CHAPTER 2

LAND COVER CLASSIFICATION AND MAPPING

2.1 Introduction

Mapping natural land cover requires a higher level of effort than the development of data for animal species, agency ownership, or land management, yet it is no more important for gap analysis than any other data layer. Generally, the mapping of land cover is done by adopting or developing a land cover classification system, delineating areas of relative homogeneity, then labeling these areas using categories defined by the classification system. More detailed attributes of the individual areas are added as more information becomes available, and a process of validating both polygon pattern and labels is applied for editing and revising the map. This is done in an iterative fashion, with the results from one step causing re-evaluation of results from another step. Finally, an assessment of the overall accuracy of the data is conducted. The final assessment of accuracy will show where improvements should be made in the next update (Stoms et al. 1994.)

In its "coarse filter" approach to conservation biology (e.g., Jenkins 1985, Noss 1987), gap analysis relies on maps of dominant natural land cover types as the most fundamental spatial component of the analysis (Scott et al. 1993) for terrestrial environments. For the purposes of GAP, most of the land surface of interest (natural) can be characterized by its dominant vegetation.

Vegetation patterns are an integrated reflection of the physical and chemical factors that shape the environment of a given land area (Whittaker 1965.) They also are determinants for overall biological diversity patterns (Franklin 1993, Levin 1981, Noss 1990), and they can be used as a currency for habitat types in conservation evaluations (Specht 1975, Austin 1991.) As such, dominant vegetation types need to be recognized over their entire ranges of distribution (Bourgeron et al. 1994) for beta-scale analysis (*sensu* Whittaker 1960, 1977.) These patterns cannot be acceptably mapped from any single source of remotely sensed imagery, therefore, ancillary data, previous maps, and field surveys are used. The central concept is that the physiognomic and floristic characteristics of vegetation (and, in the absence of vegetation, other physical structures) across the land surface can be used to define biologically meaningful biogeographic patterns. There may be considerable variation in the floristics of subcanopy vegetation layers (community association) that are not resolved when mapping at the level of dominant canopy vegetation types (alliance), and there is a need to address this part of the diversity of nature. As information accumulates from field studies on patterns of variation in understory layers, it can be attributed to the mapped units of alliances.

2.2 Land Cover Classification

Land cover classifications must rely on specified attributes, such as the structural features of plants, their floristic composition, or environmental conditions, to consistently differentiate categories (Küchler and Zonneveld 1988.) The criteria for a land cover classification system for GAP are: (a) an ability to distinguish areas of different actual dominant vegetation; (b) a utility for modeling vertebrate species habitats; (c) a suitability for use within and among biogeographic regions; (d) an applicability to Landsat Thematic Mapper (TM) imagery for both rendering a base map and from which to extract basic patterns (GAP relies on a wide array of information sources, TM offers a convenient meso-scale base map in addition to being one source of actual land cover information); (e) a framework that can interface with classification systems used by other organizations and nations to the greatest extent possible; and (f) a capability to fit, both categorically and spatially, with classifications of other themes such as agricultural and built environments.

For GAP, the system that fits best is referred to as the National Vegetation Classification System (NVCS) (FGDC, 1997.) The origin of this system was referred to as the UNESCO/TNC system (Lins and Kleckner in press) because it is based on the structural characteristics of vegetation derived by Mueller-Dombois and Ellenberg (1974), adopted by the United Nations Educational, Scientific, and Cultural Organization (UNESCO 1973) and later modified for application to the United States by Driscoll et al. (1983, 1984.) The Nature Conservancy, Natural Heritage Network (Grossman et al. 1994), and NatureServe have been improving upon this system in recent years with partial funding supplied by GAP. The basic assumptions and definitions for this system have been described by Jennings (1993.) The basic units of vegetation classification in the NVCS are termed “alliances”.

The National Vegetation Classification System was adapted for vegetation mapping in West Virginia by aggregating alliance-level vegetation classes into alliance groups / ecological complexes. The alliance level represents vegetation based on species composition of the dominant vegetation type such as the forest over-story deciduous trees. The most detailed level of the National Vegetation Classification System is the community, which includes species composition for multiple vegetation physiognomic types such as trees, shrubs, ground covers and herbaceous vegetation.

Alliance groups or ecological complexes created and used by WV-GAP represent natural groupings of alliance level vegetation classes based on physiognomic (structural), species composition, and ecological characteristics. Alliance aggregation was required since the draft Nature Conservancy alliance list for West Virginia (Sneddon et al., 1994) was still under revision during the planning stages of this work. Any future revisions of West Virginia alliances will be taken into account in future, more detailed mapping to be based on groups designated by NatureServe ecologists. Alliance additions can also be easily incorporated into the WV-GAP ecological complex classification system.

It proved extremely difficult to describe and map detailed vegetation alliances for West Virginia with Landsat TM data due to structural and ecological similarity of the alliances and the coarse spectral and spatial nature of the data. Future vegetation mapping could potentially utilize improved data sources such as Landsat 7 – ETM+ or IKONOS satellite data. This would allow future efforts to map more precise vegetation classes and be compatible with this mapping for updating and time series comparison purposes.

Figure 2-1. WV-GAP Alliance Group development framework.

