USDA FOREST SERVICE MAPPING STANDARDS FOR EXISTING VEGETATION – A TEST OF BASE LEVEL MAPPING STANDARDS

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ABSTRACT

Early in 2003, the USDA Forest Service released draft vegetation classification and mapping standards. The standards were designed to ensure consistency with Federal Geographic Data Committee (FGDC) standards, address the ongoing information needs of the Forest Service, and provide a consistent but flexible basis for classifying and mapping existing vegetation. As the final phase of a draft review process, the mapping standards were applied through a pilot project. The base (i.e., most detailed) level mapping standards were tested on a watershed in the Stanislaus National Forest of California using a combination of remote sensing technologies and direct field observations. The reported results are intended to give insight into the feasibility, cost effectiveness, and accuracy of mapping the standard vegetation attributes, including National Vegetation Classification System (NVCS) equivalent alliances and associations.

INTRODUCTION

Mapping existing vegetation has been and continues to be one of the most necessary and fundamental data capture activities practiced in the Forest Service. Numerous business functions within the agency require current knowledge of the composition, distribution and condition of the vegetated landscape. It is also necessary to understand the spatial relationship of vegetation with the non-vegetated and primary land use portions of the landscape.

Despite the historical and continued development of vegetation maps, no comprehensive effort to define minimum content standards had previously been completed or implemented within the Forest Service. Significant content and spatial variability exists between map products developed across the agency and through time. The obvious benefit of data consistency between similar products and the emphasis toward a corporate data environment have further necessitated the development of such standards.

As with any data type, meaningful content standards for existing vegetation and associated land cover are needed to ensure complete content, content consistency, currency of information, and data quality. Furthermore, standards should be achievable using the tools and resources available to the agency. These are basic concepts embodied in the recently developed Forest Service standards for classification and mapping of existing vegetation (Warbington, 2002; Brohman, 2004). The purpose of this paper is to report on a pilot mapping effort designed to implement the new standards and provide insight into the preparation, process, and feasibility of developing a standard vegetation map.

BACKGROUND

The vegetation classification and mapping standards that were recently developed by the USDA Forest Service are the result of a multi-year effort directed by the Ecosystem Management Conservation staff of the Washington office. A core standards development team, comprised of vegetation ecologists, mapping and inventory specialists, remote sensing specialists, and database developers were responsible for producing and editing the document that is pending formal release. In addition to a core team of resource professionals from within the agency, numerous experts from external academic and professional societies were consulted on topics ranging from historical ecological doctrine to current classification and mapping practices. Extensive review periods were also initiated internally and externally to provide an opportunity, for those not directly involved, to influence the final document. The most current version of the draft document is available at www.fs.ged.us/emc/rig. Official publication in the forms of a manual and handbook is expected in late 2004.

The standards document provides protocols on both classification and mapping of existing vegetation. The most fundamental notion of the document is that a vegetation classification system is developed prior to mapping. The development of an exhaustive and mutually exclusive classification system provides the basis for map units, keys and descriptions necessary to spatially depict (map) vegetation composition and structure. The pilot test described in this paper focused on the mapping portion of the protocols, specifically on the most detailed (Base) level of the mapping standards. The availability of a national vegetation classification system (NVC) compliant with Federal Geographic Data Committee (FGDC) standards (FGDC, 1997) is central to the development of a Base level map product. Information on developing a standard NVC is located in section 2 of the standards document. This project relied on the availability of a previously developed NVC for an adjacent area due to resource limitations.

Section 3 of the document presents content and format standards specific to vegetation mapping. Four hierarchical levels organize the standards, each addressing a level of spatial and thematic detail commonly required for various business functions in the Forest Service. The basic content of each map level is the same with successively more detail as mapping scale is increased. The hierarchal relationship between levels allows for upward migration of data developed at finer levels. Table 1 illustrates the four levels defined by the mapping standards.

