An Approach for Determining Regional Land Cover and Species Habitat Conservation Status in the American Southwest: the Southwest Regional Gap Analysis Project

William G. Kepner[1], David F. Bradford[1], and Todd D. Sajwaj[2]

1. U.S. Environmental Protection Agency, Office of Research and Development, 944 E. Harmon Ave., Las Vegas, NV; 2. Lockheed Martin Environmental Services, 1050 E. Flamingo Rd., Las Vegas, NV

ABSTRACT

The Southwest Regional Gap Analysis Project (SWReGAP) improves upon previous GAP projects conducted in Arizona, Colorado, Nevada, New Mexico, and Utah to provide a consistent, seamless vegetation map for this large and ecologically diverse geographic region and to generate other GAP-related products (e.g. vertebrate species distribution maps). Three methodological improvements are employed to increase the accuracy and utility of the vegetation map: 1) a universal standard for the identification of plant communities, the National Vegetation Classification System, 2) the use of a single methodology for constructing predictive models of plant community distribution, classification and regression trees (CART), and 3) the subdivision of the 5-state regions into mapzones, or provinces of homogeneous geology, climate and phenology, to reduce the complexity of predictive land cover models. More than 92,100 vegetation training sites were collected in the field to develop the digital land cover map; 17,500 in Nevada. The procedures used in field data collection, training site classification, predictive model generation, and vegetation map production are illustrated with examples from the Mojave Desert mapzone of southern Nevada. A regionwide digital vegetation map and database has been produced enabling land managers, scientists, and policy makers to make informed decisions regarding land use.

INTRODUCTION

GAP Program Overview:

A "gap" is the lack of representation or under-representation of an element of biodiversity (plant community or animal species) in an area intended for its long-term maintenance. Gap analysis is a national program about keeping common species common by providing a geographic approach to map biological diversity (Scott et al. 1993). The GAP methodology is straightforward: 1) map the distributions of natural plant communities, 2) map predicted distributions of terrestrial vertebrate species, 3) map the degree of management for biodiversity maintenance, and 4) analyze the representation of vegetation and animal species distributions in the conservation network to identify "gaps" in long-term security. This type of coarse-filter approach can be used for research, land management, and conservation planning purposes by land managers, scientists and policy makers at both regional and ecosystem levels (Noss 1987).

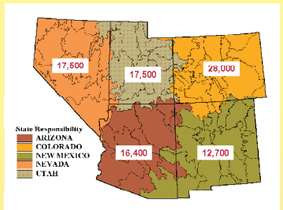

Figure 1

Land Cover Mapping and First Generation GAP:

While the first generation of western GAP projects was highly innovative for their time, there were unforeseen problems (Jacobs et al. 2001). As the various western GAP projects were completed and stitched together, the vegetation maps exhibited abrupt changes in their classification systems and community distributions at state boundaries. Animal species distribution maps, modeled largely from vegetation maps, also revealed abrupt changes at state boundaries. Three sources of these problems were identified: 1) separate vegetation classification systems for each state, 2) unique methodologies for constructing predictive maps of plant communities, and 3) state-by-state differences in habitat modeling protocols.

MATERIALS AND METHODS

Field Data Collection Methodology:

To classify the vegetation of a 5-state region (Figure 1) requires thousands of training sites. Because of the large volume of data required, only enough time is spent at each site to collect the minimum amount of ecological detail to confidently assign alliance and ecological system labels. Field crews select training sites opportunistically based on homogeneity of plant species composition, landform, and spectral characteristics. Three essential steps are performed at each site: plant community characterization, site delineation, and photographic documentation.

Plant Community Characterization: Two basic types of information are collected for each training site: 1) ocular estimates of vegetative cover by life form and abiotic ground cover (e.g. rock fragments, bedrock, water) and 2) measurements and classification of the communities' landscape setting (e.g. landform, topographic attributes).

Site Delineation: A polygon delineating the training site is hand-digitized in the field utilizing satellite imagery, digital elevation models (DEMs), and digital raster graphs (DRGs) as guides.

Photographic Documentation: To document each training site, a digital photograph is collected as a reference should any questions arise regarding its alliance or ecological system labels.

Plant Community Classification:

The National Vegetation Classification System (NVCS), developed by NatureServe, is the basis for plant community classification for the SWReGAP project (Comer et al. 2003). The "alliance" level (see Table 1) of the NVCS was the initial goal of the SWReGAP land cover maps. As land cover mapping has proceeded, it was determined that mapping at the alliance level was infeasible, and alliances had to be aggregated. NatureServe developed a modified classification system (see Table 2) to be used by the SWReGAP project. Based on the plant community characterization data collected in the field, each site is assigned an alliance, ecological system, and National Land Cover Data (NLCD) label.