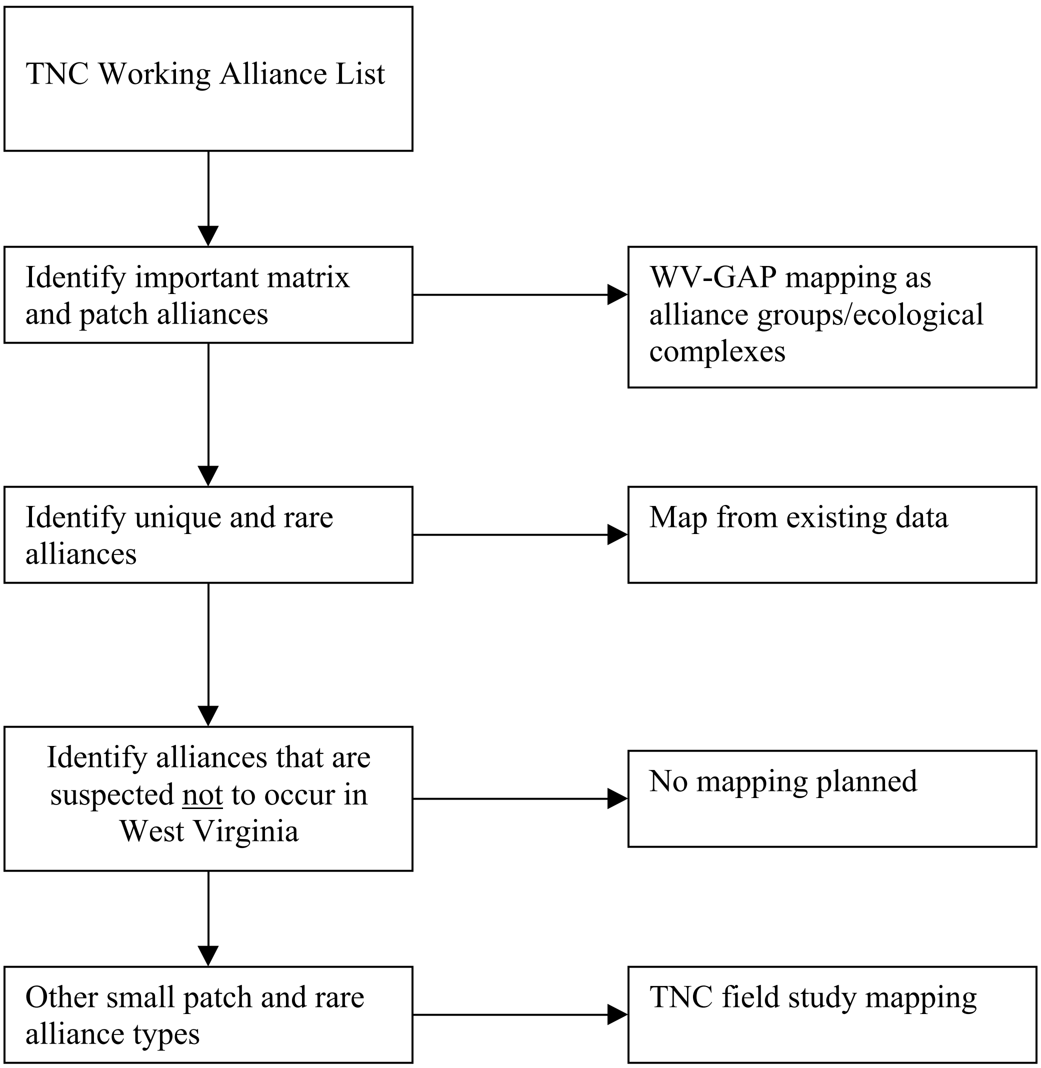


Figure 2-1 illustrates the approach that was used to develop the Alliance Groups for WV-GAP. A working list of alliances was obtained from TNC. This list was reviewed by an informal panel of experts and the important forest patch and forest matrix alliances (alliances with significant area extents) were selected and grouped into alliance groups / ecological complexes by WV-GAP. These alliance groups were mapped and classified using Landsat TM and associated GIS ancillary data such as topography, surface hydrology, historic land use, and forestry data. Alliances that appeared on the draft TNC alliance list (Sneddon et al., 1994) that were not suspected to actually occur in West Virginia were excluded from the project, at least for the present.

In addition, important or critical unique and rare alliance types and specialized habitat features were identified. These alliances were incorporated into the project database for mapping only when sufficient existing map and tabular data existed. The extent of many of these areas is generally so minor that mapping from satellite data was not possible. Examples of such areas include cave entrances, shale barrens, and hillside springs.

2.3 Mapping Standards

WV-GAP developed mapping standards to be compatible with overall GAP standards recognizing limitations in available existing data sets and conditions in the West Virginia landscape that make mapping natural vegetation extremely difficult. Among these conditions are the extremely uneven mountainous terrain and poorly defined boundaries between different vegetation communities and land uses.

2.3.1 Positional / Location Standards

Landsat images were registered and rectified so that major linear features were no more than three pixels offset from the feature location in ancillary data themes such as USGS Digital Line Graph data for streams, roads, and power lines. This represents a general offset of no more than 75 meters. At the time the images were registered, the only available ancillary data for registration and rectification were 1:100,000 Digital Line Graphs and scanned USGS 1:24,000 quadrangle maps that were scanned but not rectified to current USGS DRG standards. The only approach to improving this positional accuracy would necessarily include ortho-rectification.

2.3.2 Classification Standards

The classification standards that were developed for WV-GAP were derived from Lillesand and Kiefer (1992.) These standards included:

1. Reaching an acceptable minimum level of classification accuracy that would be similar for all vegetation (alliance groups) and disturbed land cover or land use classes.
2. Repeatability of results if the same methodology is followed for updates and time comparisons.
3. The same methodology could be applied over the entire state recognizing peculiarities of the available satellite data set, including no consistency in imagery dates for both leaf-off and leaf-on imagery. The classification would utilize mutually exclusive categories that would capture meaningful differences in natural and disturbed land cover in the West Virginia landscape.
4. The resulting mapping categories would be divisible into more detailed categories: Alliances for natural land cover types and land uses for disturbed land cover types.
5. Aggregation of categories would be possible for use with other data sets such as the National Land Cover Dataset (NLCD.)

2.3.3 Minimum Mapping Unit

The minimum mapping unit (MMU) for land cover mapping for WV-GAP is approximately one hectare (ha). The final land cover map was the result of multi-stage filtering of 30m pixel data, so a precise final minimum mapping unit was not actually applied to the project. Polygons smaller than one hectare were maintained in our final mapping if the polygons were not removed during filtering and data merging processes.

2.4 Methods

WV-GAP followed a modified supervised classification method for land cover mapping (Figure 2-2.) The major elements of this methodology are listed here and described subsequently in greater detail.

- Georeferencing and segmenting TM imagery
- Pre-classification operations
- Use of aerial videography
- Image clustering
- Classification/cluster assignment
- Ancillary data sources for cluster labeling
- Edge matching, adjustments
- Filtering and spatial merging

Figure 2-2. WV-GAP remote sensing classification methodology.

