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The Natural Resources Conservation Service Land Resource Hierarchy and Ecological Sites

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Resource areas of the Natural Resources Conservation Service (NRCS) have long been important to soil geography. At both regional and landscape scales, resource areas are used to stratify programs and practices based on geographical areas where resource concerns, problems, or treatment needs are similar. However, the inability to quantifiably delineate and classify resource area boundaries hinders communication across the NRCS and federal agencies. Without strong standards delineating geography and concepts, resource areas become less scientifically defensible and inconsistent in addressing similar resource management issues. Furthermore, with continued development of ecological site (ES) concepts, there is a renewed interest in understanding the relationships between resource areas and ESs. In this paper we: (i) review the concepts and history of landscape classifications leading to the predominant regional classification systems used by federal agencies in the USA, (ii) propose strengthening the NRCS's Land Resource Hierarchy (LRH) by building resource area concepts on nesting principles of subdivision instead of aggregation, and (iii) place ecological site concepts as a nested resource area within the LRH.

Abbreviations: BLM, Bureau of Land Management; CRA, Common Resource Areas; EPA, Environmental Protection Agency; ES, ecological sites; GES, general ecological sites; LRH, land resource hierarchy; LRR, land resource regions; LRU, land resource units; MLRA, major land resource areas; NRCS, Natural Resources Conservation Service; STATSGO2, States General Soils dataset; SSURGO, Soil Survey Geographic dataset; USDA, United States Department of Agriculture; USFS, United States Forest Service.

Landscape classifications are designed to divide landscapes into units with significance for the provisioning and regulating of ecosystem services and the development of conservation plans for natural resources. More specifically, such classifications serve as the basis for stratifying management strategies relevant to any given ecosystem's biotic and abiotic properties. Classifying the landscape helps to reduce system complexity so it can be rationalized as a process of rendering order.

The purpose for delineating resource units is to identify geographical areas at different levels of resolution that have similar capabilities and potentials for management (Bailey, 2014). The landscape classification system of the U.S. Department of Agriculture (USDA)-NRCS is the LRH (Fig. 1) which defines resource areas of the USA (Land Resource Units [LRU], Major Land Resource Areas [MLRA], and Land Resource Regions [LRR]). Since its first publication, resource areas of the LRH were defined as aggregations of the lower scale[1] resource area (see Austin, 1965; USDA-SCS, 1981; USDA-SCS, 1997; USDA-NRCS, 2006). For example, MLRAs were defined as geographically associated LRU, with LRUs being the smaller-scaled resource area.

[1] In this paper we refer to ecological scale of the spatial domain instead of cartographic scale.

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Core Ideas:

- **Propose the creation of Land Resource Areas through landscape ecology principles of subdivision.**
- **Integrate nested hierarchical relationships into the NRCS Land Resource Hierarchy.**
- **Place Ecological Sites as a nested resource area scale in the NRCS Land Resource Hierarchy.**