Table 1; Standard Vegetation Map Levels

Map Level	**Forest Service Program Areas**	**Forest Service Business Requirements**	**Ecological Unit Hierarchy**	**Ecological Analysis Scale (Range)** ECOMAP 1997	**Potential Natural Vegetation Classification**	**Existing Vegetation Classification**	**Existing Vegetation Map Unit Design**	**Map Extent**
1 **National**	FIA, RPA, International Forestry, Fire, FHM	National Strategic Inventory (FIA Phase I), Forest Cover, Forest and Rangeland Health/Sustainability	Division Province	1:30,000,000 to 1:5,000,000; gen poly size 10,000-100,000 sq. mi.	Class and Subclass	NVCS Class and Subclass, MLRA	National Land Cover Database, NVCS Class + Subclass	National (millions of square miles)
2 **Broad**	RPA, FIA, Fire, FHM	Bioregional Assessments, Conservation Strategies (Region/Subregion)	Section Subsection	1:7,500,000 to 1:250,000; gen poly size 10-1,000 sq. mi.	Series	Dominance Types, Alliances (example SRM, SAF cover types)	Dominance Type Groups, Alliance Groups	Multi-state or State (20+ million acres)
3 **Mid**	Forest Planning and Monitoring, Fire, FIA	Forest/Mulit-forest Planning/Monitoring, 4th/5th HUC Watershed Assessments, National Fire Plan Implementation (Forest Level) Forest and Rangeland Health Assessments, Terrestrial and Aquatic Habitat Assessments	Land Type Association	1:250,000 to 1:60,000; gen poly size 1,000-10,000 acres	Series, Climax Plant Association (sensu Daubenmire)	Dominance Types, Alliances, (Associations optional where needed)	Dominance Types, Alliances, Alliance Groups and/or Complexes, Canopy Cover Groups, Size/Height Groups (e.g., VSS)	Multi-forest or Forest (50,000+ Acres)
4 **Base**	Project Planning, Forest Plan Implementation, Land Treatments	Forest Plan Implementation Project Planning & Land Treatments • Fuel Treatments • Grazing Management • Timber Management • Habitat Management • *Etc.* Range Analysis Stand Exams Effectiveness Monitoring	Landtype, Landtype Phase	1:60,000 to 1:24,000; gen poly size <1000 acres	Climax Plant Associations and Phases (sensu Daubenmire)	Alliances, Associations	Alliances, Association, Association Complexes, Canopy Cover Classes, Size/Height Classes, Vertical and Horizontal Structure	5th/6th HUC Watershed or Project Area (<50,000 Acres)

Tables 2.1 – 2.5 illustrate the content and spatial standards that apply to the map levels. Standards for the Base level are highlighted in red. Mapping the standard elements contained in the following tables was the procedural focus of the base level pilot test.

Table 2.1; Physiognomic Map Attributes

Physiognomic Classification Category	**Map Level**			
	National	Broad	Mid	Base
Physiognomic Order*	*R*	*R*	*R*	*R*
Physiognomic Class**woody vascular plants (tree/shrub) required, herbaceous and non-vascular optional*	*R*	*R*	*R*	*R*
Physiognomic Sub-class**woody vascular plants (tree/shrub) required, herbaceous and non-vascular optional*	*O*	*R*	*R*	*R*

*Reflects NVC physiognomic hierarchy with modifications necessary to meet the Forest Service business requirements.

Note: R=required, O=optional

Table 2.2; Floristic Map Attributes

Floristic Classification Category	**Map Level**			
	National	Broad	Mid	Base
Cover Types and Type Groups (SAF/SRM)	*O*	*R*	*R*	*R*
Dominance Types (locally defined)	*O*	*O*	*R*	*R*
Alliances*	*O*	*O*	*O*	*R*
Associations*	*O*	*O*	*O*	*O*

*Currently defined levels of the NVC hierarchy

Table 2.3; Structural Map Attributes

Structural Categories	**Map Level**			
	National	Broad	Mid	Base
Tree Canopy Closure	*O*	*R*	*R*	*R*
Overstory Tree Size	*O*	*R*	*R*	*R*

