# REQUIREMENTS OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS TO MEET THE NEW FOREST SERVICE EXISTING VEGETATION CLASSIFICATION AND MAPPING STANDARDS

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## ABSTRACT

Existing Vegetation has been identified as a National Geographic Information Systems (GIS) standard layer for the Forest Service. National classification and mapping standards have recently been established to guide the development of future classification and mapping products at four landscape scales; national, broad, mid and base levels. Care was taken to follow as closely as possible the National Vegetation Classification Standard (NCVS) published by the Federal Geographic Data Committee (FGDC) and to accommodate a bottom up project-to-planning nested approach, in both classification and mapping. Mapping standards and minimum accuracy requirements were set considering available sources of remotely sensed data as well as existing GIS and image processing technology. Standard mapping methods using photo interpretation and image processing will be adequate to meet the new standards, however, different methods are likely to vary at each mapping levels. Producing vegetation maps that follow standards, are accurate, and yet affordable will continue to challenge the remote sensing and GIS community.

## Need for USFS Existing Vegetation Classification and Mapping Standards

Existing vegetation is one of the primary natural resources managed by the Forest Service. The Agency is charged with managing vegetation for a variety of human uses, while maintaining the integrity of ecosystem components and processes at national, regional, and local levels. A Team of Ecologists, Foresters, and Remote Sensing specialists, representing Regions throughout the Forest Service, is tasked with developing existing vegetation classification and mapping standards. The standards are needed to create consistency across National Forests and Ecological Regions and meet the agency's business at various levels of the organization, including project areas ranging from a site-specific stand to a bioregion. Along with the standards, the desire for consistent classification and mapping, led to development of National protocols for classification, mapping, data base design, metadata, and accuracy assessment (U.S.D.A., 2002). With standards and protocols in place in the form of Forest Service Manual, Handbook and Technical Guide, National Forest corporate databases can be consistently populated with existing vegetation information. Having standard GIS layers and data for existing vegetation enables sharing of information within the agency and with others.

## Vegetation Classification Standards - Federal Geographic Data Committee (FGDC)

Classification is considered a prerequisite for mapping vegetation types; it provides the definitions of what is to be mapped. The major task in classification is to develop and describe vegetation types and create keys to distinguish between types. Any classification work conducted by the Forest Service must be consistent with the existing FGDC National Vegetation Classification Standards (FGDC, 1997). The FGDC standards specifically define the upper levels of physiognomic hierarchy for vegetation growth habits as well defining specific vegetation lifeform and cover breaks as shown in Table 1 below. However, the specific floristic classification levels, while generally defined as plant associations and alliances, are currently not available as part of the formal FGDC classification. Therefore, the Forest Service Team recognized the need for ongoing development of existing vegetation classification work as an integral part of any new mapping project. To meet the FGDC standards, any new floristic classification work must be based on collection and analysis of plot data to ensure the classification categories are precisely defined and mutually exclusive.

## Floristic Requirements

The classification system must be hierarchical, with varying levels of detail available to address management issues and guide vegetation mapping at multiple levels. Recognizing that developing a complete floristic classification system could take as long as 20 years, the Team agreed on an interim strategy to using existing cover types and regional dominance types for upper level mapping work, substituting more formal classifications as they are developed. Specifically for national and broad level mapping the classification standards are as follows: the Society of American Forestry (SAF) Forest Cover Types of the United States and Canada (Eyre, 1980.), and Society for Rangeland Management (SRM) Rangeland Cover Types of the United States (Shiflet, 1994). And for mid level mapping, the classification are regional dominance types, such as Region 5's CALVEG System (U.S.D.A., 2001a, 1981), until formal plant associations are available.

