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PROFILE

Developing a Spatial Framework of Common Ecological Regions for the Conterminous United States

GERARD McMAHON*
US Geological Survey
Raleigh, North Carolina 27607, USA

STEVEN M. GREGONIS
US Forest Service
Golden, Colorado 80225, USA

SHARON W. WALTMAN
US Department of Agriculture Natural Resources Conservation Service
Lincoln, Nebraska 68508, USA

JAMES M. OMERNIK
US Environmental Protection Agency
Corvallis, Oregon 97333, USA

THOR D. THORSON
US Department of Agriculture Natural Resources Conservation Service
Portland, Oregon 97204, USA

JERRY A. FREEOUF
US Forest Service
Denver, Colorado 80225, USA

ANDREW H. RORICK
US Forest Service
Portland, Oregon 97055, USA

JAMES E. KEYS
US Forest Service
Washington, DC 20250, USA

ABSTRACT / In 1996, nine federal agencies with mandates to inventory and manage the nation's land, water, and biological resources signed a memorandum of understanding entitled "Developing a Spatial Framework of Ecological Units of The United States." This spatial framework is the basis for interagency coordination and collaboration in the development of ecosystem management strategies. One of the objectives in this memorandum is the development of a map of common ecological regions for the conterminous United States. The regions defined in the spatial framework will be areas within which biotic, abiotic, terrestrial, and aquatic capacities and potentials are similar. The agencies agreed to begin by exploring areas of agreement and disagreement in three federal natural-resource spatial frameworks—Major Land Resource Areas of the US Department of Agriculture (USDA) Natural Resources Conservation Service, National Hierarchy of Ecological Units of the USDA Forest Service, and Level III Ecoregions of the US Environmental Protection Agency. The explicit intention is that the framework will foster an ecological understanding of the landscape, rather than an understanding based on a single resource, single discipline, or single agency perspective. This paper describes the origin, capabilities, and limitations of three major federal agency frameworks and suggests why a common ecological framework is desirable. The scientific and programmatic benefits of common ecological regions are described, and a proposed process for development of the common framework is presented.

Historically, earth science and resource management agencies that manage land and other resources within a common geographic area have worked independently. Understandably, the activities of each agency centered around the individual agency's mission and areas of expertise. These differences also have been reflected in the spatial frameworks that agencies use in the planning, design, implementation, and evaluation of their work.

A spatial framework is a mapped set of geographic regions that supports agency programs or studies. Frameworks may be used in a variety of ways, including stratifying variability over the landscape in a characteristic of interest or helping an agency develop regionally

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*Author to whom correspondence should be addressed.

generalized results from individual local investigations. Mapped at a particular scale, each region is relatively homogeneous and distinct from adjoining regions. These distinctions may be drawn in terms of a specific characteristic of interest, such as climate, soils, vegetation, or land use. This may be appropriate when a framework is serving a research or management purpose associated with a particular resource; for example, delineating soil erosion potential or assessing spatial patterns in water quality. Regions also may be distinguished in terms of broader categories of resource potential. This would be appropriate when the activities of an agency depend on a broad ecological understanding of the landscape. In this case, regions would have to reflect patterns in the interaction of multiple biotic and abiotic resources, rather than a single resource.

Spatial frameworks used by different agencies for the same regions often are distinct and not spatially coincident (Table 1). From the perspective of an agency addressing a particular resource-related management purpose, such a distinct framework may be entirely appropriate. However, noncoincident frameworks designed to meet management needs associated with a single resource also can cause practical problems. It may be difficult to aggregate and compare data collected by multiple agencies for the same general locale if they are using spatial frameworks that are not coincident. This may unintentionally limit the possibilities for sharing information and collaborating on management strategies across agency and program lines. Public interest in efficient and well integrated resource management may not be well served.

In 1996, nine federal agencies—Natural Resources Conservation Service (NRCS), US Department of Agriculture Forest Service (USFS), Agricultural Research Service, Bureau of Land Management, US Geological Survey (USGS), National Park Service, Fish and Wildlife Service, National Biological Service (currently known as the Biological Resources Division of the USGS), and US Environmental Protection Agency (EPA)—with mandates to inventory and manage the nation's land, water, and biological resources signed a memorandum of understanding (MOU) entitled "Developing a Spatial Framework of Ecological Units of the United States" (US Department of Agriculture and others 1996). The agencies agreed to review areas of agreement and disagreement in three federal natural-resource spatial frameworks—major land resource areas (MLRA) of the US Department of Agriculture (USDA) NRCS, national hierarchy of ecological units of the USFS, and ecoregions of the US EPA. Agreement was reached to develop a spatial framework that would provide the basis for interagency ecosystem management.

The common ecological regions (CER) defined in this spatial framework will be developed in accordance with several objectives. First, the regions are to be areas within which biotic and abiotic capacities and potentials are similar. The intention is that the framework will foster an ecological understanding of the landscape, including terrestrial and aquatic resources, rather than an understanding based on a particular resource or discipline. The framework also is intended to provide the basis for interagency coordination and collaboration in the design and implementation of ecosystem research, assessment, and management. Finally, the regions are intended to be a fully integrated national map, developed with common objectives, and reviewed by a single group of experts representing the participating agencies. The objectives are consistent with efforts by the federal government, in partnership with states, tribes, local government, and private landowners, to recognize and manage areas in which the composite of environmental resources and ecosystems are similar (US General Accounting Office 1994). Thus, within the same natural geographic area, agencies and programs with interests in and responsibilities for different resources could more effectively coordinate their activities.

This new framework is not intended to replace individual agency frameworks. These individual frameworks will continue to be used when they serve the specific agency research or management purpose for which they were developed. It is hoped, however, that all participating agencies will use the new framework for agency activities that are ecologically oriented and involve the interests of several participating agencies.

This spatial framework will be hierarchical, with common ecological regions defined at two map scales—1:7,500,000 (small-map scale; typically less resolution and greater extent) and 1:250,000 (large-map scale; typically more resolution and less extent). The 1:7,500,000-scale regions will subdivide the conterminous United States into 80–90 regions for state-level and broad regional and national assessment, management, and inventory needs. The more detailed 1:250,000-scale regions will subdivide the coarser regions, with the number of subdivisions varying depending on the complexity of the source maps. Map compilation will rely on appropriately scaled information about factors that affect ecological potential, such as soils, vegetation, geology, geomorphology, water, climate, and land use. The goal of this hierarchical effort is that regions defined at the larger map scale will nest into the smaller map scale framework.

Table 1. Regional and national frameworks used by resource management agencies

Agencies, organizations	Programs that use spatial frameworks	Regional and national frameworks
US Department of Agriculture, Natural Resource Conservation Service (NRCS)	National Cooperative Soil Survey National Resource Inventory Agricultural Census Conservation programs (Conservation Reserve Program, National Nutrient Strategy, Farm Bill Compliance, Farmland protection Programs, etc.) National Agricultural Statistical Service Soil Carbon Sequestration Research (Lal and others 1998) International Resource Assessment (Yost and Eswaran 1990) Farmland Protection (Sorensen and others 1997)	Land resource regions and major land resource areas (MLRA) (US Department of Agriculture 1984, 1997) Land Resource Unit (LRU) (US Department of Agriculture 1984) State Soil Geographic Database (STATSGO) (US Department of Agriculture 1994, Lytle and others 1996) National Resource Inventory (US Department of Agriculture 1992)
US Department of Agriculture, Forest Service (USFS)	Sustainable forest management Forest management plans Large area assessments Landscape analysis and assessment (multiple scales) Multiforest analysis and planning Determination of desired future conditions Biodiversity analysis Assessing ecosystem conditions for contiguous Forest Service and non-Forest Service lands	Ecoregions (Bailey 1976, 1998, Bailey and others 1994) National hierachical framework of ecological units (McNab and Avers 1994, Keys and others 1995, Cleland and others 1997). Hierarchical framework of aquatic ecological units (Maxwell and others 1995)
US Department of Interior, US Geological Survey (USGS)	National water-quality assessment program (Leahy and others 1990) GAP (Scott and Jennings 1998)	Hydrologic units (HUCs) (Seaber and others 1987) National water quality assessment program (NAWQA) crop groups (Gilliom and Thelin 1997) NAWQA climatic settings (Lopes and Price 1997) GAP land cover (Bara 1994, Lillesand 1996) GAP vegetation alliances (Grossman and others 1998) Distribution of freshwater fishes (Walsh and Meador 1998)
US Environmental Protection Agency (USEPA)	Biocriteria development (US Environmental Protection Agency 1998a) Nutrient Strategy (US Environmental Protection Agency 1998b)	Ecoregions (Omermik 1987, Gallant and others 1995) HUCs (Seaber and others 1987)
States	Biocriteria (Davis and others 1996) Water-quality monitoring Natural heritage inventory	Mapped distribution of freshwater fishes (Holcutt and Wiley 1986, Warren and Burr 1994) HUCs (Seaber and others 1987) Level III ecoregions of the US (US Environmental Protection Agency 1998a)
Nongovernmental organizations	Multistate ecological planning Biodiversity protection	National vegetation classification system (Grossman and others 1998) The Nature Conservancy (TNC) critical watersheds (Master and others 1998) TNC terrestrial vegetation of the US WWF map (Abell and others 1997)
Commission for Environmental Cooperation (CEC)	USEPA/NAFTA Pesticide Harmonization Project (Kroetsch and others 1998) North American State of the Environment Report (Wiken 1997, Wiken and Gauthier 2000, Wiken and Lawton 1995) North American section of the World Commission on Protected Areas (Gauthier and Wiken 2000)	CEC map (Commission for Environmental Cooperation 1997)

Table 2. Organizational structure for development of common ecological regions

Team	Primary functions
National Interagency Steering Committee (NISC)	■ Developing strategic interagency policy and guidelines ■ Providing national coordination and guidance to the NITT ■ Seeking priority support for projects from within respective agencies ■ Ensuring that final products are available for dissemination
National Interagency Technical Team (NITT)	■ Developing national standards, guidance, and procedures for mapping, describing map units, and developing map data bases, including drafting an ecological map for consideration and guidance of the state/regional coordinators ■ Providing technical oversight for the mapping effort ■ Coordinating with state/regional coordinators to ensure consistency and quality ■ Ensuring integration of regional review results into the national framework
Agency State/Regional Coordinators (S/RC)	■ Assembling and leading interdisciplinary federal and state agency teams ■ Using national standards and procedures in review and development of the common interagency framework and associated descriptions and database, consistent with project objectives

Staff from the signatory agencies, as well as scientists from state agencies, academia, and nonprofit agencies, are involved in development of this framework (Table 2). The MOU-commissioned National Interagency Steering Committee (NISC) and Technical Team (NITT) each draw on staff from signatory agencies, while the state and regional review effort, led by state/regional coordinators, will involve a much larger group of scientists and policy-makers.

