USDA Forest Service TEUI-Geospatial Toolkit: A Case Study in Pre-Mapping for an Ecosystem Inventory

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Abstract

The TEUI-Geospatial Toolkit (Toolkit) is an operational ecological inventory application used by the USDA Forest Service and other land management agencies. In the winter of 2006 and spring of 2007, the Caribou-Targhee National Forest used the toolkit to complete Terrestrial Ecological Unit Inventory (TEUI) at the land type level in a previously unmapped portion of the forest. This was completed by an interdisciplinary team who collaboratively borrowed concepts from adjacent soil surveys, accessed corporate database information, and used the Toolkit to implement the TEUI pre-mapping process. A local soil scientist on the Caribou Targhee NF, a corporate data steward from the Intermountain Regional Office, and staff from the Remote Sensing Applications Center (RSAC) comprised the interdisciplinary team. This presentation reviews the case study and highlights some of the economies afforded by digital soil mapping technologies as compared to traditional alternatives.

In this project, the team integrated the core activities of the TEUI pre-mapping process: Map Unit Design, Landscape Stratification and Map Unit Validation. They defined map unit concepts for the study area based on fundamental soil-forming factors: climate, organisms, relief, parent material, and time that originated from completed and adjacent soil surveys. Geospatial data streamlined the delineation of initial landscape stratification and labeling of polygons according to the map unit definitions. The resulting map unit polygons were inspected visually against topographic and multi-spectral imagery and evaluated more rigorously against geospatial data layers to assure consistency within the study area. Finally, the local soil scientist associated connotative legend map units to adjacent soil survey map units and subsequently used the resulting TEUI pre-map to plan and collect the necessary field inventory data.

The costs to develop and execute this study were about one-third the costs of traditional pre-mapping methods. These modest savings may be significantly increased provided

that similar pre-mapping methods are applied to larger study areas where economies of scale are realized.

1 Introduction

The Forest Service uses Terrestrial Ecological Unit Inventory (TEUI) as the land survey system for classifying and mapping ecological types. Ecological types are defined by abiotic and biotic environmental factors that incorporate combinations of climate, physiography, geology, soil, and vegetation. The purpose of TEUI is to classify ecosystem types and map land areas that have similar management capabilities (Cleland et al., 1997). The TEUI Technical Guide (Winthers *et al.*, 2005) presents specific methods and procedures for inventorying lands administered by the agency. Ecological types provide basic land-unit information for land planners to assess ecosystem capabilities, potentials, and limitations for informed and practical management decisions.

As of 2007, 55 million acres of National Forest land lacked modern TEUI or Soil Resource Inventory (SRI), and an additional 18 million acres did not meet standards of the National Cooperative Soil Survey (NCSS). The size of the backlog coupled with the cost of traditional TEUI or SRI surveys (estimated $0.50 to $1.00 an acre) have made the use of traditional methods inadequate with regard to meeting timelines and budgets. Therefore, the Forest Service has searched for new ways to complete ecological-unit inventory faster and more economically. In 2001, the agency investigated new technologies as a solution to support ecosystem inventory and streamline the TEUI pre-mapping process (Lane and Fisk, 2002). Since 2005, the Toolkit has provided field units and resource management a cost-effective alternative to traditional pre-mapping methods.

The Caribou-Targhee National Forest needed to complete TEUI at the landtype level for a previously unmapped portion of the forest. A local soil scientist on the forest contacted the Remote Sensing Applications Center (RSAC) about using the Toolkit to prepare a TEUI pre-map. The Intermountain Regional Office supported RSAC and provided guidance and direction on accessing and using corporate TEUI and SRI databases. This interdisciplinary team completed pre-mapping in the off-season in a timely and cost-effective manner.

2 Methods

The core activities of the TEUI pre-mapping process involve: Map Unit Design, Landscape Stratification and Map Unit Validation (Winthers *et al.*, 2005). These activities guide the development of ecological unit inventory. In this project, the pre-mapping process consisted of: data acquisition, map unit design, landscape stratification, map unit correspondence, and map unit validation (Figure 1). Although not part of this case study, the pre-mapping effort was followed by field work to document site-specific soil, vegetation, and geologic properties used to develop interpretations.

