

Integrating Vegetation Classification, Mapping, and Strategic Inventory for Forest Management

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Abstract—Many of the analyses needed to address multiple resource issues are focused on vegetation pattern and process relationships and most rely on the data models produced from vegetation classification, mapping, and/or inventory. The Northern Region Vegetation Mapping Project (R1-VMP) data models are based on these three integrally related, yet separate processes. This paper describes the integration of vegetation classification, mapping, and inventory to produce the basic vegetation data for land and resource planning and management for the USDA Forest Service Northern Region. The conceptual relationships between classification, mapping, and inventory are discussed and the operational integration of the resulting data is described.

Introduction

Existing vegetation is the primary natural resource managed by the USDA Forest Service and most forest landowners and land management agencies. 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 scales. One of the fundamental informational needs in land management planning is consistent and continuous existing vegetation data of sufficient accuracy and precision to address resource analysis objectives. These analyses rely on the data models produced from vegetation classification, mapping, and/or inventory processes. This paper discusses the integration and utilization of these data models in the Northern Region Vegetation Mapping Project (R1-VMP).

R1-VMP provides robust existing vegetation information for a wide variety of analysis applications. R1-VMP data models are based on three integrally related, yet separate processes: vegetation classification, vegetation mapping, and vegetation inventory. The integration of these processes and the resulting data models represents the basic vegetation information used in resource planning and management by the USDA Forest Service Northern Region.

Maps are the most convenient and universally understood means to graphically represent the spatial arrangement and relationships among features on the earth's surface (Mosby 1980). A map is indispensable

for recording, communicating, and facilitating analysis of such information relating to a specific area. Maps are commonly used for inventorying, monitoring, and managing numerous resources on National Forests.

Historically, vegetation inventory and mapping was conducted through two-stage sampling of forest stands. This process consisted of the delineation of "timber stands" with stereo aerial photography. The basis for delineation of stands was discontinuities in texture (reflecting stocking and crown size differences) or apparent tree height (Stage and Alley 1972). The second stage was normally field sampling of all the delineated stands or a stratified random sample of the stands with subsequent inference to unsampled stands within the strata. This process also involved transferring the photo delineations to a base map. These stand delineations reflected management considerations as well as vegetative composition and structure and often included several vegetation types that were different in terms of composition and structure, but were similar in terms of management implications and/or history. The term stand was also extended to specifically describe conditions other than forested stands, such as non-forest vegetation, rock/barren areas, or water bodies. While extending the stand-mapping concept made these maps more comprehensive, they did not map fundamental units of vegetation that could be interpreted to address numerous questions. Another limitation of these data is that they apply almost exclusively to the suitable timber base, those areas outside the suitable base have few stand exam inventory data even though many of the questions

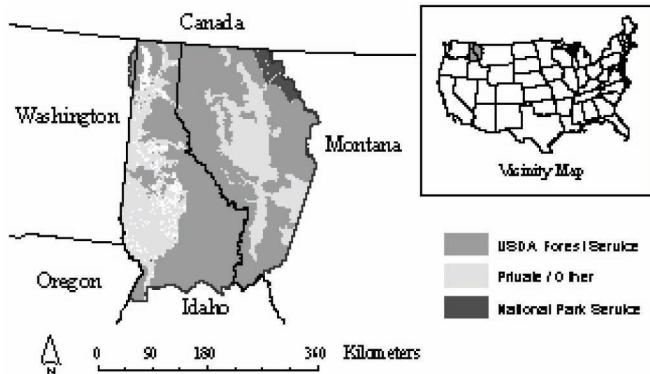


Figure 1. Northern Region Vegetation Mapping Project area.

and issues apply to all lands. Additionally, these maps represent a dynamic ecosystem component and have a finite period of currency.

In response to this informational need, the Regional Forester for the Northern Region initiated a R1-VMP to provide the Region and cooperating agencies with a geospatial database of land cover produced following consistent methods and mapped continuously across all ownerships. This database with associated inventory data provides the basis for vegetation pattern and process analyses to support land management planning. The project area for R1-VMP encompasses approximately 27,000,000 acres (11,000,000 hectares) of the USDA Forest Service, Northern Region (fig. 1).