However, base level mapping, that supports on-the-ground detailed management of the National Forests, will require a formal classification be conducted before any mapping takes place (U.S.D.A. 2002). These classifications must be based on inherent vegetation attributes such as physiognomy, floristic composition, and structure. The classification categories must be clearly defined, exhaustive, and mutually exclusive to facilitate map unit design and accuracy assessment. The classification system must employ a simple dichotomous key with unambiguous criteria so that all users can consistently identify the vegetation types. Existing vegetation classification from sample plots are used to define plant associations as the most detailed level of the classification, these are then grouped into plant associations, and finally cross-walked to regional dominance types and SAF or SRM cover types. To meet the floristic hierarchy, crosswalks are required between detailed formal classifications of plant associations, to alliances, to more general dominance types and cover types. This facilitates the integration of classification and map information from detailed to general.

Table 1. Physiognomic Classification

| **Vegetated Division** | | |
|---|---|---|
| ***Order*** | ***Class*** | ***Subclass*** |
| Tree Dominated | Closed tree canopy - forest | Evergreen |
| | | Deciduous |
| | | Mixed |
| | Open tree canopy - savannah | Evergreen |
| | | Deciduous |
| | | Mixed |
| Shrub Dominated | Shrubland | Evergreen |
| | | Deciduous |
| | | Mixed |
| | Dwarf shrubland | Evergreen |
| | | Deciduous |
| | | Mixed |
| Herbaceous and Non-vascular Dominated | Herbaceous - shrub steppe | Perennial grasses |
| | | Perennial forbs |
| | | Annuals |
| | | Hydromorphic rooted |
| | Herbaceous - grassland class | Perennial grasses |
| | | Perennial forbs |
| | | Annuals |
| | | Hydromorphic rooted |
| | Non-vascular class | Bryophyte |
| | | Lichen |
| | | Alga |
| No dominate lifeform | Sparsely vegetated | Consolidate rock |
| | | Boulder, gravel, cobble, talus |
| | | Unconsolidated material |
| | | Urban or build-up |
| **Non-Vegetated Division** | Non-vegetated | Non-vegetated |

## Structural Requirements

Specific structural classification breaks in tree canopy closure and shrub cover classes as well as tree size classes were added to the minimum FGDC required breaks. These additional breaks were designed to meet the business needs the Forest Service including planning, inventory, assessment, monitoring and management. Shrub cover, down to as little as 5 percent, was recognized as ecologically significant for range and wildlife management, and resulted in the addition of the herbaceous shrub steppe physiognomic order to the upper vegetation classification (See Table 1.).

Breaks in tree canopy closure and size were defined to be consistent with existing definitions and standards found in the USGS Anderson Land Use Land Cover, (Anderson, 1976) Northwest Forest Plan Vegetation Strike Team Standards (REO, 1995), and National Forest System definition of forestland (RPA, 1974). Ideally, cover and size classification attributes would be continuous, however, current image processing and photo interpretation methods, expected accuracies, and potential costs, limit the possibilities. Where possible, class ranges were defined in equal widths to approximate continuous values, while remaining discernable. Classes decrease in detail as business requirements change from base level mapping, to more general mid and broad levels.

Table 2. Total Cover, Shrub Cover and Tree Canopy Closure Classifications

| **Base Level Mapping** | | **Mid Level Mapping** |
|---|---|---|
| ***Definition*** | | ***Definition*** |
| Less than 1 percent | | Less than 10 percent |
| 1 - 9.9 percent | | 10 - 29.9 percent |
| 10 -19.9 percent | | 30 - 59.9 percent |
| 20 -29.9 percent | | 60 - 79.9 percent |
| 30 -39.9 percent | | 80 - 100 percent |
| 40 - 49.9 percent | | |
| 50 - 59.9 percent | | **Broad Level Mapping** |
| 60 - 69.9 percent | | ***Definition*** |
| 70 -79.9 percent | | Low less than 30 percent |
| 80 - 89.9 percent | | Medium 30 - 59.9 percent |
| 90 - 100 percent | | High 60 - 100 percent |