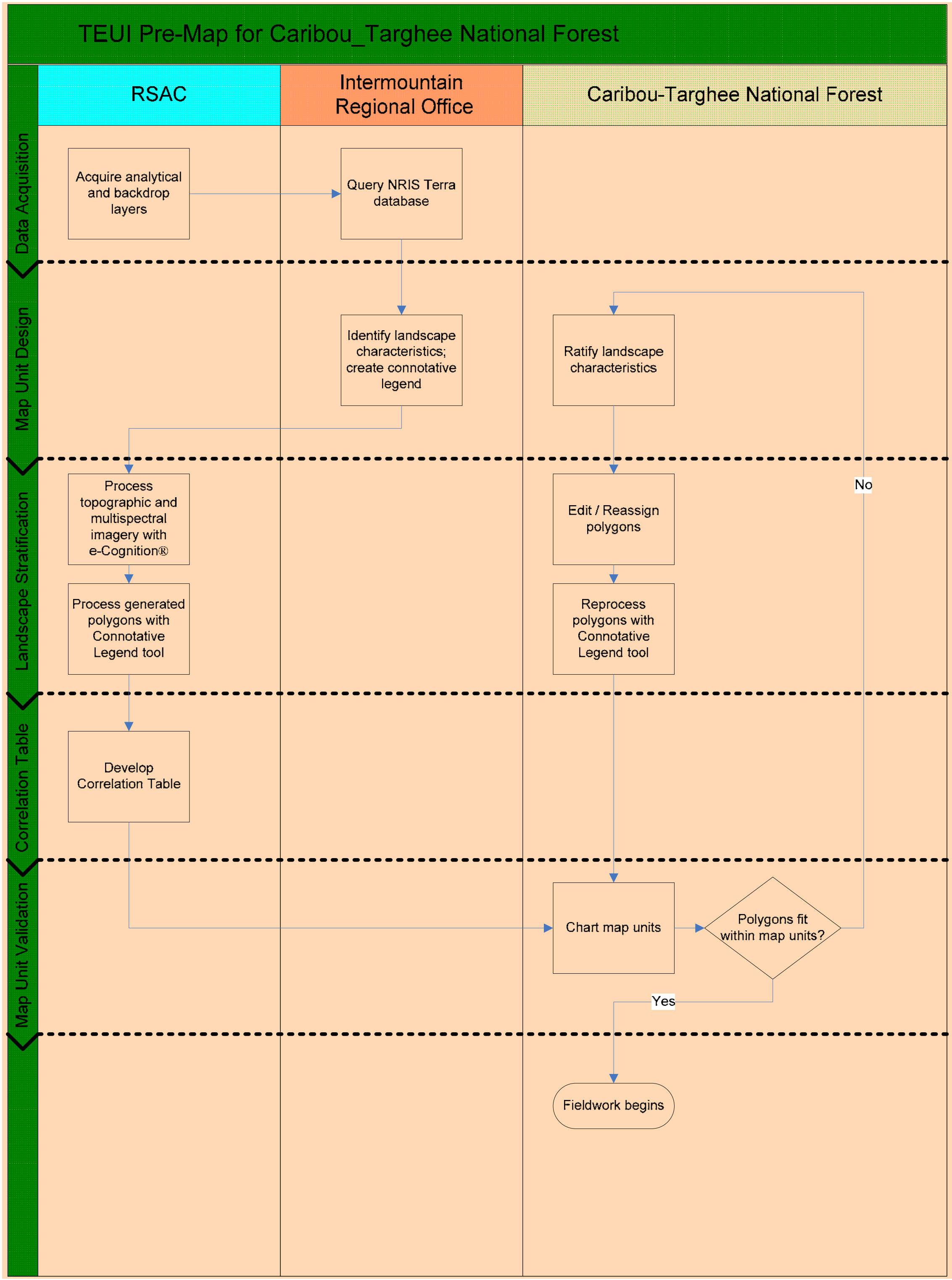

Figure 1: TEUI pre-map workflow for the Caribou-Targhee National Forest involving team members in multiple locations.

