Developing an Ecosystem Diversity Framework for Landscape Assessment

Robert D. Pfister
Michael D. Sweet

Abstract—Ecological diversity is being addressed in various research and management efforts, but a common foundation is not explicitly defined or displayed. A formal Ecosystem Diversity Framework (EDF) would improve landscape analysis and communication across multiple scales. The EDF represents a multiple-component vegetation classification system with inherent flexibility for a broad range of applications. Examples are drawn from experience in the Bitterroot Ecosystem Management Research Project to demonstrate concepts and applications. Continuing work will address integration of evolving protocols in western Montana.

A shared understanding of vegetation patterns at landscape scales is essential for implementing ecosystem management concepts. Classification and mapping are the primary tools for describing the existing vegetation conditions across a given landscape. However, if different classifications are used for each unique landscape, then we are faced with three problems: (1) integration for analysis of larger areas is difficult and uncertain, (2) communication is hampered, and (3) knowledge accumulated in relation to specific classes cannot be extrapolated to other areas.

Ecologists have been searching for the best, single, all-purpose classification system for the past century. Various task forces and committees have proposed universal, hierarchical classification systems that seek to address the issues of the time. Each are used and supported for a period of time until new needs for classification emerge. Then we go through the process of inventing a new classification protocol. Advances in information science and technology suggest designing classification systems with greater flexibility and inherent utility. Relational data bases provided the first breakthrough in organizing information to retain information content while offering unlimited combinations to simplify the abstraction of that information through classification. Geographic information systems incorporate that flexibility and apply it for explicit spatial relationships.

An Ecosystem Diversity Framework uses multiple classification systems in unique combinations to address different questions. Traditional ecosystem classification systems have been designed as multiple factor hierarchies, with different variables used at different levels of the classification. Although useful for many interpretations, the hierarchical ordering offers only a single, inflexible alternative. In contrast, an EDF will encourage development of standards for several, basic, relatively simple, classification components. Then, unique combinations of the components serve many needs for summarizing and displaying information by "types." The intent is to maintain the integrity of each component classification and afford versatility in designing more than one logical combination to simplify the complexity of ecosystems.

Integration and standardization of vegetation and habitat type classifications have been an ongoing dialogue with USDA Forest Service Northern Region specialists and BEMRP researchers during the past several years. Individually and jointly we have been in the learning process of integrating vegetation information across landscape scales and planning scales. The Ecosystem Diversity Framework is an attempt to synthesize many of these efforts in a format helpful for future landscape analyses.

Objectives and Scope

The objective of this ongoing study is to develop an Ecosystem Diversity Framework for western Montana that will have direct application to landscape assessment and planning on a broad range of ownerships. The purposes of this paper are to present the classification concepts, demonstrate some applications in BEMRP, and describe some logical next steps to complete the EDF.

Framework Concept and Components

The Ecosystem Diversity Framework is superficially similar to some previous classification systems. However, the emphasis is shifted from the final integrated classification to the essential components as building blocks. The EDF will be an explicit classification model combining many good ideas of the past in a format to efficiently meet current and projected future needs. Five components are currently being evaluated for incorporation in the EDF. Individual components can be defined at more than one level of resolution (preferably in a nested hierarchical fashion) to communicate at different levels of generalization and to link across different spatial scales. The five basic components are (1) Site, (2) Composition, (3) Successional Stage, (4) Vertical Structure, and 5) Density.

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Robert D. Pfister is a Research Professor of Ecology and Michael D. Sweet is an Information Research Specialist, School of Forestry, University of Montana, Missoula, MT 59812; e-mail: rpfister@forestry.umt.edu; sweet@forestry.umt.edu

Site Classification

The primary method of site classification for vegetation interpretation in the western United States is the habitat type approach pioneered by Daubenmire (1952). Review of alternative groupings (Pfister and others 1977; Fischer and Bradley 1987; and Greene and others 1992) provides a basis for recommended standardization where appropriate. This component is technically not classification of existing vegetation but is directly derived from the late-successional vegetation types (associations—sensu Daubenmire). It provides a description of potential vegetation and also provides spatial stratification to understand (and display) how vegetation varies in relation to physical environments.