Existing Natural Resource Management Frameworks

Natural-resource agency activities are guided by the agency's mission, responsibilities, and scientific specialty. Even though several resource management agencies may undertake one or more complementary programmatic tasks in the same location—inventorying resources; resource monitoring; characterizing resource status, potential, and trends; modeling cause and effect; evaluating policy—each agency is likely to operate within programmatic boundaries that limit the kinds of information that are collected, analyzed, and shared.

Such limitations are evident in the diversity of spatial frameworks used to organize agency resource management efforts (Table 1). Differences in the frameworks are driven by different objectives, compilation methods, and agency perspectives. Some of these frameworks reflect a single resource orientation; others reflect a multiple resource perspective. None of the three agency frameworks reviewed here accomplishes the objectives of the interagency effort—to define regions with similar biotic, abiotic, terrestrial, and aquatic characteristics, reviewed by a single group of interagency experts, and accepted by multiple agencies as a basis for interagency cooperation.

In recent years government agencies at all levels have adopted more interdisciplinary approaches to accomplishing programmatic tasks. Indeed, tasks often are redesigned in ways that mandate interagency cooperation and a multidisciplinary perspective. For example, the Water-Quality Criteria and Standards Plan (US Environmental Protection Agency 1998a) defines the conservation and enhancement of ecological health of the nation's waters and aquatic ecosystems as a central planning goal. This goal was established under the Government Performance Results Act (GPRA), a federal law requiring agencies to improve performance through better management (Office of Management and Budget 1997). An ecological approach to resource management, rather than a focus on a single resource characteristic, requires collaboration by various agencies to integrate ecological, economic, and social information. By its very nature, an ecological approach is multidisciplinary and requires consideration of biotic (including humans), abiotic, terrestrial, and aquatic characteristics.

This integrated ecological perspective on natural resource management will have implications for the frameworks currently (2001) used by agencies. The US General Accounting Office (1994) and the Interagency Ecosystem Management Task Force (1995) suggested that delineating the boundaries of geographic areas with similar ecosystem patterns is a prerequisite to ultimately managing activities on the basis of ecological conditions. These geographic areas would delineate regions within which the aggregate of ecosystem components would be distinct from adjoining regions. These regions may serve as a common spatial framework for resource-management agencies responsible for managing differing aspects of the environment (Omernik and Bailey 1997).

Evaluation of Three Principal Federal Agency Frameworks

Three federal agency resource management frameworks serve as the starting points for the common ecological regions mapping effort. All three frameworks have evolved since their inception. This evolution arises from increasingly sophisticated resource management missions that have been undertaken by such agencies as the USFS, NRCS, and the US EPA. These missions have expanded to meet a broad range of social priorities associated with legislation, such as the Multiple Use Sustained Yield Act, the Clean Water Act, the Endangered Species Act, and the Farm Bills of 1985 and 1995. The evolution of these three agency frameworks also reflects a general commitment toward more ecologically focused management.

US Forest Service National Hierarchical Framework

Early versions of the USFS framework were largely based on the work of Wertz and Arnold (1972), Bailey (1976), and Driscoll and others (1984). Wertz and Arnold delineated larger scale (less resolution) ecological areas primarily on the basis of geomorphology and soils. Bailey emphasized climate as a controlling factor at all spatial scales, with landform modifying climatic influences as reflected by vegetation at finer spatial scales (Bailey 1998). Beginning in the mid-1980s, an integrated approach using biotic and abiotic factors at multiple scales began to take precedence (Cleland and others 1985, McNab 1987). This work was built upon concepts and applications developed in Germany (Barnes and others 1982, Barnes 1984), Canada (Hills 1952, Rowe 1980, 1984, Jones and others 1983), and the United States (Jordan 1982, Pregitzer and Barnes 1984, Spies and Barnes 1984), employing hierarchy theory (Allen and Starr 1982) and the ecosystem concept in the classification, mapping, and interpretation of units.

In 1992, the USFS adopted an ecosystem-based approach to managing national forests and grasslands. This approach included a commitment to develop a national hierarchical framework of ecological units (Cleland and others 1992, US Department of Agriculture 1993, Bailey and others 1994, McNab and Avers 1994, Keys and others 1995, Miles and Goudy 1997, Nesser and others 1997). In 1995, the agency also adopted a watershed-based, complementary system, called the hierarchical framework of aquatic ecological units (Maxwell and others 1995), using physical and biological criteria deemed important to aquatic ecosystems. Both frameworks called for the systematic classification, mapping, and regionalization of units that nest together across multiple spatial scales ranging from global to project levels.

The reason for the development of the aquatic hierarchy is that terrestrial units alone do not explain all patterns of aquatic biota, including speciation within geographically isolated populations, or account for all boundaries that constrain flows of energy and material within aquatic ecosystems (Hughes and others 1994). Although watersheds in many regions of the country are distinct geographic units bounded by drainage divides, watersheds alone do not account for changes in climate, elevation, slope, aspect, geologically controlled soil parent materials, and other key conditions affecting ecosystems. Both frameworks are needed to comprehensively identify linkages among land and aquatic units and to analyze mutually dependent terrestrial and aquatic patterns and processes. As stated by Maxwell and others (1995), "By understanding these linkages, we can analyze attributes of aquatic systems together with the climate, geology, and landform attributes of the land units within which they are nested."

These frameworks jointly group stable biophysical components of a large variety of terrestrial and aquatic ecosystems into a limited number of discrete mappable units that, at any given scale, can be distinguished from one another by differences in various structural or functional characteristics (US Department of Agriculture 1993, Maxwell and others 1995, Cleland and others 1997). Separate maps, complementary to the ecological units maps, have been developed for factors considered more transient, such as current vegetative or wildlife and fish distributions, road densities, insect infestations, natural disturbance regimes, and land use. When used in conjunction with maps of these more transient factors, the national hierarchical frameworks provide a means of addressing the structure, function, and management potentials of all ecosystems managed by the USFS. Combined, this information provides the understanding needed for meeting the goals of the USFS—to maintain and restore ecological sustainability and watershed health.

The nested spatial hierarchies not only facilitate understanding of the nature of complex ecological systems, but also allow evaluation of information for multiscaled analysis and reporting purposes. Uses of the

USFS national hierarchical frameworks include (1) national assessment and reporting under the Resource Planning Act and Government Performance and Results Act, (2) regional, multiforest analysis and assessment, (3) forest-level analysis and planning under the National Forest Management Act, and (4) smaller scale landscape and project-level determination of land use and watershed capability, desired future conditions, and biodiversity analysis. Ecological subregions, for example, were mapped at a scale of 1:250,000 and published at the 1:1,000,000 scale for the eastern United States (Keys and others 1995) for regional assessments and analyses.

The USFS frameworks have two important limitations with respect to the objectives of the MOU. The separation of the terrestrial and aquatic hierarchies into different frameworks makes it more difficult to foster an ecological understanding of biotic and abiotic capacities of the landscape than it would be with a single framework. The USFS will continue evaluating the interrelationships of aquatic and terrestrial systems, adjusting each of these two frameworks to the extent possible as they are implemented and as new scientific information becomes available. A second limitation is that subsections of the USFS hierarchy were developed by different administrative units without national oversight and review. However, with the development of the common ecological regions framework, interagency participation, with a national perspective, will allow the terrestrial and aquatic frameworks to be refined for consistency with the CER framework.

Natural Resources Conservation Service Major Land Resource Area

Early development of the USDA-NRCS major land resource areas (MLRA) framework was strongly influenced by pedology, the scientific study of the composition, distribution, and formation of soils as they occur naturally and as influenced by human activities. This framework addressed the practical need within USDA to classify soil capabilities and associate these capabilities with agricultural potential and land use. An important conceptual predecessor of the MLRA framework, "Natural Land-Use Use Areas of the United States," by Barnes and Marschner (1933), first appeared as a land-use map based on generalization of local and national soil-survey maps (Coffey 1911, Marbut and Marschner 1931, Marbut 1935). This 1:4,000,000-scale map of the 48 states contained 272 areas that were grouped into 24 broader regions according to potential land-use constraints for agriculture. Many boundaries on the Barnes and Marschner map bear a striking resemblance to the MLRA map in use today, which has 270 areas (including Hawaii, Alaska, Puerto Rico, and the Pacific Basin nations) that are grouped into 26 land resource regions at a scale of 1:7,500,000 (Austin 1965, US Department of Agriculture 1984, 1997).