Table 3. Tree Size Classification

| ***Class*** | ***Definition*** | |
|---|---|---|
| Seedlings | 0 to .9 inches QMD | Tree size class is determined by calculating the diameter (usually at breast height) of the tree of average basal area (Quadratic Mean Diameter or QMD) of the top story trees that contribute to canopy closure, tree cover as seen from a birds eye view from above. |
| Saplings | 1 to 4.9 inches QMD | |
| Poles | 5 to 9.9 inches QMD | |
| Small | 10 to 19.9 inches QMD | |
| Medium | 20 to 29.9 inches QMD | |
| Large | 30 to 39.9 inches QMD | |
| Very large | 40 to 49.9 inches QMD | |
| Giant | 50+ inches QMD | |
| Large to giant | For mid level mapping, use code for 30 inches and greater size. | |

## Integrating Anderson Land Use Land Cover Mapping

In order to have map coverage of all land and water surfaces, the USGS Anderson Classification has been adopted for general land use and land cover (U.S.D.A., 2002). As a minimum, the Anderson Level 1 is to be used for mapping sparsely vegetated, non-vegetated, and open water areas. This classification, when used in concert with FGDC physiognomic levels, allows for the identification of non-natural man made landscapes where land use dominates and non-vegetated areas. Examples of these landscapes include urban intersection with vegetation such as an urban forest, wetland conditions as well as non-vegetated types of barren, ice and open water. The intersection of these two classification systems is show below in Table 4.

Table 4. Relationship between Anderson 1 and FGDC Physiognomic Class

| | **Anderson 1 Land Use Land Cover** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **FGDC Physiognomic Class** | Urban or Build-up land | Agricult-ural land | Range-land | Forest-land | Water | Wetland | Barren land | Tundra | Perennial Snow or Ice |
| *Closed tree canopy - Forest* | **X** | **X** | | **X** | | **X** | | | |
| *Open tree canopy - Savannah* | **X** | **X** | | **X** | | **X** | | | |
| *Shrubland* | **X** | **X** | | **X** | | **X** | | **X** | |
| *Dwarf shrubland* | **X** | | **X** | | | **X** | | **X** | |
| *Herbaceous - Shrub Steppe* | **X** | **X** | **X** | | | **X** | | **X** | |
| *Herbaceous Grassland* | **X** | **X** | **X** | | | **X** | | **X** | |
| *Non-vascular* | | | | | | **X** | **X** | **X** | |
| *Sparsely Vegetated* | **X** | **X** | | | | | **X** | | |
| *Non-Vegetated* | **X** | | | | **X** | | **X** | | **X** |

Note: Herbaceous – Shrub Steppe is added as a Forest Service refinement of FGDC.