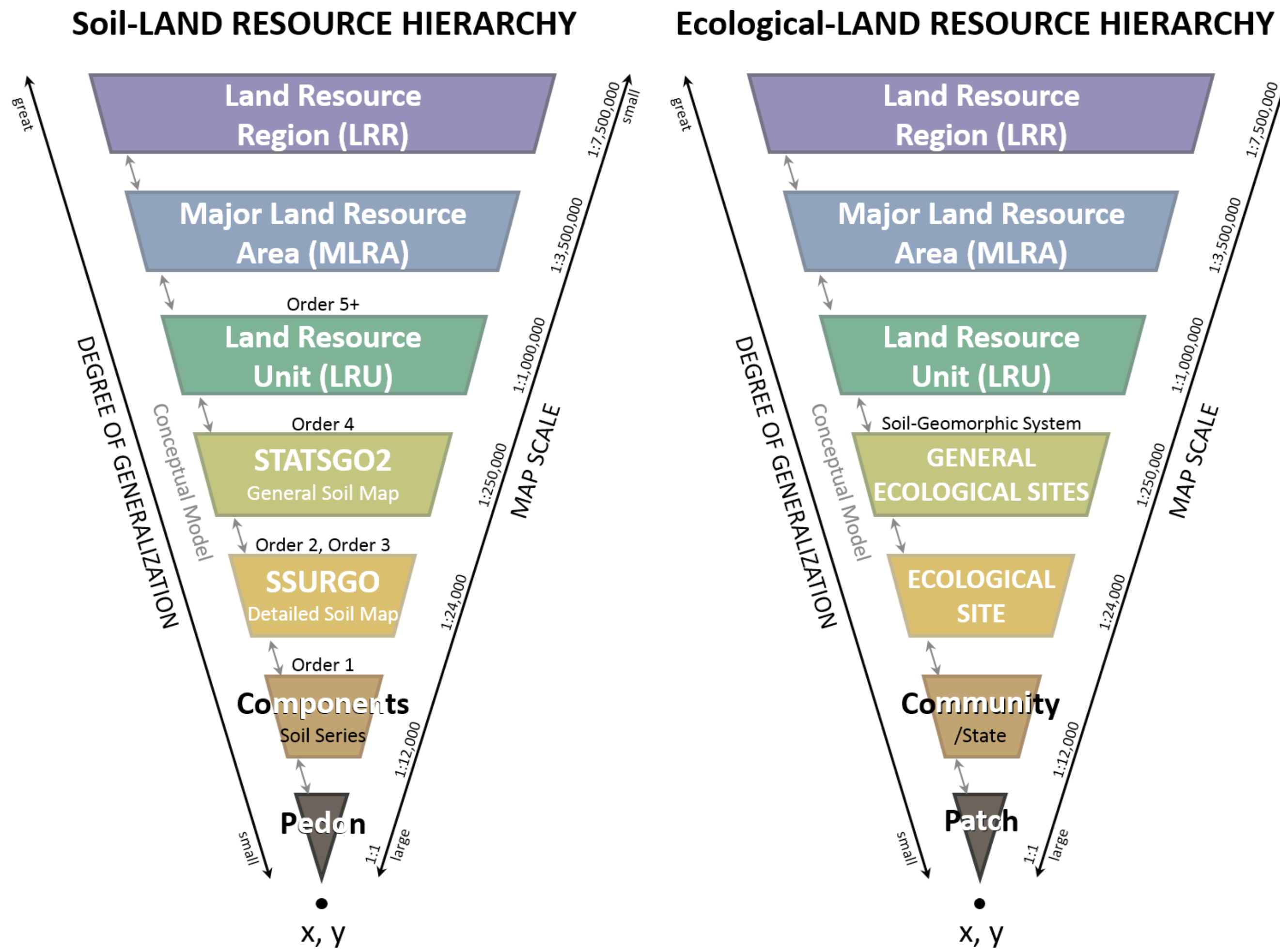

Fig. 1. NRCS Land Resource Hierarchy of soil resources (left) and ecological resources (right) with the most general spatial hierarchy resource areas at the top and specific soil and ecological classification hierarchy at the base.

As MLRA are currently used as the primary organization of programs and practices of the NRCS (USDA-NRCS, 2007), their classification systems must adequately represent the biotic and abiotic components of each resource area. Furthermore, because development of ES concepts is intended to be stratified by resource areas (USDA-NRCS, 2007), it is vital that the NRCS LRH is functional and built on scientific principles.

Because soil and ESs operate differently at specific scales of interest, systems are grouped into nested hierarchies (Bestelmeyer et al., 2011). Hierarchies are often used to describe complex systems to define entities and order for landscapes at particular scales, requiring a basic understanding of the patterns and processes of both upscale and downscale information. Information is typically passed both upscale and downscale in environmental systems, allowing landscape classification construction through the process of both *aggregation* and *subdivision* (or bottom-up and top-down).

Aggregation classifications begin with a universe of individual objects and then group them into classes based on similarities. Those classifications are typically applied when the coarse-scaled events are not well understood or when constructing taxonomic characterizations without respect to geographic location. Through the process of aggregation, classifiers start with individual objects and group them into classes based on their similarities. Subdivision begins with the whole (e.g., continent) and subdivides into smaller units based on regions that have a degree of internal homogeneity. Top-down landscape classifications are based on the assumption that global processes, such as macroclimates which regulates energy and water gradients, override local mesoscale and microscale processes. Both aggregations and subdivisions are structured into individual hierarchies unique to their own procedures, concepts, and applications. As resources can be classified using both processes (aggregation and subdivision), intermediate scales are often the most important scale linking the flow of information from the bottom-up and the top-down.

Since 2010, the Ecological Site (ES) has been an agreed on unit for land management applications for the NRCS, Bureau of Land Management (BLM), and United States Forest Service (USFS). Initially developed for the identification, monitoring, evaluation, and management of rangelands of the United States, ES concepts have now been expanded to all of the United States, including humid and forested regions (Johanson and Brown, 2012). Because ES concepts are uniquely developed within individual MLRAs or LRUs, having a functional spatial hierarchy that can properly nest ES concepts is vital for their success. This paper has three objectives: (i) to review concepts and history of the landscape classifications in the USA, (ii) propose redefining NRCS resource area concepts based on nesting principles of subdivision instead of aggregation, and (iii) to place ecological site concepts as a nested resource area within the LRH.

REGIONAL LAND CLASSIFICATION IN THE UNITED STATES OF AMERICA

The earliest regional land classifications were used to divide the whole into "natural regions" based on climate, configuration, and vegetation. For example, animal geographers described basic patterns of species distributions (Merriam, 1898), and physical geographers looked at underlying process governing divisions of the landscape (Davis, 1899). Two early influential examples of genetic landform classifications include Fenneman's (1928) physiographic divisions of the USA and Köppen's (Köppen, 1931) classifications of the climate.

In the 1930s the U.S. federal government initiated a nationwide effort to study and plan for the development of its natural resources. One land-use map during this period, "The Natural Land Use Potential" (Barnes and Marschner, 1933), is based on generalizations of soil survey maps existing at that time. Ecological classifications of this era were largely defined by groupings of vegetation, ostensibly combining the effects of environmental features such as climate, soils, and topography. Climax vegetation types (for example forest, grasslands, and deserts) with associated fauna defined biomes and biome types, and they were communally mapped as ecological regions (Clements and Shelford, 1939).