The present-day MLRA framework relies on the delineation of regions that share common patterns of land use, climate, soils, water resources, terrain, topography, geology, and potential natural vegetation at a particular scale (Austin 1965, US Department of Agriculture 1984). The MLRA framework is the second level in a four-tiered hierarchical framework. MLRAs nest within land resource regions (LRR), the first and most general tier. Land resource units (LRU), also called common resource areas (CRA), are the third tier and nest together to form MLRAs. The LRU/CRA represent landscape segments, several thousand acres in extent, and are created from state general soil map units. The state general soil map units are the fourth tier in the hierarchy. This hierarchy existed for LRR and MLRA in hand-drawn maps and only conceptually for LRU/CRA and state general soil map units until the publication of the digital State Soil Geographic Data Base, referred to as STATSGO (US Department of Agriculture 1994a, 1994b).

Using the digital STATSGO maps and their associated physical and chemical properties, plus other digitally mapped natural-resource data, NRCS pedologists are examining and challenging old assumptions about traditional MLRA and LRU/CRA concepts and uses. NRCS scientists are creating new digital versions of these maps to improve the delivery of conservation programs for the private landowner. The NRCS Field Office Technical Guide contains recommended best-management practices (BMPs) for landowners who make conservation management decisions, and these recommendations are linked to the geography of MLRA and CRA units.

Agricultural researchers in the land-grant university system and within the Agricultural Research Service (USDA-ARS) also use MLRAs to investigate crop management approaches that are both sustainable and environmentally sound. The conceptual framework underlying such investigations has been referred to as agroecology (Gliessman 1998). In agronomic terms, MLRAs have been used to develop crop growth zones or soil productivity zones, sometimes called agroecozones or agroecoregions, that integrate climate and soil landscapes across the Nation (Follett and others 1996).

Finally, the LRR and MLRA maps are used to stratify the statistical design of the National Resources Inventory (NRI) (US Department of Agriculture 1992). The MLRAs provide one of the few nongeopolitical geographic frameworks. These maps provide surrogate model input parameters for climate and soil properties Models are used to predict leaching and runoff of agrichemicals, water and wind soil erosion, and soil productivity (Goss and others 1998, US Department of Agriculture 1999). MLRAs provide the geographic framework for correlating the range and extent of soil series information for the US Soil Survey Program (Indorante and others 1996, US Department of Agriculture 1997). USDA pedological work in foreign nations often begins with broad regionalizations using the MLRA concept (Yost and Eswaran 1990). The MLRA concepts are an integral part of the large National Cooperative Soil Survey and National Resource Inventory attribute data bases managed by NRCS; conceptual changes to the MLRA would have a large impact on these data bases.

The present MLRA framework possesses several limitations with respect to the objectives of the MOU and CER framework. Its early development, using technologies and climate, land use, and soil data summaries that reflected the knowledge available for that time, predated the adoption of present-day ecological approaches to resources management and conservation by NRCS (Austin 1965). As with many historic map products, the rationale underlying region delineation was poorly documented; instead, this rationale presently resides in the expert knowledge of NRCS and cooperator personnel at state and regional levels. There is disparity in the interpretation of MLRA definitions from state to state within NRCS. The more narrowly focused peer-review standards required by the NRCS Soil Survey Program MLRA maintenance fall short of the broader, national peer-review required for the CER framework.

US EPA Level III and Level IV Ecoregions

The impetus for the development of the US EPA framework was to provide state resource-management agencies with a spatial framework to structure their regulatory programs more effectively, particularly regarding water-quality and biological criteria (Omernik 1995). The premise of this original framework was that the quality and quantity of water at any point reflected the aggregate of upstream characteristics. Subsequent development of the US EPA ecoregions has been oriented toward a broader understanding of ecosystem conditions.

More recent versions of the US EPA framework have been based on the premise that ecological regions should be determined by identifying areas in which coincidental patterns of natural and human-related geographic phenomena occur that reflect spatial differences in ecosystems and their components. Regions are defined where the aggregate of biotic (e.g., potential natural vegetation and fish communities), abiotic (e.g., elevation and physiography), terrestrial, and aquatic characteristics are similar. This approach assumes that the relative importance of each of these phenomena may vary from one region to another, regardless of scale or hierarchical level. A weight-of-evidence analysis is used to assess mapped information and define regional boundaries. The analysis accounts for differences in map accuracy and generalization and for differences in the relative importance of the source maps relative to ecological classification at any particular location.

In mapping ecoregions, the US EPA approach considers humans as part of the biological component of ecosystems. Spatial patterns in human activities help reveal ecological regions that are coincident with patterns of nonhuman geographic phenomena. For example, in the western Great Plains of the United States, the north–south border in natural grassland types is supported by the division between areas of winter and spring wheat and between areas of sorghum production and barley/rye/oats production.

Since 1994, US EPA researchers have collaborated with other federal agencies and with states to refine and subdivide the US EPA framework on a state-by-state basis. These state-level efforts have provided multiple federal and state agencies an opportunity to develop large-scale, state-level frameworks, referred to as level IV ecoregions. Most of these projects were initiated by state resource management agencies to structure their regulatory programs more effectively. The projects also have provided the USFS, NRCS, USGS, US EPA, and other federal agencies with an opportunity to reach consensus on the delineation of ecoregion boundaries at the larger level IV scale. States with successful level IV projects include Indiana, Ohio, North and South Dakota, Montana, western Oregon and Washington, and Wisconsin (Woods and others 1998, Bryce and others 1998, Pater and others 1998, Omernik and others 2000).

Uses of the US EPA framework include support of development of aquatic biological criteria (Hornig and others 1995, Davis and others 1996), determination of lake water-quality management goals (Heiskary and Wilson 1989), assessment of state water-quality data (Larsen and others 1986, US Environmental Protection Agency 1986, Hughes and others 1987, 1994, Hughes and Larsen 1988, Bahls and others 1992, 1994, Hughes 1995), poststratification and reporting of data developed as part of the US EPA Environmental Monitoring and Assessment Program (EMAP) (Larsen and others 1994), development of land-cover maps based on data generated by the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer (AVHRR) sensor (Loveland and others 1995), and design of the National Nutrient Strategy (US Environmental Protection Agency 1998b).

In recent state and regional projects to revise and subdivide the US EPA ecoregions, many agency signatories to the MOU, along with state, university, and nonprofit natural-resource organizations, have participated in developing ecological rather than single resource regions. As these projects have continued and as the initial draft CER map has been developed, the US EPA framework has been substantially modified by changing boundaries and adding regions so that it is coincident with the draft CER 1:7,500,000 framework.

The initial version of the US EPA framework was limited in its usefulness to address the objectives of the MOU for three reasons. First, the original focus of the framework was on water-quality and nonpoint-source issues, rather than the broader ecological risk assessment and ecological management objectives that the framework has addressed in more recent years. Second, the earlier versions were developed in a somewhat cursory manner, being largely based on patterns of geographic characteristics indicated on relatively small-scale maps. Although the use of national and broad multistate maps helped to increase spatial consistency of the framework, the relatively small scale of these materials at times led to overly generalized alignments. Third, the development of the original versions lacked the close involvement of a broad group of experts from all disciplines regarding ecosystem components (plant ecologists, geologists, soil scientists, agronomists, limnologists, aquatic biologists, etc.).

Need for a Framework of Common Ecological Regions

None of the three agency frameworks has been developed in a manner consistent with the challenges presented by the MOU. The biotic and abiotic factors needed for ecological understanding are not adequately accounted for in the regions defined by any single agency framework and have not been developed by consistent methods across the country and reviewed by a single group of experts. In addition, the US EPA, USFS, and NRCS frameworks have distinct affiliations with the agency associated with their development. It is unlikely that any of the agencies with existing frameworks would consider adopting another agency's framework as the basis for meeting the CER objectives.

The existence of multiple frameworks limits the ability of agencies to coordinate their individual resource-management efforts. This is a concern not simply for efficiency reasons; constraints on coordination among agencies may limit the ability of personnel to meet agency management obligations. Legislative and regulatory mandates require agencies to bring an increasingly sophisticated ecological perspective to their work and to support resource-management efforts that extend throughout North America.

A collaboratively developed framework that does not have its origins associated with any single agency has practical advantages. The map resulting from a common framework can serve some of the same purposes as the individual agency frameworks described earlier. A common framework also enables agencies to more effectively coordinate interagency regional planning. Other primary benefits will accrue as much from the map-development process as from the resulting map itself. Because the mapping process requires individual agencies to collaborate, the agencies will benefit from the shared knowledge of the missions, expertise, and programs among agencies.

Improving Interagency Coordination

Federal and state agencies rarely coordinate the collection of natural-resources data by using coincident spatial frameworks. At least two problems can result from this situation. First, the agencies involved lose the opportunity to collect multiple lines of evidence related to resource-management issues. Multiple frameworks for collecting resource information lead to data collected in units that are difficult to compare. It may be difficult to evaluate the overall impact of public policy and associated expenditures when data are collected by individual agencies and cannot easily be aggregated to the same spatial area.

Second, when multiple agencies design and implement data-collection and resource-management activities without using a common spatial framework, duplication of effort may occur. In addition, the opportunity to supplement information generated by one agency with overlapping information collected by another agency may be missed. Only when agencies are aware of each other's missions, activities, and priorities can they avoid duplicating the same tasks in the same general locations. A common framework alone is insufficient to ensure avoidance of such duplication, but it does provide the basis for agencies to track and integrate their work more easily than has been possible with individual, noncoincident frameworks.