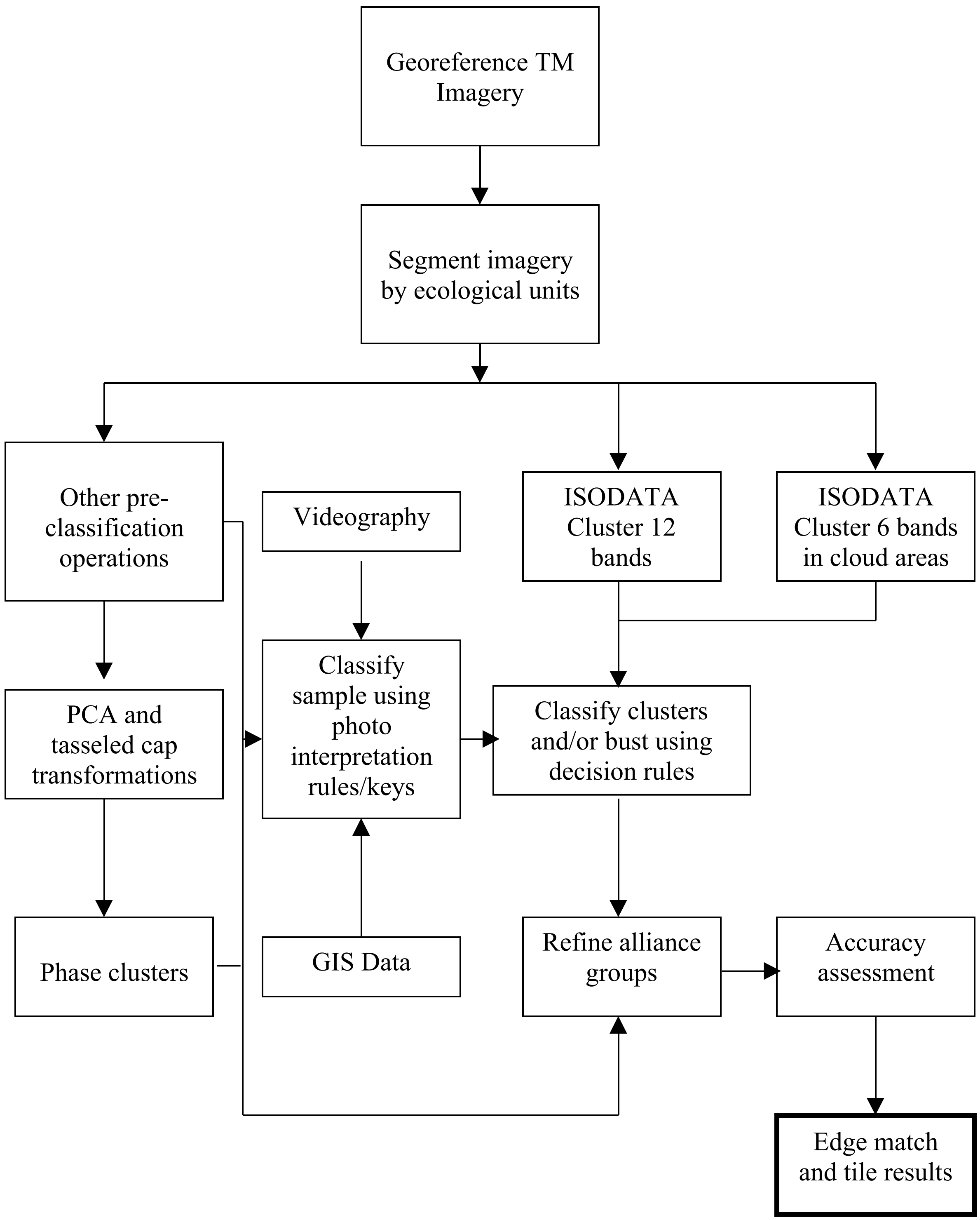
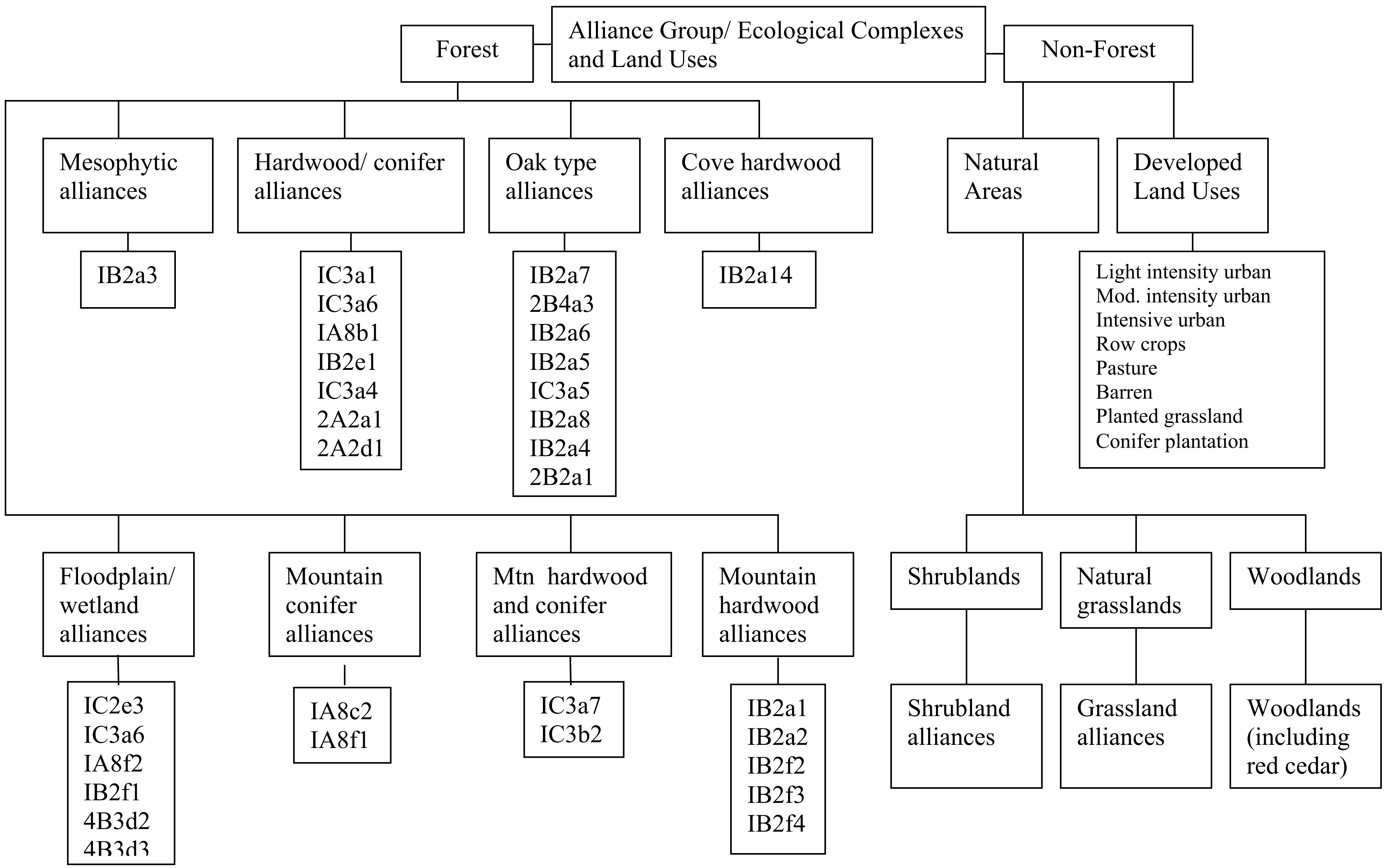


Figure 2-3. WV-GAP land cover classification framework.