In the early stages of the project it became obvious that R1-VMP was not a mapping project but, in fact, a classification, mapping, and inventory project. Numerous problems had been identified with the existing Regional classification logic and associated algorithms including the fact that the classes were not exhaustive and/or mutually exclusive and concerns regarding the integration of the maps inventory data were also raised. The R1-VMP team coordinated the effort to modify the classification logic and integrate strategic inventory data collected through the USDA Forest Service Forest Inventory and Analysis (FIA). Accordingly, this paper describes the general relationship of vegetation classification, mapping, and inventory and describes these processes relative to R1-VMP. A more detailed discussion of these relationships is included in Brohman and Bryant (2004).

General Relationship of Classification, Mapping, and Inventory

Vegetation classification is the process of grouping of similar entities into named types or classes based

on shared characteristics. Vegetation classification defines and describes vegetation types and/or structural characteristics (in other words, what is it?). **Vegetation mapping** is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characteristics. Vegetation mapping spatially depicts the distribution and pattern of vegetation types and/or structural characteristics (in other words, where is it?). Vegetation inventory is the process of applying an objective set of sampling methods to quantify the amount, composition, and condition of vegetation within specified limits of statistical precision. Vegetation inventory quantifies the amount, composition, and condition of vegetation (in other words, how much is there?). The conceptual relationships between classification, mapping, and inventory are schematically depicted in figure 2.

A one-to-one relationship between vegetation types (from a classification) and vegetation map units is uncommon given the limitations of mapping technology and the level of floristic detail in most classifications. Mapping, therefore, usually entails trade-offs among thematic and spatial resolution and accuracy, as well as cost. The goal is constrained optimization, not perfection. This problem is reduced somewhat when vegetation types, such as dominance types, and structural classifications are designed to be applied to mapping projects. Similarly, there is rarely a sufficient sample size to quantify all vegetation types so inventory compilation usually involves trade-offs to aggregate vegetation types and/or structural classes to achieve the desired sample size.

Because these ecosystems are dynamic, evolutionary, and have limited predictability many of the analyses needed for ecosystem management strategies require a variety of simulation models. The majority of these simulation models rely heavily on accurate and relatively detailed vegetation data. These models vary in the specific vegetation data needed and the detail needed in those data, but most of them require continuous spatial data with consistently classified attribute data. Classification, mapping, and inventory each contribute data to these simulation models.

Vegetation Classification

Following the general principles and the mid-level classification standards included in the Brohman and Bryant (2004), the Northern Region developed and adopted the following vegetation and landcover classifications.

Physiognomic and floristic classification

Physiognomic and floristic composition are the most fundamental components of a vegetation map. The

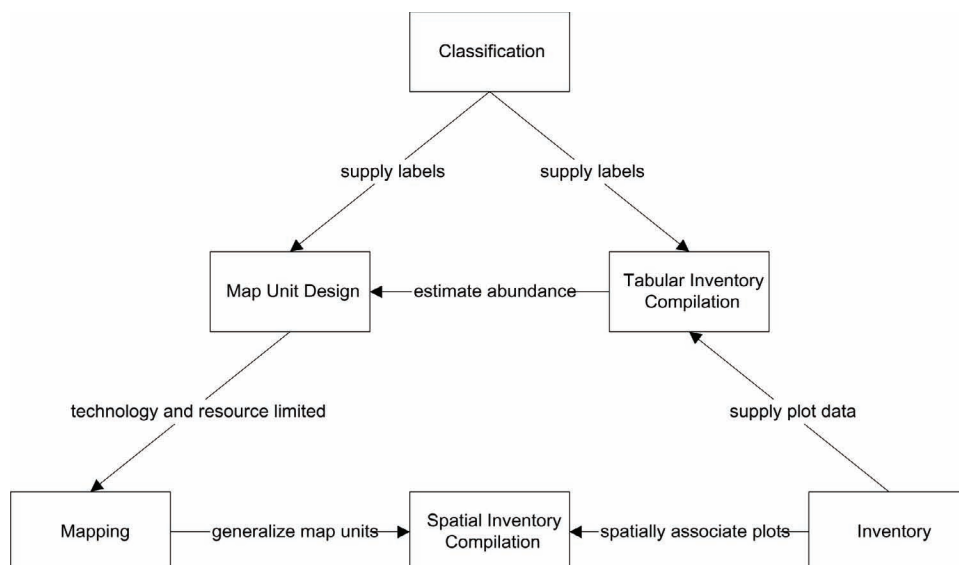


Figure 2. Relationships of vegetation classification, mapping, and inventory.

National Vegetation Classification (NVC) (FGDC 1997) has defined a hierarchical system for arranging these components into taxonomic units, which is the foundation for this mapping hierarchy.