2.1 Project Area

The Observation Peak Project Area spans about 40,000 acres of the Snake River Range southwest of Jackson, Wyoming (Figure 2). This area is high and rugged terrain of steeply-dipping limestone, dolomite and sandstone ridges and valleys or saddles where softer shale, siltstone and mudstone weather easily. The project area is partially bounded by existing TEUI (Palisades Ranger District of the Targhee National Forest) and SRI (Greys River Ranger District of the Bridger-Teton National Forest) surveys.

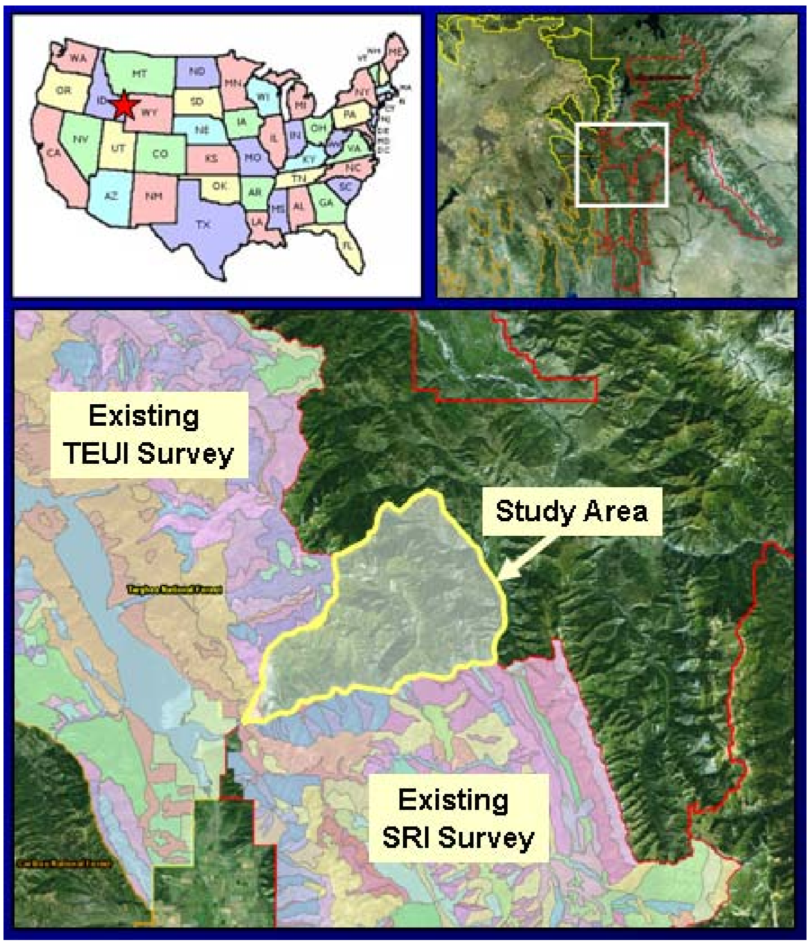

Figure 2: Observation Peak Project locator

2.2 Data Acquisition

Consistent and continuous geospatial data is vital for conducting resource inventory in a digital GIS environment. The data acquisition process proceeded as follows. First, the Caribou-Targhee National Forest provided an area of interest file in ESRI *.shp* format to RSAC staff. Next, RSAC generated standard spatial data layers, via a data provision system, compressed the data package, and delivered it to the forest. The TEUI Geospatial Data Package (TEUI-GDP) contained 32 raster (pixel-based) and 16 vector (point, line and polygon) layers, which provided the foundation for conducting pre-mapping in a digital environment. Finally, the soil scientist supplied additional local spatial data to the standard TEUI-GDP.

The corporate data steward, from the Intermountain Regional Office queried the Forest Service Natural Resource Information System database and retrieved tabular survey information from adjacent projects. Copies of final survey reports were also acquired and used to fill information gaps and build a complete set of mapping definitions (Figure 3). Fields describing existing landtype map units included ranges and representative values of elevation, aspect, and slope, vegetation types according to the national land cover data (NLCD), composition (percentage) of the unit, geological formation, parent material and landform.