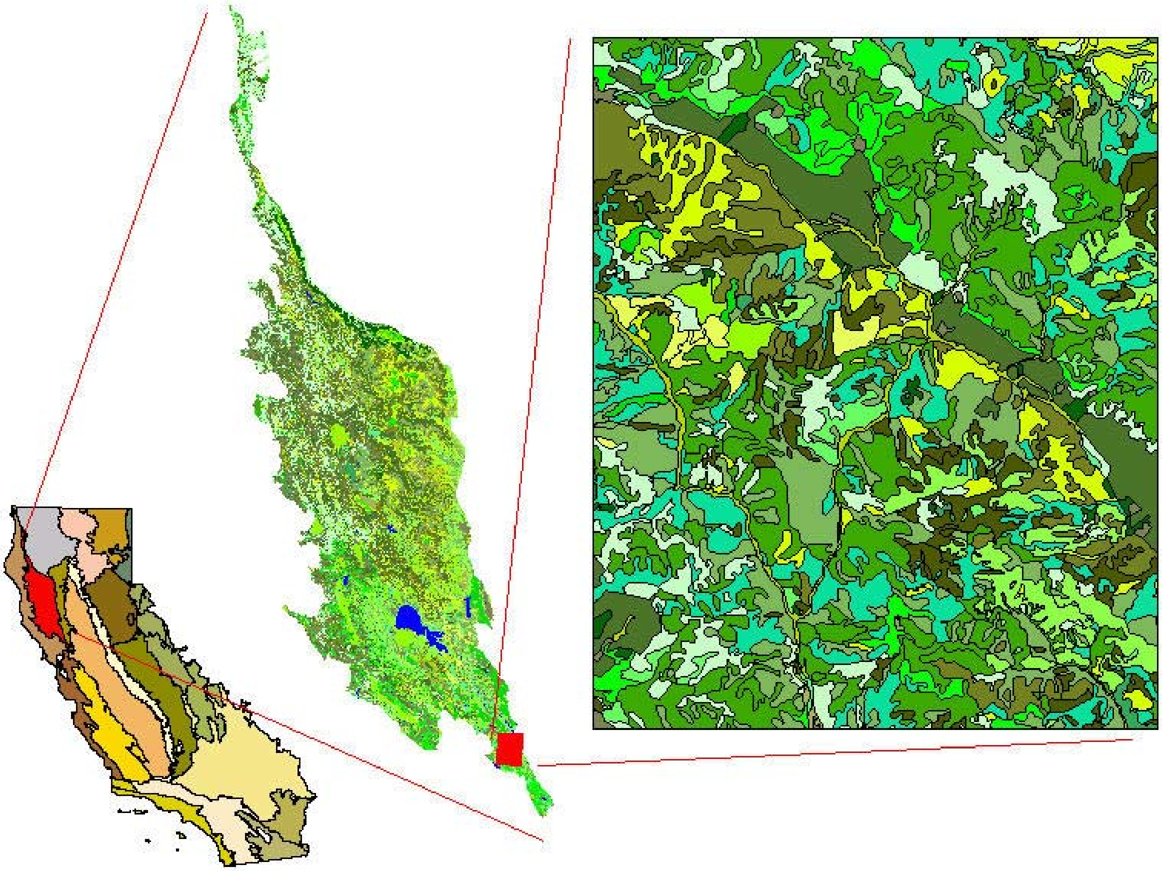
## Corporate Database Requirements

The Forest Service existing policy requires data collected for vegetation classification or mapping be stored in the Agencies Natural Resource Information Systems (NRIS) corporate databases (USDA, 2001b). To facilitate the loading of data, classification codes and definitions, where suitable, were adopted from existing valid value tables from the NRIS databases, Field Sample Vegetation (FSVEG), and Terrestrial Resources (TERRA). Some changes and adaptations will be necessary by these same databases to accommodate the existing vegetation classification standards, coding, data collection and linkages to GIS existing vegetation map polygons and plot sample locations.

## Vegetation Mapping Standards

Mapping standards for existing vegetation consist of setting requirements for meeting Forest Service business needs at various levels of the agency. Four map levels have been recognized, 1) National, 2) Broad, 3) Mid, and 4) Base. These levels are analogous to soil survey orders, in that each level has an increasing amount of detail in both classification and map features as well as their associated map attributes. Each of these mapping levels is referenced to the appropriate Forest Service National Hierarchical Framework, consisting of ecoregions at a range of scales: Domain, Division, Province, Section, Subsection, Land Type, and Land Type Phase (Bailey, 1994). The upper levels of this ecological framework provide the context for the appropriate vegetation classification and are useful in setting mapping extents. See Figure 1 for an example of Mid and Base levels.

Figure 1. Example of Mid and Base Level Existing Vegetation Maps from Northern California



## Mapping Requirements at Four Map Levels

For each map level, a set of requirements were established for minimum mapping unit size, registration map scale, required attributes, accuracy goals, database structure, valid codes and definitions, and GIS metadata requirements. Examples of previous mapping projects for each map level were also identified to show the linkages with business needs. Care was taken to maintain a hierarchical relationship for all types of mapping classes, to facilitate integrating maps from the bottom up: from Base to Mid, Mid to Broad, and Broad to National level. Specific requirements follow in Tables 5 through Table 11. For these tables, *R* equals required, *O* equals optional.

Table 5. Minimum Mapping Unit

| | Map Level | | | |
|---|---|---|---|---|
| | National | Broad | Mid | Base |
| **MMU (acres)** | 500 | 20 | 5 | 5 |

The minimum mapping unit defines the smallest polygon feature to be mapped at a given map level. Features smaller than the specified minimum can be mapped to meet local business requirements. This may be desirable for highly contrasting features such as water bodies, rock outcrops and meadow areas.