Mapping continuous areas requires using land use and cover as well as vegetation classification systems. While many areas of the National Forests could be mapped using map units defined by vegetation physiognomic classification only, sparsely vegetated and non-vegetated areas mapped solely as such, give little information to the map user. Water was explicitly included as a lifeform-level land cover class and classes such as snow, clouds, and shadows were replaced using adjacent lifeforms. The lifeforms mapped in R1-VMP included:

- Grass/forb dominated lifeform
- Shrub dominated lifeform
- Tree dominated lifeform
- Water landcover
- Sparsely vegetated landcover

Floristic map units were based on a consistent classification of dominance types. Dominance types have been widely used in the development of map units where remotely sensed imagery is the primary basis for map feature delineation. "Dominance types provide a simple method of classification based on the floristic dominant (or group of closely related dominants) as assessed by some measure of importance such as biomass, density, height, or leaf-area cover (Kimmins 1997). They represent one of the lowest levels in several published classification hierarchies (for example, Cowardin and others 1979; Brown and others 1980)." The dominance type classification adopted for R1-VMP is based on relative canopy cover and is exhaustive and mutually exclusive. The basic classification logic is illustrated in the following tree dominance type key:

A. Single most abundant species > 60% of total canopy cover

List single species

A. Single most abundant species < 60% of total canopy cover

Go to B

B. 2 most abundant species > 80% of total canopy cover and each species individually is >20% of total canopy cover

List 2 species, in order of abundance

B. 2 most abundant species < 80% of total canopy cover

Go to C

C. 3 most abundant species > 80% of total canopy cover and each species individually is >20% of total canopy cover

List 3 species, in order of abundance

C. 3 most abundant species < 80% of total canopy cover

Go to D

D. Shade intolerant species total CC > shade tolerant species total CC

IMXS

D. Shade intolerant species total CC < shade tolerant species total CC

Go to E

E. GF+C+WH canopy cover > AF+S+MH canopy cover

TGCH

E. GF+C+WH canopy cover < AF+S+MH canopy cover

TASH

Tree diameter classification

Tree diameter class is defined here as any of the intervals into which a range of tree diameters may be

divided for classification (Helms 1998). In R1-VMP the mean diameter at breast height (4.5 ft. 1.37 m. above the ground) is calculated for the trees forming the upper or uppermost canopy layer (Helms 1998). This mean is calculated as the canopy-cover-weighted mean diameter (in inches). The tree diameter classes mapped in R1-VMP included:

- Seedling/Sapling (0 to 4.9)
- Small tree (5 to 9.9)
- Medium tree (10 to 14.9)
- Large tree (15 to 19.9)
- Very Large tree (20 +)

Tree canopy cover classification

Tree canopy cover is defined here as the total non-overlapping tree canopy in a delineated area as seen from above. (Note: Tree canopy cover is not defined by a hemispherical projection as seen from below.) Tree canopy cover below ten percent is considered a non-tree polygon. The tree canopy cover breaks are consistent with the physiognomic class breaks for vegetation. The tree canopy cover classes mapped in R1-VMP included:

- Low (10 to 24.9 percent)
- Moderate (25 to 59.9 percent)
- High (60 to 100 percent)

Map Design

Map design involves two fundamental processes: map unit design and map feature design. Map unit design identifies the vegetation characteristics to be mapped and assembles or develops classification keys for each of the map attributes used to describe those characteristics. This process establishes the relationship between vegetation classification and mapping. Map feature design, concurrently, identifies the spatial characteristics and structure of the map.

A vegetation map unit is a collection of areas defined and named the same in terms of their component classes from the classifications described above (adapted from USDA, Soil Survey Division Staff 1993). The map unit design process establishes the criteria used to aggregate or differentiate vegetation classes to establish corresponding map units. Therefore, a mapping unit is comprised of one or more classes from one or more specific classifications. The criteria used to aggregate or differentiate within physiognomic types, dominance types, or structural classes to form mapping units will depend on the purpose of, and the resources devoted to, any particular mapping project (Jennings and others 2002). For example, map units designed to provide information on existing forest structure to characterize wildlife habitat or fuel condition

would be based on a combination of tree canopy cover classes and tree diameter classes. The map unit design process is more complex for floristic classifications than for relatively simple structural classifications.

Map units depicted on maps within individual areas or delineations that are non-overlapping and geographically unique are referred to as **map features** (in other words, polygon delineations or region delineations). Typically, one map unit is repeated across the landscape in many individual map feature delineations. The map design process for the primary R1-VMP map products is described in the following sections.