Table 2.4; Accuracy Goals and Requirements

Vegetation Map Attribute	**Map Level**			
	National goal-standard	Broad goal-standard	Mid goal-standard	Base goal-standard
Physiognomic Order	80%-70%	90%-80%	90%-80%	90%-80%
Physiognomic Class	80%-70%	90%-80%	90%-80%	90%-80%
Physiognomic Sub-class		90%-80%	90%-80%	90%-80%
Alliance		80%-65%	85%-65%	85%-65%
Association		80%-65%	85%-65%	85%-65%
Cover Type		80%-65%	85%-65%	85%-65%
Dominance Type		80%-65%	85%-65%	85%-65%
Tree Canopy Closure		80%-65%	85%-65%	80%-65%
Overstory Tree Size			80%-65%	80%-65%

Table 2.5; Spatial Accuracy and Area Requirements

	Map Level			
	National	Broad	Mid	Base
Map Scale	1:1000000	1:250000	1:100000	1:24000
Horizontal Accuracy	+/-1666 ft	+/-416 ft	+/-166 ft	+/-40 ft
MMU	500	20	5	5

OBJECTIVE

In addition to mapping the standard elements of a base level map, this project sought to report on issues that might arise from the use of a previously developed vegetation classification not originally intended for this mapping effort. It was expected that geographic separation between the original classification area and the project area would leave unclassified vegetation types to be mapped. Resources were not available to fill classification gaps identified in this project. Identifying the degree of applicability of an existing vegetation classification provided insight into the resources required for base level mapping.

It was also the objective of this project to evaluate a specific process for developing a base level map using available technology and commonly practiced mapping methods applied at the project level. A process combining automated polygon delineation with field observation and photo interpretation was subjectively assessed for feasibility and cost effectiveness.

PROJECT AREA

The primary selection criterion for the project area was adjacency to an existing vegetation classification system. Other important factors for area selection included national forest ownership, broad representation of vegetation types within the respective National Forest, and local interest. Given that the only extensive and available NVC compliant system in California covered the greater Yosemite area, the Forests immediately adjacent to Yosemite National Park were the default candidates.

The selected project area fell within the Stanislaus National Forest located in the central portion of the Sierra Nevada range and to the north of Yosemite National Park. The upper portion of the Clavey river watershed was specifically selected because of active interest in the vegetation composition and structure of the watershed. A local watershed group made up of diverse resource interests, along with Stanislaus NF personnel, required large-scale vegetation information to aid in detailed resource assessments. The adjacency to Yosemite combined with information need made for a logical project area selection in the watershed. Figure 1 illustrates the relative location of the project area in California and the Stanislaus NF.

The aerial extent of the project was approximately 19,000 acres and was representative of western, mid-montane coniferous forests found throughout the Sierra Nevada. The area reflected a long history of management and disturbance including harvest, fire, grazing, and high intensity recreational use. The project area also contained unique features, including the western-most stands of Aspen in California.

