

THE DEVELOPMENT OF MAPPING ZONES TO ASSIST IN LAND COVER MAPPING OVER LARGE GEOGRAPHIC AREAS

A Case Study of the SW ReGAP Analysis Project

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Published in:

GAP Analysis Bulletin No. 9, 2000. E. Brackney, R. Brannon, P. Crist and K. Gergley, editors.
U.S. Geological Survey, Biological Resources Division, Reston, VA.

ABSTRACT

A significant issue that must be addressed when classifying remotely sensed imagery at a regional scale is spectral sensitivity to discontinuities across the landscape. Spectral variability may be attributed to physiography and phenology of surface features, as well as varying solar angles and atmospheric influences within and between remotely sensed images. The objective of developing mapping zones is to define regions that can be used to improve the efficiency by which spectral modeling, and ultimately land cover classification can be accomplished. By defining mapping zones, the sensitivity of spectral signatures to land cover variation can be controlled by limiting analysis to an area of uniform ecological and spectral characteristics. Mapping zones are defined using established ecoregion concepts, geomorphic and soil characteristics, and by visually interpreting existing imagery. Throughout the process of delineating optimal mapping zones, economies of the mapping process must be considered.

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 sub-regions of similar biophysical characteristics. This process is not new to remote sensing and has been widely used as a post-processing method to improve accuracy (Pettinger, 1982, White et al., 1995). The process we have applied to land cover mapping over large landscapes involves partitioning the area into regions with similar spectral, ecological and phisognomic characteristics. Lillisand (1996) refers to this process as

“stratifying” the study area and the resulting stratification units 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 total and encompasses 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 post-classification modeling and improve classification accuracy. Based on previous work by Bauer et al. (1994) overall classification accuracy could be improved by 10 to 15 percent using physiographic regions.

BACKGROUND

The underlying concept of mapping zone delineation is to divide the landscape into a finite number of units. These units represent homogeneity with respect to landform, soil, vegetation, spectral reflectance, and overall ecological physiology. In our application, delineating mapping zones is a preliminary step to classification or post-classification modeling. Since delineating mapping zones is done prior to classification, much of the process involves human interpretation of the landscape. Ancillary data such as Digital Elevation Models (DEMs), existing imagery, soils and/or geologic data are helpful in guiding the delineation of boundaries. 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 subjective decision-making in striking the balance between affordable economic units, optimal ecological units, and reasonable spectral units.

To delineate mapping zones for the five state Southwest ReGAP region we focused on an iterative process using a number of factors to partition the landscape into ecological and logical units. The concept of landtype associations was used to define boundaries utilizing topography, soils, geology, spectral uniformity and economics. The concept of economics helps determine minimum size of mapping units. In general, as the average size of mapping units decrease, their

number increases. This relationship increases the time and therefore cost of developing models for each mapping zone to map surface cover. Therefore, we must balance the need for an ecologically and spectrally homogeneous unit with time and resources available to complete the mapping process.

Landtype Associations

A landtype association is thought of as a grouping of closely associated landtypes, defined by similar geology, soils, climates and vegetation that may be interpreted at differing scales of resolution for different purposes (McNab and Avers, 1994). While this definition represents a wide range of possible criteria that define landtype associations—from the broad scope of “geomorphic process” to the narrowly defined “plant association”—it identifies two important keys, namely *groupings* and *similarities*. For the SW ReGAP Project, we are interested in landtype associations defined within the context of a regional or landscape scale to develop mapping zones. Landtype 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.

Biophysical Factors

The Intermountain West is characterized by variable topographic terrain, geology, and soils that help define habitats that are used by specific organisms (plant and animal) to form communities. Topographic variability helps define climatic variation and water availability. Topography and geology help define soil chemistry and texture. To take advantage of these relationships, we first utilized topography in the form of a shaded relief map to define major breaks in topography (Figure 1). To effectively define lines in context with existing data, we used a combination of existing Landsat imagery, 1:250,000 scale soils (NRCS STATSGO), and a 1:500,000 scale geology map.



Figure 1. Color shaded relief map of the SW ReGap study area.

