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The Development of Mapping Zones to Assist in Land Cover Mapping over Large Geographic Areas: A Case Study of the Southwest ReGAP Project

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Introduction

Spectral classification of satellite imagery to map land cover across large landscapes involves the effective identification of spectral gradients resulting from the variability of physiographic and phenologic variables, ground variability, as well as solar and atmospheric influences within and between remotely sensed imagery. A common method of identifying spectral gradients is to stratify landscapes into subregions of similar biophysical characteristics. This process is not new to remote sensing and has been widely used as a postprocessing method to improve accuracy (Pettinger 1982, White et al. 1995). Lillesand (1996) refers to this process as "stratifying" the study area, and the resulting stratification units are called "spectro-physiographic areas" or "spectrally consistent classification units (SCCUs)."

This paper outlines the development of similar stratification units, which we refer to as "*mapping zones*." Our study area is comprised of the five states in the Southwest ReGAP Project (Arizona, Colorado, Nevada, New Mexico, and Utah), covering approximately 530,000 square miles and encompassing a wide variety of ecosystems.

By partitioning the five-state study area into mapping zones, we hope to maximize spectral differentiation within areas of uniform ecological characteristics. From a project management and logistical standpoint, mapping zones will facilitate partitioning the workload into logical units. Finally, we anticipate that the development of mapping zones will simplify postclassification modeling and improve classification accuracy. Based on previous work by Bauer et al. (1994) overall classification accuracy could be improved by 10 to 15% using physiographic regions.

Background

The underlying concept of mapping zone delineation is to divide the landscape into a finite number of units that represent homogeneity with respect to landform, soil, vegetation, spectral reflectance, and overall ecological physiology. Ancillary data such as Digital Elevation Models (DEMs), existing imagery, soils, and/or geologic data are the primary source of quantitative information guiding the delineation of mapping zones. However, the most critical component is a familiarity with the study area and an intimate knowledge of the biophysical features of the landscape. Delineating mapping zones requires a degree of subjective decision making to strike the balance between affordable economic units, optimal ecological units, and reasonable spectral units. The concept of economy helps determine mapping zone size. A large number of small zones become uneconomic since quasi-independent mapping efforts are required for each zone.

To delineate mapping zones for the five-state Southwest ReGAP project we focused on an iterative process using a number of factors to partition the landscape into ecological units. We created boundaries for land type associations using topography, soils, geology, spectral uniformity, and economics. A land type association is a grouping of related units with similar biophysical features. Ecological units may be designed for different scales of analysis depending on the objective (McNab and Avers 1994). Land type association boundaries in the Intermountain West tend to be reasonably identifiable, characterized by features such as prominent escarpments, the foot slopes of large mountain ranges, or the edges of vast lake basins.

Methods

Developing mapping zones for the five-state area was a collaborative effort involving input from representatives of each of the five participating states. Through the course of discussion the five-state group determined that approximately 75 mapping zones for the region would be optimal to define ecologically distinct areas and be affordable. Refinement of the mapping zone boundaries was achieved by introducing additional ancillary information and through periodic consultation and input from SW ReGAP state collaborators.