Physiognomic and floristic map design

The lifeform and landcover classes described above were adopted and mapped as classified. A variable minimum map feature (MMF) standard was implemented as follows:

- Grass/forb dominated lifeform (2.5 Acre MMF)
- Shrub dominated lifeform (2.5 Acre MMF)
- Tree dominated lifeform (5 Acre MMF)
- Water landcover (1 Acre MMF)
- Sparsely vegetated landcover (5 Acre MMF)

The dominance type map units, tree canopy cover map units, and tree diameter map units, described above nest hierarchically under lifeform and follow the same minimum map feature standard.

The dominance type classification described above was aggregated and generalized using the following logic to identify the map units used in R1-VMP.

Dominance Type 1 – Elemental Classification (Dom1)

Classification Rule set:

1 species >60% tot CC

that species

2species >80% tot CC

those 2-species - listed in order of abundance

3species >80% tot CC

those 3-species - listed in order of abundance

Shade intol > Shade tol

IMXS [intolerant mixed spp.]

Shade tol > shade intol

G, WRC,WH > AF,ES,MH

TGCH

G, WRC,WH < AF,ES,MH

TASH

Results in Over 850 Different Types

Dominance Type 4 –Species Groups (Dom4)

Classification Rule set:

1-species: same as DOM1

2-species: All 2-species DOM1-types with the same most abundant species are grouped into SPPP-1MIX [for example ABGR-PSME, ABGR-PICO, etc = ABGR-1MIX]

3-species: All 3-species types with the same most abundant species [from DOM1] are grouped into SPPP-2MIX [for example ABGR-PSME-PICO, ABGR-PICO-LAOC, etc = ABGR-2MIX]

IMXS, TASH, TGCH: same as DOM1

Results in 42 Different Types

Dominance Type 4m –Species Groups Map Units
[Dom4m]

Map Unit Design

A frequency distribution of DOM4 types is made from FIA PSU data.

If either the single-species or the single-species-1MIX are less than 1% of the total number of forested FIA PSUs, they are collapsed into a single-species mega-mix [SPPP-MMIX].

All 3-species DOM1 types [or DOM4, SPPP-2MIX] are collapsed into IMXS, TASH, or TGCH.

Results in 15 To 18 Different Types

Tree diameter class and tree canopy cover class map designs

The tree diameter classes and the tree canopy cover classes described above were mapped as classified.

Vegetation Mapping

Vegetation mapping is the process of delineating the geographic distribution, extent, and landscape patterns of vegetation types and/or structural characteristics. Satellite-based remote sensing classifications with their associated GIS coverages or grids and attribute databases have increasingly been used for large area, low-cost vegetation and landcover mapping (Lachowski and others 1996; Redmond and others 1996; Johnston and others 1997; Cohen and others 1998; Mickelson and others 1998; Stoms and others 1998). These satellite-based classifications are gradually replacing aerial photography as the primary image data for vegetation mapping. Wynne and Carter (1997) compare characteristics of satellite remote sensing data and aerial photography relative to these mapping applications:

- Satellite images are digital; they provide direct and cost effective GIS coverages and databases. The spatially accurate conversion of aerial photo delineations to digital coverage is expensive and time consuming.
- Digital images are easy to send over computer networks; they can be delivered within hours of acquisition.

- Given a specified resolution, satellite images typically provide greater coverage than aerial photography.
- Satellite images often have better geometric fidelity than aerial photos because of their altitude and stability of orbits.
- Some spaceborne sensors include wavelengths band, such as mid-infrared, and thermal infrared, that cannot be detected by film.
- Repeat coverage is easily obtained; it is easily co-registered and used for applications such as change detection and monitoring.

The USDA Forest Service national direction contained in Brewer and others (2004) reflects the trend toward the use of satellite remote sensing classification for vegetation mapping. The following sections, excerpted and condensed from Brewer and others (2003), describe the analytical logic and general methodology utilized in the R1-VMP mapping process.

Acquisition and pre-processing of image and ancillary data

Landsat TM imagery was chosen for this work because the near-infrared and mid-infrared reflectance of vegetation is strongly related to important vegetation canopy characteristics. Additionally, the high spectral resolution of Landsat TM imagery was preferred above the high spatial resolution of other sensors, such as SPOT. Additionally, Landsat TM data are acquired continuously and archived data could be purchased to meet the time and area needs. Landsat TM data can also be purchased as “floating scene” or “path-level” data purchasing the equivalent of up to three TM scenes as a single field of view, thereby reducing the image handling and pre-processing requirements as well as costs.