2.4.1 The Land Cover Classification Scheme

The Land Cover Classification Scheme that was developed combined the Alliance Groups for categorization of natural land cover types and land use categories for description of man-influenced for disturbed cover types (Figure 2-3.) The scheme was developed as a nested classification using the following classification framework.

- Separation of forest and non-forest cover types by clustering TM data.
- Grouping forest cover types into alliance groups – associated Alliances are included and identified by pertinent TNC alliance codes (TNC 1996.)
- Separation of non-forest cover types into non-forest natural cover, surface water, and developed land uses using satellite data classification and ancillary GIS data.
- Separation of non-forest natural cover types into wetlands, shrublands, grasslands, and woodland Alliance groups using satellite data classification and ancillary data.
- Identification of all surface water features using satellite data classification and ancillary data.
- Separation of developed land uses into appropriate land use categories using satellite data classification and ancillary data. Land use categories were defined to be compatible with the developing National Land Cover Data Set (NLCD) and historic data sets such as USGS Land Cover (LUDA) data with either direct cross-walks or category aggregation.

2.4.2 Imagery Used and Classification Procedures

WV-GAP utilized TM data that was obtained as part of an initial Multi-Resolution Landscape Characterization (MRLC) data procurement. Eight TM scenes are required for full statewide coverage (Figure 2-4.) The initial 1992 – 1995 scenes were augmented with three additional scenes because of poor image quality in the initial data. Even with these additional scenes, cloud cover was present in the majority of the data. Only two flightline-adjacent scenes were procured for the same date with less than 10% cloud cover. Following are more detailed discussions of our image classification procedures.

Two seasons of imagery (leaf-on, leaf-off) were obtained for statewide coverage. Some of the images were from less than optimal dates due to cloudy conditions that are prevalent in the Central Appalachians in the spring and summer months.

Georeferencing and Segmenting TM Imagery

The images were geo-referenced to the best available ancillary reference data, generally 1:100,000 Digital Line Graph (DLG) data.

Images were subdivided by scene according to USDA Forest Service “ecological regions” or subsections which are broad land areas with similar landform, geologic, and vegetation characteristics (Figure 1-1, Figure 2-4.) These areas were subdivided to develop “response units” for data analysis and classification. These units were therefore similar not only in landform, geology, and vegetation, but in spectral response as captured by the individual satellite images.

The goal of this procedure was to classify these subsection / image areas independently. This approach accounted for the vegetation and land use similarity of each ecological subsection in addition to the spectral characteristics of each scene due to atmospheric and time-of-the-year differences. This produced a total of 29 subsection and TM scene combinations that were each classified separately (Figure 2-4.) TM scenes were clipped to allow a 100 m buffer between subsection boundaries and a 1,000 m buffer along the state border.

Pre-classification Operations

The segmented images were processed using a number of pre-classification operations to provide improved image characteristics for classification and anecdotal review. These included principal components, tasseled cap transformations and phase clusters (which are used to develop images suitable for visual interpretation.) The resulting principal components and phase cluster images were not used directly in the classification process but rather were developed for use as extra supporting data for analysis.

Use of Aerial Videography

Due to inadequate classification support and field verification data, videography imagery was flown to develop high-resolution Global Positioning System (GPS) linked data that could be treated as ground sampled data for classification support. The data were flown at two different resolutions with linked cameras providing one-half kilometer and thirty meter image swaths for the entire state. Flight lines were generally oriented in a north-south direction with an average fifteen-minute flight line spacing. Over 250,000 frames of videography were obtained and approximately 40,000 frames were actually classified using manual photo-interpretation / heads-up digitizing and classification. The project Alliance Group and land use categories were used for this classification.

The videography points were classified using standard visual photo-interpretation methods. Once the videography data were collected, we identified a sample of 250 points for field visitation to collect species data for photo-interpretation training. These data were used to guide the photo-interpretation process by developing species keys for labeling the vegetation type in each high-resolution videography frame. Over 40,000 videography frames were classified during this effort. Individual vegetation species were identified and natural cover types and land uses were assigned based on a rule set that considered vegetation species importance and a range of land use signature keys. A GIS point coverage was developed for the location and assigned land cover class for the classified videography frames.

Image Clustering

A modified unsupervised classification approach was utilized for image classification. The segmented two-season TM images were initially clustered into 255 clusters using all available bands except for the thermal band. Where significant cloud cover existed, one season or the other was clustered into 255 clusters. Clustering was performed using Isodata clustering, which is an iterative clustering routine used to identify natural groupings of data (ESRI 2001, Richards 1986, Ball and Hall 1965.)

Classification/Cluster Assignment

Videography classification and ancillary GIS were utilized to develop rules to assign clusters with an associated Alliance Group or land use category. Classification methods also included aggregating multiple clusters, breaking clusters up into multiple land uses or Alliance Groups, and in some cases overriding the resulting categories with ancillary data. Cluster labeling was primarily based on the most likely land cover class (from cross-tabulation with classified videography point locations) and the interpreter's best judgment considering the ancillary data. In certain cases, decision rules based on slope / aspect, elevation, and generalized soils also were applied to cluster labeling.

Figure 2-4. Landsat TM scenes used for WV-GAP land cover classification. Path/row for each scene is indicated by numbers within the scene boundaries. Scene boundaries are represented with dashed lines and subsection boundaries are thin solid lines. Subsection names are found on Figure 1-1.

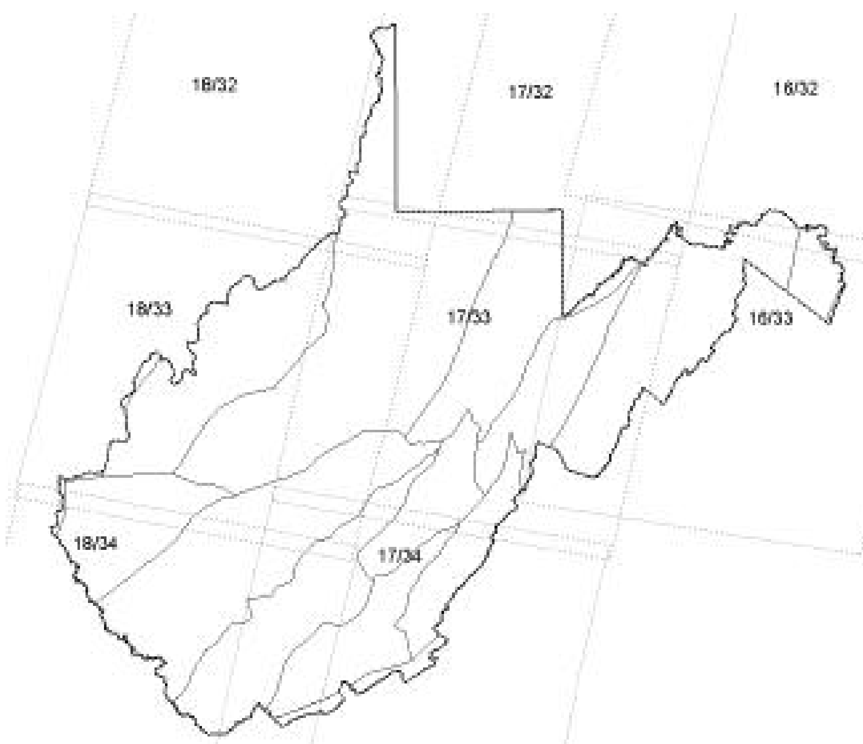


Table 2-1. Ancillary data sets used to aid cluster labeling for land cover mapping in West Virginia.