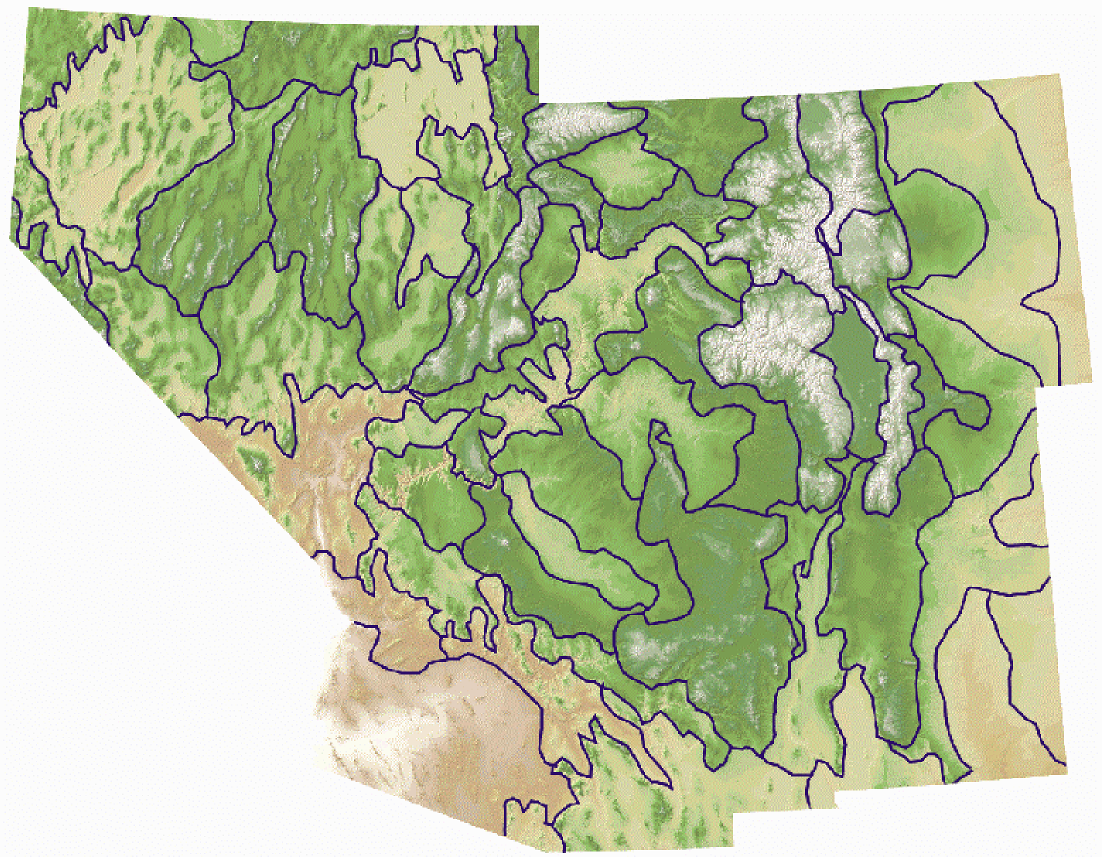

Figure 1. Color-contour shaded-relief map with refined Bailey lines.

Initial research into an ecological evaluation of the region focused on ecoregions defined by Bailey et al. (1994) and Omernik (1987). These sources provided an overview of the landscape with consideration to climate, vegetation and landform. Bailey's ecoregion sections provided an initial "starting point" for mapping zone boundaries. To refine the boundaries, a GIS coverage of Bailey's ecoregions was plotted over a high-resolution, color-contour shaded-relief base map created from a 3-arc second DEM (Figure 1). The resulting map was an interpretation of land type zones guided by Bailey's section boundaries and was used as a starting point for discussion with SW ReGAP collaborators.

Following comment from state collaborators, a second draft of mapping zones was created using existing Landsat TM images to help identify major life zones. This phase of the refinement process accounted for the spectral characteristics of the landscape. Interpretation of imagery improved the delineation of major physiographic "seams," such as escarpments and/or clear geologic formation boundaries.

Most mapping zone boundaries are boundaries between landscape features that appear to best define life zone boundaries. In areas that lack clear distinction between life zones, an attempt was made to identify approximate boundaries by identifying spectral patterns that could be related to vegetation communities and or geology. For example, major agricultural areas were used as a surrogate for natural vegetation patterns and became mapping zone boundaries in some areas to assist in the separation of natural vs. man-made environments.

A third phase of refinement involved the use of soils data. Soil is an integral component of the landscape/vegetation relationship and provides great potential in guiding mapping zone delineation. A soil map reflects not only edaphic conditions, but climatic conditions as well, reflecting elevation and latitude gradients over large areas. The State Soil Geographic (STATSGO) database is a nationwide digital (state-level) soil geospatial database. While the Soil Survey Geographic (SSURGO) database is more accurate and detailed than STATSGO, complete coverage for the five-state region is not available.

The original STATSGO GIS coverage for the five-state region contains approximately 2,100 soil mapping classes, each with multiple soil components. With a goal of 75 mapping zones for the five-state region, the STATSGO database clearly had to be simplified to be useful for delineating mapping zone boundaries. To simplify STATSGO, we developed a protocol for aggregating soil mapping classes. The protocol can be summarized as follows:

1. Component soils were re-classified based on a hierarchy of soil temperature regime, soil order, soil rooting depth classes, wetness classes, flooding regime, and broad soil texture groups. This established a reasonable evaluation of which soil types were similar in their capacity to support vegetation.
2. General soil classes were sorted based on composition of similar soils, similar range of slopes, and similar range of non-soil components, i.e., rock outcrop, badlands, playas, etc.

