDS: Quantitatively assessed, validation 85% (producers) and 51% (users) based on 26 independent samples. This system was confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (2 of 26 reference sites) due to the presence of a dense herbaceous under-story in some training sites.

S025 ROCKY MOUNTAIN SUBALPINE-MONTANE LIMBER BRISTLECONE PINE WOODLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. Thematic accuracy cannot be assessed with a single reference site. Even a qualitative assessment of this system is difficult since this is a relatively rare ecological system in the Great Basin ecoregion.

S026 INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS: Quantitatively assessed, validation 33% (producers) and 33% (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 ROCKY MOUNTAINS SUBALPINE-MONTANE LIMBER-BRISTLECONE PINE WOODLANDS (1 of 3 reference sites).

S028 ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLANDS: Quantitatively assessed, validation 50% (producers) and 33% (users) based on 4 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was confused with both INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS (1 of 3 reference sites) and GREAT BASIN PINYON JUNIPER WOODLANDS (1 of 3 reference sites).

S030 ROCKY MOUNTAINS SUBALPINE MESIC SPRUCE-FIR FOREST AND WOODLANDS: Quantitatively assessed, validation 25% (producers) and 67% (users) based on 8 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was confused with both ROCKY MOUNTAINS SUBALPINE DRY-MESIC SPRUCE-FIR FOREST AND WOODLANDS (2 of 8 reference sites) which suggest possible label errors in the reference data set.

S040 GREAT BASIN PINYON-JUNIPER WOODLANDS: Quantitatively assessed, validation 59% (producers) and 57% (users) based on 22 independent samples. This system was confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 22 reference sites) and GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (2 of 22 reference sites) at lower elevations, and INTER-MOUNTAIN BASINS MONTANE SAHEBRUSH STEPPE (5 of 22 reference sites) at higher elevations. Given the large number of training sites of this montane wooded system, it is perhaps not entirely surprising that it may have been over-mapped at the expense of other woodland and forested systems in the montane zone.

S050 INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS: Quantitatively assessed, validation 25% (producers) and 43% (users) based on 12 independent samples. This system is confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (5 of 12 reference sites) and ROCKY MOUNTAINS ASPEN FOREST AND WOODLANDS (3 of 12 reference sites) that sometimes occurs in similar ecological settings.

S053 GREAT BASIN SEMI-DESERT SHRUBLANDS: Quantitatively assessed, validation 14% (producers) and 25% (users) based on 7 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was confused with ROCKY MOUNTAINS ASPEN FOREST AND WOODLANDS (5 of 7 reference sites). The majority of training data for this system comes from the Ruby and Jarbidge Mountains where this systems seems to be mapped adequately from a qualitative perspective. However it may be over-mapped in other mountain ranges.

S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 82% (producers) and 46% (users) based on 71 independent samples. This system was most commonly confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (6 of 71 reference sites) at higher elevations and INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (3 of 71 reference sites) at lower elevations. This matrix system was over-mapped largely at the expense of INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE (17 reference sites) and GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (14 reference sites).

S055 GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 49% (producers) and 63% (users) based on 39 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 also confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPEGREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (4 of 39 reference sites) which shares similar ecological settings at higher elevations.

S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 23% (producers) and 43% (users) based on 13 independent samples. This system was confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (7 of 13 reference sites) and INTER-MOUNTAIN BASINS GREASEWOOD FLATS (2 of 13 reference sites) near the upper fringes of lake bottoms.

S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE: Quantitatively assessed, validation 76% (producers) and 46% (users) based on 51 independent samples. This system was confused with several ecological systems (i.e. INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS, GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS, and GREAT BASIN PINYON-JUNIPER WOODLANDS) at the transition between lower elevations and the montane zone. Qualitatively, this system was mapped well, however it was over-mapped at the expense of INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS (8 reference sites), INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS (5 reference sites), and INTER-MOUNTAIN BASINS CLIFF AND CANYONS (5 reference sites).