Data	Source	Date
MRLC Land Cover for West Virginia	EPA	1991-1993
USGS GIRAS land use data	USGS	1976
Historic Land Cover for West Virginia	WVDNR	1950
Spruce/mountain conifer stand maps	USFS	1988-1989
Timber stand maps	Private corporations	1993
National Wetlands Inventory digital data	USFWS	Varies
1:24,000 Digital Raster Graphics	USGS	Varies
1:100,000 Digital Line Graphs	USGS	Varies
USFS FIA data points and tabular data	USFS	1992
River Reach Hydrography, version 3	EPA	
NRCS STATSGO soils data	NRCS	1992
Population data – 1990 and 1996	Census Bureau	1996
Slope, aspect derived from 30m Digital Elevation Models	USGS	-

Ancillary Data Sources for Cluster Labeling

While the primary reference data source for cluster labeling was the videography points, other ancillary data sets also were used for reference (Table 2-1.) Certain land cover types in the ecological subsection/TM scene combinations lacked sufficient videography points for cluster labeling. This was generally due to a relatively small patch size or regular pattern (e.g., occurrence in narrow north / south oriented valleys) for certain cover types that resulted in those cover types being underrepresented in the videography due to the systematic pattern of videography data collection.

An important ancillary data source proved to be the historic 1950s vegetation maps that were available for the entire state (West Virginia Conservation Commission and USDA Forest Service, 1950.) These maps were the result of an intensive five-year photo-interpretation and field data collection effort resulting in highly detailed mapping units and classification categories. These 1950s vegetation maps were scanned and digitized as part of WV-GAP. We also examined 1992 Forest Inventory and Analysis (FIA) data to verify that many of the cover types that were identified on the historic maps were essentially still intact. FIA data points were used to generate a point to polygon GIS coverage for the state. These data were compared to the general vegetation patterns in the historic data to separate stable and transitory vegetation types in the historic data. Other historic maps also were utilized to identify areas of continuous natural vegetation coverage since the 1950s.

Edge Matching, Adjustments

Once all clusters for each subsection and scene combination (29 sub-study areas) had been assigned to a land cover class, all classified grids were merged into a single statewide classified land cover grid. A second-degree polynomial transformation was applied to the preliminary statewide land cover to improve the registration of the final grid. Transformation was performed using the Warp Environment Sample Extension for ArcView GIS (ESRI 1998.) The original subsection/scene images had been individually registered and rectified; however, certain areas of the state still required additional adjustment.

Certain TM images acquired by WV-GAP were not completely cloud-free, which produced minor "no data" areas in the final classified land cover grids. Image registration also produced slight gaps (only a few cells wide) at scene borders in two cases. In order to produce a seamless final land cover map product, "replacement" data was inserted for the cloud areas and image seam gaps.

Replacement data were derived from MRLC land cover data for West Virginia (EPA 1993.) MRLC forest data types (deciduous, mixed, coniferous) were cross-walked to the more detailed WV-GAP forest cover types based on the predominant forest cover types and the cluster labeling decision rules for that particular ecological subsection. For example, the TM imagery for Western Coalfields subsection contained a fair amount of cloud cover for all available imagery dates. The predominant deciduous cover type in this subsection is diverse/mesophytic hardwood forest, so MRLC deciduous forest cells were assigned to this cover type before insertion into the WV-GAP land cover grid based on the occurrence rules for diverse / mesophytic hardwood forest in that particular subsection if no other ancillary data were available.

Certain types of land cover features are difficult to distinguish clearly or completely with satellite image classification techniques due to the size or shape of the features and confusion with other cover types (e.g., maintaining a continuous powerline feature.) To improve the spatial representation of wetland and anthropogenic features in our final land cover grid, we superimposed "masks" of these features over or in conjunction with the results of the cluster labeling described previously. A mask of certain forest types was also superimposed over the cluster labeling results to improve classification of commonly confused forest types.

Wetland and surface water features make a significant contribution to wildlife habitat in the state. There are two relatively large wetland areas in West Virginia (Canaan Valley and the Meadow River wetlands complex), and a multitude of smaller wetland features. However, it is difficult to adequately capture these smaller features using 30m satellite imagery. We chose to incorporate the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) data into our final land cover map as a means of ensuring that wetland features were not excluded or overlooked. The NWI data were available in digital form for the entire state of West Virginia. The NWI wetland areas are classified according to Cowardin et al., (1979.) We chose to group the NWI wetlands into 4 major classes for purposes of the WV-GAP land cover map: herbaceous wetland (includes NWI palustrine emergent wetlands), forested wetland (NWI palustrine forested), shrub wetland (NWI scrub-shrub wetlands), and surface water (NWI open water, rivers, and all other palustrine categories.) Surface water features were also augmented with reservoirs and major rivers (5^{th} order and above) from the EPA River Reach version 3 digital data for West Virginia. Where wetlands were lost to subsequent urbanization or other disturbance additional masking was utilized to update these wetland features.

An anthropogenic features mask was applied to the clustered land cover results to improve the spatial integrity of urban land cover classes and to add linear features not always captured by 30m satellite imagery (Table 2-2.) Various classes of urban land cover were captured as a result of the cluster labeling process. However, linear features such as major roadways and powerline cuts were occasionally incompletely represented by the classified cluster data, as these features may not completely fill given 30 meter pixels.

Linear anthropogenic features (roads, powerlines) were superimposed after the filtering and merging process described in the following section after it was discovered that the merging process tended to over-emphasize and widen these linear features.

Table 2-2. Human-influenced land cover classes superimposed on classified cluster land cover grid.