A CER framework can help agencies in several ways to undertake more coordinated programmatic efforts. First, a common framework that documents the rationale behind the mapped regions can help scientists at other agencies appreciate how their investigations fit into a broader conceptual framework. An ecological framework integrates a great deal of information relative to a framework based on one discipline only, and this larger perspective can help scientists consider their work in interdisciplinary terms.

Next, a common environmental framework can be used to stratify the variability in certain natural characteristics, allowing agency scientists to more effectively study the effects of human activities. For instance, scientists can more effectively study the effects of land use on water quality by stratifying the selection of study sites to remove the influence of natural gradients in factors such as climate and elevation, which would affect water quality and obscure the impact of humans (McMahon and Cuffney 2000). A common framework, even at a small map scale such as 1:7,500,000, can allow scientists from multiple agencies to design studies that employ diverse measures of environmental response for locations that have common biotic and abiotic characteristics. This increases the possibility of complementary studies.

Third, the CER is expected to assist agencies in coordinating tasks that are similar in terms of focus and locale (for example, multiple agencies monitoring water quality in the same drainage basin). By providing a spatial framework that identifies regions sharing known resource characteristics, the CER increases the potential for coordinated efforts. This may be especially important in the establishment and ongoing monitoring of reference sites within any ecological region. The maintenance of such sites can be costly, and reference sites may be the first element of an environmental monitoring program to be dropped when project funding decreases. Reference sites are required, however, to understand the status of resources in nonreference areas and the degree of resource integrity that is attainable within any region. If multiple agencies can share in establishing a common reference site network, it increases the possibility that an adequate number of such sites can be maintained.

Fourth, the CER provides agencies with a context for generalizing the results of studies conducted in any one region. This generalization may be based on a statistical study design or on an expert judgment-based design. In either case, by controlling for the variability of many key factors, the framework allows investigators an increased measure of confidence in moving from the results of their investigations to characterizing the region as a whole.

Finally, the development and use of the CER addresses government objectives related to minimizing redundancy (National Partnership for Reinventing Government 1999). According to Circular A-16 (Office of Management and Budget 1990), which established the Federal Geographic Data Committee (FGDC), federal geographic data stewards, including the NRCS, Forest Service, and US EPA, are encouraged to work cooperatively to build their respective geographic databases. The CER effort goes beyond Circular A-16, by allowing federal data stewards and their state partners to create a product with shared ownership using collective skills and knowledge. The CER could serve as an effective geographic index to access data through the National Spatial Data Infrastructure (NSDI), as mandated in Executive Order 12906 (The White House 1994), and the National Information Infrastructure on the Internet. The executive order requires the consultation of the NSDI prior to expending federal resources to create new geographic data, thereby reducing further redundancy. Policy-makers could view the separate and independent development of USFS ecological units, NRCS major land resource areas, and US EPA ecoregions as competing and redundant efforts. However, the collaborative CER effort removes the basis for this criticism.

Continuing the Trend Toward Ecologically Oriented Management

The evolution of the three federal resource-management frameworks reflects an understanding that successful natural resource-management is based on a broad, multidisciplinary understanding of natural resources. Early work on classification of habitat types assumed that the climax vegetative community reflected the most meaningful integration of environmental factors affecting vegetation (Cleland and others 1997). Other researchers have disputed this point of view, commenting that any factor that is used to define habitat types related to forest potential is just one part of the ecosystem and is likely to be deficient in classifying habitat types (Rowe 1984). Studies comparing habitat classification systems have shown that combinations of physiography, soil, and vegetation data provide better classification than any single component used separately (Pregitzer and Barnes 1984, Spies and Barnes 1984, Palmer 1990).

Government agencies at state, regional, national, and international levels are attempting to adopt a more interdisciplinary, ecological approach to accomplishing programmatic tasks. At the state level, NRCS has collaborated with the US EPA, the USFS, and other federal and state agencies to adopt an integrated resource perspective and to translate this viewpoint into ecologically oriented frameworks (Mausbach and Weber, Nat-

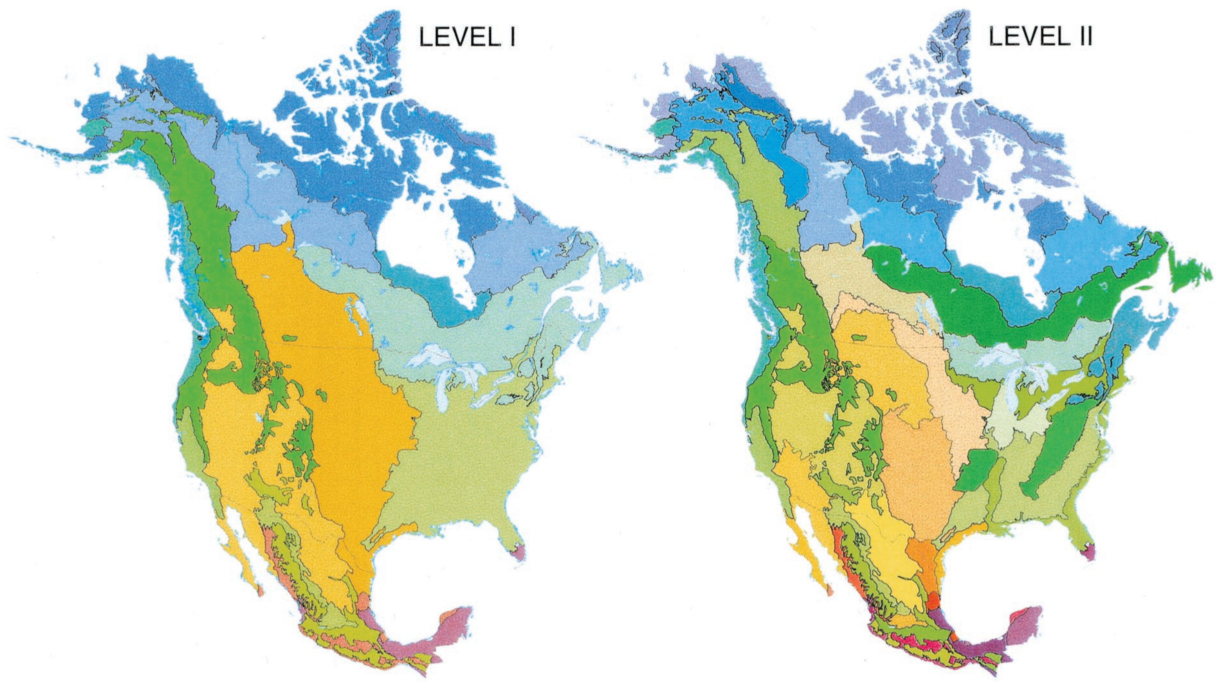


Figure 1. Level I and level II ecological regions of North America (Commission for Environmental Cooperation 1997).

ural Resources Conservation Service, written communication 1998). At the regional and national levels, the USFS has initiated a process for delineating large-scale ecological regions that are to be used for ecological management. In all of these efforts, the delineation of regions reflects the expert judgment of a working group of local, state, and federal scientists.

Increasing the Opportunities for International Cooperation and Conservation

The international management of environmental resources and ecosystems also is hindered by the use of inconsistent spatial frameworks. The health, capacities, and potentials of ecosystems tend to be similar within ecological regions. However, ecological regions do not recognize political boundaries, and the intensity and type of human impacts are often quite different from one country to another, as are the spatial frameworks for managing environmental resources. A common framework of ecological regions such as that developed for North America (Commission for Environmental Cooperation 1997) provides a potential mechanism for integrating management of ecosystems among agencies and programs in Mexico, Canada, and the United States (Figure 1). The MOU-based regionalization effort will attempt to reconcile CER boundaries with the regional boundaries of the CEC framework at the borders of the United States with Mexico and Canada.

Description of CER Effort

The objective of the MOU is that the existing NRCS, USFS, and US EPA frameworks be viewed as starting points for developing a map of common ecological regions for the conterminous United States. This effort represents a substantial step by the signatory agencies to improve interagency coordination.

Scientific Process for Delineating Common Ecological Regions

NITT representatives considered several issues related to the delineation of common ecological regions. Together, the issues define two axes in a typology of regionalization techniques. Along one axis are the methods for analyzing data used to develop the regions. These methods can be classified as quantitative or qualitative; the qualitative method is a weight-of-evidence, expert judgment-oriented approach for developing regions. Along the other axis is the primary perspective employed in developing relatively homogeneous regions. Two distinctive perspectives commonly are used in developing spatial regions—one looking from the top down to recognize visual patterns and the other looking for patterns from the bottom up, as revealed in physical, chemical, and biological process information to define patterns. Approaches along both axes are not mutually exclusive, but regionalization efforts commonly rely on one or the other method to define regions.

Quantitative versus Weight-of-Evidence Methods

The questions of how to define regions and whether the process should be quantitative or based on a weight-of-evidence approach have been a matter of debate among geographers (Hart 1982, Omernik 1995). Both approaches share the overall goal of uncovering patterns in factors that characterize ecological regions. Each approach results in regional boundaries that are hypotheses about the identity and location of these homogeneous regions (Whittier and others 1988, Heiskary and Wilson 1989, Hughes 1995).

Those favoring a quantitative approach, which may rely on a geographic information system and multivariate techniques for assessing the relationship between multiple factors, argue that quantitative approaches define regions that are objective and reproducible. The claim to objectivity rests in the direct lineage between the source maps and resulting regions. The use of numerical methods to define class limits allows reproduceability. In addition, proponents of this approach argue that quantitative methods, including eigenanalyses and clustering techniques, can reveal associations among large and complex data sets that may not be evident in a weight-of-evidence approach (Zhou 1996).

