An Inter-Agency Approach for Determining Regional Land Cover in the American Southwest: The Southwest Regional Gap Analysis Project

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Abstract

The Gap Analysis Program is a national inter-agency program that maps the distribution of plant communities and selected animal species and compares these distributions with land stewardship to identify "gaps" in biodiversity protection. GAP uses remote satellite imagery (Landsat 7) and Geographic Information System (GIS) technology to assemble and view large amounts of biological and land management data to identify areas where conservation efforts may not be sufficient to maintain diversity of living natural resources. Historically, GAP has been conducted by individual states. However, this has resulted in inconsistencies in mapped distributions of vegetation types and animal habitat across state lines because of differences in mapping and modeling protocols. This was further compounded from the lack of a national vegetation classification nomenclature. In response to these limitations, GAP embarked on a second-generation effort to conduct the program at a regional scale using 1) a vegetation classification scheme applicable across the U.S.; 2) ecoregional units as the basis for segmenting the landscape into manageable units; and 3) inter-agency investigator teams with land cover analysis and environmental protection expertise. The program's first formalized multi-state effort includes five Southwestern states (Arizona, Colorado, Nevada, New Mexico, and Utah), which comprise nearly one-fifth of the conterminous United States.

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. 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.

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. 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

The National Vegetation Classification System (NVCS), developed by NatureServe, is the basis for plant community classification for 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).

To classify the vegetation of a 5-state region (Figure 1) requires thousands of training sites. 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 landscape setting (e.g. landform, topographic attributes).

Table 1. 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 •Shrub 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

Table 1

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.

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 used 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.

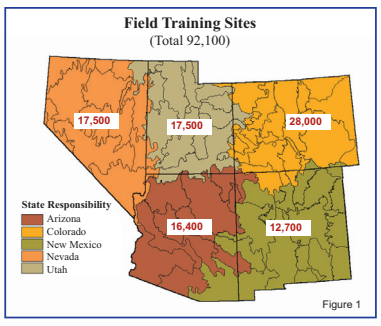


Figure 1

Classification and Regression Trees: Classification trees recursively partition a data set 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

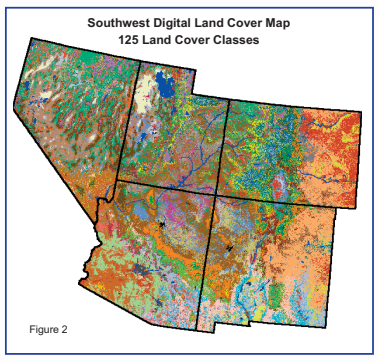


Figure 2

Figure 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 from 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. 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.) were 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 five Southwestern states (Arizona, Colorado, Nevada, New Mexico, and Utah), the actual GIS dataset can be downloaded as a subset of the 5-state region using state, county,

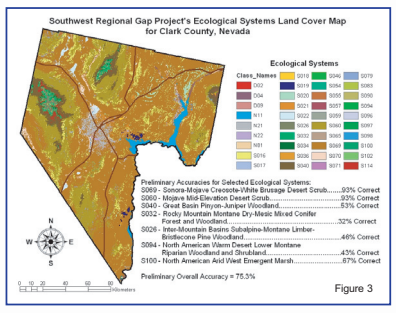
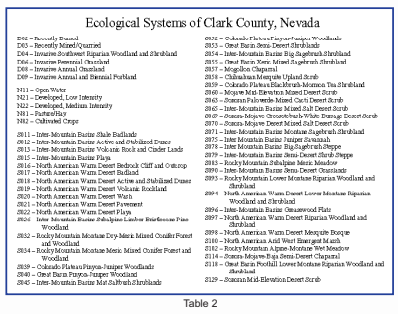


Figure 3


Ecological Systems of Clark County, Nevada

D42 – Recently Burned
D43 – 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