Land Cover Class	Data Source
Populated areas	US Census Bureau 1990,1996
Light intensity urban	MRLC
Moderate intensity urban	MRLC
Intensive urban	MRLC
Major highways	USGS DLG data for WV interstates 79, 68, 81, 77, and 64
Major powerlines	USGS DLG data

Historic forested land cover data were also incorporated as a mask superimposed on the classified cluster land cover grid. Historic data were incorporated on a limited basis for certain WV-GAP land cover classes, and only in subsections for cover types where cluster labeling was considered to be confused (Table 2-2.) Addition of historic data was limited to areas classified as forested by the WV-GAP cluster labeling. Historic data included the1950 land cover and 1988 spruce/mountain conifer data from the U.S. Forest Service Northeast Forest Experiment Station. Subsections where this technique was applied are detailed in Appendix 2-3.

Floodplain areas were determined from path distance analysis of slope surrounding 5^{th} order and above streams (see Section 3.3.5.) Cells classified by WV-GAP cluster labeling as forest within floodplain/riparian areas were recoded as having floodplain forest land cover for the final WV-GAP land cover map. Floodplain forest types were generally under-represented in the videography sample in all ecological subsections due to the narrow form of floodplains in West Virginia.

Filtering and Spatial Merging

Following cluster labeling and the addition of the superimposed mask data, different spatial filtering techniques were applied to the resulting preliminary statewide land cover grid. Filtering procedures are often used to reduce the inherent heterogeneity that results from numerical image classification techniques, such as clustering. We first applied a majority filter, which acts as a 3x3 pixel moving window to smooth pixel values based on the values of surrounding pixels. This type of filter helps to eliminate single pixel areas of different land classes.

After majority filtering, the resulting land cover grid was subjected to a spatial land cover class merging process. We used the Mega Merge version 5.2 intelligent filtering program to merge pixels with adjacent areas of similar land cover classes (Ford and Barsness 1998.) Similarity of land cover classes was controlled through a cover class similarity matrix, and certain cover classes were excluded from merging (including surface water and wetland features.) The Mega Merge program also allows the user to specify minimum mapping unit size (in pixels) and cell neighborhood. For creation of the final WV-GAP land cover map, we used a 9 pixel minimum mapping unit (0.81 ha) and a 4 cell neighborhood. An 8-cell neighborhood produced more "speckle" in the output data sets. Following the Mega Merge process, the output grids were majority filtered one additional time.

The final WV-GAP land cover map was produced by superimposing the non-linear anthropogenic features upon the majority filtered Mega Merge output grids. The result was then clipped to the WV state border. The resulting land cover grid has 25 different mapped land cover classes (Table 2-3.) Slightly different Mega Merge specifications were used to produce the final WV-GAP habitat map (detailed in next section.)

2.4.3 Habitat Map Development

The final land cover map for WV-GAP animal species distribution modeling was produced with slightly different specifications than the land cover map. In order to produce a more manageable habitat map file size, the final habitat map was created using a 25 cell minimum mapping unit input to the Mega Merge software. Certain land cover classes in the resulting grids were also combined for purposes of mapping animal distributions (populated areas were merged with light intensity urban, and powerline cuts were merged with shrubland.) The final habitat map was converted to polygon topology, and totaled just under 260,000 polygons statewide. Habitat polygons were then intersected with subsection boundaries to eliminate large polygons of a single cover type that extended across large portions of the state.

2.5 Results

The WV-GAP land cover classification system uses 24 land cover types, including 10 natural or forested land cover types, 4 water or wetland cover types, 4 agricultural cover types, and 6 development-influenced cover types (Figure 2-5, Appendix 2-3.)

As previously described, the 10 natural or forested land cover types represent aggregate alliance groups or ecological complexes that are logical groupings of the more detailed alliance-based cover types (Sneddon et al., 1994). These groups were derived on the basis of ecological, structural, and species similarity of the alliance cover types. The 4 water or wetland cover types (excluding forested wetlands) represent aggregate Cowardin / NWI wetland groups and are compatible with the MRLC and National Land Cover (NLCD) dataset wetland categories. The 4 agricultural categories also were developed to be compatible with MRLC and NLCD data. The 6 development influenced cover types represent cover types that are both logical Anderson Level 2 aggregations and are obtainable with the desired precision from satellite and ancillary data.

West Virginia is dominated by forested land cover types that occupy over three-quarters of the state (Table 2-3.) The majority of the forested area in the state is diverse mixed mesophytic hardwood forest. Oak dominant forest covers one-fifth of the state, while northern forest types (mountain hardwoods and conifers) concentrated in the higher elevations cover almost 11 % of West Virginia. Only 3.6 percent of the state's land falls into developed cover classes, with just under 16% of the state in agricultural land uses. Agricultural lands are most often pasture or old fields rather than row crops. All final land cover area figures were computed from 30x30 m grid cells, and areas are approximate.

Table 2-3. Total area (ha) and percent of state's area for 24 land cover classes mapped by WV-GAP. General land use category totals are also given in bold.

Cover Type	**Mapped Area (ha)**	**% of State's Area**
Developed Lands	**228,956.0**	**3.6**
Major roads	3,015.4	0.0
Major powerlines	18,856.4	0.3
Light intensity urban	111,044.5	1.8
Moderate intensity urban	31,365.0	0.5
Intensive urban	19,620.6	0.3
Agricultural Lands	**987,330.5**	**15.7**
Planted grassland	835.8	0.0
Conifer plantation	14,015.9	0.2
Row crop agriculture	35,372.5	0.6
Pasture/grassland	937,106.3	14.9
Shrubland/Woodland	**131,996.8**	**2.1**
Shrubland	79,610.4	1.3
Woodland	52,386.4	0.8
Forested Lands	**4,820,420.5**	**76.8**
Floodplain forest	41,831.6	0.7
Cove hardwood forest	196,461.0	3.1
Diverse/mesophytic hardwood forest	2,382,945.7	38.0
Hardwood/conifer forest	250,658.6	4.0
Oak dominant forest	1,263,191.0	20.1
Mountain hardwood forest	653,079.5	10.4
Mountain hardwood/conifer forest	20,805.7	0.3
Mountain conifer forest	11,447.6	0.2
Barren Lands	**45,054.1**	**0.7**
Barren land - mining, construction	45,054.1	0.7
Water/Wetlands	**106,068.8**	**1.7**
Surface water	85,145.4	1.4
Forested wetland	5,358.3	0.1
Shrub wetland	4,715.4	0.1
Herbaceous wetland	10,849.7	0.2
TOTAL	**6,274,772.6**	**100.0**