Those arguing in favor of a weight-of-evidence approach note that maps of any particular resource characteristic, such as soils, are representations of aspects of those characteristics rather than an objective one-to-one characterization of what exists on the ground. These representations depend heavily on tacit knowledge and the artfulness of the map compiler (Hudson 1992). For example, in order to create accurate maps of soil patterns by extrapolating from a relatively small number of samples, the mapper has to learn how to visualize the landscape in a holistic sense. This requires an understanding of the relationships between soils and patterns of related geographic phenomena, such as vegetation, climate, physiography, geology, and land use, that is based on subjective expert judgment as well as objective understanding of the physical processes reflected in the source maps. The multiple lines of evidence used to understand and define regional boundaries act as a type of safety net to guard against the overriding influence of any one source map (McNab and Avers 1994, Omernik 1995).

The use of these two approaches to ecological mapping—quantitative and weight-of-evidence—should not be mutually exclusive. The two traditions for generating knowledge about the Earth's surface can complement each other, much as deductive and inductive reasoning are complementary in other areas of scientific endeavor. A quantitative, reductionistic approach to scientific efforts can provide the bricks, while a holistic, inductive approach can provide the architectural design (Holling 1996).

At the 1:7,500,000 scale, the CER approach relies primarily on weight-of-evidence techniques for mapping common ecological regions. Quantitative tools, including use of GIS capabilities to examine the coincidence between multiple source maps and landscape patterns characterized from remotely sensed data, also can be used to support judgments used to make regional boundary choices.

Visual Pattern Recognition Versus Data-Driven Perspectives

A visual pattern recognition approach to delineating ecoregions identifies patterns in the spatial coincidence of factors thought to be important in defining the regions. Although this approach may be used at any map scale, it often has been associated with the use of relatively small-scale (less detail shown over a large area) source maps to delineate small-scale regions, perhaps because many more small-scale national maps of the factors used to define national-level ecological regions are available than large-scale ones. The USFS (Bailey 1998) and US EPA (Omernik 1995) approaches for delineating provinces and level III ecoregions, respectively, can be considered examples of approaches that seek to define regions by identifying patterns in small-scale mapped data.

A data-driven approach for boundary delineation is based on consideration of the physical, chemical, and biological processes associated with a factor (e.g., soil carbon or shrubby vegetation) or factors (e.g., abiotic and biotic landscape characteristics associated with forested vegetation) for which regions are being mapped. These data-driven regions reflect areas of relative homogeneity in the processes associated with single or multiple factors. Although a data-driven approach could conceivably be used at any scale, the detailed information needed to support process-level understanding of landscape characteristics typically may be available only for relatively small areas. A data-driven approach could be used to develop regions of comparable extent to the USFS sections or EPA ecoregions by first delineating much smaller regions, based on detailed information related to ecological processes. These regions could then be aggregated to a size comparable to USFS sections or US EPA level III ecoregions. An important barrier to the success of such a project would be the availability of source data sets for the entire US that are large scaled and include all themes that would be useful in developing ecological regions.

Conceptually, the visual pattern recognition and data-driven approaches to identifying regions are not mutually exclusive. Both approaches consider spatial patterns and physical, chemical, and biological processes associated with the factors for which regional maps are being derived. The differences in the methods are primarily due to the relative emphasis placed on spatial pattern recognition or understanding of the process. Visual pattern recognition and data-driven approaches also can be used together. For example, a small-scale product of a visual pattern recognition regionalization approach can serve as an overall framework to guide the data-driven approach. Thus, the data-driven effort results in smaller mapped units that are essentially subunits, which nest into the larger units defined through the visual pattern recognition approach. In turn, the smaller units may be used to refine the larger unit boundaries.

An example of a coordinated effort to use visual pattern recognition and data-driven approaches is provided by an interagency effort in Oregon and Washington to reach consensus on large-scaled ecological units. The US EPA, NRCS, and USFS used level III ecoregions as a framework into which smaller units, developed using both approaches, would nest. These subregions were agreed upon by the participating agencies and are considered level IV ecoregions by US EPA, common resource areas (CRA) by the NRCS, and subsections by USFS.

Another example can be found in the effort by the USFS, state agencies and the academic community to delineate ecological subsections in the eastern half of the United States, which culminated in the publication of a map and CD-ROM (Keys and others 1995). State- and region-wide teams developed large-scale units through a data-driven process, while the USFS national team used the visual pattern recognition approach to delineate small-scale boundaries.

As an increasing number of large-scale resource maps become available (e.g., Landsat-based land cover, 1:24,000-scale soil series), it will become possible to use the data-driven approach to develop smaller and smaller regions that are relatively homogeneous at a large-scale in terms of a particular set of characteristics. These large-scale frameworks may provide useful information for individual agency programs.

Long- and Short-Term Goals of the CER Process

One of the goals of the MOU is to produce maps of common ecological regions at two scales. The 1:7,500,000-scale map serves as an upper-level framework into which the 1:250,000-scale regions nest. As the 1:250,000-scale regional boundaries are developed, they can be used to focus and refine the boundaries of the 1:7,500,000 framework.

The responsibility for developing the actual boundaries at the two scales is shared by the NITT and the state and regional teams. The MOU directs the NITT to provide to state/regional coordinators the initial small-scale draft map and a set of national standards, recommended procedures, and other technical guidance for the production of a map of ecological regions that meets the objectives of the MOU. The state/regional coordinators are responsible for convening multidisciplinary review teams for a multistate area (two to six states), representing the expertise of federal and state agencies, nongovernmental agencies, and others with an interest in ecological regions. The state and regional review teams are responsible for identifying and using frameworks such as those listed in Table 1, frameworks developed for their locales, and other local information to conduct a review of the 1:7,500,000-scale set of common ecological regions, boundaries, and descriptions of the primary distinguishing characteristics of these regions and to ensure that boundaries for their region are integrated with adjoining regions. Development of the 1:250,000-scale regions is to be completed by the state and regional teams by using NITT guidelines to ensure consistency with MOU objectives. As the 1:250,000-scale boundaries are completed, they can be used to refine the smaller-scale map. The NITT has the responsibility for ensuring that various regional components of the national framework are integrated into a coherent national ecological framework.

Development of the First Approximation 1:7,500,000-Scale CER Map

The NITT, as part of its function to develop national standards, guidance, and procedures for mapping common ecological maps, was directed to develop a 1:7,500,000-scale map that reconciles differences in the three agency frameworks as much as possible and identifies areas that need additional consideration (US Department of Agriculture and others 1996). This map is to serve as a starting point for the ensuing state and regional review process.

The NITT compiled a 1:7,500,000-scale map of common ecological regions during meetings held in Corvallis, Oregon, in November 1997 and January 1998.

The major objectives of these meetings were for the NITT to consider the purposes and intent of each framework and then to draft a map of common ecological regions. These regions identify areas of agreement between the three frameworks and areas where a common regional boundary, or even a commonly agreed upon region, could not be established. NITT members also agreed that the regions resulting from this effort may fit within, and potentially may be used to revise the framework of, ecological regions of North America developed by the Commission for Environmental Cooperation (1997), as part of the North American Free Trade Act.

The perspective used in compilation of this 1:7,500,000-scale map was primarily that of expert judgment-based visual pattern recognition, using a number of small-scale national maps. Emphasis was placed on assessing the weight-of-evidence suggested by these multiple maps in recognizing regions. The map units were approximately the size of US EPA level III ecoregion units and comparable in scale to the USFS sections, the NRCS MLRA regions, and the CEC level III regions (Figure 2).

The process began with a comparison of each of the three frameworks and an evaluation of the purposes and initial intent of each framework compared to the objectives of the common interagency framework. The comparison was conducted by using both paper maps and transparencies of the national atlas maps (e.g., land use, geology, potential natural vegetation, and soils), the NRCS and US EPA maps, and the eastern and western ecological unit section maps of the USFS framework (Table 3). The comparison was primarily oriented to identifying patterns from simultaneously viewing the agency frameworks and the ancillary information from the other maps. This approach, however, was greatly improved by on-the-ground familiarity and expertise of the NITT members with ecological processes and large-scale landscape processes in many portions of the country.

Other thematic maps were used by the NITT to supplement information contained in the national atlas and agency framework maps, including a national shaded relief map developed by Thelin and Pike (1991) and a national land cover map developed by USGS researchers using AVHRR satellite information (Loveland and others 1995). Consideration of uncertain boundary location also was aided by 1:1,000,000-scale plots of the STATSGO and MLRA map units, 1:3,500,000-scale plots of large-scale USFS ecological subsections, and a number of state atlases, maps, and reports of natural areas.

Because the national atlas maps were compiled at a 1:7,500,000 scale and are the smallest scale maps used in the compilation of the CER map, the NITT determined that the CER map should be considered as having been compiled at a 1:7,500,000-scale. An earlier NITT decision to compile the CER map at a 1:1,000,000 scale was determined to be untenable for several reasons. Although the STATSGO map was compiled at a scale larger than 1:1,000,000, the remainder of the maps used by the NITT to compile the CER were at a scale of 1:2,000,000 or smaller. The limits to the information content of these small-scale maps were apparent when they were plotted at a scale of 1:1,000,000. Patterns that were apparent when comparing the various source maps at the 1:7,500,000 or even 1:3,500,000 scales were often obscured or not visible when maps were compared at a 1:1,000,000 scale.