Table 6.  Map Reference Scale

| | 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 |

Each level of the map hierarchy is intended to cover a general ecological analysis scale and/or business function area.  Correspondingly, a measure of spatial precision and accuracy is implied at each level.  Spatial precision is generally determined by the data sources and methods used to develop a map.  Map scale equivalencies are established for each map level in Table 6 above.  While map scale is technically a measure of distance at a given extent of display or publication, it is used here to give reference to the horizontal and vertical accuracy of a map. National Map Accuracy Standards (NMAS) for map products (U.S. Bureau of the Budget, 1941) as further refined by the USGS National Mapping Program, serve as a logical guideline for horizontal accuracy (U.S.G.S., 2000).

Table 7.  FGDC Physiognomic Classification

| | Map Level | | | |
|---|---|---|---|---|
| **Category** | National | Broad | Mid | Base |
| Physiognomic Order* | *R* | *R* | *R* | *R* |
| Physiognomic Class* | *R* | *R* | *R* | *R* |
| Physiognomic Subclass | *O* | *R* | *R* | *R* |

Subclass mapping of evergreen, deciduous and mixed for tree and shrub dominated orders is the only requirement for this category (U.S.D.A., 2002).

Table 8.  Floristic Classification

| | Map Level | | | |
|---|---|---|---|---|
| **Category** | National | Broad | Mid | Base |
| Cover Types | *O* | *R* | *R* | *R* |
| Dominance Types | *O* | *O* | *R* | *R* |
| Alliances | *O* | *O* | *O* | *R* |
| Associations | *O* | *O* | *O* | *O* |

Through detailed Base level classification and mapping projects, local Dominance type classifications will be replaced with formal Plant Alliances and Associations.

Table 9.  Total Vegetated Cover, Shrub Cover and Tree Canopy Closure Classification

<table>
<tr><th rowspan="2">Cover Classes</th><th colspan="4">Map Level</th></tr>
<tr><th>National</th><th>Broad</th><th>Mid</th><th>Base</th></tr>
<tr><td>0%</td><td rowspan="4">R</td><td rowspan="4">R</td><td rowspan="2">R</td><td>R</td></tr>
<tr><td>1-9.9%</td><td>R</td></tr>
<tr><td>10-19.9%</td><td rowspan="2">R</td><td>R</td></tr>
<tr><td>20-29.9%</td><td>R</td></tr>
<tr><td>30-39.9%</td><td rowspan="3">R</td><td rowspan="3">R</td><td rowspan="3">R</td><td>R</td></tr>
<tr><td>40-49.9%</td><td>R</td></tr>
<tr><td>50-59.9%</td><td>R</td></tr>
<tr><td>60-69.9%</td><td rowspan="4">R</td><td rowspan="4">R</td><td rowspan="2">R</td><td>R</td></tr>
<tr><td>70-79.9%</td><td>R</td></tr>
<tr><td>80-89.9%</td><td rowspan="2">R</td><td>R</td></tr>
<tr><td>90-100%</td><td>R</td></tr>
</table>

National and Broad level mapping vegetation cover breaks are those required for mapping FGDC physiognomic levels.  Tree canopy closure is defined here as the total non-overlapping tree canopy in a delineated area as seen from above. Tree canopy closure below 10% is considered a non-tree polygon. Any further divisions necessary to meet local requirements must be subdivisions of the classes listed in the table.

Table 10. Tree Diameter Classification

<table>
<tr><th rowspan="2">Tree Diameter Classes (inches/DBH)</th><th colspan="4">Map Level</th></tr>
<tr><th>National</th><th>Broad</th><th>Mid</th><th>Base</th></tr>
<tr><td>0-4.9</td><td rowspan="7">O</td><td rowspan="7">O</td><td>R</td><td>R</td></tr>
<tr><td>5-9.9</td><td>R</td><td>R</td></tr>
<tr><td>10-19.9</td><td>R</td><td>R</td></tr>
<tr><td>20-29.9</td><td>R</td><td>R</td></tr>
<tr><td>30-39.9</td><td rowspan="3">R</td><td>R</td></tr>
<tr><td>40-49.9</td><td>R</td></tr>
<tr><td>50+</td><td>R</td></tr>
</table>

Tree diameter class breaks that are mandatory for base and mid-level mapping. Developing tree size map classes at the broad and national level is optional. Additional class breaks necessary to meet local requirements, within the mid and base levels, must aggregate to the specified tree diameter classes.