Table 1. Hierarchy of the National Vegetation Classification Systems

Level	Primary Basis for Classification	Example
Class	Growth form and structure of vegetation	Woodland
Subclass	Growth form characteristics, e.g. leaf phenology	Deciduous Woodland
Group	Leaf types, corresponding to climate	Cold-deciduous Woodland
Subgroup	Relative human impact (natural/semi-natural, or cultural)	Natural Semi-Natural
Formation	Additional phyiognomic and environmental factors, including hydrology	Temporarily-flooded Cold-deciduous Woodland
Alliance	Dominant diagnostic species of the uppermost stratum	*Populus deltoides* Temporarily-flooded Woodland Alliance
Association	Additional dominant diagnostic species from any strata	*Populus deltoides* - (*Salix amygdaloides*) / *Salix exigua* Woodland

Table 2. Modified NVCS for the SWReGAP Project

Level	Primary Basis for Classification	Examples
NLCD	Coarse land use/land cover classes	•Barren •Deciduous/Evergreen Forest •Short/Tall Shrublands •Herb Herbaceous •Grassland •Woody/Herbaceous Wetland
Ecological System	Aggregation of plant communities that occur in similar ecological settings	•Sonora-Chihuahua Desert Riparian Mesquite Bosque •Sonora-Mojave Creosotebush-White Bursage Desert Scrub •Inter-Mountain Basins Mixed Salt Desert Scrub •Great Basin Pinyon-Juniper Woodland
Alliance	Dominant diagnostic species of the uppermost stratum	*Populus deltoides* Temporarily-flooded Woodland Alliance

Standardized Data Layers:

Once all of the training site polygons for a mapzone are collected, they are intersected through various digital datalayers. In order to further standardize methodologies throughout the five states, we will use consistent datalayers for modeling. The geospatial data layers include Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery acquired between 1999 and 2001 for 3 seasons (spring, summer, fall), digital elevation model data, and STATSGO soils data.

Modeling:

The SWReGAP project is faced with a daunting task, namely constructing predictive vegetation models and subsequent vegetation maps for a diverse region that is nearly one-fifth the size of the conterminous U.S., or 535,175 square miles. At the project's outset it was recognized that this large region had to be subdivided, hence mapzones were developed. Even with a single mapzone, vegetation diversity can be substantial. Classification and regression trees can handle large numbers of predictor variables and are relatively insensitive to "noisy" data. Therefore, the SWReGAP modeling approach is centered on the use of classification and regression trees.

Classification and Regression Trees: Classification trees recursively partition a dataset into increasingly "pure" subsets based on a multitude of predictor variables. In the case of SWReGAP, the pure subsets are groups of field sites that belong to the same alliance or ecological system. The output of a classification tree is a set of decision rules.

Accuracy Assessment: The final predictive vegetation maps were completed and subjected to various accuracy assessment procedures. Our methods include withholding a proportion (20%) of the training dataset to use in a conventional accuracy assessment and review of draft vegetation maps by regional experts.

RESULTS

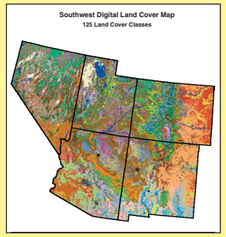

Figure 2

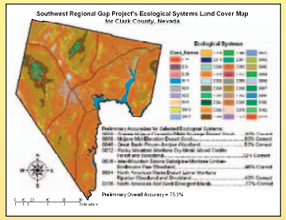

Figure 3

Figure 2 depicts the digital land cover produced for the SWReGAP project. More than 1.5 billion 30m pixels have been classified into 125 land cover classes to develop a seamless land cover map for the 5-state area. The information is available at the Utah State University server based at **http://earth.gis.usu.edu/swgap/**.

Multi-season satellite imagery (Landsat ETM+) from 1999-2001 was used in conjunction with digital elevation model (DEM) derived datasets (e.g. elevation, landform, aspect, etc.) to model natural and semi-natural vegetation. Land cover classes are drawn from NatureServe's Ecological System concept, with 109 of the 125 total classes mapped at the ecological system level. For the majority of classes, a decision tree classifier was used to discriminate land cover types, while a minority of classes (e.g. urban classes, sand dunes, burn scars, etc.) was mapped using other techniques. Twenty mapping areas, each characterized by similar ecological and spectral characteristics, were modeled independently of one another. These mapping areas, which included a 4-km overlap, were subsequently mosaicked to create the regional dataset. An internal validation for modeled classes was performed on a withheld 20% of the sample data. While the modeling area encompassed these 5 southwestern states (Arizona, Colorado, Nevada, New Mexico, Utah), the actual GIS dataset can be downloaded as a subset of the 5-state region using state, county, TNC ecoregion, Bailey ecoregion, and SWReGAP mapping zone configurations. Each file contains a folder with the dataset in ArcInfo grid or ERDAS Imagine format as specified, FGDC (Federal Geospatial Data Committee) metadata file(s) and a .pdf document of land cover class descriptions.