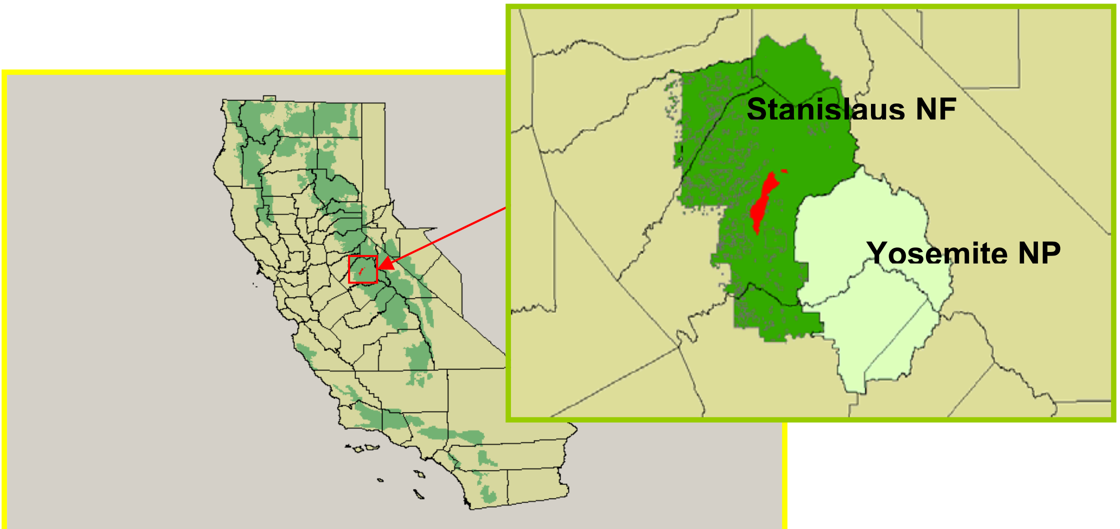

Figure 1. Project Area

METHODS

Map Unit Design

Prior to mapping vegetation composition and structure, exhaustive and mutually exclusive mapping classifications must be in place. Developing these mapping systems has been identified in the standards document as the first step in the mapping process. This project bypassed the map unit design process by using map units previously developed for an earlier Yosemite National Park mapping effort (U.S. Geological Survey, 1998). Additional map unit classifications for tree size and tree canopy closure were taken directly from the standards document. The implications associated with applying existing map unit designs, not specific to a mapping project, are discussed in the conclusions. It was expected that using an independently developed mapping classification, particularly for vegetation associations, would result in unnecessary and/or unfeasible map classes.

Several factors were identified prior to selecting a methodological approach for mapping. Efficiency, feasibility and realistic application at the project level were considered necessary characteristics for the method(s) selected. An approach relying on both remotely sensed data and extensive field observations was used. Processing efficiency was expected from the use of medium resolution satellite imagery for feature delineations. Large-scale aerial photography and extensive field observations were used to provide the finer scale information necessary to map detailed floristic and structural attributes. Table 3 lists the data sources that were used throughout the project.

Table 3; Remotely Sensed Data Sources

Data Type	Spatial Resolution/Scale	Spectral Resolution	Date
Landsat ETM path/row 43/34	Medium (30m)	Multispectral (6 bands – 0.45-2.35□)	8/00
IRS 1C path/row 247/43d	Medium (5m)	Panchromatic (1 band – 0.50-0.75□)	8/00
Aerial Photography - Hardcopy	1:15840	Natural Color	7/00

Data Preprocessing

The use of medium resolution imagery for base level mapping raised questions of feasibility, given the detail required by the standards. Several preprocessing steps were taken in order to attain the necessary spatial accuracy, ensure realistic feature delineations, and promote user confidence in the final products. The first was to co register the five meter IRS imagery to digital ortho quads (DOQ). DOQ data meet the 1:24000 USGS standard for spatial accuracy (U.S. Geological Survey, 2000) and are also the visual standard by which many users subjectively assign confidence to geospatial information. Second, the thirty meter Landsat ETM data and five meter IRS data were fused into a pan-sharpened multispectral data set that maximized pattern recognition potential from the two image data types (Riley, 2002). Figure 2 illustrates the raw data and the resulting fused image that was input into pattern recognition software.

