

Relationships and Divergence of Vegetation and Mapping Classifications

Douglas M. Muchoney

Conservation and Research Center
National Zoological Park
Smithsonian Institution
1500 Remount Road
Front Royal, Virginia 22630
NZPEM055.SIVM.SI.EDU

Remote sensing data are used to identify conservation sites, to direct field sampling and research for biological and ecological data acquisition and to provide mapped descriptions of landscape units at varying spatial and temporal scales. Remote sensing-based mapping is reliant on classification systems describing natural and modified vegetation communities for the development of correspondingly appropriate map units.

Mapping of vegetation classifications has generally relied on the use of remotely sensed data to define landscape patches, or polygons, and to relate a class identifier to these polygons. This is the point where many of the current problems in landcover mapping occur. The field data-derived classes are stripped of their quantitative underpinnings and converted to nominal (categorical) variables for one-to-one translation to map units. This process substantially reduces the dimensionality and content of the original data, and inappropriately attempts a translation contrary to spatial and temporal scales. Mapping should be equally dependent on analysis of quantitative field data rather than solely aerial photography, videography, satellite image, biogeophysical or other thematic map data interpretation, which has generally not been the case. More thoughtful approaches must be developed that allow for the parameterization of biogeophysical data and relationship to specific remote sensing data and types of analysis.

The purpose of this paper is provide an analysis of the relationship between ecological classification and mapping, and the development of functional remote sensing-based classifications to support landscape-level characterization. Recommendations on the integration of classification development and refinement are provided.

1.0 INTRODUCTION

Remote sensing can be defined as the measurement or acquisition of information of some property of an object or phenomena by a recording device that is not in direct or physical contact with the object or phenomenon, or more simply "the acquisition of information about an object without physical contact" (Simonett 1983). Remote sensing allows for changing the vantage point from which the environment is observed, hence its application to local, regional and global studies. Remote sensing data have been used extensively for the mapping and characterization of habitat and natural communities. Remote sensing data are acquired from both air and space-borne analog (photographic and videographic) and digital sensors. These data are visualized and analyzed in both digital and film formats and are often used to derive thematic information to describe physical and biological elements of the landscape.

Remote sensing data, techniques and methods have been used to provide the multiple scale, current information required to support biological inventory and vegetation mapping. Remote sensing data are used to identify conservation sites, to direct field sampling and research for biological and

PROCEEDINGS OF THE 5th ASIS SIG/CR CLASSIFICATION RESEARCH WORKSHOP

ecological data acquisition and to provide mapped descriptions of landscape units at varying spatial and temporal scales. Remote sensing-based mapping is reliant on classifications of natural and modified vegetation communities for the development of correspondingly appropriate map units. The resulting maps may be representations of vegetation classes based on structural, physiognomic or species parameters. Remote sensing analogues to these classifications may also be based on observable parameters such as reflectance or radiation, texture and leaf area. There are three representations of vegetation and ecological community types that must be considered in the development of ecological relevant maps from using remotely-sensed data:

1. Reality, which is the intrinsic nature of the vegetation.
2. Classification systems which are generalizations of reality. These are developed through quantitative analysis of field data using techniques such as statistical clustering and ordination.
3. Remote sensing-based maps where remote sensing data are used to apply a vegetation or ecological community to a landscape.

The purpose of this paper is provide an analysis of the relationship between ecological classification and mapping, and the development of functional remote sensing-based classifications to support landscape-level characterization. Recommendations on the integration of classification development and refinement are provided. The discussion does not address related topics regarding other conservation objectives or remote sensing data and systems.

2.0 CLASSIFICATION AND MAPPING

2.1 Vegetation and Ecosystem Classification

For the purposes of this paper, a classification is defined as a systematic organization and description of landscape parameters into homogeneous units based on criteria or decision rules. As in statistical clustering, the objectives are to minimize intra-class variance and maximize inter-class variance. The purpose of a classification can be to simplify descriptions of vegetation and to create standards for evaluation (Mueller-Dombois and Ellenberg 1974) and to permit information storage and the analysis of vegetation at different levels of abstraction (Fosberg 1967).

The first systematic descriptions of vegetation were developed by Von Humboldt (1806) who categorized recurring vegetation patterns and growth forms into types and Schouw (1823) who developed systematic descriptions of plant communities. Previous work consisted primarily of landscape unit description which led to identification of distinctions between life-form and vegetation types (Mueller-Dombois and Ellenberg 1974).

Vegetation classification developed in the 20th century to allow for standardization for further description, research and comparison between types (Mueller-Dombois and Ellenberg 1974). Classification evolved into methods based on either subdivision of vegetation units based on their differences (divisive clustering) or segregation of minimum units and their subsequent aggregation based on measures or perceptions of similarity (agglomerative clustering) (Fosberg 1967).