Table 11. Accuracy Goals for Vegetation Map Attributes

| **Vegetation Map Attribute** | **Map Level** | | | |
|---|---|---|---|---|
| | National | Broad | Mid | Base |
| Physiognomic Composition | 80-70 | 90-80 | 90-80 | 90-80 |
| Floristic Composition | | 80-65 | 85-65 | 85-65 |
| Tree Canopy Closure | | 80-65 | 85-65 | 80-65 |
| Tree Diameter Class | | | 80-65 | 80-65 |

Table 11 lists accuracy goals and standards (goal-standard) for the required map attributes at each map level. Accuracy standards are addressed at two levels: Minimum accuracy required for a National standard vegetation layer, and ideal accuracy goals based on what can feasibly be obtained. It is recognized that increased map class detail and/or increased mapping difficulty, usually results in a higher probability of map error. As an example, physiognomy is less detailed and considered less difficult to map than the other map attributes and therefore has higher accuracy standards associated with it. Mapping feasibility, however, does not take precedence over the need for accuracy standards that ensure a useful product. The inability to achieve the accuracy standards will dictate a change in mapping methodology or change in the level of the map product.

## Accuracy Assessments

Standard accuracy assessments are a required step of any mapping project. Aerial photos, at scales of 24,000 or larger, may be used it establish reference data for physiognomic class and subclass, tree size and vegetation cover. However, detailed floristic information of growth habit, species and cover will need to be collected on the ground. National Forest Inventory and Analysis (FIA) plots are suitable for reference data at the National and Broad levels. Mid level mapping will require additional samples for rare types and non-forest conditions, as the systematic sample design of the FIA plot locations often misses rare forest types and conditions. In addition, the FIA program samples forest vegetation only; so additional sampling will be needed in non-forest lands. Base level mapping will require special sampling for map accuracy assessment, since few FIA plots are likely to occur in small project areas (U.S.D.A., 2002).

## Map Update Cycle

Vegetation composition and structure are in a constant state of flux and changes in vegetation regularly necessitate the refreshment of existing vegetation maps. Each map level has an associated temporal scale that determines the frequency of map maintenance. Within the extent of the time identified, a given map product will be updated to account for changes in vegetation that have typically resulted from sudden disturbance such as fire, insect and disease caused mortality, silvicultural treatments, rapid growth, etc. Gradual successional changes are more difficult to identify and may need to be accounted for over longer time frames.

Business needs and resource constraints will play a major role in determining the update cycle (Warbington, 2000). A time range is listed for each map level to allow for flexibility in planning map maintenance. Map products that have a hierarchical relationship should be on a coordinated schedule to ensure that updates in the most detailed map are incorporated into upper level maps in a timely fashion. Table 12 lists a reasonable temporal scale, or update period, for each map level.

## Table 12. Map Update Cycle

| | **Map Level** | | | |
|---|---|---|---|---|
| | National | Broad | Mid | Base |
| **Temporal Scale** | 5-10 years | 5-10 years | 1-5 years | 1-5 years |

## Examples of Map Levels and Remote Sensing Source Data

The following are examples of the four mapping levels, amount of map details, and appropriate remote sensing imagery used. The existing projects and ongoing program examples were reviewed and kept in mind when developing the Forest Service standards.