A good seasonal image data acquisition window for forest vegetation opens slightly after the date at which the forest vegetation is fully mature and closes just prior to its senescence. In this case, the “peak green” and “fall” image data were obtained from the EROS Data Center. All images were ortho-rectified to previously terrain-corrected images for the respective paths using the Geometric Correction Module and the Landsat orbit model in ERDAS IMAGINE as well as 7.5-minute digital elevation models.

Ecogeographic stratification

Lilles and Kiefer (2000) discuss the commonality of using ancillary data to perform geographic stratification of an image dataset prior to classification. They further describe the aim of this process is to “...subdivide an image into a series of relatively homogeneous geographic areas (strata) that are then classified separately.”

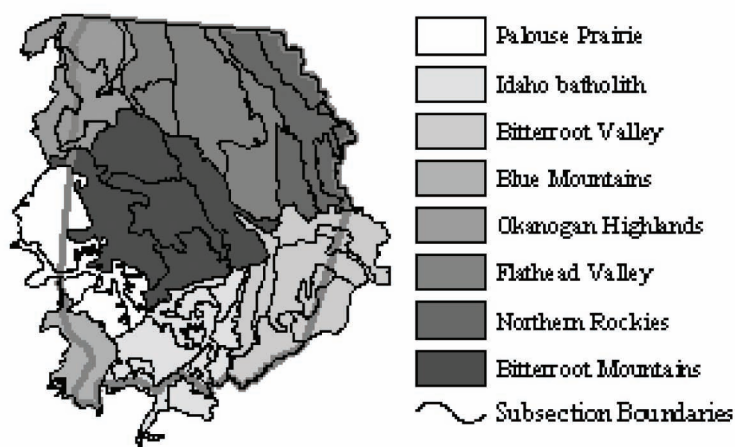


Figure 3. Section- and Subsection-level delineations in the ECOMAP hierarchy.

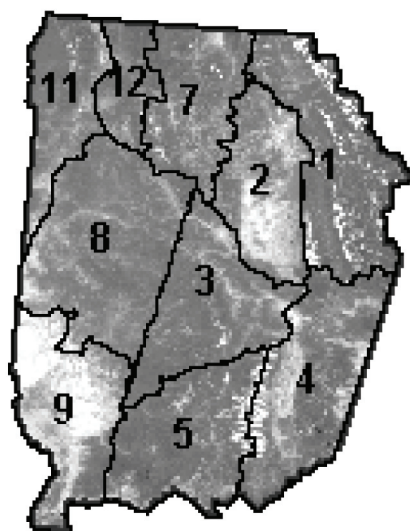


Figure 4. Sub-path data models used for ecogeographic stratification of Landsat ETM floating scenes.

The homogeneity of these geographic areas is largely determined by the composition of biophysical environments included in the stratification. These biophysical environment settings are important for stratification in this type of project because they facilitate the delineation and description of ecosystems that behave in a similar manner and influence the natural disturbance processes that create finer-scale vegetation patterns (Jensen and others 1997). The USDA Forest Service National Hierarchical Framework of Ecological Units (Bailey and others 1994) provided the delineations used for geographic stratification of the R1-VMP project area. The appropriate level of this hierarchy for ecogeographic stratification in this project is the section-level delineation described by McNab and Avers (1994) and illustrated in figure 3. These delineations were used to stratify Landsat

ETM floating scene sets resulting in ten sub-path data models (fig. 4) rather than eight Landsat TM scene models. This stratification improves model performance by limiting the variance associated with vegetation types and increases the utility of reference data.

Image segmentation

As stated in Ryerd and Woodcock (1996), “Image segmentation is the process of dividing digital images into spatially cohesive units, or regions. These regions represent discrete objects or areas in the image.” This segmentation and merging process is influenced by

the variance structure of the image data and provides the modeling units that reflect life form composition, stocking, tree crown size differences, and other vegetation and/or landcover characteristics (Haralick and Shapiro 1985; Ryerd and Woodcock 1996). Segmentation and merging of Landsat ETM satellite imagery in R1-VMP utilized the segmentation functionality within the software eCognition (Baatz and others 2001). The segmentation process in eCognition is based on both the local variance structure within the imagery and shape indices. This segmentation process produced image objects that served as the base classification units within the object-oriented classification programs. The image objects delineated through the R1-VMP image segmentation process and modeled in eCognition readily aggregate thematically and comprise vegetation and landcover patches that represent the various map units in the hierarchy.