	Bridger West							
PROJEC	MapUnit	Elevation ft (Low)	Elevation ft(H	lope(High)	Veg	NLCD	Parent material	Landform
BW	102	7000		30	Mountain Big Sagebrush/Id	Shrubland	Alluvium/Colluvium	Alluvial Fans/Terrac
					Tall forb	Grassland	Alluvium	Alluvial Fans/Terra
BW	221	5500		20	Doug Fir/Common Snowberry		Alluvium/Colluvium	Alluvial Fans/Terra
BW	243	6000		30	Aspen/Snowberry	Deciduous	Colluvium	Landslide Deposits
					Aspen/Snowberry	Deciduous	Colluvium	Landslide Deposits
BW	244	7000		50	Sub Alpine Fir/Pine Grass	Evergreen	Colluvium(Ls)	Landslide Deposit
					Doug Fir/Huckleberry	Evergreen	Colluvium(Ls)	Landslide Deposit
BW	274	6500		70	Sagebrush/Snowberry/Gras	Shrubland	Colluvium Ss-Si	Side slopes
					Subalpine Fir/White Spirea	Evergreen		Side slopes
BW	315	6500		60	Sub Alpine Fir/Snowberry	Evergreen	Colluvium	Side slopes
					Sub Alpine Fir/Pine Grass	Evergreen	Colluvium	Side slopes
BW	316	5500		90	Sub Alpine Fir/White Spire	Evergreen	Colluvium (Ls-Do)	Avalanche Chute
					Sub Alpine Fir/Ninebark	Evergreen	Colluvium (Ls-Do)	Avalanche Chute
					Rubble Land	Bare Groun	Colluvium (Ls-Do)	Avalanche Chute
BW	404	6500		60	Sagebrush/Snowberry/Gras	Shrubland	Residuum-Colluvium	Dissected Mount
					Bitterbrush/ Bluebunchwee	Shrubland	Residuum-Colluvium	Dissected Moun
					Sagebrush/Needle and Thre	Shrubland	Residuum-Colluvium	Dissected Mount
BW	[illegible]	[illegible]		90	Doug Fir/Mountain Maple	Mixed Forest	Residuum-Colluvium	Side Slopes/La
					Rubble Land	[illegible]	[illegible]	[illegible]

Figure 3: Data Compiled from Adjacent Studies

2.3 Map Unit Design

Accessing the existing survey information of adjacent areas strengthened the development and design of map unit concepts for the project area. After reviewing the available survey information, the team observed that elevation, aspect, slope, vegetation, and geology supported ecological type mapping. These spatial layers formed the foundation for a rational method of extrapolating adjacent survey map unit concepts into the project (Figure 4). The team then developed a connotative legend to capture the important environmental factors. Each map unit symbol in the legend was comprised of four elements: elevation, aspect, slope and vegetation type (Figure 5). The classification values were derived from the identified breaks in adjacent surveys.