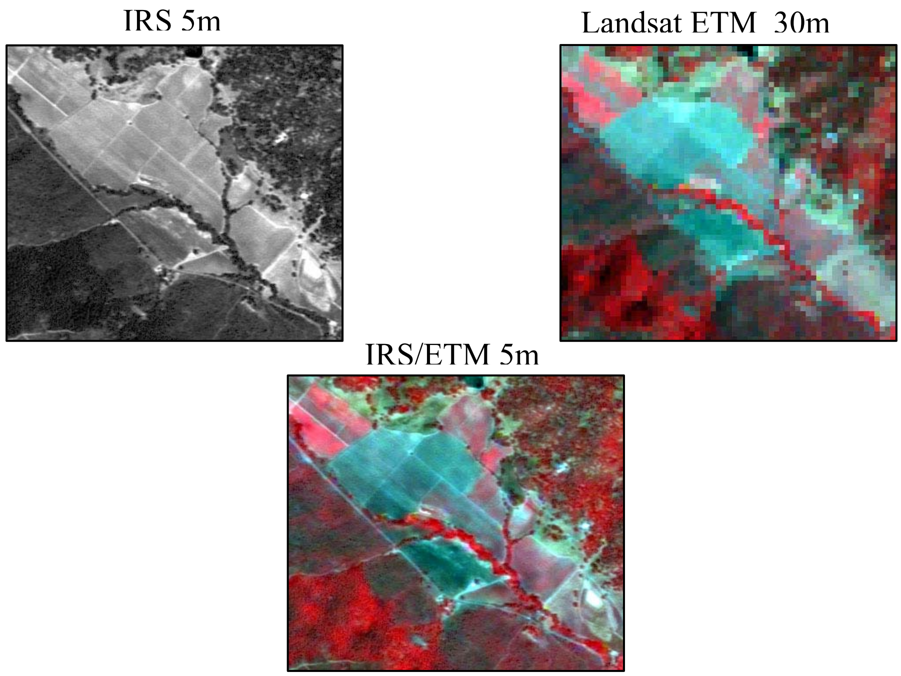

Figure 2. Image Data Sources

Feature Delineation

Map features (polygons) were delineated on the fused satellite imagery prior to labeling the vegetation attributes. The delineations were derived through image segmentation software and provided the most significant opportunity for mapping efficiency from systematic processing. Figure 3 illustrates an example of map features produced within the project area. Automated delineation of vegetation and landscape features via algorithmic pattern recognition on remotely sensed data has been shown to be cost effective and reasonably accurate (Ryerd and Woodcock 1996; Milliken, 1998). Determining the feasibility of image segmentation on the prescribed image data, for base level mapping, was an important objective of this project. If successful, significant cost and methodological implications would be known. The net effect would be fewer resources needed for developing the spatial component of a map, leaving more resources available for field and labeling efforts. Image segmentation was accomplished using the software eCognition 3.0 developed by Definiens Imaging (http://www.definiens-imaging.com).