Spectral Uniformity

One of the primary objectives of developing mapping zones is to control spectral variability within a geographic area. By controlling spectral variability, spectral differentiation among cover types can be maximized within a given mapping zone. Delineating mapping zones, therefore must also involve an interpretation of the landscape as viewed from the remote sensing platform. This was done by visually interpreting large-scale landtype associations on existing Landsat TM imagery (Lillisand 1996). This process is also tempered with the economic viability of the mapping process. Within this project, areas of major physiognomic or life zone differences (such as shrub-steppe to montane) were separated by spectral variation using available Landsat Thematic Mapper imagery.

Economics of Size and Shape

A final and most important consideration in delineating mapping zones is the size and shape of the mapping zone. Mapping zones require independent treatment in classification, training site collection, modeling, and assessment. One way to view the economics of mapping zones is to calculate the number of independent classifications the project can afford. Understanding the resources available can help size the mapping zones across the landscape into an affordable grain size optimizing appropriate landtype and spectral grouping. While smaller mapping zones may reflect the best detail of the landscape, they can be undesirable due to the accompanying increase in total cost. Mapping zones provide a logical unit for managing data and workloads.

Another economic consideration in defining mapping zones is the selection of appropriate satellite images to effectively map surface variations within a particular zone. It is important to keep in mind that not just the size, but also the shape affects the economies of mosaicking and processing TM scenes. Ideally, each mapping zone covers a minimal number of TM scenes. Zones with long north-south orientations are not desirable due to the latitudinal variation within the zone reflecting gradients in phenology. The east-west extent of mapping zones are determined primarily by topographic variation and secondarily by image boundaries.

METHODS

Developing mapping zones for the five state region was a collaborative effort involving input from representatives of each of the five participating states. Arriving to the current mapping zone boundaries involved an iterative process of delineation and refinement. Two meetings with SW ReGAP collaborators focused in part on refining mapping zones and determining the optimal number of mapping zones. Through the course of discussion the group determined that approximately 75 mapping zones for the five state region would be optimal and affordable. Refinement of the mapping zone boundaries was achieved through periodic consultation and input from SW ReGAP state collaborators, and by introducing additional ancillary information as it became available (figure 2).