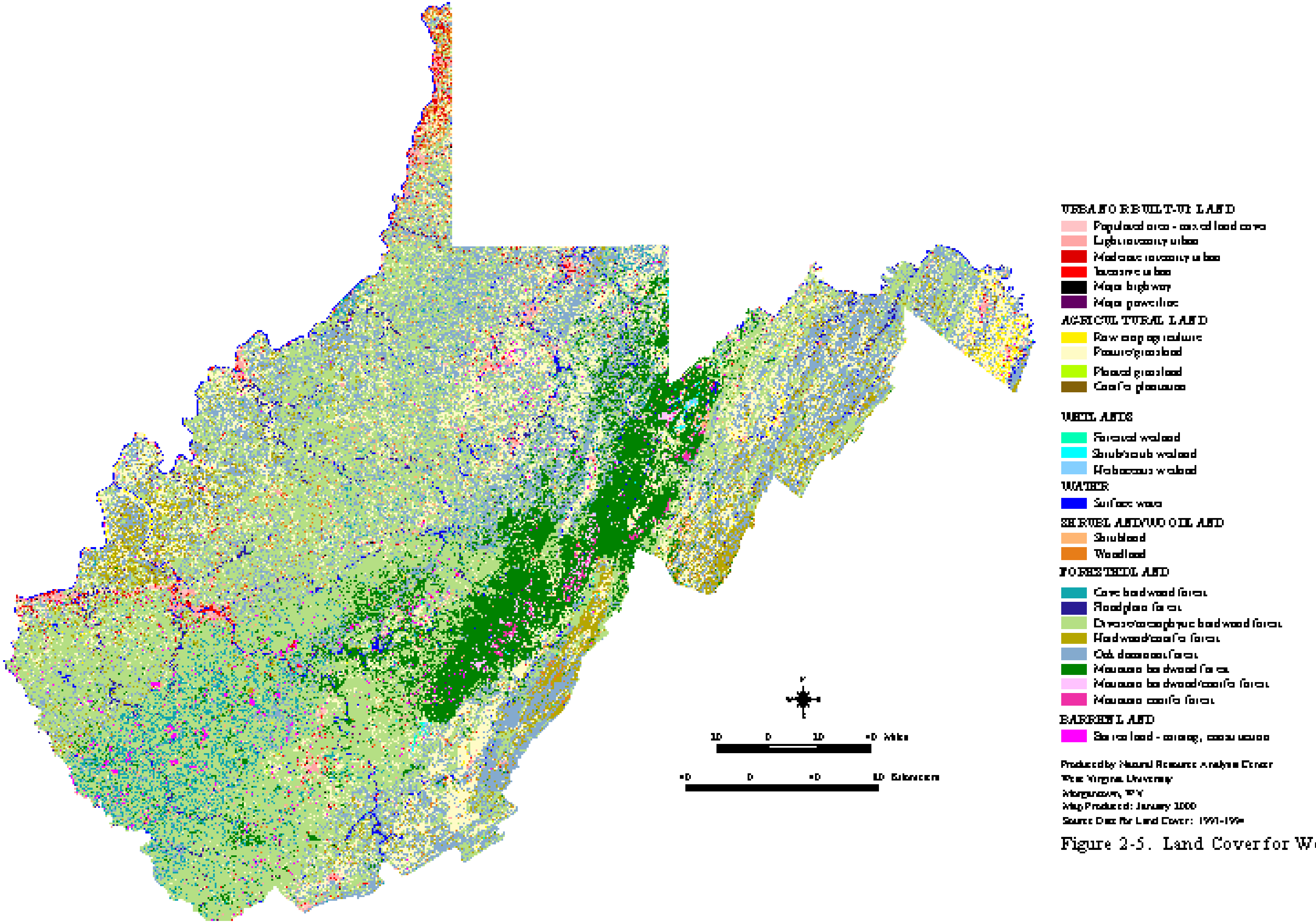


Figure 2-5. Land Cover for West Virginia

2.6 Accuracy Assessment

2.6.1 Introduction

GAP land cover maps are primarily compiled to answer the fundamental question in gap analysis: what is the current distribution and management status of the nation's major natural land cover types and wildlife habitats? Besides giving a measure of overall reliability of the land cover map for Gap Analysis, the assessment also identifies which general classes or which regions of the map do not meet the accuracy objectives for the Gap Analysis Program. Thus the assessment identifies where additional effort will be required when the map is updated. We report the results of the accuracy assessment, believing that the map is the best map currently available for the project area.

The purpose of accuracy assessment is to allow a potential user to determine the map's "fitness for use" for their application. It is impossible for the original cartographer to anticipate all future applications of a land cover map, so the assessment should provide enough information for the user to evaluate fitness for their unique purpose. This can be described as the degree to which the data quality characteristics collectively suit an intended application. The information reported includes details on the database's spatial, thematic, and temporal characteristics and their accuracy.

Assessment data are valuable for purposes beyond their immediate application to estimating accuracy of a land cover map. The reference data is therefore made available to other agencies and organizations for use in their own land cover characterization and map accuracy assessments (see Data Availability – Chapter 7 - for access information.) The data set will also serve as an important training data source for later updates.

Even though we have reached an endpoint in the mapping process where products are made available to others, the gap analysis process should be considered dynamic. We envision that maps will be refined and updated on a regular schedule. The assessment data will be used to refine GAP maps iteratively by identifying where the land cover map is inaccurate and where more effort is required to bring the maps up to accuracy standards. In addition, the field sampling may identify new classes that were not identified at all during the initial mapping process.

2.6.2 Methods

The basis for the WV-GAP accuracy assessment was comparison of WV-GAP land cover classifications with land cover classifications from two existing and two new data sets. Comparisons were completed on a pixel basis.

Datasets used for accuracy assessment comparisons (with limitations noted) include:

1. USDA Forest Service Forest Inventory and Analysis (FIA) data points. Due to data confidentiality requirements, exact West Virginia FIA point locations and associated data could not be obtained. Instead, WV-GAP provided the Forest Service's Northeast Experiment Station FIA Program with a copy of the GAP land cover results and the Forest Service then provided a correspondence table of FIA data results and the associated GAP land cover categories without the location data. However, the detail associated with the FIA data required that category cross-walks be developed for all of the cover types. Data for 1,800 FIA data points were obtained (out of the approximately 5,000 FIA points in West Virginia) but only 1,400 data points were used because:

    a. Some points represented rare or unique cover types with areas too small or occurrences too limited to be addressed by WV-GAP at present.
    b. The Forest Service acknowledged positional accuracy limitations with some of the data.

2. WV-GAP field plots. WV-GAP established approximately 200 permanent-vegetation plots statewide during the initial phases of the project. Plot location data were captured using differentially corrected GPS. Plot information was collected for over-story vegetation as well as shrub and herbaceous layers under the canopy. Vegetation mapping accuracy assessment utilized 160 of these plots. Some plots were excluded since they captured either atypical or rare and unique natural cover types that were currently not the focus of WV-GAP. In addition, it became apparent during data verification that there were positional problems with some of the plots. WV-GAP cover types were cross-walked from vegetation importance data that were calculated for each plot and compared with the associated WV-GAP cover types from the land cover map.