The NITT determined that 25 regions of the conterminous United States were recognized similarly by all three agencies as USFS sections, US EPA level III ecoregions, and NRCS MLRAs. Many of these regions were in states where collaborative work among the US EPA, USFS, NRCS, and other federal and state agencies has been conducted with the aim of reaching consensus in the definition of larger scale (approximately 1:250,000 and 1:1,000,000) ecological regions.

Where there was disagreement among the three frameworks, the NRCS MLRAs and USFS national hierarchy sections generally were more detailed (smaller units) than the US EPA level III ecoregions, in part reflecting differences in agency missions and differences in compilation scale. Understandably, the NRCS MLRAs were more reflective of differences in soils and agricultural potentials. Likewise, in many areas the USFS framework was more reflective of patterns in potential plant communities and associations of vegetation with geology, soils, hydrology, climate, and physiography.

In most of the areas where the three frameworks diverged, NITT members were able to use information from the USFS and NRCS frameworks and resources listed in Table 3 to identify spatial patterns indicative of distinct ecological regions, and they could bring the three framework boundaries into a common location. For example, patterns of USFS provinces in the northeast, supported by water-quality maps and patterns in vegetation and physiography, have been used by the US EPA to make major modifications to their level III boundaries. In the Great Plains, the NITT identified a few relatively small regions, such as the Edwards Plateau, the Flint Hills of Kansas and Oklahoma, and Sand Hills of Nebraska and South Dakota, that are distinctly different from surrounding regions, based on patterns shown in most small-scale (1:7,500,000) maps of vege-

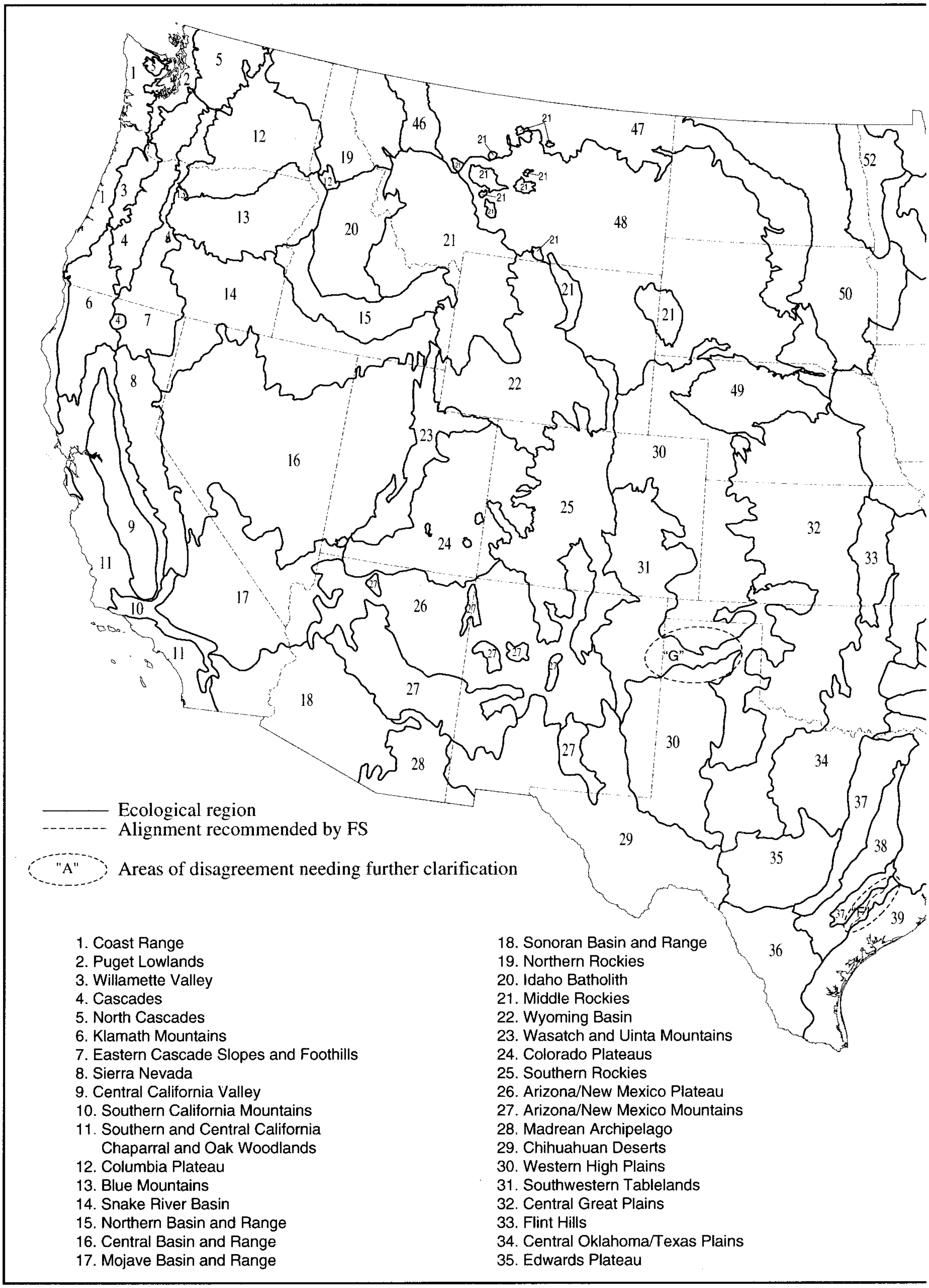
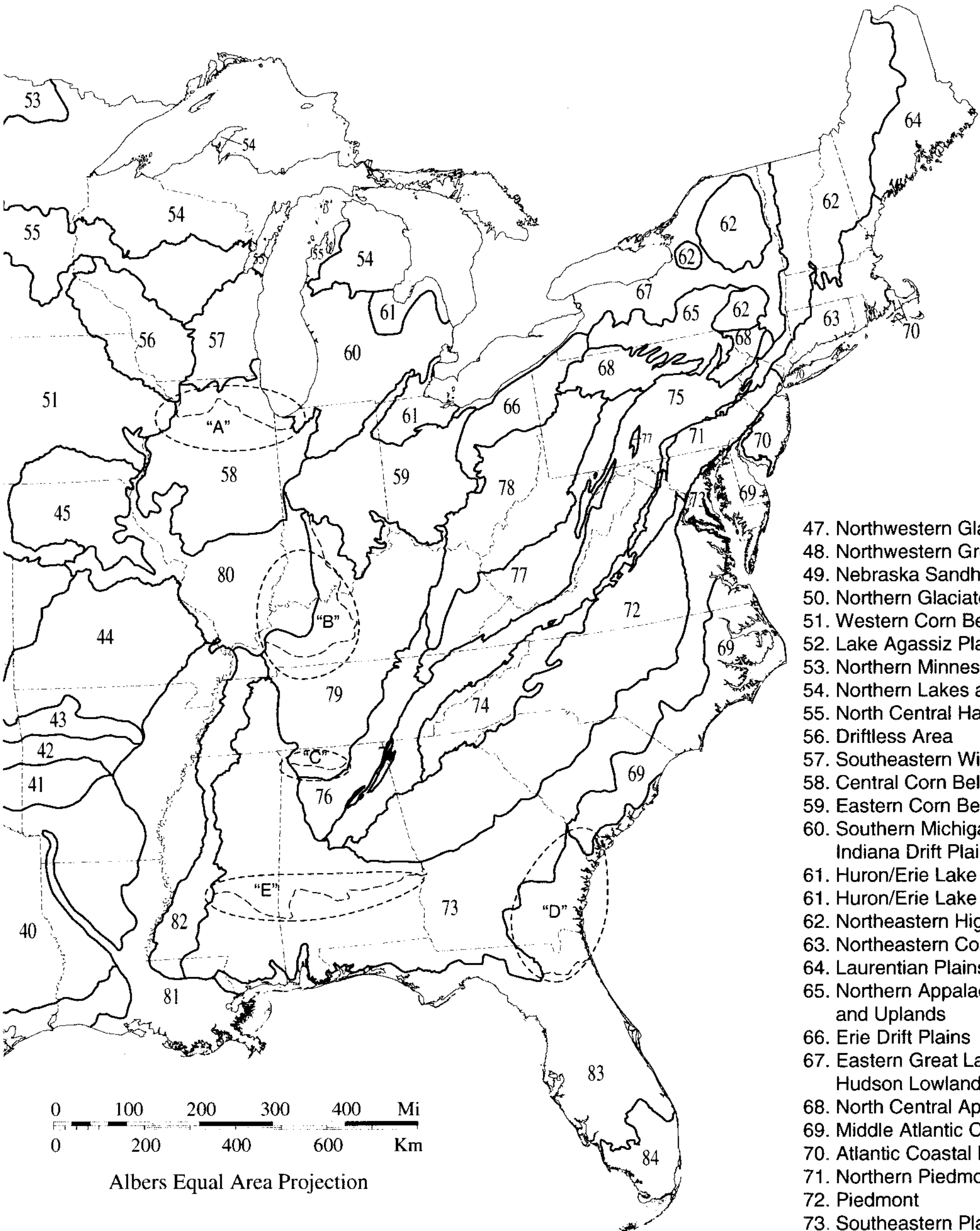


Figure 2. Draft common ecological regions of the conterminous United States.