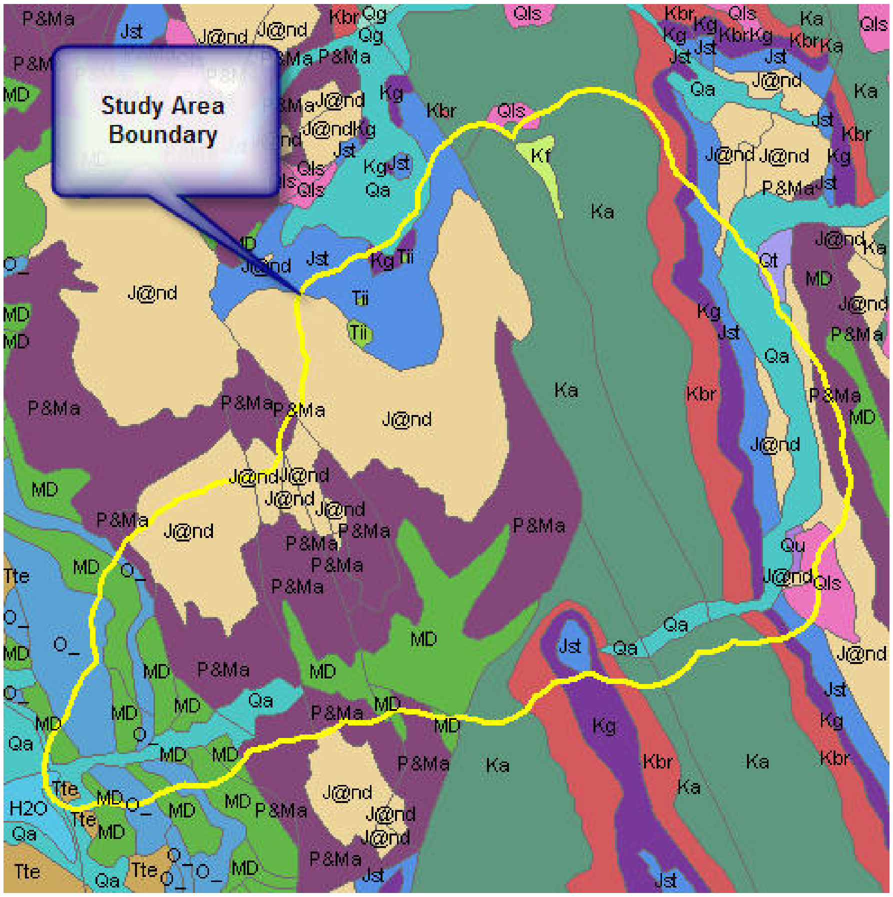

Figure 4: Shows the project area (yellow) overlaid on a digital geologic map of Wyoming (USGS, 1994).

Elevation	Aspect	Slope	NLCD
1 - Low (0-2,000 m)	1 - NE (1-90)	1 - Flat (0-4%)	11- Water
2 - Medium (2,000-2,300 m)	2 - SE (90-180)	2 - Gentle (4-15%)	23 - Commercial
3 - High (2,300-2,600 m)	3 - SW (180-270)	3 - Moderate (15-40%)	31- Bare
4 - Very High (2,600+ m)	4 - NW (270-360)	4 - Steep (40-60%)	41- Deciduous
	5 - Flat	5 - Very Steep (60+%)	42 - Evergreen
			43 - Mixed
			51 – Shrub
			71 - Grass

Observation Peak Project Connotative Legend

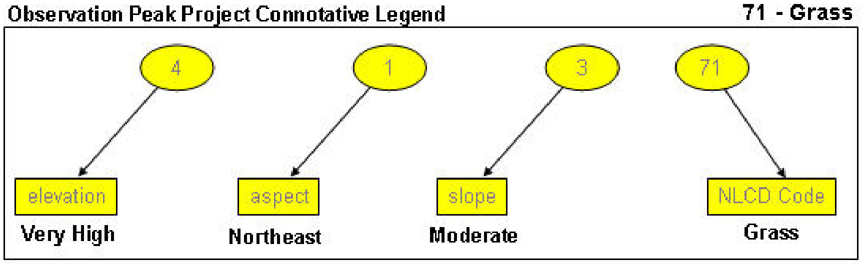

Figure 5: Connotative Legend Classification Scheme

2.4 Landscape Stratification

The TEUI-GDP included seven hierarchically nested landscape stratification layers called natural segments. These divided the landscape into relatively homogeneous polygons at progressively larger scales and were based on image segmentation and filtering procedures. The image segmentation procedure incorporated topographic and spectral imagery and used e-Cognition® software. The outputs were converted to Imagine® *.img* files where they were filtered, smoothed, converted to ESRI coverage files, and finally included in the standard TEUI-GDP.

For this project, natural segments from the third level were chosen as a starting point for the landscape delineation activity. This level of segmentation was more detailed than what was expected in the final map unit delineations. However, the team thought there would be less work involved with merging polygons to the desired polygon density as opposed to re-delineating coarser line work. The next step involved labeling the polygons according to map unit concepts, which was accomplished by using a custom application, called the Connotative Legend (CL) tool. Figure 5 shows how the CL tool works and how underlying geospatial layers (i.e., elevation, aspect, slope and vegetation) are used to assign individual map unit symbols to each polygon. In addition to classifying and labeling the polygons, the CL tool enforced topology rules that merged adjacent polygons with the same map unit symbol.