Composition Types

The Society of American Foresters (SAF) cover types (Eyre 1980) are almost exclusively single species dominance types (designed to be compatible with Forest Survey) for the eight Rocky Mountain States. Therefore, we are closer to a consensus starting point than many regions of the United States. They also are potentially similar to the National Vegetation Classification Alliances (Grossman and others 1998), if and when a workable, standard approach is used to define/identify them. Mixed-species types have been a nemesis for inventory, description, and mapping because of the extremely large number of possible combinations. Clearly, a standard protocol is needed that allows unambiguous definition, definitive inventory procedures, and consistent aggregation protocols to replace approximate "cross-walking" procedures.

Successional Stage

Structural stages that reflect changes in vegetation with time through natural successional processes have been described qualitatively in many ways. Age may seem the appropriate variable but is too expensive to inventory adequately. The traditional size classes of forest management have been adopted quite successfully with a few modifications for general utility. Several variations of subdividing this continuous variable have been proposed. Furthermore, diameter of the dominant/codominant layer seems preferable to quadratic mean diameter in order to establish a better relationship of dynamic change with age and to address stands containing multiple age classes.

Vertical Layering

This variable has become increasingly important for interpreting wildlife habitat, insect relationships (e.g., spruce budworm, *Choristoneura occidentalis*) and forest fire behavior (e.g., ladder fuels, fire severity). It is also of special importance as we increasingly manage for multiple aged stands with various forms of partial cutting practices. Although the classic examples of one-layer, two-layer, and three-layer stands are easy to visualize on paper, field identification is quite subjective. Standards for inventory and field identification are still in formative stages.

Density Types

This continuous variable has also been subdivided many ways. The Vegetation Subcommittee of the Federal Government Data Committee (FGDC 1997) and The Nature Conservancy (Grossman and others 1998) standards of 25 percent and 61 percent canopy cover are in general agreement with a long history of physiognomic literature (Penfound 1967; Mueller-Dombois and Ellenberg 1974). Subdivisions within these categories may be necessary for some applications to provide two, nested, hierarchical levels of density. For example, the Forest Service, by law, must recognize land with more than 10 percent canopy cover of trees as "forest land." On the other hand, the FGDC (1997) classifies lands with less than 25 percent canopy cover as "nonforest."

Integrating the Components for Multidimensional Perspectives

Each of the components can be viewed independently or in various combinations. The number of possible combinations from one-at-a-time to five-at-a-time provides 31 unique classification options. Varying arrangement of the axes for combined variables allows 325 unique visual configurations. This is one reason why we see so many unique ways of trying to classify the same thing. Should we ignore the many perspectives, attempt to force standardization, or embrace the diversity? We recommend a learning process of using flexibility as a powerful tool for communication and utilization of classification concepts. First, we can organize and simplify information complexity by using relational databases for inventory information on each component. Secondly, we can utilize Geographic Information Systems to provide visual displays of various combinations of components. This allows us to match appropriate information with each unique question and quickly abstract answers. It also provides for systematic development, storage, and access of knowledge as foundations for informed decisions. Furthermore, this kind of information system offers numerous opportunities for improving technical communication among disciplines, between researchers and managers, and between professionals and the public.

Historical Combinations of Components

A brief review of the literature provides several examples that implicitly used parts or most of this EDF. Daubenmire and Daubenmire (1968) first introduced two-way tables of distribution of Tree Species (Component 2—interpret as possible cover types) in relation to Habitat Types (Component 1) for northern Idaho and eastern Washington. A landmark summary of wildlife knowledge used a standard framework of 15 Ecosystem Types (Component 1) and 6 Structural Stages (Component 3) for eastern Oregon (Thomas and others 1979). A similar state-of-knowledge wildlife habitat summary used SAF Cover Types (Component 2), four Size Classes (Component 3) and three Density Classes

(Component 5) for the western Sierra Nevada in California (Verner and Boss 1980). The Northern Region of the USDA Forest Service also began building a regional wildlife database in the early 1980's using Habitat Types (Component 1) and Structural Stages (Component 3). A prototype study to define successional plant community types within individual major Habitat Types (Component 1) used Structural Stage (Component 3) and Plant Community Types (refinement of Component 2) to define types and pathways connecting the types (Arno and others 1985). State of knowledge summaries of fire ecology and succession formulated Habitat Type Groups (Component 1) and made use of Structural Stages (Component 3), Cover Types (Component 2) and Density (Component 5) for forests of western Montana (Fischer and Bradley 1987). Development of the SIMPPLLE model for predicting landscape pattern and processes used all of the components of the EDF to provide unique "states" within the object-oriented "expert system" pathway model (Chew 1995, 1997). Most of these components were also used in several ways at generally broader scales (coarser resolution) in the Interior Columbia River Basin Project.