**National Level:**

*Ecological Framework* - Division / Provinces

*FGDC Physiognomic* - Class or Subclass

*Vegetation Attributes* – none to broad cover types

Examples:
MODIS Land Cover – MODIS Imagery based (Strahler, 1999.)
Muti-Resolution Land Characterization - TM Imagery based (MRLC, 2002)
U.S. Forest Types and Cover – AVHRR Imagery based (Zhu, Z., 1994)

**Broad Map Level:**

*Ecological Framework* - Province / Sections

*FGDC Physiognomic* – Class and Subclass

*Vegetation Attributes* – broad cover types to dominance types

Examples:
Statewide GAP- TM Imagery based (reference)
Southern Appalachian Assessment - TM Imagery based (U.S.D.A., 1996)

**Mid Map Level:**

*Ecological Framework* – Section / Subsections

*FGDC Physiognomic* - Class and Subclass

*Vegetation Attributes* – dominance types to plant associations, tree size, canopy closure

Example:
Northwest Forest Plan Vegetation Mapping in California – TM, Spot, IRS Imagery based, and 1:15,840 to 1:40,000 scale aerial photos (Schwind, 1999.)

**Base Map Level:**

*Ecological Framework* – Subsections / parts of subsections

*FGDC Physiognomic* - Class and Subclass

*Vegetation Attributes* – plant associations to alliances, tree size, canopy closure, and vegetation cover

Example:
National Park System – Digital Orthophoto Quads, 1:12,000 to 1:15,840 scale aerial photos (U.S.G.S, 2002)

## Challenges to the Remote Sensing and GIS Community

Multiple sources of information, available for a given resource theme, is one of the continuing challenges of the modern day information age. Often resource analysts find there are multiple layers of existing vegetation such as, MRLC, GAP and some local map covering the same area. The challenge is to match the appropriate map level with the questions being asked by management. Ideally, one base map of high detail and accuracy, covering all lands of interest, would meet everyone's needs. However, due to the large cost of classification and mapping at the base level, it is highly unlikely that this will ever be done for large land areas. Therefore, maps of less detail are often developed for cost efficiencies and answering the larger questions, and will likely be more readily available. Further mapping of specific vegetation attributes, spatial detail, and or ground sampling may be necessary, and can be done while still adhering to the mapping standards.

Moving detailed map attributes from Base map level up to Mid and Broad map levels will be a continuing challenge to the Forest Service. Updating Mid and Broad level maps with Base level maps will ensure that the best information is available. While the standards will assist in consistent classification and mapping attributes, differences in mapping methods and minimum mapping units could lead to inconsistent upward integration. In addition, bringing in information from various sources will lead to variance in source dates as well as accuracy. Care will be required to address these issues when appending or updating different map vegetation map levels, and in nesting polygons from small to large.

Developing accurate maps with limited dollars will be a continuing challenge. Efforts to achieve a highly accuracy map, increase the need for large scale aerial photos, numerous ground samples, field review of draft maps, and correcting and editing of non-systematic or random errors. All of these activities are costly and many are labor intensive, increasing the overall cost of mapping production.

There is more than one recipe for mapping vegetation. While one prescribed method would produce consistent results, consistent errors are more likely consequences. Vegetation is a complex resource and one method is not likely to work for different plant communities and environmental settings. Where common image processing methods do not produce adequate results, creative mapping solutions will be necessary using the lasted remote sensing imagery, image processing software and geospatial modeling. Integration of existing information of known accuracy could lead to substantial cost savings. The fall back will likely be traditional photo interpretation and ground visitation, both of which are costly alternatives.

Existing vegetation is alive and constantly changing due to man's and natures activities. Fire, floods, wind damage, harvest, land conversion, natural growth and mortality all lead to the need for map updating. Maintaining and updating maps for large changes can be directed using remote sensing based change detection and agency's activity records (Levien, 1998). More subtle changes in forest and shrub growth of structural characteristics, background mortality and successional changes will also lead to the need for updating, however, these changes will be harder to detect.

## Summary - Conclusion

National Standards are a new way of doing business. They provide the sideboards for developing consistent and shareable data within the Agency. Standards set the objectives for end products and approaches of known accuracy. These in turn will assist the Forest Service supportable management decisions based on sound vegetation resource information. Selection of appropriate imagery and mapping methods remains with the Remote Sensing and GIS specialist to develop consistent yet accurate maps in a cost efficient and timely way. Creativity should be directed at developing new methods for increasing map accuracy and utility, using the standards are the guide to developing sound resource information.

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