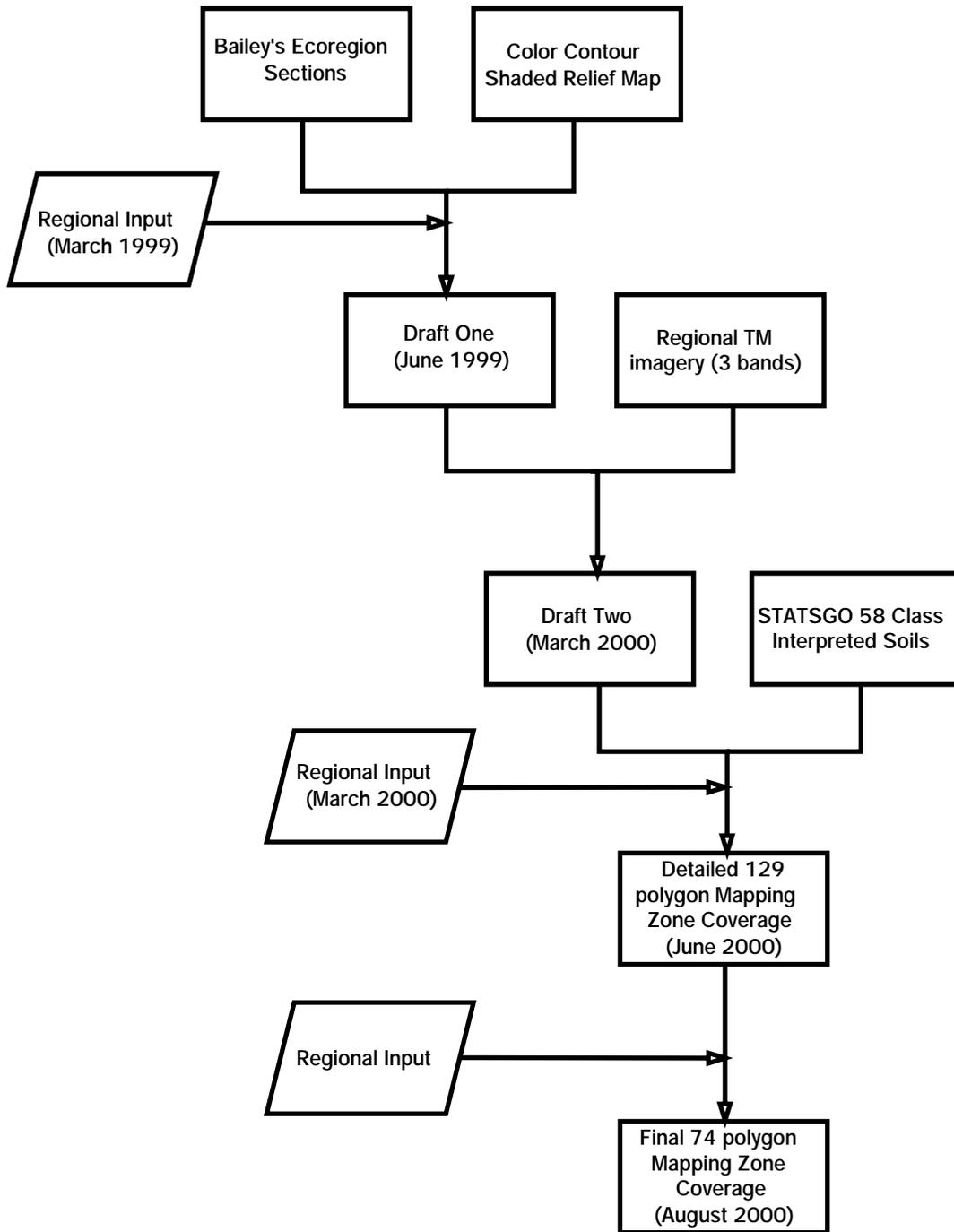


Figure 2. Flow diagram of Mapping Zone refinement process

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 digital elevation model (DEM). Using topography and elevation as guidelines it was possible to refine some of the coarseness in Bailey's delineations (drawn at a broad national scale), thus creating more detailed mapping zones based on landform (Figure 3). The resulting map was an interpretation of landtype zones guided by Bailey's ecoregion boundaries, and was used as a starting point for discussion with SW ReGAP collaborators in a start-up meeting in March 1999.