As an example, we demonstrate land cover for Clark County, Nevada in Figure 3. In this example, 39 land cover classes (Table 3) are displayed with mapping accuracies varying from 32 to 93% per class. The total map accuracy for Clark County was estimated at 75.3%.

Ecological Systems of Clark County, Nevada

D62 – Recently Burned
D63 – Recently Mined/Quarried
D64 – Invasive Southwest Riparian Woodland and Shrubland
D66 – Invasive Perennial Grassland
D68 – Invasive Annual Grassland
D69 – Invasive Annual and Biennial Forbland
...
N11 – Open Water
N21 – Developed, Low Intensity
N22 – Developed, Medium Intensity
N81 – Pasture/Hay
N82 – Cultivated Crops
...
I011 – Inter-Mountain Basins Shale Badland
I012 – Inter-Mountain Basins Active and Stabilized Dunes
I013 – Inter-Mountain Basins Volcanic Rock and Cinder Land
I015 – Inter-Mountain Basins Playa
I016 – North American Warm Desert Bedrock Cliff and Outcrop
I017 – North American Warm Desert Badland
I018 – North American Warm Desert Active and Stabilized Dunes
I019 – North American Warm Desert Volcanic Rockland
I020 – North American Warm Desert Wash
I021 – North American Warm Desert Pavement
I022 – North American Warm Desert Playa
I024 – Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland
I032 – Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
I034 – Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
I039 – Colorado Plateau Pinyon-Juniper Woodlands
I040 – Great Basin Pinyon-Juniper Woodland
I045 – Inter-Mountain Basins Mat Saltbush Shrubland
I052 – Colorado Plateau Pinyon-Juniper Woodlands
I053 – Great Basin Semi-Desert Chaparral
I054 – Inter-Mountain Basins Big Sagebrush Shrubland
I055 – Great Basin Xeric Mixed Sagebrush Shrubland
I057 – Mogollon Chaparral
I058 – Chihuahuan Mesquite Upland Scrub
I059 – Colorado Plateau Blackbrush-Mormon Tea Shrubland
I060 – Mojave Mid-Elevation Mixed Desert Scrub
I063 – Sonoran Paloverde-Mixed Cacti Desert Scrub
I065 – Inter-Mountain Basins Mixed Salt Desert Scrub
I069 – Sonora-Mojave Creosotebush-White Bursage Desert Scrub
I070 – Sonora-Mojave Desert Mixed Salt Desert Scrub
I071 – Inter-Mountain Basins Montane Sagebrush Shrubland
I075 – Inter-Mountain Basins Juniper Savannah
I076 – Inter-Mountain Basins Big Sagebrush Steppe
I079 – Inter-Mountain Basins Semi-Desert Shrub-Steppe
I083 – Rocky Mountain Subalpine Mesic Meadow
I090 – Inter-Mountain Basins Semi-Desert Grassland
I093 – Rocky Mountain Lower Montane Riparian Woodland and Shrubland
I094 – North American Warm Desert Lower Montane Riparian Woodland and Shrubland
I096 – Inter-Mountain Basins Ornamental Flats
I097 – North American Warm Desert Riparian Woodland and Shrubland
I098 – North American Warm Desert Mesquite Bosque
I100 – North American Arid West Emergent Marsh
I102 – Rocky Mountain Alpine-Montane Wet Meadow
I114 – Sonora-Mojave-Baja Semi-Desert Chaparral
I118 – Great Basin Foothill Lower Montane Riparian Woodland and Shrubland
I129 – Sonoran Mid-Elevation Desert Scrub

Table 3

FUTURE DIRECTIONS

The SWReGAP project will be complete in 2005. At this time, stewardship maps which depict land ownership and conservation management status in seamless digital format for the 5 states are being developed. Simultaneously, habitat models for 833 terrestrial vertebrates which reside, breed, or use habitat in the 5-state region for a substantial portion of their life history are being developed. Ultimately, these information layers, i.e. potential habitat and land stewardship, will be intersected to identify "gaps" in long-term security for biodiversity protection. This information will be provided in publicly available format and will enable land managers, scientists, and policy makers to make better informed decisions regarding land use.

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FOR MORE INFORMATION

http://www.epa.gov/nerlesd1/land-sci/gap.htm

http://earth.gis.usu.edu/swgap/

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