2.5 Map Unit Correspondence

Consistently applying the map unit concepts of adjacent survey areas required building a table to relate connotative map unit symbols and existing map unit descriptions. The map unit correspondence process involved assessing the landscape elements (elevation, aspect, slope and vegetation) of the existing map unit against the expressed range of each map unit. For example, the Bridger West (BW) map unit, 102, occurred at elevations ranging from 7,000 ft. to 9,000 ft. (Figure 3). In the connotative legend, values “3” and “4” fell within this range (Figure 5). In this proves the local soil scientists also determined the set of element values that represented the existing map unit, all such values were combined to make a universe of legend symbols that potentially represented it. The new map unit legend was associated with the existing map unit in a spreadsheet (Figure 6). In the case of BW102, there were ten possible map units in the OPP study area that were similar. This table was called the “crosswalk” by the project team.

2.6 Map Unit Validation

The polygons prepared during the landscape stratification process were an expression of the map unit design (classification scheme). Map unit validation involved evaluating polygons and assessing the distribution of the characterization criteria. This process was part of a cycle: in which outliers in the classification were identified; adjustments to the classification scheme or landscape stratification were implemented; and the effects of the adjustments were observed and reevaluated. Local soil scientists iterated through this cycle until they were satisfied that individual polygons fit within the assigned map units.

The Toolkit provided three features to help evaluate map units: computing tabular statistics, analyzing unit properties and comparing contrasting map units. Together, these features provided a quantitative assessment of how closely the landscape segmentation corresponded to ideal concept underpinning the classification scheme.

The charts were the most heavily used of the features (Figure 7). They depicted the pixel