36. Southern Texas Plains
37. Texas Blackland Prairies
38. East Central Texas Plains
39. Western Gulf Coastal Plain
40. South Central Plains
41. Ouachita Moutains
42. Arkansas Valley
43. Boston Mountains
44. Ozark Highlands
45. Central Irregular Plains
46. Canadian Rockies
47. Northwestern Glaciated Plains
48. Northwestern Great Plains
49. Nebraska Sandhills
50. Northern Glaciated Plains
51. Western Corn Belt Plains
52. Lake Agassiz Plain
53. Northern Minnesota Wetlands
54. Northern Lakes and Forests
55. North Central Hardwood Forests
56. Driftless Area
57. Southeastern Wisconsin Till Plains
58. Central Corn Belt Plains
59. Eastern Corn Belt Plains
60. Southern Michigan/Northern Indiana Drift Plains
61. Huron/Erie Lake Plain
61. Huron/Erie Lake Plain
62. Northeastern Highlands
63. Northeastern Coastal Zone
64. Laurentian Plains and Hills
65. Northern Appalachian Plateau and Uplands
66. Erie Drift Plains
67. Eastern Great Lakes and Hudson Lowlands
68. North Central Appalachians
69. Middle Atlantic Coastal Plain
70. Atlantic Coastal Pine Barrens
71. Northern Piedmont
72. Piedmont
73. Southeastern Plains
74. Blue Ridge
75. Ridge and Valley
76. Southwestern Appalachians
77. Central Appalachians
78. Western Allegheny Plateau
79. Interior Plateau
80. Interior River Lowland
81. Mississippi Alluvial Plain
82. Mississippi Valley Loess Plains
83. Southern Coastal Plain
84. Southern Florida Coastal Plain

Figure 2. (Continued).

Table 3. Maps used in compilation of draft 1:7,500,000 CER map

Map	Reference	Compilation scale
Potential natural vegetation	Kuchler (1964)	1:3,168,000
Physical divisions of the United States	Fenneman and Johnson (1946)	1:7,500,000
Seasonal land cover regions	Loveland and others (1995)	1:2,000,000
Major forest types	US Forest Service (1967)	1:7,500,000
Major land uses	Marschner (1976)	1:7,500,000
Surficial geology	Hunt (1979)	
Geology (bedrock)	King and Beikman (1974)	1:2,500,000
Land surface form	Hammond (1964)	1:5,000,00
Tectonic features	King (1969)	1:5,000,00
Soils (distribution of principal kinds of soils: orders, suborders, and great groups)	US Department of Agriculture (1984, 1997)	1:7,500,000
Dominant soil orders	US Department of Agriculture (1997)	1:250,000
Soil rating for plant growth themes	US Department of Agriculture (1999)	1:250,000
Various state and regional maps of phosphorus in lakes, lake regions, and alkalinity of surface waters.	Rohm and others (1995)	Varies
Agricultural atlas of the United States (1992)	Sommers and Hines (1991)	Tabular—can be mapped to county boundaries
Landforms (shaded relief)	Thelin and Pike (1991)	1:3,500,000
Ecological regions of North America	Commission for Environmental Cooperation (1997)	1:2,500,000
National ecological framework for Canada	Ecological Stratification Working Group (1995)	1:7,500,000

tation, soils, physiography, land use, land cover, and geology. Most other regions of the Great Plains were considerably larger. For example, the Northwestern Great Plains in southeastern Montana, northwestern Wyoming, western South Dakota, and southwestern North Dakota is a relatively large, unglaciated region compared to regions to the north and east, where the more nutrient-rich soils and greater precipitation result in more cropland agriculture. The Northwestern Great Plains had a different mix of potential vegetation than surrounding regions and is now mostly in grazing land. The surface configuration is less rugged than that of the mountains to the southwest, but more irregular than the regions to the north and east.

At the end of the Corvallis meetings there were only five regional boundaries that team members could not agree upon. For all regions where agreement was achieved, a description of the regions was written (National Interagency Technical Team 1999). Boundaries and regional definitions that could not be agreed upon will be considered during a state and local peer review process. The NITT expects the review teams to make recommendations about the location of these boundaries, in part by considering locally available larger-scale information that was not used by the NITT.

In summary, an iterative process was used by NITT members, who looked for coincidence among the three agency frameworks, compared agency boundaries against the objectives of the CER effort, and evaluated mapped information on characteristics that help define ecological potential and capacity. This process resulted in a CER map that contained regional boundaries most of which were agreed upon by agency representatives. A key task of the state and local peer review process, in addition to reviewing the boundaries where agency agreement was achieved, is to use local expertise to refine the final location for all boundaries.

Finalization of the 1:7,500,000-Scale CER Map

The NITT plans several activities to finalize the 1:7,500,000-scale CER map. NRCS Soil Survey Region leaders at regional offices are to serve as the state/region coordinators for the peer review of the draft 1:7,500,000-scale CER map. In addition to MOU signatory agencies, the participants involved in the reviews include other state and federal agencies, nongovernmental groups, natural heritage groups, and individuals. Coordinators for map tile areas must initiate contact with potential participants and use the guidelines provided in this document to organize and carry out the interagency review.

The map manuscript prepared by the NITT for the review teams to use in documenting their suggested changes to the draft map is to be plotted at a scale of 1:1,000,000. This larger scale allows review team members to consider the CER prepared by the NITT in the context of the larger-scale information likely to be available during the local review process. The NITT plans to provide the NRCS Soil Survey Region leaders (who will coordinate activities for each review) with plots of the major maps used in the Corvallis mapping effort at both 1:7,500,000 and 1:3,500,000 scales. These maps enable reviewers to examine the source materials that were used to develop the CER. Plots and transparencies of the draft map of common ecological units and a map indicating the three agency frameworks are to be provided at 1:7,500,000, 1:3,500,000, and 1:1,000,000 scales. Plots of the STATSGO and shaded relief maps are to be provided at a 1:1,000,000 scale. The shaded relief map also will include water features, state boundaries, and the common ecological units indicated for use as the base map on which proposed changes made by the state/regional coordinator reviewers can be recorded. Because STATSGO and the shaded relief maps are the only maps used by the NITT in the original compilation of the draft CER to be provided at the 1:1,000,000 scale, reviewers will be cautioned to not let these two single-purpose maps exert unwarranted influence on determining suggested ecological boundaries. This also is likely to be an issue for other locally available, large-scale thematic coverages.

Among the instructions that the NITT plans to provide to the review teams are the following:

1. The common ecological regions should have a size range that roughly corresponds to the regions and units shown on individual agency framework maps (e.g., USFS national hierarchy provinces and sections, US EPA level III ecoregions, and NRCS MLRAs), with a minimum delineation 1 sq cm on a 1:3,500,000 scale map.
2. Any new common ecological region should reflect differences in ecosystems in the broad sense of objectives of the interagency effort, rather than the characteristics of a single biotic or abiotic characteristic. This is especially true regarding the influence of STATSGO and shaded relief maps.
3. Larger-scale maps (e.g., maps of individual resource themes, such as STATSGO products, or locally available thematic maps) should be used by the review team to fine tune the map unit boundaries. These large-scale maps should not be used to identify new common ecological regions that would not otherwise be indicated at a scale of 1:3,500,000 or smaller.
4. The CER may be reviewed by using quantitative and weight-of-evidence approaches, as well as visual pattern recognition and data-driven regionalization approaches.

The review plan is to have one or more NITT members available to explain these guidelines and clarify and assist at the request of the the state/regional coordinators and review teams. A record is to be maintained of meetings held, participants attending, and materials used, along with a written record of the rationale used in making decisions related to boundary placement and other suggested changes affecting the identification of common ecological regions. This record is to be included with materials returned to the NITT upon completion of the state and regional review portion of the project. The NITT, in turn, plans to document its reconciliation process for handling the review comments and make these notes available to the review teams. Eventually, the NITT also plans to develop a routine process for reviewing and accommodating proposed changes to the small and large-scale CER maps.

Developing the 1:250,000 CER Map

The NISC and NITT have not yet developed detailed guidelines for producing the 1:250,000-scale CER framework, but intend that several principles should guide this effort. NITT and the state and local regional teams will have responsibilities similar to those described for the 1:7,500,000-scale development process. Existing 1:250,000-scale ecological frameworks are to be an important basis for the 1:250,000 CER and in most cases are to serve as an initial draft to be considered by the state and regional teams. Finally, the NITT and NISC have the responsibility for overseeing the mapping process, including reviewing the state and regional products for national consistency and endorsing the product as the official 1:250,000-scale CER.

Several ongoing multiple-agency efforts to develop ecological regions at this scale may provide useful guidance in the preparation of a 1:250,000 CER framework. Efforts to delineate comparably scaled ecological regions are underway or completed in all or parts of many states (Figure 3) (US Department of Agriculture 1994b, Keys and others 1995, Bryce and others 1998, Pater and others 1998, Woods and others 1998). Because these efforts usually involve the same agencies that are signatories to the MOU, along with colleagues from state agencies, universities, and nongovernmental organizations, the state efforts represent a potentially informative mechanism for developing and publishing more detailed maps of ecological regions. In these maps, both quantitative and weight-of-evidence techniques have been useful, along with a data-driven approach for analyzing a variety of large-scale source information. A process for formally adopting existing 1:250,000-scale maps of ecological regions under the CER framework has not been finalized, but many of the existing prod-