Change detection

Change detection methodologies using digital data have been used extensively for a wide variety of analysis applications including: fire impact studies (Parra and others 1996), land cover change in wetland areas (Hashem and others 1996; Mahlke 1996), air pollution damage detection (Hogda and others 1995; Solheim and others 1995), and forest-canopy change (Coppin and Bauer 1994; 1995). Within the context of the vegetation mapping objectives R1-VMP, the change detection method is designed to exploit phenological differences in vegetation types (in other words, deciduous tree or shrub species dominance types or senescent grasses and forb species dominance types). Coppin and others (2001) demonstrated that a solid biophysical link is found between forest canopy features and the Kauth-Thomas transform, a particular case of a principal components analysis. The three main components of Kauth-Thomas variability are termed brightness, greenness and wetness and are the result of a Gram-Schmidt orthogonalization

process (Kauth and Thomas 1976). Changes in these three components constituted the basis of the R1-VMP analytical logic to exploit phenological differences in vegetation types.

Ecological modeling and other ancillary data

Ecological modeling and other ancillary data were used extensively by R1-VMP to improve classification results. These ecological modeling approaches were incorporated into the multi-source system through knowledge-based classification and reference data stratification within the object-oriented image analysis software, eCognition (Baatz and others 2001). This process facilitated the use of additional data such as potential vegetation settings (Pfister and others 1977; Mueggler and Stewart 1980; Cooper and others 1991), subsection level ecological units (McNab and Avers 1994), topography, and image illumination strata for grouping or splitting classes to improve classification accuracy (Cibula and Nyquist 1987; Bolstad and Lillesand 1992; Cohen and Spies 1992; Brown and others 1993; Coppin and Bauer 1994; Goodchild 1994). In addition to PNV and subsection level ecological units, R1-VMP incorporated two indices of insolation derived from combinations of slope and aspect generated from 30m DEM data. R1-VMP also stratified the image data by the illumination at the time of image acquisition. Additional ancillary data were provided by fire severity data classifying recently burned areas, operationally produced by the USDA Forest Service (Gmelin and Brewer 2002) following major fire events in 2000 and 2001 and were used to characterize first order fire effects on vegetation. These data were generated from a Normalized Difference Burn Ratio (NBR) analytical approach, following Key and Benson (1999) as adapted by Brewer and others (In press).

Reference data

The most common sources of reference data for remote sensing projects are aerial photo interpretation and field data collection. It is quite common for remote sensing projects to use photo interpretation as a primary source of reference data or to combine these two sources. In R1-VMP, training and accuracy assessment data were generated through a structured aerial photo interpretation process that integrated a variety of field sampled inventory datasets. Our experience suggests that an aerial perspective is often useful for remote sensing training data acquisition and that skilled interpreters can add local knowledge and experience to the classification process. Additionally, resource aerial photography remains the most commonly available remotely sensed data source. Common image interpretation techniques were used to characterize elements of vegetation pattern

that comprise lifeform, dominance type, tree size class, and tree canopy cover (Avery 1977; Campbell 1987; Lillesand and Kiefer 1987; Lachowski and others 1996). The variables collected include lifeform/landuse class cover percent and connectivity, dominance type cover percent and connectivity, tree size class cover percent, tree canopy cover percent, and connectivity, and total vegetation canopy cover percent. Field-sampled tree, vegetation composition, and ground-cover composition data were collected on a subset of a randomly-selected set of region-polygons as a means to validate the photo interpretation reference data collection.

Hierarchical classification

A nested hierarchical classification scheme (described above under vegetation classification) was applied in R1-VMP that used membership functions derived from knowledge bases for the physiognomic and structural classifications and fuzzy-set classifiers based on reference data and nearest neighbor algorithms for the dominance type classification. This design provided a consistent linkage between the dominance type and structural classifications commonly used by the agency at the mid-level and the physiognomic classifications used at the broad-level and national-level and required by the FGDC vegetation classification standards (Brohman and Bryant 2004).

Implementation of this classification hierarchy produces separate GIS coverages, grids, and associated geospatial databases for four primary attributes. These attributes include lifeform, dominance type, tree canopy cover, and tree size class. The hypothetical dominance type, tree size class, and tree canopy cover map products included in figure 5 illustrate the relationships of these attributes to the original image objects. These original image objects were merged following the minimum map feature standards. The merged image objects were then used to produce the GIS coverages and grids for the four primary map products. Any combination of these four primary map products could be produced to meet specific analysis objectives, with the logic of the combination defined by the end user.