S011 – Inter-Mountain Basins Shale Badlands
S012 – Inter-Mountain Basins Active and Stabilized Dune
S013 – Inter-Mountain Basins Volcanic Rock and Cinder Lands
S015 – Inter-Mountain Basins Playa
S016 – North American Warm Desert Bedrock Cliff and Outcrop
S017 – North American Warm Desert Badland
S018 – North American Warm Desert Active and Stabilized Dunes
S019 – North American Warm Desert Volcanic Rockland
S020 – North American Warm Desert Wash
S021 – North American Warm Desert Pavement
S022 – North American Warm Desert Playa
S024 – Inter-Mountain Basins Subalpine-Limber-Bristlecone Pine Woodland
S032 – Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
S034 – Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
S039 – Colorado Plateau Pinyon-Juniper Woodlands
S040 – Great Basin Pinyon-Juniper Woodland
S045 – Inter-Mountain Basins Mat.SaltBush-Shrublands

S050 – Colorado Plateau Pinyon-Juniper Woodlands
S053 – Great Basin Semi-Desert Shrublands
S054 – Inter-Mountain Basins Big Sagebrush Shrubland
S055 – Great Basin Xeric Mixed Sagebrush Shrubland
S057 – Mogollon Chaparral
S058 – Chihuahuan Mesquite Upland Scrub
S059 – Colorado Plateau BlackBrush-Mormon Tea Shrubland
S060 – Mojave Mid-Elevation Mixed Desert Scrub
S065 – Sonoran Palo verde-Mixed Cacti Desert Scrub
S067 – Inter-Mountain Basins Mixed Salt Desert Scrub
S069 – Sonora-Mojave Creosotebush-White Bursage Desert Scrub
S070 – Sonora-Mojave Desert Mixed Salt Desert Scrub
S071 – Inter-Mountain Basins Montane Sagebrush Shrubland
S075 – Inter Mountain Basins Juniper Savannah
S078 – Inter Mountain Basins Big Sagebrush Steppe
S079 – Inter-Mountain Basins Semi-Desert Shrub Steppe
S083 – Rocky Mountain Subalpine Mesic Meadow
S090 – Inter-Mountain Basins Semi-Desert Grassland
S093 – Rocky Mountain Lower Montane Riparian Woodland and Shrubland
S094 – North American Warm Desert Lower Montane Riparian Woodland and Shrubland
S096 – Inter-Mountain Basins Greasewood Flats
S097 – North American Warm Desert Riparian Woodland and Shrubland
S098 – North American Warm Desert Mesquite Bosque
S100 – North American Arid West Emergent Marsh
S102 – Rocky Mountain Alpine-Montane Wet Meadow
S114 – Sonora-Mojave-Baja Semi-Desert Chaparral
S118 – Great Basin Foothill Lower Montane Riparian Woodland and Shrubland
S129 – Sonoran Mid-Elevation Desert Scrub

Table 2

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) meta-data 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 2) are displayed with mapping accuracies varying from 32 to 93% per class. The total map accuracy for Clark County was estimated at 75.3%.

Future Directions

The SWReGAP project has recently developed an online *Nevada Geospatial Data Browser*. It includes complete GIS coverages and meta-data for the entire state of Nevada. The intent of the Nevada Geospatial Data Browser is to 1) develop a central repository for the Nevada SWReGAP spatial data and 2) to provide a mechanism for public distribution of Nevada geospatial information to other researchers, public agencies, resource managers, non-governmental organizations, decision-makers, and user groups. This product will provide for long-term record keeping (archiving) and easy online public access. The coverages are available for download and the meta-data include important information relative to acquisition, location, processing level, file size and format.

For More Information

http://www.epa.gov/nerlesd1/land-sci/gap.htm
http://earth.gis.usu.edu/swgap/

Partner Agencies:

USGS science for a changing world · Utah State University · New Mexico State University · U.S. Department of the Interior Bureau of Land Management · NatureServe · Arizona Game and Fish Department

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