The habitat type approach (Daubenmire 1952) to landscape mapping is based on habitat factors being represented within existing vegetation as an indicator of ecosystem units (Komarkova 1983). In these systems, different vegetation units represent a different habitat type or that set of environments that support a stable or climax plant community. Potential natural vegetation (PNV)

is a conceptual abstraction based on existing vegetation, developmental tendencies and site relationships (Kuchler 1964, Mueller-Dombois 1984). PNV is generally not appropriate for vegetation or habitat mapping since it does not represent current or even projected condition.

2.2 Classification Systems and Criteria

The criteria for classification are generally based on functional and structural attributes of vegetation. Primary classification schemes represent phytosociological, physiognomic and floristic criteria and categorization can be largely considered as being physiognomic-structural, floristic, physiognomic-floristic, dynamic-floristic, areal-geographic and ecological based (see Table 1.) (Kuchler 1988). The most prominent classification systems in use have been the physiognomic classification of Kuchler (1949), physiognomic-structural classifications by Schimper (1898), Schimper and von Faber (Schimper and von Faber 1935), Beard (1944), and UNESCO (1973), and the ecosystem classifications of Fosberg (1967). For detailed discussion of classification approaches and history, see Whittaker (1962), Mueller-Dombois and Ellenberg (1974) and Kuchler (1988).

Classification systems are based on vegetation characteristics which correspond to the nature of the classification system. Table 2B lists generic or standard classification system units and an incomplete list of related system unit characteristics. A floristic classification system may be based on dominant species or the presence of key indicator species, while a physiognomic formation is based on "appearance". The functional unit of a physiognomic classification system may use the dominance of a given growth form (e.g. tree or shrub) in a particular stratum (tree or shrub layer) (Whittaker, 1962). Structural systems are based on the spatial arrangements of vegetation components and functional systems take into account adaptation to environmental conditions such as fire resistance and seed dispersal (Fosberg 1967).

2.3 Remote Sensing-Based Classification

A classification can be applied by various means to segregate the Earth's surface into homogeneous units and apply labels in accordance with a classification to generate a mapped surface. These units can represent land cover, land use, vegetation classes, habitat types, ecological communities or other physical or environmental /biological or institutional parameters. The objective of classification and mapping include land management issues such as human impact and natural disturbance assessments (Komarkova 1962; Dombois and Ellenberg 1974) as well as evaluation of successional changes and dynamics.

A number of classification schemes have been developed for use with specific remote sensing data. The most widely used are the hierarchical classifications of Anderson et al. (1976) and Loelkes et al. (1983) which combine land cover and land use classes, and Cowardin et al. (1979) which classifies wetland and deepwater habitats based on similarity of hydrologic, geomorphologic, chemical, or biological factors. Although not specifically designed for use with remote sensing data, the Forest Cover Types of the US classification is widely used (Society of American Foresters 1980). There is also significant experience in direct parameterization of remote sensing observations such as leaf area index (LAI) measurements and estimates of biomass based on vegetation indices (Tucker 1979). Spectral mixing models describe contributions of varying environmental components, or end-members such as shade/shadow, woody material, bare soil and vegetation (Smith et al. 1990)

Table 1.
Classification Systems and Unit Characteristics
(from Kuchler 1988, Mueller-Dombois and Ellenberg 1974, Fosberg 1967)

A. Classification Systems

physiognomic
physiognomic-structural
floristic
physiognomic-floristic
dynamic-floristic
areal-geographic
ecological
habitat

B. Generic Classification System Units and Characteristics

morphology:	dominant life form, height strata, leaf periodicity
physiognomy:	growth form (formation)
structure:	trees per hectare
function:	fire resistance, drought tolerance
floristic composition:	dominant species, indicator species
dynamics:	successional stage:
habitat:	species
environmental (environmental relation):	
history:	human impact
taxonomy:	
geographic:	location
topographic:	elevation
physiographic:	landform
climatic:	temperature, precipitation

Classification development generally takes two forms: the use of a priori or classifications pre-determined prior to field observation and a posteriori, or classifications developed based on field-sampled data (Kuchler 1951). Remote sensing-based classifications should represent vegetation parameters such as pattern, structure, physiognomy and morphology, and therefore *a posteriori* approaches are recommended although this method requires continuing development of the classification dependent on field observation. This may not lend itself to development of regional or global-scale classifications.