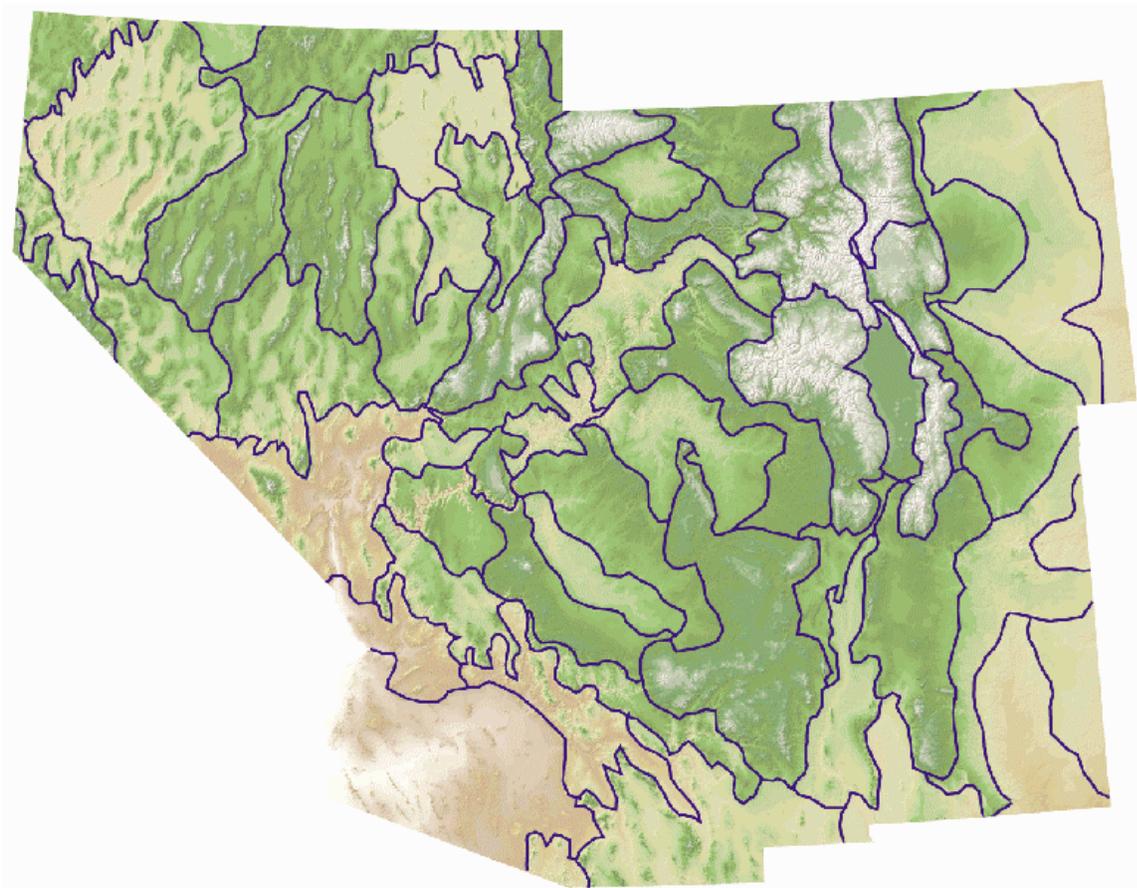


Figure 3. Color-contour shaded-relief map with refined Bailey lines

Following comment from state collaborators on the first draft of the mapping zones, several refinements were made based on the recommendations. The second draft mapping zone map was further refined using existing Landsat TM images to identify major life zones. This phase of the refinement process accounts 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 contacts of landscape features that appear to best define life zone boundaries. In areas that lack clear landscape/life zone connections, an attempt was made to identify approximate boundaries by identifying spectral patterns that could be related to vegetation communities and or geology. Major agricultural patterns were taken as a surrogate for natural vegetation patterns and became mapping zones 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 and another review in March 2000 by state collaborators. Because of the strong interrelationship between soil and plant communities, and since soil type is an integral component of the landscape/vegetation relationship, soils data were viewed as holding great potential as an aid in guiding mapping zone delineation. A soils map reflects not only edaphic conditions, but climatic conditions as well, thereby bridging the elevation to latitude shifts that occur 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. Given that STATSGO provided complete coverage for the five state region, and was somewhat less complex than the SSURGO database it offered an appropriate soils data for the scale of this project.

Making STATSGO useful for delineating mapping zones required some manipulation. 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 to a simpler system based on a hierarchy of soil temperature regime, soil order, soil rooting depth classes, wetness

- classes, flooding regime, and broad soil texture groups. This step established a reasonable evaluation of which soil types (as components of mapping classes) are similar in their capacity to support vegetation.
- 2) Mapping classes were then 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 aggregated polygons over TM imagery, with subsequent adjustments of slope limits and soil component differentia to preserve the most definitive delineations while merging the least definitive polygon delineations. 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 (or new mapping class). This table names and describes the range of soil Great Groups, slopes, major life zones, non-vegetated landscape features, soil textures, and a simplified mapping unit description.

Following this protocol, 2,100 soil mapping classes within the five state region were aggregated to 58 “generalized landtype” classes. The aggregation merged about twenty-five percent of the total number of polygons while retaining much of the substantive detail defining each mapping class. The aggregated 58-class STATSGO data layer was first used as an informal “test” of mapping zone boundaries derived in phases one and two. It was discovered that the derived STATSGO data layer could be used to successfully improve the delineation of some of the more problematic polygons. This especially proved to be the case in areas with little topographic relief such as the plains of eastern Colorado and New Mexico.

As a result of the refinement phases beyond Bailey’s ecoregion boundaries, the mapping zone GIS coverage consisted of 129 polygons. While this reflected a reasonable stratification of the landscape, it still exceeded of our target of 75 mapping zones. To achieve a mapping zone coverage closer to the 75-polygon target, we first compared it to earlier drafts of the mapping zones, especially Bailey’s ecoregion sections. This was to make sure that there was a logical explanation for the final mapping zone delineations, and to see where mapping zones could be grouped. The smallest polygons were then merged into adjoining polygons where it seemed logical to do so, 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 mapping zone polygons. Through consultation with each of the collaborating states, each state accepted responsibility for mapping zones that roughly correspond to the area within their state boundary (Figure 4).