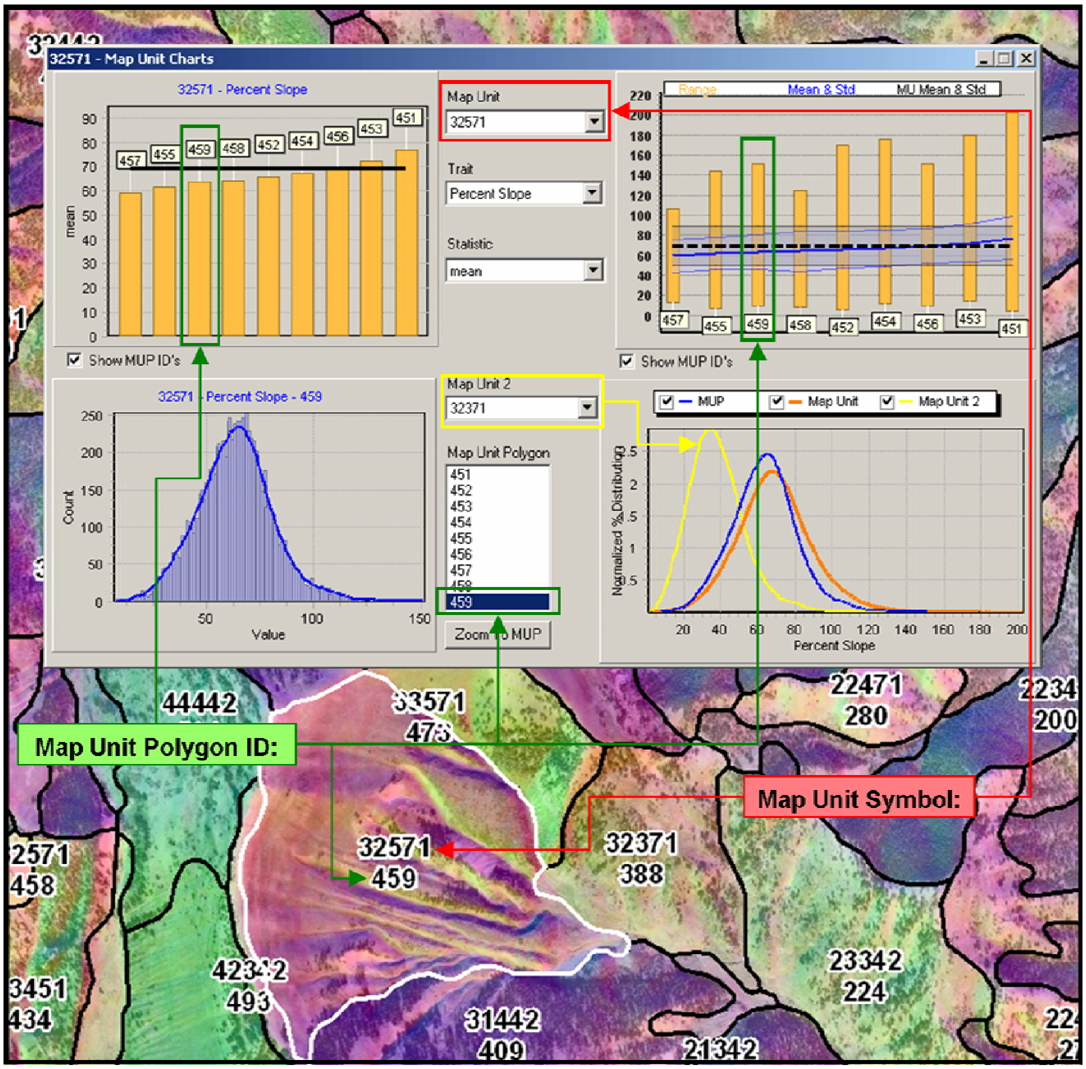

Figure 7: This rather dense figure represents a view of the Map Unit Chart utility unique to the Toolkit. The lower left displays pixel-level values (frequency distribution) of an environmental trait (percent slope) for an individual map unit polygon (id 459). The upper left and upper right portions of the view display polygon-level statistics for a specific map unit (32751). The lower right features a normalized comparison of an individual polygon (id 459) to the associated map unit (32751), as well as secondary map unit (32371).

distribution curves and standard statistical measures of central tendency and variance for individual polygons and individual map unit populations. These measures and distribution curves were used to directly compare individual polygons, and to analyze the composition of individual polygons for conformity or nonconformity with the entire map unit distribution. This unique functionality allowed for visual distribution curve comparisons, and the capability to quickly toggle through map unit curves for similar distributions. The process helped the soil scientist bring consistency to the preliminary stratification and strengthen overall mapping. After the second iteration, the initial stratification was complete and provided the Caribou-Targhee National Forest with a reasonable TEUI pre-map (Figure 8).