Vegetation Inventory

The vegetation inventory data for most land management agencies and private companies only partially covers their ownership, are often out of date, and are rarely compatible with adjacent landowners. This is particularly true for federal land management agencies such as the USDA Forest Service, Northern Region, that manage large geographic areas for a variety of management objectives. Historically, most ground-based inventory data have been collected using standard plot

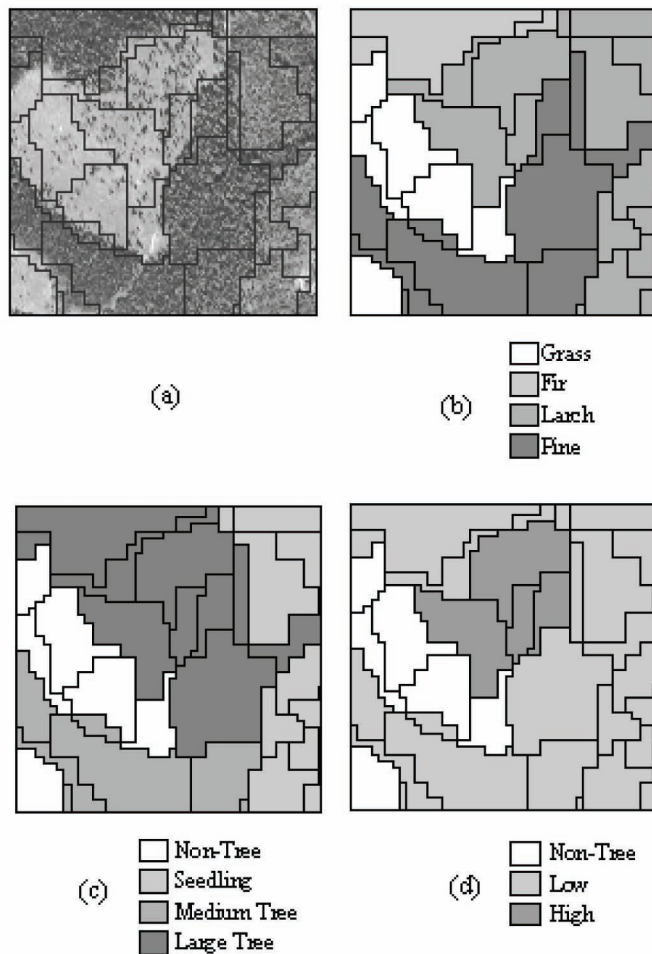


Figure 5. Hypothetical classification attributes (map units) and image objects. a) base imagery, b) dominance type, c) tree size class, d) tree canopy cover.

and quick plot stand exams (USDA Forest Service, FSH 2709). Using the USDA Forest Service, Northern Region, as an example, Brewer and others (2002) observed that most of these data apply almost exclusively to the suitable timber base, as defined by the National Forest Management Act of 1976 (US Public Law 94-588 1976). The remaining areas outside the suitable base have few stand exam data even though many of the resource questions and issues apply to all lands. The collection of stand-based data on part of the land base introduces an unknown bias when these data are used to represent the whole land base. In addition, there are no specific design considerations for the collection and storage of these data to facilitate their use by other land management agencies or private landowners.

Declining budgets for public land management agencies have resulted in dramatic reductions in the amount and geographic extent of current, detailed inventory data. The precipitous decline in standard plot

and quick plot stand exams reflects budget trends for inventory programs throughout the USDA Forest Service. Brewer and others (2002) describe the effects of these reductions on current data and graphically depict the status of stand exam based inventory data for the USDA Forest Service, Northern Region (fig. 6). This graph illustrates the decline in acreage of stand exams, by year, from 1980 to 2001.

Reductions in timber sale programs on public lands, particularly National Forests, have had effects on the management (in other words, harvest schedules) of both industrial and non-industrial private forests (Flowers and others 1993). This change in harvest schedules has affected the currency and completeness of inventory data from private forests; proprietary data private forest landowners are reluctant to share.