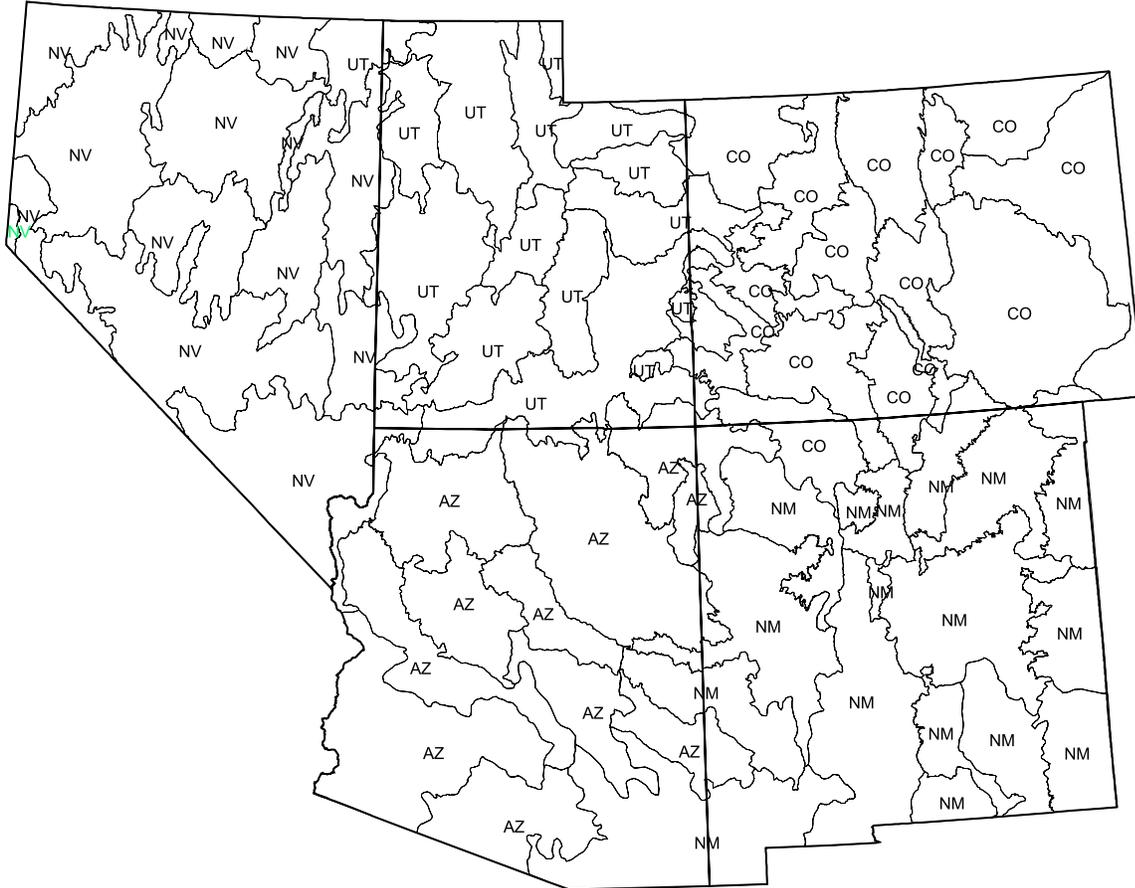


Figure 4. Final Mapping Zones for the SW ReGAP region.

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 micro-climatic 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 GIS 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 post-classification modeling layer.

Taking time in the early stages of the SW ReGAP project to develop well-defined mapping zones is expected to 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. While ancillary data sources, such as digital topographic maps, existing TM imagery and digital soils databases are helpful in delineating mapping zones, 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. While mapping zones are broadly based on biotic and abiotic features of the landscape, and the spectral characteristics of the imagery, the economics of mapping zone size and shape must be considered as well.

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