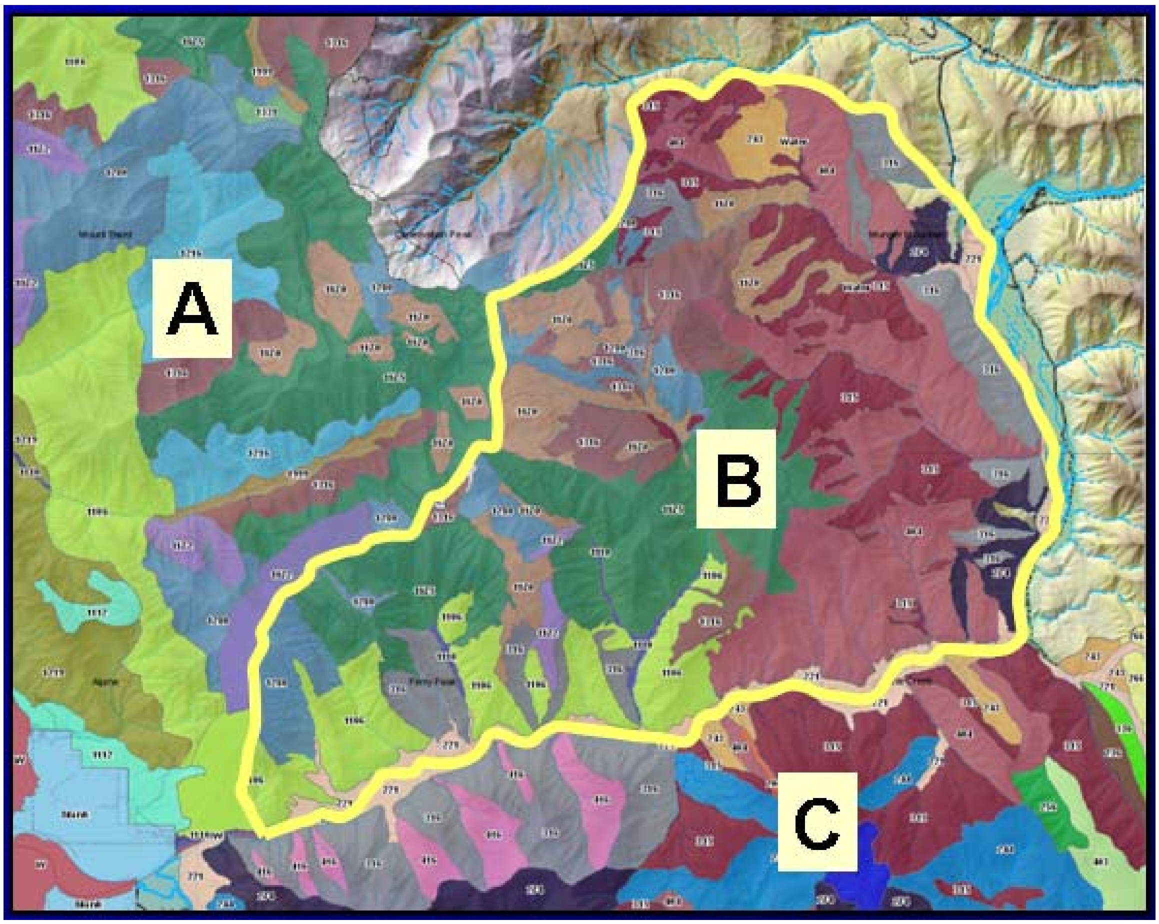

Figure 8: Shows the TEUI and SRI survey map units extended into the Observation Peak Project area: A) Caribou-Targhee TEUI (completed 1999); B) final pre-map of Observation Peak Project (completed 2007); and C) Bridger-Teton SRI (completed 1990).

3 Discussion

Toolkit offered several advantages over the traditional aerial photographic methods of mapping soils and terrestrial ecological units. For pre-map tasks, the Toolkit relied heavily on remotely sensed data and was consistent with traditional reliance on aerial photography. In both cases, initial delineations were made using only what could be observed remotely such as landform, elevation, topography, and vegetation. The computer used the same information content but was able to draw from a variety of sources in a near-simultaneous manner. In addition, the computer drew lines consistently and without bias, processing multiple variables that are difficult for humans to achieve using traditional methods.

To satisfy themselves that machine-generated delineations were equal in quality to manually-generated delineations, the team draped the polygons over high-resolution NAIP imagery. Inspection showed that machine-generated delineations were similar to those that would have been drawn by hand. Pre-mapping was quicker, cheaper, and more consistent using the Toolkit than traditional aerial-photography based pre-mapping.

The scientifically-based stratification better met the Data Quality Act (DQA) of 2001 which required federal agencies to develop information quality guidelines. The Toolkit was the first corporate application that relied on a scientifically-based approach to create, correlate and validate soil survey or TEUI stratifications. The tool used raster-based storage and analyses of ecological indicator variables to quantify distributions within and between map unit polygons. Through the use of the statistical and graphic capabilities, specialists assessed pixel distributions, identified outliers and updated mapping to tighten mapping concepts. The pixel-level database persists as a quantification of the environmental variables used in pre-mapping, and the resultant delineation compositions of the polygons and map units.

As a final advantage, the Toolkit leveraged technology to increase productivity of the Caribou-Targhee National Forest’s dedicated soil scientists. Capabilities such as data provisioning, edit functionality, and standardized map production allowed this application to be used by field specialists with only basic GIS skills. In addition to bridging the technology gap for non-technical resource specialists, the Toolkit allowed local soil scientist to work independently. As a result this enabled local GIS specialists to concentrate on other project assignments.

4 Conclusions

The Forest Service needed basic terrestrial resource information to practice sustainable resource management. The Toolkit supported resource management by integrating geospatial technology with Forest Service TEUI protocols. It also bridged an important technology gap that exists for many resource specialists by allowing them to access geospatial data, design ecological map units, delineate landscape patterns, analyze map unit properties and generate standard field maps. Products derived using the application also complied with corporate information-system standards. Finally, the cost of pre-map tasks was reduced from an estimated $0.50 - $1.00 per acre using traditional methods to approximately $0.15 - $0.20 per acre using the TEUI pre-mapping process described in this paper.

6 References:

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