A formal recommendation to use an "Ecosystem Diversity Matrix" to provide a practical coarse-filter approach for planning to conserve biodiversity was set forth by Hauffler, Mehl and Roloff (1996). Their ecosystem diversity matrix for the Southern Idaho Batholith Landscape included 11 Habitat Type Classes (Component 1), 10 Vegetation Growth Stages (each with 3 Density Classes) (Components 3, 4 and 5) to provide a two-dimensional 11 x 10 matrix. Within each cell, the potential major tree species were listed (Component 2). Once inventory has been translated to quantify the acres in the cells of the matrix, landscape analysis for biodiversity can begin. This includes estimation of adequate ecological representation with a species assessment, which helps lead to determination of the desired future condition.

Demonstration of the EDF Concept for Stevi-WC Resource Area

A post-facto demonstration was selected because many people have become familiar with the area through the BEMRP studies of the past five years. All of the five components were used in several different applications, but not always the same way. This is a common occurrence if a standard framework has not been provided at the start of a project. It seems appropriate to demonstrate the EDF for an area where we have an adequate database, familiarity, and an opportunity to use hindsight to ask the question: Would an EDF have improved our effectiveness?

A concerted effort was made in the first year of BEMRP to reach consensus on a vegetation classification system among several of the scientists. Standards were proposed but not universally adopted. A preliminary conclusion of this effort was that several researchers did not want to have their research efforts constrained by a standard classification, although consensus may be more important for managers doing landscape analysis (R. Pfister 1995 BEMRP Workshop Report). Although we did not have an explicit EDF for the collaborative work on the Stevensville-West Central (Stevi-WC) Integrated Resource Area, components of the proposed EDF were an implicit part of several BEMRP studies. The second purpose of this paper is to illustrate some uses that were made of the components and some potential uses that could have been made. Examples are drawn from collaborative work of the Stevi-WC I.D. Team and the Landscape Analysis Team (GIS, SIMPPLLE, and MAGIS).

Examples of Use of Components

Numerous examples were presented with colored maps in the oral symposium presentation and in a complementary poster presentation. Due to space constraints they are just listed in this paper. The first set of examples is used to illustrate sharing information about a specific landscape for each of the individual components. Both colored maps and summary tables of acres and percent of area by type are easily extracted from a GIS. The following components were displayed:

1. Eleven habitat type groups.
2. Twenty-nine composition types (species groups).
3. Five structural stages (size types).
4. Two layer types.
5. Four density types.

In addition, a display of combining components 3 and 4 displayed nine Size x Layer Types.

Applications From Components

Modeling Applications

All five components were used as part of SIMPPLLE (Chew 1995, 1997) and MAGIS (Zuuring and others 1995) model applications working with the Stevi-WC I.D. team. Two examples developed within the MAGIS applications were Thermal Cover from Components 3 and 5 and Hiding Cover from Components 1, 3, 4 and 5. Three examples from SIMPPLLE were Western Spruce Budworm Probability from Components 1 to 5, Stand Replacing Wildfire Probability from Components 1 to 5, and Bark Beetle Probability from Components 1 to 3 and 5. These disturbance process interpretations were initially abstracted from literature and expert opinion to provide probability of occurrence coefficients for stochastic pathway selections in SIMPPLLE (Chew 1995, 1997). The model also adjusts probabilities based on spatial stand adjacency relationships. Recently, a method was also developed to spatially display these relative probabilities for management interpretations of risk. Both of these models are being refined to provide greater compatibility in model input, presentation of information and linkage with GIS. The EDF is an integral part of these efforts.

Other Applications

The EDF provides for a consistent presentation of inventory information. The same kinds of interpretation

incorporated in the above models can be made independently of the models. Interpretations can be made from the relational database through query routine, and spatial displays can be made directly from GIS. Sweet provided unique summaries of acres by types (Components 2, 3, 4, and 5) in 1996 for use by Fiedler and Keegan in their silviculture/economics BEMRP studies. Pfister also used this output for several intra-working group meetings.