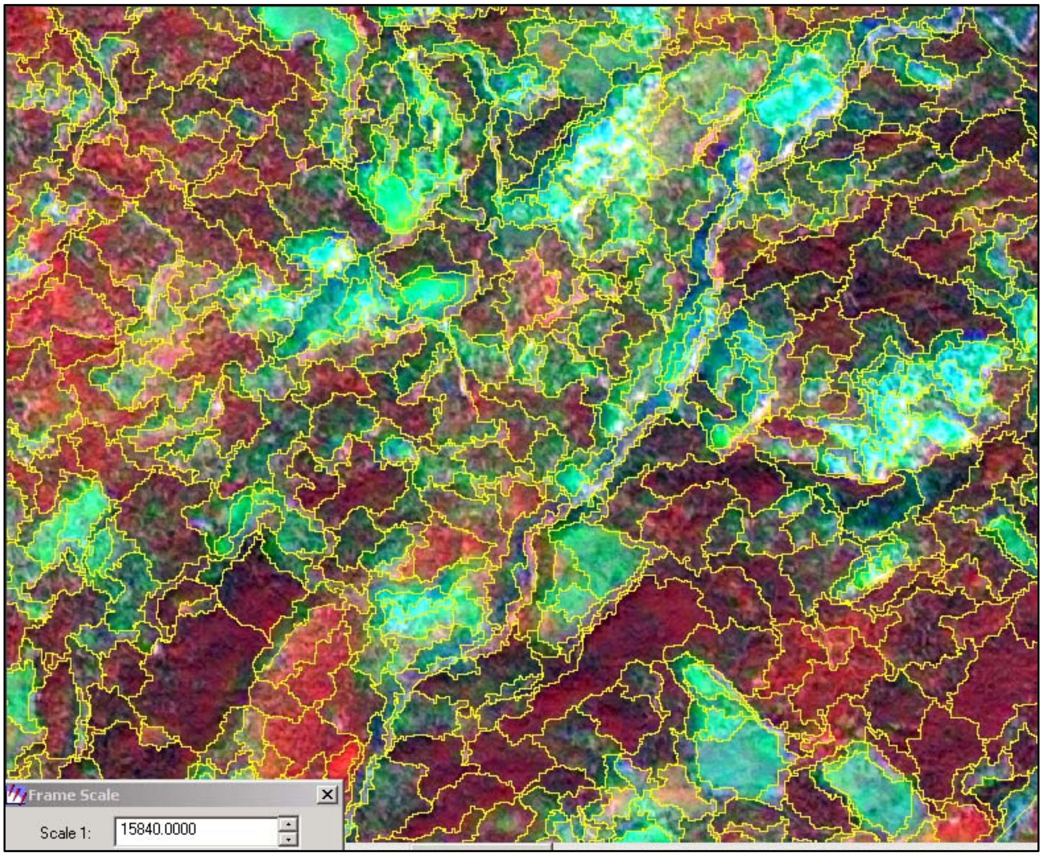

Figure 3. Map Features Derived from Image Segmentation

Feature labeling

A combination of ground based observations and photo interpretation was used to label the features derived through image segmentation. While both activities are labor intensive and relatively immune to economies of scale, they provided the necessary resolution for detailed vegetation mapping. These methods have also been the historical means for deriving vegetation maps in the Forest Service and are accepted and applicable methods for developing information necessary for project planning and implementation.

Ground observations were recorded in summary form over 1:24000 scale hardcopy maps depicting a base DOQ image overlain with topography, hydrography and transportation features. Spatially specific notes detailing dominant species and overstory tree diameter class were recorded on the maps. Initial efforts made an attempt to label image segmentation features in the field using a laptop computer, but were quickly abandoned due to concerns over efficiency of data collection. Approximately 20% of the project area was observed and summary notations recorded in the field. The remaining area was interpreted from aerial photography and extrapolated from field notations.

The labeling of map features was done in the office using Arcgis software. A database structure, containing the standard data elements as individual fields, was established for the unlabeled map features. The primary fields of vegetation association, vegetation alliance, dominance type, tree diameter class, and tree canopy closure were manually attributed. Where vegetation characteristics were observed as understory components, second and third most dominant labels were also assigned.

An additional tool was used to help attribute tree canopy closure for the forested features. A newly developed GIS application, built as an ARCMAP extension, was used to help consistently label canopy closure classes. The extension, known as the Digital Mylar (Clark, 2004), provides a two dimensional grid of tree cover generated from a forest visualization model. The intent is to mimic traditional mylar grids used for photographic interpretation of canopy closure in a digital environment. The use of the Digital Mylar was limited, however, due to time constraints. A mixed approach of existing data and new interpretations was ultimately used to achieve tree canopy closure labels. The probable effect of an inconsistent canopy mapping approach is discussed in the results.

RESULTS

Results were determined using two approaches. The first, a traditional accuracy assessment based on an independently collected set of reference data. Hard and fuzzy set accuracies were generated using software previously developed by the Forest Service in California (Gopal and Woodcock, 1994; Milliken, 1998). A more subjective assessment was made using the local watershed group as a test audience. This was done as a means of determining potential user confidence in the final product.

Accuracy Assessment

Reference data for the accuracy assessment were collected based on a stratified random sample, subject to resource constraints of the project. Each of the standard map attributes was used as individual stratum from which reference sites were selected to maximize sampling frequency. A uniform, fifty acre grid was intersected with the project area and sites were selected to ensure reasonable sampling density within as many vegetation conditions as resources allowed. A stratification priority was established based on the variety of map classes per attribute and the significance of each attribute to local information needs. The floristic map attributes (association, alliance, dominance type) contained the highest number of classes and were used as the primary selection strata followed by tree size class and tree canopy closure respectively.

Each grid point selected as a reference data sample determined the location of a plot where vegetation species and structure were recorded. A four point cluster plot design was used based on a previous inventories conducted in California (USDA, 2002), though streamlined to include only the data necessary to calculate vegetation type, tree size class, and tree canopy closure. This was done to minimize cost and ensure that Regional accuracy assessment software could be utilized. The software was used to calculate attribute labels for each reference site, excluding vegetation association and alliance. Attempts were made to manually calculate association and/or alliance labels using the classification keys available for the Yosemite classification. A number of difficulties were encountered with the Yosemite keys and confidence in their use for calculating reference labels was low. Accuracies for the association and alliance attributes were not reported for this reason. The effect of the difficulty in using the Yosemite classification keys is discussed as part of the conclusions. Table 4 summarizes overall users accuracy for each of the standard map attributes.