Given the discontinuous and incomplete nature of most forest inventory data, as well as the difficulty in maintaining currency and sharing with other landowners, data generated by the Forest Inventory and Analysis (FIA) program of the USDA Forest Service provides a viable alternative. FIA utilizes a systematic random grid of plot clusters, re-measured periodically, to monitor the extent, condition, uses, impacts of management, and health of forest ecosystems across all ownerships in the United States. These data provide an unbiased sample for many inventory related questions. The Society of American Foresters (2000) state that “FIA is the only program that monitors the extent, condition, uses, impacts of management, and health of forest ecosystems across the United States.” They further state... “FIA data serve as the foundation of large-scale policy studies and perform a pivotal role in public and private forest planning.” They cite examples of regional and sub-regional analyses that influence major economic and ecological management decisions including:

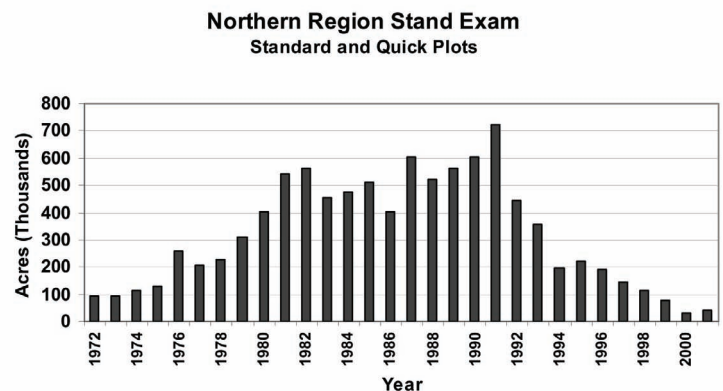


Figure 6. USDA Forest Service, Northern Region, stand exam program status summary for 1980 to 2001. USDA Forest Service, Northern Region, stand exam program status summary for 1980 to 2001.

- Strategic planning efforts by wood-using industries routinely incorporate FIA data into timber supply and timber product outputs.
- Development of criteria and indicators of forest sustainability depend on the growth removals, and inventory data compiled by FIA (Reams and others 1999).
- National forest carbon budgets for reporting under international agreements are dependent on FIA data (Heath and Birdsey 1997).
- Assessment of ecological change and economic damage resulting from disasters such as hurricanes or widespread wildfires.

Van Deusen and others (1999) suggest a current and accurate forest ecosystem inventory is prerequisite to substantive discussion of issues like sustainability, national forest policy, carbon sequestration, changes in growth and productivity, changes in landuse and demographics, ecosystem health, and economic opportunities in the forest sector.

Over the past decade concerns have been raised regarding the currency of FIA data, historically re-measured every 6 to 18 years (Gillespie 1999). These concerns prompted the American Forest and Paper Association (AF&PA) to convene two Blue Ribbon Panels on FIA (AF&PA 1992, 1998). The high level of user community support and concerns regarding currency of FIA data surfaced by these panels and subsequent Congressional hearings resulted in legislation to implement an annualized forest inventory and monitoring program to reduce the re-measurement interval (Czaplewski 1999). It is expected that the annualized inventory design will result in substantial improvements in the currency of FIA data.

Historically, the FIA program produced area estimates of forest types in two phases following a double sampling design (Reams and VanDeusen 1999). Phase one placed a systematic random grid on aerial photography (normally 1:40,000 scale National Aerial Photography Program NAPP). These points (with a minimum area of at least 1 acre or a strip at least 250 feet wide) were then classified as forest or non-forest based on the FIA definition of at least 10% tree canopy cover. The second phase sub-sampled the first phase points in the field to confirm the classification. This process provided the forest area estimation for the application of the field sampling of the permanent plot clusters in the third phase. Reams and VanDeusen (1999) suggest the following three problems associated with this historical method:

- No forest non-forest map is produced
- The photo interpretation process is time-consuming and labor intensive
- Current aerial photography is not always available

These issues become increasingly problematic with the shift to an annualized inventory program. R1-VMP utilizes FIA data for two important processes. In the map unit design process FIA data are classified and utilized to estimate abundance of dominance types. These estimates are used to define the dominance types with sufficient aerial extent to include as a map unit and to identify logical aggregation strategies for dominance types with insufficient extents. The FIA data are also used for the development of sample-based map unit descriptions. In this process the FIA data are spatially associated to the R1-VMP map products and are then compiled to quantify various vegetation characteristics for each of the thematic classes in the map product (for example, dominance types, tree diameter classes, and/or tree size classes). The compilation of the FIA data by R1-VMP map classes represents the final step in the integration of classification, mapping and inventory to support forest management in the USDA Forest Service Northern Region.

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