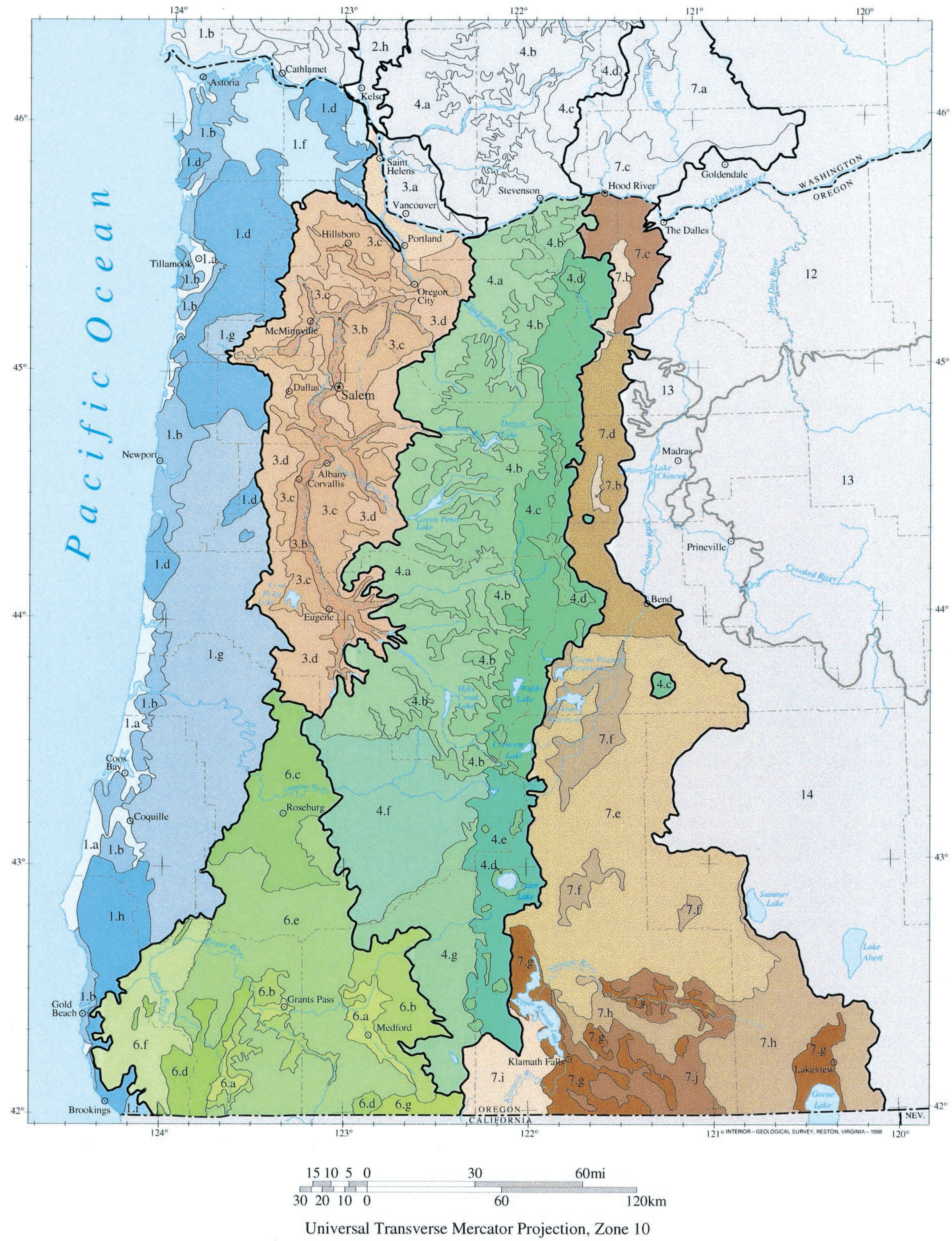


Figure 3. **A** Interagency large-scale ecological regions for western Oregon (adapted from Pater and others 1998). **B** Legend for maps units shown in A.

	A	B	C	D	E
1	Common Ecologi	Common Ecological Region (CER) Name	USEPA Level III and IV	USFS Sections and Subsections	NRCS MLRA and CRA
2	cec_symbol	cec_name	epa_symbol	usfs_symbol	nrcs_symbol
3	1	Coast Range	1	M242A	1 and 4
4	1.a	Coastal Lowlands	1a	M242Aa	1.3,1.8
5	1.b	Coastal Uplands	1b	M242Ab	1.2
6	1.d	Volcanics	1d	M242Ad	1.5,1.6
7	1.f	Willapa Hills	1f	M242Af	1.7,1.1
8	1.g	Mid-Coastal Sedimentary	1g	M242Ag	1.1
9	1.h	Southern Oregon Coastal Mountains	1h	M242Ah	1.4
10	1.I	Redwood Zone	1i	263Ab	4.1,4.2
11	3	Willamette Valley	3	242B	2
12	3.a	Portland/Vancouver Basin	3a	242Ba	2.1
13	3.b	Willamette River and Tributaries Gallery Forest	3b	242Bb	2.2
14	3.c	Prairie Terrances	3c	242Bc	2.3
15	3.d	Valley Foothills	3d	242Bd	2.4
16	4	Cascades	4	M242B	3, some 5
17	4.a	Western Cascades Lowlands and Valley	4a	M242Ba	3.1
18	4.b	Western Cascades Montane Highlands	4b	M242Bb	3.2
19	4.c	Cascade Crest Montane Forest	4c	M242Bc	3.5
20	4.d	Cascade Subalpine/Alpine	4d	M242Bd	3.4
21	4.f	High Southern Cascades Montane Forest	4e	M242Be	3.3
22	4.f	Umpqua Cascades	4f	M242Bf	3.1,3.2,5.7
23	4.g	Southern Cascades	4g	M242Bg	3.2,5.7
24	6	Klamath Mountains	78	M261A	5
25	6.a	Rogue/Illinois Valleys	78a	M261Av	5.1
26	6.b	Siskiyou Foothills	78b	M261Aw	5.2
27	6.c	Umpqua Interior Foothills	78c	M261Ax	5.5
28	6.d	Serpentine Siskiyous	78d	M261Ab	5.3
29	6.e	Inland Siskiyous	78e	M261Ac,M261Aa,M261An	5.4
30	6.f	Coastal Siskiyous	78f	M261Ay	5.6
31	6.g	Klamath River Ridges	78g	M261Ae,M261Da	5.2,5.4,5.7
32	7	Eastern Cascades Slopes and Foothills	9	M242C	6 and 21
33	7.b	Grand Fir Mixed Forest	9b	M242Cb	6.4
34	7.c	Oak/Conifer Eastern Cascades Columbia Foothills	9c	M242Cc	6.5
35	7.d	Ponderosa Pine/Bitterbrush Woodland	9d	M242Cd	6.3,6.4
36	7.e	Pumice Plateau Forest	9e	M242Ce	6.1
37	7.f	Cold Wet Pumice Plateau Basin	9f	M242Cf	6.2
38	7.g	Klamath/Goose Lake Warm Wet Basins	9g	M261Ga,M261Ge	21.1,21.6
39	7.h	Fremont Pine/Fir Forest	9h	M261Gc,M261Gf	21.2,21.3,21.5
40	7.I	Southern Cascade Slope	9i	M261Dh,M261Da	21.3
41	7.j	Klamath Juniper/Ponderosa Pine Woodland	9j	M261Gb	21.4

Figure 3. (Continued).

ucts appear to be consistent with the regionalization objectives proposed in this paper. NISC and NITT intend to endorse and adopt some of these products as components of the larger-scale CER framework.

Individual agencies that are participants in the interagency MOU plan to revise their frameworks during this same time period. Both the STATSGO and USFS section and subsection maps are scheduled to be revised in coordination with the ongoing 1:250,000 CER effort.

The NITT recognizes that the 1:250,000-scale CER regions are likely to provide the primary benefits of the CER project at the level of day-to-day agency operations. Because of their expected spatial extent (Mausbach and Weber, Natural Resources Conservation Service, written communication 1998), these regions are intended to be used by agencies to plan and implement programmatic efforts related to resource management. Such efforts are at the heart of the individual agency missions, such as inventory, characterization of potential and capability, monitoring, status; trends, cause and effect modeling, and policy evaluation. Because it is intended that these regions will be recognized by the agencies with primary federal responsibilities in these programmatic areas, the regions may support realization of interagency benefits in the areas of communication and programmatic coordination. Finally, these large-scale regions are intended to provide a basis for further refinement of the smaller scale common ecological region map.

Conclusion

The 1996 memorandum of understanding among federal agencies with primary responsibilities for understanding and managing the nation's natural resources has a goal of developing a map of common ecological regions for the conterminous United States. The regions defined in this spatial framework are areas within which biotic, abiotic, terrestrial, and aquatic capacities and potentials are similar. The framework is intended to provide the basis for interagency coordination in ecosystem research, assessment, and management strategies. The framework will foster an ecological understanding of the landscape, rather than an understanding based on a single resource, scientific discipline, or agency perspective.

This common framework recognizes the unique perspective and contributions of individual agency frameworks, and the ongoing necessity for agency use of these frameworks. At the same time, the interagency effort is motivated by a desire to address shortcomings in individual frameworks, particularly as these frameworks limit interagency communication and programmatic coordination. The interagency steering committee and technical teams intend, as an objective in developing a common ecological regions map, that agencies will have access to a framework that meets individual agency planning and operational requirements but also serves broader needs for coordinated ecologically oriented resource-management.

Success in this interagency mapping effort is likely to depend on two factors. First, broad-based participation is necessary at the map-review stage to help ensure the integrity and defensibility of the mapped regions. The weight-of-evidence, expert-judgment-based process used to delineate regions in the common ecological region framework relies on integrating a breadth of perspectives, rather than the opinions of a few experts. Second, success of the common ecological region effort also depends on the degree to which participants focus on objectively mapping ecological regions. This is not intended to be a framework of regions based on a single scientific perspective. Perspectives from several scientific disciplines enhance the possibility for ecological management. For any one participant, this may require sacrificing a regional boundary that makes sense from a single perspective, or accepting a regional boundary where one did not exist previously. To adopt this ecological perspective successfully, participants must hear each other's arguments and reasoning, share insights and information, and remain committed to the integrity of the process.

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