Potential Applications

Specific Applications

As we learn the potential uses of information technology, we see a wide range of further interpretations that could be made for landscape assessment and planning. For example, a first approximation of Possible Old Growth could be obtained from a query of Components 1 and 3. Potential Forest Productivity (Yield Capability) can be estimated from Component 1 and refined by considering Component 2. Forage Production could be estimated from Components 1 and 5. The interesting challenge is to explore many other questions about ones landscape of interest using the powerful combination of classification and information technology. These could include locating potential opportunities for certain kinds of silvicultural prescriptions, ecosystem burning, wildlife browse production, and forest health. In addition, the EDF could be utilized in other model applications.

Mixed Ownership

Collaborative landscape or watershed assessment of mixed ownership presents a major challenge because of incompatible inventory information. A formal EDF should provide common ground at some level of resolution for shared analysis and interpretation.

Explicit Conditions

A major application of the EDF may be in moving toward explicit quantitative and spatial descriptions of Vegetation Conditions. This includes Historic Conditions, Existing Conditions, Alternative Future Conditions, Desired Future Conditions, and the explicit relations among them. These have been useful concepts that have not reached their full potential use because of our limited ability to communicate specifically what they mean relative to an entire landscape or specific locations within the landscape.

Biodiversity Planning

Availability of an EDF would have been very useful for the Biodiversity Discussion Group session held as part of the 1996 annual BEMRP Workshop. The work by Haufler and others (1996, 1999) would have fit right in then and remains just as important today. As they described, once existing acreage within cells of the "ecosystem diversity matrix" has been determined then specific landscape analysis of biodiversity leading to practical recommendations for Desired Future Conditions can begin.

Illustration of Framework

With a look to the future, we prepared an illustration of one possible way to integrate and display the five components in two dimensions. Figure 1 represents a modification of the Southern Idaho Batholith Landscape (Haufler and others 1996) to represent the Stevi-WC Landscape. It is presented as a partial vision of what might be used to illustrate an EDF for western Montana. In hindsight, we all might have benefited if we had this when we started BEMRP!

Framework Value

Approaching this as a framework, rather than a single multiple-factor classification, appears to have certain values. Information system technology allows many combinations of components for a wide range of applications. Maintaining the unique identity of each component in the database provides integrity. The level of inventory controls the precision of possible interpretation relative to each component, but aggregation of each component can be made for generalization at broader scales. For example, maps were displayed in the symposium presentation to show: 30 habitat types and phases aggregated into 10 habitat type groups aggregated into 4 "super groups." Abstraction is a powerful tool for communicating with specialists from other disciplines and helping to provide public understanding of many of the broader level issues.

Standardization by Components

Emphasis for standardization should be placed at the component level to provide consistent building blocks for an EDF. Standardization is essential for comparing landscapes and aggregating information to larger landscapes or ecological regions. Standardization is more critical for components (technical) than for combinations (communication). Standardization of components may also be critical for modeling applications. Recommended standards for variables #3 to 5 are documented in a 1998 draft manuscript. Recommended standards for #1 (Habitat Types and Groups) and #2 (Composition) are being explored and will be forthcoming. These proposed standards might affect inventory protocols, model formulation, and the synthesis of knowledge.

Lessons Learned to Guide Formalizing the Framework for Western Montana

Formalization of the EDF requires coordination with evolving protocols by the Northern Region of the Forest Service, other agencies, and other land managers. Continuing work will incorporate the latest revisions of classification parameters used in the SIMPPLLE and MAGIS models. Continuing work will also incorporate and interact with the classification components of the Forest Service Draft Inventory Standards (4/99). Formalization also requires seeking

		Habitat Type Group					
		A		B		J	
Size	Structure	Density	Species[a]	Density	Species	Density	Species
Class	Class	Class		Class		Class	
Seedling - Sapling	Single	1	PP	1	DF	1	AL
		2	DF	2	PP	2	WB
		3		3	WL	3	AF
		4		4	LP	2	ES
Pole	Single	1	PP	1	DF	1	AL
		2	DF	2	PP	2	WB
		3		3	WL	3	AF
		4		4	LP	2	ES
	Multi	1	PP	1	DF	1	AL
		2	DF	2	PP	2	WB
		3		3	WL	3	AF
		4		4	LP	2	ES
Medium	Single						
	Multi						
Large	Single						
	Multi						
Very-large	Single						
	Multi						