2.4 Remote Sensing Classification Criteria

Remote sensing using both photointerpretative and computer-assisted analysis has relied on a number of characteristics inherent in landscape units and observable through the use of these systems. The elements include both reflective information as tone, color and hue, and spatial and geometric information such as texture, shape, size, pattern and height (Estes et al. 1983). Higher level interpretative clues include contextual information such as proximity and association. Multitemporal data allow for further information on seasonality, leaf periodicity and dynamics.

There has been a great failure in the quantification of remote sensing-observable criteria. Remote sensing-supported mapping should be based on direct observed parameters, much as vegetation classification is based on direct observation and statistical analysis of field data (Kuchler, 1951). Given, there is a fundamental problem with relating remote to field observation because of the usual vertical perspective of remote sensing data. The lack of measurement throughout the vertical profile makes measurements such as leaf area index which are generalizations and oversimplifications of vegetation structure and morphology. Table 2 lists a non-comprehensive suite of variables that can be extracted from remote sensing data using both manual interpretative and digital image processing techniques.

Table 2. Remote Sensing Classification Criteria

reflectance
tone
color
extravisual electromagnetic
temperature
texture
canopy
structure
crown closure
height
vertical distribution
cover
density
structural geometry
spatial pattern
size
shape
context
topographic
slope
aspect
elevation
floristics
species
morphology
temporal dynamics
leaf periodicity
moisture regime
physiography
land form
soil moisture
direct parameterizations
Leaf Area Index (LAI)
Vegetation Indices (NDVI)

PROCEEDINGS OF THE 5th ASIS SIG/CR CLASSIFICATION RESEARCH WORKSHOP

2.5 Relationship of Classification and Mapping

Classification and mapping are inter-related in that mapping represents the geographical distribution of classes and can serve as a test for a classification (Dombois and Ellenberg 1974). The purpose of mapping is to provide a geographical distribution of classes and to analyze geographical distribution for patterns. Mapping allows for development of sampling frames to support inventory and assessments of representativeness, and for comparison between classification units.

The relationship of vegetation parameters to remote sensing is a function of the structural components of the vegetation in relationship to cell (pixel) size, shape and orientation. A multispectral scanner on a space-borne platform may record the reflected (and emitted) electromagnetic energy corresponding to a ground area of 10 x 10, 20 x 20, 30, x 30, 60 x 60 m, or as large as 1.1 km. The relationship of pixel to patch or crown size dictates the observable parameters and influences selection of minimum mapping units for specific objects. A smaller cell size means that reflectance may be that of a single tree, rather than a group of trees.

In the past, there has been much effort in obtaining one-to-one translations of categorical (nominal) class attributes to remote sensing-derived landscape polygons based on traditional image data segregation, segmentation and pattern recognition techniques. Remote sensing-supported mapping should be based on direct observed parameters, much as vegetation classification is based on direct observation and statistical analysis of field data (Kuchler 1951). The benefits of thoughtful generation of these remote sensing classification analogues is that remote sensing-derived data will be valid in that they describe functional and structural characteristics of the landscape as observed from a vertical perspective.

A fundamental problem with the development and application by mapping of vegetation is that vegetation is continuous rather than discrete. Classes themselves may be defined by a number of continuous variables such as elevation and moisture, which is demonstrated by the use of gradient analysis to sample and describe vegetation. Another primary problem of classification and mapping is that in order to map classes reliably across regions, the classes may need to be exceedingly simple as to preclude meaningful comparison.

3.0 PROBLEMS AND RESOLUTIONS

The primary utility of using remote sensing data are their availability, cost and their utility to characterize landscapes at using different classification schemes and analytical techniques. A primary objective of the image data analysis is to accurately classify the landscape which in turn enables biological inventory to proceed. A secondary objective is the capture of the spatially referenced into GIS for information storage, analysis, management and generation of map products.

Remote sensing data can be used in conjunction with existing physiographic and biological information to provide a framework for biological inventory and conservation planning. The community and land cover classification information, coupled with existing cadastral, species occurrence and conservation data provide a basis for vegetation classification, inventory characterization and mapping. Potential threats such as soil erosion and habitat fragmentation can

be identified. Natural community modification and encroachment of exotic species may be identifiable depending on the extent and type of degradation, and a framework is established for subsequent monitoring.

Remote sensing-based classifications obviously reflect the qualities of the remote sensing data in terms of spatial, spectral and temporal resolution, the nature of other biological and geophysical data incorporated into the classification and mapping process, as well as analytical techniques and process. Since different remote sensing classifications exist at different spatial, spectral, temporal and analytical scales, problems of data integration, accuracy assessment and validation are confounding. Therefore, it is mandatory that thoughtful development of remote sensing-based classifications be undertaken and incorporated into the characterization and mapping process.