3. Logical aggregations were evaluated by viewing the polygons over TM imagery, with subsequent adjustments of slope limit and soil component differentia to preserve the most definitive delineations while merging the least definitive. Aggregations that were of small size, except those of unique value like dunes or playas, were merged with the adjacent, most similar aggregation.
4. A table was developed to describe each aggregated class, such as the range of soil great groups, slopes, major life zones, nonvegetated landscape features, soil textures, and a simplified mapping unit description.

Following this protocol, we generated 58 "generalized land type" classes based on soil characteristics. The aggregated 58-class STATSGO data layer was first used as an informal "test" of mapping zone boundaries derived in phases one and two. We found that the derived STATSGO data layer could be used to improve the delineation of some of the more problematic mapping zones. This was most important in areas with little topographic relief such as the plains of eastern Colorado and New Mexico.

As a result of the refinement phases, the mapping zone GIS coverage consisted of 129 polygons. While this reflected a reasonable stratification of the landscape, it still exceeded our target of 75 mapping zones. We compared this coverage to earlier drafts of the mapping zones and Bailey's ecoregion sections. The smallest polygons were merged into adjoining polygons, based on the distinctive qualities of the surrounding polygons and a general agreement or disagreement with Bailey's ecoregions. The final mapping zone coverage contained 74 polygons (Figure 2).

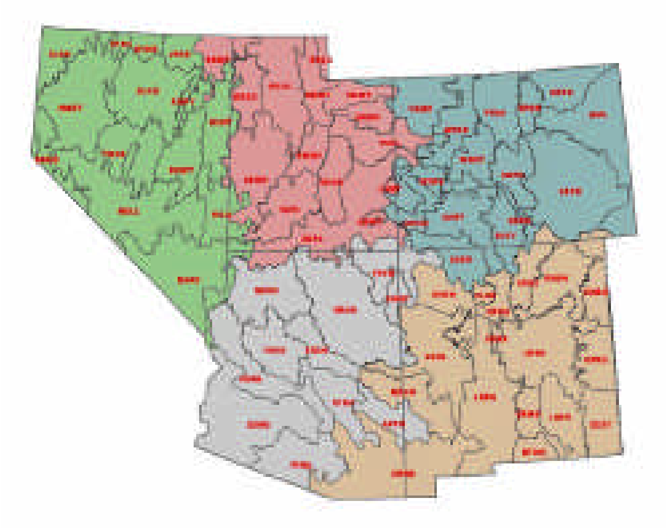

Figure 2. Final mapping zones for the SW ReGAP region.

Discussion

The southwest United States provides a unique landscape with discrete mountain ranges and complex structural geology and soils, which helped provide a basis to delineate mapping zones. A possible limitation of using geomorphic boundaries to identify mapping zones is that the coincidence of microclimatic and soil factors controlling vegetation will not always coincide with geomorphology. Certain landscapes such as cuestas tend to be problematic because long dip slopes imply an unbroken elevation gradient. We have tried to resolve disagreement between landscape boundaries and apparent vegetation boundaries by deferring to vegetation, as interpreted on existing TM imagery, as the primary criteria. However, positive geomorphic boundaries took precedence over small-scale or uncertain vegetation patterns.

The amount of effort placed in deriving the soils GIS coverage from the STATSGO database was significant and alone did not substantially help in defining the mapping zone boundaries. In fact, a state-level geology coverage could very well be used as a surrogate for the soils data produced from STATSGO. What the derived STATSGO data provided was ancillary information useful in verifying and refining some of the more problematic mapping zoning boundaries. The effort to aggregate the STATSGO database was not wasted as it holds great potential as a postclassification modeling layer.

We anticipate that well-defined mapping zones will improve image classification and, ultimately, land cover mapping. One of the important lessons learned from this effort is that delineating mapping zones for the five-state region is an iterative process involving input from collaborating participants and refinement using multiple ancillary data sources. In addition, a significant amount of personal and collective knowledge and a sound understanding of the general mapping process is required to interpret the ancillary data in a way that is meaningful.

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