Table 4; Overall Users Accuracy for the Base Level Map Attributes

Map Attribute	Map Accuracy %	Goal – Standard %
Order	95	90 – 80
Class	73	90 – 80
Subclass	87	90 – 80
Alliance	NA	85 – 65
Association	NA	85 – 65
Dominance Type	84	85 – 65
Tree Canopy	50	85 – 65
Tree Size	92	85 – 65

The attributes highlighted in red on the previous table are those that met the requirement defined by the Forest Service map accuracy standards. Vegetation association and alliance are not reported and future investigations into the ability to map detailed floristics using the approaches described in this report are warranted. Notable in this table, are the substandard accuracies of tree canopy closure and the related class attribute. The accuracies of these attributes were unexpectedly low and the probable result of an inconsistent mapping approach for canopy closure. Most significantly, in attempt to complete the project within budget, the use of a coarser scale vegetation map as a means of labeling higher density stands likely resulted in systematic error. Accuracy assessment of the canopy closure classes revealed error to be the greatest in map labels of seventy percent or higher canopy closure. This is due to the mapping technician systematically adjusting the previous map 70 percent class to 50 percent without adequate evaluation Tree stands with canopy closure greater than seventy percent are common in the project area and the weighted effect of error in this condition was significant.

The applicability of the Yosemite vegetation classification to the project area was quantified by the total acres in the final map not having a vegetation association or alliance label. Ten percent of the mapped area was not labeled with a vegetation association or alliance. Figure 4 provides a graphic depiction of the classification gaps relative to the project area. This included areas labeled with Yosemite defined map units that were not derived from the original vegetation classification. Map features not labeled with an association or alliance, were assigned a primary floristic map label from the Regional dominance type system (USDA, 2000). These areas would logically be considered for additional field sampling to augment the vegetation classification.