Remote sensing mapping efforts must reflect reality (as defined by vegetation and ecological classification systems) rather than isolated remote sensing-observable parameters. If a vegetation classification system segregates evergreen and deciduous trees based on ground observations, then a remote sensing approach must be able to isolate that variable, or a surrogate or replacement variable such as tree height, tree crown width or number of trees per hectare. It is therefore mandatory that remote sensing analogues to, or adaptations of, vegetation and ecological classifications be developed. For example, a classification of vegetation types using natural-color aerial photography at a scale of 1:24,000 (one inch = 2,000 feet). This would enable translation of remote sensing information to biological and ecological reality. The vegetation types defined using that type of photography at that scale may not exist at smaller or larger scales, or be visible using black and white photographs.

4.0. LITERATURE CITED

- Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. *A Land Use and Land Cover Classification System for Use with Remote Sensor Data*. U.S. Geological Survey Professional Paper 964, 28.p.
- Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. U.S. Dept. of Interior, Fish and Wildlife Service, Washington, D.C., 131 p.
- Daubenmire, R.F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. *Ecological Monographs* 22: pp. 301-330.
- Estes, J. E., E.J. Hajic and L.R. Tinney. 1983. Fundamentals of Image Analysis: Analysis of Visible and Thermal Infrared Data. In *Manual of Remote Sensing* (D.S. Simonett, ed.), Vol. I, pp. 987-1124.
- Fosberg, F.R. 1967. *A Classification of Vegetation for General Purposes*. IBP Handbook No. 4, 120 pp.
- Komarkova, V. 1983. *Comparison of Habitat Type Classification to Some Other Classification Methods*. pp. 21-31.
- Kuchler, A.W. 1949. A Physiognomic Classification of Vegetation. *Annals of the Assoc. of Am. Geographers* 39: pp. 201-210.
- Kuchler, A.W. 1951. The Relation between Classifying and Mapping Vegetation. *Ecology* 32, pp. 275-283.

PROCEEDINGS OF THE 5th ASIS SIG/CR CLASSIFICATION RESEARCH WORKSHOP

- Kuchler, A.W. 1964. *Potential natural vegetation of the conterminous United States*. Amer. Geog. Spec. Pub. No. 36. New York: Am. Geog. Soc. 115 pp.
- Kuchler, A.W. 1988. The Classification of Vegetation. In *Vegetation and Mapping*, A.W. Kuchler and I.S. Zonneveld (eds.). Norwell MA: Kluwer Academic Publishers, pp. 67-80.
- Loelkes, G.L., G.E. Howard Jr., E.L. Schwertz, P.D. Lampert and S.W. Miller. 1983. *Land Use/Land Cover and Environmental Photointerpretation Keys*. U.S. Geological Survey Bulletin 1600. U.S. Geological Survey, Reston VA.
- Mueller-Dombois, D. 1984. Classification and Mapping of Plant Communities: a Review with Emphasis on Tropical Vegetation. In *The Role of Terrestrial Vegetation in the Global Carbon Cycle: Measurement by Remote Sensing*, pp. 21-88.
- Mueller-Dombois, D. and H. Ellenberg. 1974. *Aims and methods of vegetation ecology*. New York: Wiley. 547 pp.
- Schouw. 1823. *Grundzuge einer allgemeinen Pflanzengeographie*. Berlin: Reimer, 524 pp.
- Schimper, A.F.W. 1898. *Pflanzengeographie auf physiogischer Grundlage* Gustav Fischer, Jena.
- Schimper, A.F.W. and F.C. von Faber. 1935. *Pflanzengeographie auf physiogischer Grundlage* Gustav Fischer, Jena.
- Simonett, D.S. 1983. The Development and Principals of Remote Sensing. In *Manual of Remote Sensing* (D.S. Simonett, ed.) Vol. I, pp. 1-36.
- Smith, M.O., S.L. Ustin, J.B. Adams and A.R. Gillespie. 1990. Vegetation in Deserts: I. A Regional Measure of Abundance from Multispectral Images. *Remote Sensing of Environment* 31: pp. 1-26.
- Society of American Foresters. 1980. *Forest Cover Types of the United States and Canada*. Eyre, F.H. (ed.). Society of American Foresters, Bethesda, MD.
- Tucker, C.J. 1979. Red and Photographic Infrared Linear Combinations for Monitoring Vegetation. *Remote Sensing of Environment* 8: pp.127-150.
- UNESCO. 1973. *International Classification and Mapping of Vegetation*, Series 6, Ecology and Conservation. Paris: UNESCO, 93 pp.
- Von Humbolt 1806. *Ideen zu einer Physiognomik der Gewachse*. Tubingen.
- Whittaker. R.H. 1962. Classification of Natural Communities. *Botanical Review* 28 (1): pp. 1-239