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Mapping moderate-scale land-cover over very large geographic areas within a collaborative framework: A case study of the Southwest Regional Gap Analysis Project (SWReGAP)

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Abstract

Land-cover mapping efforts within the USGS Gap Analysis Program have traditionally been state-centered; each state having the responsibility of implementing a project design for the geographic area within their state boundaries. The Southwest Regional Gap Analysis Project (SWReGAP) was the first formal GAP project designed at a regional, multi-state scale. The project area comprises the southwestern states of Arizona, Colorado, Nevada, New Mexico, and Utah. The land-cover map/dataset was generated using regionally consistent geospatial data (Landsat ETM+ imagery (1999–2001) and DEM derivatives), similar field data collection protocols, a standardized land-cover legend, and a common modeling approach (decision tree classifier). Partitioning of mapping responsibilities amongst the five collaborating states was organized around ecoregion-based "mapping zones". Over the course of $2^1/_2$ field seasons approximately 93,000 reference samples were collected directly, or obtained from other contemporary projects, for the land-cover modeling effort. The final map was made public in 2004 and contains 125 land-cover classes. An internal validation of 85 of the classes, representing 91% of the land area was performed. Agreement between withheld samples and the validated dataset was 61% (KHAT = .60, n = 17,030). This paper presents an overview of the methodologies used to create the regional land-cover dataset and highlights issues associated with large-area mapping within a coordinated, multi-institutional management framework.

Keywords: Large-area mapping; Meso-scale mapping; Moderate scale mapping; Land-cover mapping; Vegetation mapping; Southwestern U.S.; Collaborative projects; Remote sensing; Decision tree classifiers; Geographic information systems; Gap Analysis Program (GAP)

1. Introduction

Mapping the Earth's natural resources is fundamental to the inventory and subsequent monitoring of the Earth's biota, key to understanding environmental processes, and critical for effective natural resource planning and land management decision-making. The goal of the United States Geological

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Survey (USGS) Biological Resource Discipline (BRD) Gap Analysis Program (GAP) is to provide geographic information on biological diversity across large landscapes at moderate spatial resolutions for use by managers, scientists, planners, and policy makers to make informed decisions (Scott et al., 1993). A baseline GAP product is a land-cover map derived from satellite imagery.

GAP projects in the United States have traditionally operated within a state-based framework; that is, each state has had the responsibility of implementing a project design for the geographic area within their state boundaries. As a result, there have been considerable differences in mapping methodology, data collection efforts, and target land-cover legends among state-based GAP projects. To address these discontinuities, GAP was encouraged to consider adopting a regional operating framework for future gap analysis efforts (Eve & Merchant, 1998). One of the earliest state-based gap analysis efforts was the Utah project completed in 1995 (Edwards et al., 1995; Homer et al., 1997). Subsequently, GAP efforts in the adjoining states of New Mexico, Nevada, Colorado and Arizona were completed (Halvorson et al., 2001; Homer, 1998; Schrupp et al., 2000; Thompson et al., 1996). In 1999 representatives from these five states, and NatureServe (formerly with The Nature Conservancy) met to determine the feasibility of implementing a coordinated GAP project for the southwest region of the United States. Given advances in computing technologies, mapping methodologies, reduced costs of imagery and ancillary data, and perhaps most importantly—the perceived need for a regional GAP project, it was determined that a coordinated effort of this magnitude was possible. USGS BRD funded the Southwest Regional Gap Analysis Project (SWReGAP) beginning in 2000.

The primary objective of the SWReGAP effort was to create a seamless land-cover map approximating, or surpassing, the thematic level achieved by the earlier state-based gap analysis efforts for the region. The number of land-cover classes mapped in the earlier efforts for the five southwestern states ranged from 65 classes in Nevada (Homer, 1998) to 38 classes in Utah (Edwards et al., 1995). Overall map accuracy for the state maps ranged from a high of 83% to a low of 15% (Edwards et al., 1998; Falzarano & Thomas, 2004; Homer, 1998; Schrupp et al., 2000; Thompson et al., 1996). Given the results of these previous efforts, we anticipated being able to map roughly 100 land-cover classes with a goal of 80% overall map accuracy. The five-state region comprises roughly 1.4 million km^2 (540,000 sq. miles) representing approximately 1/5th the conterminous United States. Previous to SWReGAP the only U.S. land-cover mapping effort comparable to this in geographic scale was the 1992 National Land-cover Dataset (NLCD) (Vogelmann et al., 2001).

Utah State University, located in Logan, Utah was designated as the regional land-cover laboratory with the responsibility of coordinating the development of protocols for field data collection, image and ancillary data processing, and mapping methodologies for the region. Individual state teams were responsible for applying these protocols to their area of responsibility. This paper presents an overview of the methodologies used to create the regional land-cover dataset and highlights several of the issues associated with achieving this product through a regionally coordinated process.

2. Project organization

2.1. Project study area

The study area, lying between 102°–120° W longitude and 31°–42° N latitude, is diverse in its physical, climatic, and biological characteristics, and includes the states of Arizona, Colorado, New Mexico, Nevada, and Utah. Elevation ranges from approximately 22 m (72 ft) to 4405 m (14,500 ft). Precipitation, falling predominantly in summer or winter depending on location, ranges from 100 mm (4 in) to 770 mm (30 in). Vegetation covers the spectrum from sparse, hot desert scrub and cacti to more temperate shrub-steppe and grasslands, to montane and sub-alpine forests, meadows and alpine turf (Bailey, 1995).

2.2. Division of responsibilities

"Spectral-physiographic" mapping areas have proven useful for satellite-based land-cover mapping by maximizing spectral differentiation between areas with relatively uniform ecological characteristics (Bauer et al., 1994; Homer et al., 1997; Lillesand, 1996; Reese et al., 2002). We developed areas of responsibility for participating state teams by dividing the study area into spectral-physiographic "mapping zones", (in lieu of political state boundaries) which also leveraged local knowledge of the biota in each sub-region.

Ecoregions defined by Bailey (1995) and Omernik (1987) provided a starting point for determining mapping zone boundaries and were refined using heads-up screen digitizing using a regional mosaic of Landsat TM imagery and a digital shaded relief map. Initial efforts yielded 73 mapping zones for the region. Through an iterative and collaborative process involving all land-cover mapping teams and NatureServe, the final number of mapping zones was reduced to 25 (Fig. 1). A more detailed explanation of mapping zone development is found in Manis et al. (2000).

2.3. Project coordination and timeframe

Each state was responsible for four to six mapping zones roughly corresponding to state boundaries. Initial field data collection protocols were established at a workshop in Las Vegas, Nevada in the spring of 2001. Field data collection primarily occurred during 2002 and 2003. Land-cover workshops dedicated to ensuring regionally consistent mapping methods were conducted during the winters of 2002 and 2003. Yearly meetings and monthly teleconferences involving key land-cover mapping personnel from all five states and NatureServe ecologists were important to the collaborative mapping process. Mapping efforts were completed on a mapping zone by mapping zone basis by individual states, with the final integration of all mapping zones performed by the