3. Digital Ortho-quarter Quadrangle (DOQQ) photo-interpretation. Statewide DOQQ coverage for West Virginia became available during late 1998. The DOQQs were utilized to provide limited accuracy assessment for primarily disturbed cover types, particularly urban and agricultural cover types. Forest and other natural cover type areas were masked out of the WV-GAP map and 150 points were randomly selected. The DOQQs were then photo-interpreted and a WV-GAP cover type was assigned to each point.

4. WV-GAP videography points. A sample of classified WV-GAP videography points (reserved from use in cluster labeling) were interpreted and aggregated into generalized "super classes." A comparison of the videography points and associated WV-GAP map results was completed to test the WV-GAP map at a generalized cover type level.

2.6.3 Results

FIA Comparison

Approximately 1,400 FIA plots (points) were examined to test the relationship between the FIA cover types and the associated WV-GAP alliance groups. An extensive data set is available for each FIA point (USDA Forest Service 1992) composed of a range of vegetation species, site quality, land cover and forest management variables. We selected the TYPCUR variable for this accuracy assessment. The TYPCUR variable represents the current predominant forest type in the plot. It is based on the tree species that forms the plurality of all live trees in the plot. The crosswalk from TYPCUR to WV-GAP alliance group was not straightforward because there are 75 TYPCUR forest types potentially occurring in West Virginia. Developing crosswalks for a number of the types proved difficult due to the very species-specific categories used to define the TYPCUR categories. The alliance groups are combined aggregate species/ecological position groupings so there is not a definition correspondence between the two data sets. Simple comparison yielded a 69% correspondence between the two data sets. It was originally anticipated that this correspondence would be higher. However, difficulties in using the FIA data may somewhat limit its use for accuracy assessment of the WV-GAP results using the current set of alliance groups. A partial error matrix for forested points only may be found in Appendix 2-4.

These difficulties included positional inaccuracies with the FIA data. The FIA plot locations may be greater than 100 meters offset from the recorded positions. This limits their use for forest cover type mapping because of the relatively small unevenly shaped forest patch size that is characteristic of the Central Appalachian hardwood forest. This forest type pattern requires fairly exact positional precision for any data used for accuracy comparison with the classified areas.

Crosswalk difficulties were also encountered. A number of the cover type crosswalks were based on best judgments and not quantitative criteria. It would be valuable to work with the Forest Service to include their input into crosswalk definitions for future WV-GAP land cover map revisions. Better alliance group definitions and refinements should also aid in improving the relationship between FIA and WV-GAP mapping and classification efforts.

WV-GAP Field Plot Comparison

Each WV-GAP vegetation field plot was cross-walked to the nearest or most comparable WV-GAP alliance group. Field plots were then compared with the associated WV-GAP cover type map alliance groups. For the 160 plots that were used, there was a resulting 77% correspondence (122 plots) at the alliance group between the two data sets. Omission and commission errors were not calculated because of the relatively small sample size.

WV-GAP Photo-interpretation Point Comparison

WV-GAP developed land cover (land use) and agricultural land uses were compared with the associated WV-GAP land cover map categories that were assigned by photo-interpretation to point locations for 150 points (polygons were actually photo-interpreted but only the point location results were compared.) This was not done for the WV-GAP alliance groups because the 1:40,000 color infrared leaf-off DOQQ imagery could not be reasonably photo-interpreted to the alliance group level. The results indicated an 83% correspondence between the photo-interpretation results and the associated WV-GAP land cover categories. Again, omission and commission errors were not calculated.

Videography Interpretation Results

A large sample of videography points was selected for accuracy assessment at the superclass or aggregate level. The following tables (Table 2-4, Table 2-5) summarize the results of this assessment for three general land cover classes – forested, agriculture, and urban/developed.

Table 2-4. Comparison of mapped land cover superclasses to aerial videography points (% of points), producer accuracy (bold) on diagonal, commission errors are other cells. N is total number of cells (mapped land use/land cover.)

Map	Videography Points			
	Forested	Agriculture	Developed	N
Forested	**91.0**	5.6	3.4	502
Agriculture	11.8	**76.1**	12.1	331
Developed	3.5	24.3	**72.2**	115
TOTAL				948

Table 2-5. Comparison of mapped land cover superclasses to aerial videography points (% of points), user accuracy (bold) on diagonal, omission errors are other cells. N is total number of points (video.)

Map	Videography Points		
	Forested	Agriculture	Developed
Forested	**91.4**	9.1	12.1
Agriculture	7.8	**81.8**	28.6
Developed	0.8	9.1	**59.3**
N	500	308	140

2.7 Limitations and Discussion

WV-GAP land cover mapping standards and methodology were developed as a result of adapting the standard Gap mapping techniques to particular difficulties encountered in West Virginia. West Virginia's mountainous terrain and patchy forest distribution, and complex mosaic of forest types provided many challenges in land cover mapping for WV-GAP. WV-GAP final land cover map as associated wildlife habitat maps are best viewed as general approximations of ecological conditions, as natural boundaries are not nearly as distinct as those represented in digital or printed forms of these data.

The WV-GAP land cover accuracy assessment was constructed to provide a reasonable estimate of the accuracy of the land cover map and categories by way of comparison with a couple of relevant available and newly developed data sets. A number of other data sets such as the NWI wetlands and the National Land Cover Data (NLCD) data were not used for accuracy assessment because of prior use as ancillary or collateral data during WV-GAP image classification efforts.

The results of the accuracy assessment indicate strong positive correspondence between these data sets and the resulting WV-GAP land cover mapping. WV-GAP results compare favorably with data that were gathered with far greater per-unit area intensity of effort (e.g., on-the-ground vegetation sampling and manual photo-interpretation.) The FIA and WV-GAP plot data required developing and applying land cover type cross-walks and this certainly decreased the utility of those two data sets for comparative accuracy assessment purposes.

2.8 Summary and Conclusions

The WV-GAP land cover map provides a snapshot view of West Virginia's physical and ecological landscape. After a long history of deforestation and timbering, West Virginia today is again extensively forested (over 76%), dominated by predominantly mixed mesophytic deciduous forest. The natural land cover types mapped by WV-GAP are referred to as "Ecological Complexes" or "Alliance Groups" and form a best approximation of a highly diverse and varied landscape. Ecological Complexes or Alliance Groups represent aggregations of NLCD vegetation alliances that were developed by WV-GAP. Developed cover types comprised under 3% of the state's area, and just over 15% of the state is found in agricultural land use, the majority of this in pasture or old field.