S078 INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 17 independent samples. This system was confused predominantly with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (17 of 19 reference sites) due to the similarity of these systems.

S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 6 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 BIG SAGEBRUSH SHRUBLANDS (3 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.

S081 ROCKY MOUNTAINS DRY TUNDRA: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 2 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. Even a qualitative assessment is difficult for this small patch ecological system, but it was confused with ROCKY MOUNTAINS

SUBALPINE DRY-MESIC SPRUCE-FIR FORESTS AND WOODLANDS (2 of 2 reference sites).

S083 ROCKY MOUNTAINS SUBALPINE MESIC MEADOWS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 5 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This rare, small patch system was confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (2 of 5 reference sites) and ROCKY MOUNTAINS ASPEN FOREST AND WOODLANDS (2 of 5 reference sites).

S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS: Quantitatively assessed, validation 17% (producers) and 0% (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 MONTANE SAGEBRUSH STEPPE (8 of 29 reference sites) and INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (6 of 29 reference sites). This community tends to occur in patches among the matrix sagebrush systems.

S092 ROCKY MOUNTAINS SUBALPINE-MONTANE RIPARIAN WOODLANDS AND SHRUBLANDS: Quantitatively assessed, validation 25% (producers) and 50% (users) based on 4 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This rare, linear patch system was confused with ROCKY MOUNTAINS ASPEN FOREST AND WOODLANDS (2 of 4 reference sites) suggesting possible labeling errors in the training data set.

S096 INTER-MOUNTAIN BASINS GREASEWOOD FLATS: Quantitatively assessed, validation 54% (producers) and 58% (users) based on 13 independent samples. This ecological system is confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (4 of 13 reference sites) along the fringes of lake terraces.

S100 NORTH AMERICAN ARID WEST EMERGENT MARSH: Quantitatively assessed, validation 25% (producers) and 50% (users) based on 4 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 FOTTHILLS LOWER MONTANE RIPARIAN WOODLANDS AND SHRUBLANDS (2 of 4 reference sites). This confusion is like 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 57% (producers) and 75% (users) based on 21 independent sample. Qualitatively, this system appears to be mapped well, however it was confused at higher elevations with ROCKY MOUNTAIN ASPEN FOREST AND WOODLANDS (5 of 21 reference sites) and INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS (3 of 21 reference sites) which might be attributed to differences between the dates of imagery and field data collection.

7) Citations:

Carlson, T. N. and D. A. Ripley. 1997. On the relation between NDVI, fractional vegetation cover, and leaf area index. Remote Sensing of Environment. 62:241-252.

Chavez, P. S. Jr., 1988, An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data.

Chavez, P. S. Jr., 1996, Image-based atmospheric corrections—revisited and revised. *Photogrammetric Engineering and Remote Sensing* 62(9): 1025-1036.

Collins, J.B. and C.E. Woodcock. 1996. An assessment of several linear change detection techniques for mapping forest mortality using multitemporal Landsat TM data. Remote Sensing of Environment 56:66-77.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Mernard, M. Pyne, M. Ried, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of US terrestrial systems. NatureServe, Arlington, Virgina.

EarthSatellite. 2003. CART Software User's Guide, prepared by EarthSatellite Corporation for the US Geological Survey in support of the National Land Cover Database (NLCD) 2000. EarthSatellite, January 2003.

Manis, G., J. Lowry and R. D. Ramsey, 2001, Preclassification: An ecologically predictive landform model. GAP Analysis Bulletin No. 10. USGS.

Huang, C. L. Yang, C. Homer, B. Wylie, J. Vogelman and T. DeFelice, 2001a, t-sensor reflectance: A first order normalization of Landsat 7 ETM+ Images.

Huang, C., B. Wylie, L. Yang, C. Homer and G. Zylstra, 2001b, Derivation of tasseled cap transformation based on Landsat 7 at-satellite reflectance.