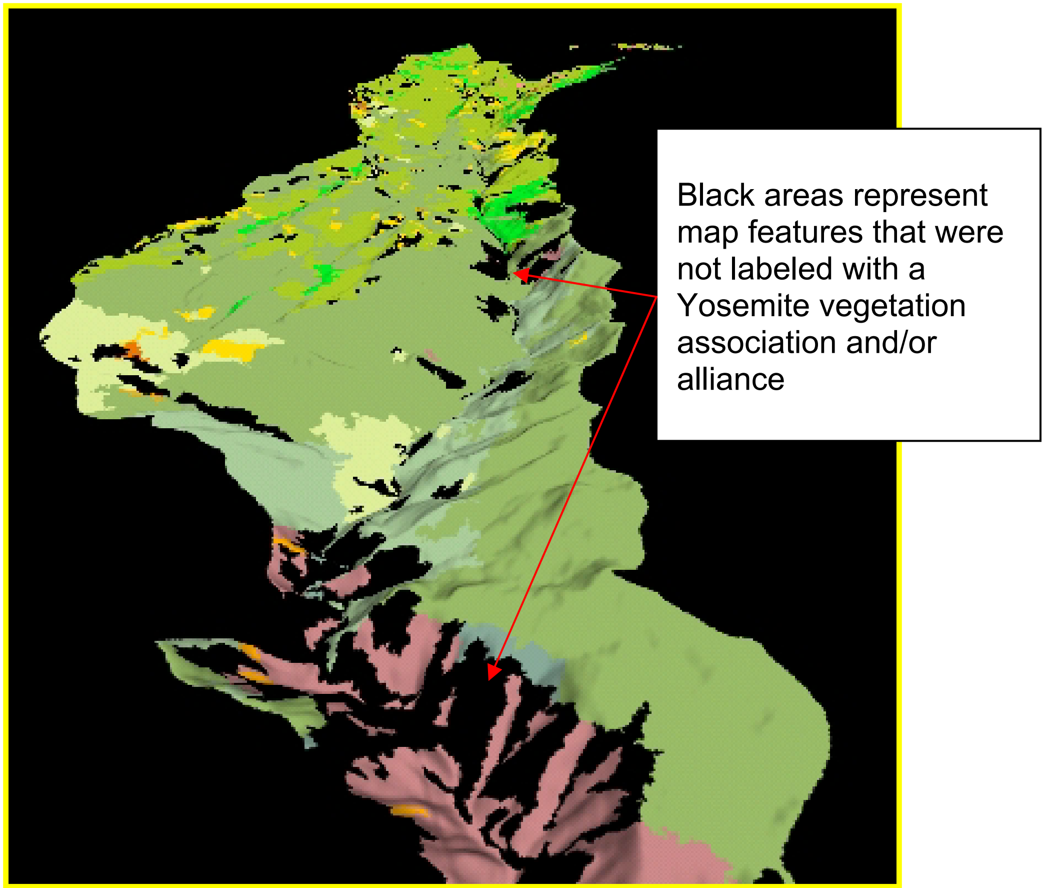

Figure 4. Gaps in the Yosemite Vegetation Classification as Applied to the Clavey River Watershed

Subjective Assessment

As a means of determining potential user confidence in the final map product, the local watershed group was invited to review two specific attributes in the field. Hardcopy maps of vegetation association/alliance and tree size class were plotted at a scale of 1:24000 and distributed to members of the group. Group members represented a range of interests and relevant experience in natural resources. The group was taken to a variety of conditions throughout the project area, given information on the map legends and keys, and encouraged to make as objective a conclusion as possible about map accuracy. The group was also encouraged to be vocal in their observations in order to get a sense of map acceptance, and specifically ask for their comments on automated segments. Reaction to the maps was inherently individual and quantifying those reactions was not attempted. Instead, the general level of acceptance and concern over accuracy was noted. The primary intent was to determine whether or not users could make a connection between the maps and the landscape they were observing.

In summary, there was a generally positive reaction to the maps. A number of label errors were observed but group members tended to view them in an ecological context. Group members appeared to conclude the map errors varied considerably and in most cases did not result in an unreasonable or unacceptable map.

CONCLUSIONS

A number of significant process implications emerged from this project. Perhaps the most significant is the result of applying an existing vegetation classification to locations outside of the original classification area. Despite immediate adjacency to the original classification area, the final map revealed a significant number of acres that could not be labeled using the original Yosemite map unit design or the basic classification. Mapping projects seeking to gain efficiencies by using an existing vegetation classification should factor in the need for additional classification efforts. Vegetation diversity should give some indication of additional classification needs. Alternatively, the basic classification would be diluted through a map unit design process that aggregates undefined vegetation conditions with defined vegetation types. Information needs will determine the significance of such aggregations.

Classification systems are continually evolving descriptions of the vegetated landscape. As such, they may contain inclusive and ambiguous terminology in order to avoid making incorrect, absolute statements about vegetation type composition and arrangement. This was apparent in the Yosemite classification but was not resolved prior to use in this project. A map unit design process must resolve ambiguities in a vegetation classification and develop a quantitative set of mutually exclusive vegetation keys. Without the ability to reference a clear set of map unit keys and descriptions, map inconsistency will occur and mapping efficiencies reduced.

Mapping the detailed vegetation attributes, that form a base level map, requires high spatial resolution data and a significant field investment. The interpretation of aerial photography, while necessary, is not capable of accurately discriminating and labeling many vegetation species. Field data are necessary to identify species composition and ultimately label many of the vegetation associations and alliances defined by a classification system.

Based on both the accuracy and subjective assessments, it is reasonable to conclude that the overall mapping approach was successful at producing a standard base level map. The combination of medium and high resolution remotely sensed data and extensive field observations appeared to provide the scale of information necessary to map the required attributes. The map attributes, with the exception of tree canopy closure, met and exceeded the minimum accuracy requirements.

With respect to tree canopy closure, the lack of consistent mapping methods was responsible for low accuracy. In this case, potential accuracy was not achieved. Careful consideration should be given to the use of existing map products or systematic adjustments as a means of streamlining the map labeling process. Future efforts should be conducted using consistent canopy mapping methods to achieve the required accuracy. Resources needed for base level mapping efforts; in terms required skills, time and labor, should not be under estimated. If they are, short cuts taken will likely show up in lower than acceptable map accuracies.

The potential for a map product with a high level of user confidence was apparent though not certain. Acceptance of vegetation maps is developed over time as a function of map quality and user understanding. The reactions of an independent group allowed us to conclude there is a good chance that vegetation maps produced with these methods can be useful at the project level.

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