[a]PP = ponderosa pine, *Pinus ponderosa*; DF = Douglas-fir, *Pseudotsuga menziesii*; WL = western larch, *Larix occidentalis*; LP = lodgepole pine, *Pinus contorta*; AL = alpine larch, *Larix lyallii*; WB = whitebark pine, *Pinus albicaulis*; AF = subalpine fir, *Abies lasiocarpa*; ES = Engelmann spruce, *Picea engelmannii.*

Figure 1—Illustration of five components of an Ecosystem Diversity Framework for Stevi-WC area displayed as a two-dimensional matrix with density and composition components within each cell.

compatibility with evolving standards for the National Vegetation Classification System (NVCS) through the FGDC (1997), The Nature Conservancy (Grossman and others 1998), and the Ecological Society of America's Vegetation Classification Panel review draft to be released in July 1999. Work during the rest of this year will concentrate on components 1 to 2 as well as seeking compatibility with the above efforts. Continuing dialogue will be maintained with professionals on the Bitterroot National Forest, the Northern Region, and colleagues in BEMRP.

Summary and Conclusions

The Ecosystem Diversity Framework uses several component vegetation taxonomies that can be aggregated in many useful ways. The EDF is as powerful as the weakest link of component inventory information. The EDF helps abstract vegetation information for a wide variety of users. The EDF should be an integral component of inventory, GIS, models, assessment, and planning.

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References

Arno, S.F.; Simmerman, D.G.; Keane, R.F. 1985. Forest Succession on Four Habitat Types in Western Montana. U.S. Gen. Tech. Rep. INT-GTR-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 74 p.

Chew, Jimmie D. 1995. Development of a System for Simulating Vegetation Patterns and Processes at Landscape Scales. Missoula, MT: The University of Montana. 182 p. Dissertation.

Chew, Jimmie D. 1997. Simulating Vegetation Patterns and Processes at Landscape Scales. In: Integrating Spatial Information Technologies for Tomorrow. Conference Proceedings from the Eleventh Annual symposium on Geographic Information Systems. 1997 February 17-20; Vancouver, British Columbia, Canada: 287-290.

Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and it's bearing on concepts of vegetation classification. Ecological Monographs. 22: 301-330.

Daubenmire, R.; Daubenmire, J. 1968. Forest Vegetation of Eastern Washington and Northern Idaho. Technical Bulletin 60. Pullman, WA: Washington Agricultural Experiment Station. 104 p.

Eyre, F.H. 1980. Forest Cover Types of the United States and Canada. Washington, D.C.: Society of American Foresters. 148 p.

FGDC (Vegetation Subcommittee) 1997. FGDC Vegetation Classification and Information Standards. Reston, VA: Federal Geographic Data Committee Secretariat. 31 p.

Fischer, W.C.; Bradley, A.F. 1987. Fire Ecology of Western Montana Forest Habitat Types. Gen. Tech. Rep. INT-223. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 95 p.

Green, P.; Joy, J.; Sirucek, D.; Hann, W.; Zack, A.; Naumann, B. 1992. Old-growth forest types of the Northern Region. R-1 SES 4/92; Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region.

Grossman, D.; Faber-Langendoen, D.; Weakley, A.S.; [and others]. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications. Arlington, VA, USA: The Nature Conservancy. 126 p.

Haufler, J.B.; Mehl, C.A.; Roloff, G.J. 1996. Using a coarse-filter approach with species assessment for ecosystem management. Wildlife Society Bulletin. 24(2): 200-208.

Haufler, J.B.; Mehl, C.A.; Roloff, G.J. 1999. Conserving biological diversity using a coarse filter approach with a species assessment. In: Baydack, R.K.; Campa, H., III; Haufler, J.B., eds. Practical approaches to the conservation of biological diversity. Washington, DC: Island Press: 107-126.

Mueller-Dombois, D.; Ellenberg, H. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons. 547 p.

Penfound, W.T. 1967. A physiognomic classification of vegetation in conterminous United States. Botanical Review. 33: 375-406.

Pfister, R.D.; Kovalchik, B.L.; Arno, S.F.; Presby, R.L. 1997. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 174 p.

Thomas, J.W., technical editor. 1979. Wildlife Habitats in Managed Forests the Blue Mountains of Oregon and Washington. Agriculture Handbook No 553. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 512 p.

Verner, J.; Boss, A.S. technical coordinators. 1980. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 439 p.

Zuuring, H.R.; Wood, W.L.; Jones, J.G. 1995. Overview of MAGIS: A Multi-resource analysis and Geographic Information System. Res. Note. INT-RN-427. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 6 p.