As a response to the soil erosional events of the 1930s, the Soil Conservation Service (SCS) developed the provisional framework for "Problem Areas in Soil Conservation" (Norton, 1937). The agency's goal was to coordinate a national research program in soil conservation by identifying regions, quality of the erosion, and susceptibility to further erosion under the present land-use, climate, soil natural vegetative cover, and history of land-use. Since Norton's map is the primary precursor of NRCS's MLRA, it is important to note the soil conservation problem areas were not differentiated according to only a single environmental factor (such as physiographic, topographic, pedologic, climatic, or other environmental factor), but rather a combination of all those features.

By the 1950s, it became apparent that looking at individual resources by themselves was too limited in scope, and a uniform and integrated classification system was needed. At this same time, land managers became aware of the integrated nature of ecosystems (e.g., Curtis, 1956). Ecosystem groupings and spatial patterning became important in resource evaluation, and the environment was finally considered as a resource in its own right. Many of the ideas governing this new outlook on landscape classifications were developed from the 1950s to the 1970s as the discipline of geography began to embrace more quantifiable theories, models, and methods.

The two most important thematic maps of the 1950s are Marschner's "Major Land Uses in the United States" (Marschner, 1950) and Kuchler's map of "Potential Natural Vegetation of the Conterminous United States" (Kuchler, 1964). Kuchler and Marschner both considered their maps representative of an integration of a range of environmental factors (Loveland and Merchant, 2004). While Marschner portrayed physical environments as they were influenced by anthropogenic activities, Kuchler believed natural vegetation integrated biophysical components of landscapes (climate, terrain, and soils). The theoretical foundations established by these two thematic maps serve as an important basis which influenced many of the ecoregion maps currently used by the federal agencies (McMahon et al., 2001).

During the 1980s, advances in GIS technologies, digital soil maps, and coarse global-change models improved the ability to synthesize and deliver geographic information (see Forman and Godron, 1981). From this time, there is abundant literature describing the principles of landscape classification (see Rowe and Sheard, 1981; Bailey, 1983; Turner, 1989) as well as the nesting of landscape units into hierarchies (Urban et al., 1987; Wiens, 1989). Since the 1980s, advances in landscape classification research and application have centered on incorporating multiple disciplines in addition to multivariate and temporal models. Computer systems with increased processing speeds as well as satellite data availability led to the debate of using either quantitative (rule based) or qualitative (weight of evidence) approaches to define regional geography (see McMahon et al., 2004; Hargrove and Hoffman, 2004; Omernik and Griffith, 2014). Some of the efforts of the past decade have been toward the global application of these models to create classifications of continents and oceans (Bailey, 2014), as well as further refinements to the agency classifications and hierarchies.

United States Forest Service. One of the main landscape classifications, the National Hierarchical Framework of Ecological Units (Cleland et al., 1997, 2007), was designed to be a scale-based, nested hierarchy (Tables 1 and 2) in which progressively more specific ecological units were developed as a vegetation classification system (Loveland and Merchant, 2004). At the broadest scale in the hierarchy, climate-influencing factors (continentality, latitude, and elevation) delineate domains, divisions, and provinces, where at the local scale, landforms, vegetation, and soil discriminate the section, subsection, landscape, land unit, and plot ecological regions. The current iteration was developed by a regionalization approach to map subregions from the top-down as well as from the bottom-up to refine boundaries at the lower tiers of the hierarchy (Cleland et al., 2007).

The upper tier units are recognized by variation in global, continental, and regional climatic regimes and apparent physiography. At these scales, the assumption is that macroclimate governs energy and water gradients, thereby acting as the overriding regulator over localized processes. At the largest subcontinental scale, domains and divisions are identified on the basis of general macroclimatic similarity. Climate is given priority at these broad

Table 1. Relationships between the ecological mapping systems of the EPA, NRCS, and USFS hierarchical classification systems based on cartographic scale (modified after Cleland et al., 1997, Caudle et al., 2013).

	Ecological mapping systems			
	EPA ecoregions	NRCS resource areas		USFS ecological units
Scale		Soil	Ecological	
1:30,000,000-1:7,500,000	Level I & II	Land Resource Region	Land Resource Region	Domain & Division
1:7,500,000-1:1,000,000	Level III	Major Land Resource Area	Major Land Resource Area	Section
1:1,000,000-250,000	Level IV	Land Resource Units	Land Resource Units	Subsection
1:250,000-1:60,000		STATSGO General Soils	General Ecological Site	Land type Association
1:24,000-1:12,000		SSURGO Detailed Soils	Ecological Site	Land Type
1:12,000-1:5,000		Component Phase	Ecological State/ Plant Community	Integrated Plot
Point		Soil Pedon	Patch	

scales due to the overriding effects on the composition and productivity of ecosystems from region to region.

Scales beneath division are mapped using finer scaled classifications and mapping through a bottom-up approach. While macroclimate roughly defines province boundaries, section and subsection boundaries are reflected by the less uniform physiographic or geologic features of individual landscapes. Thus, at scales smaller than province, ecoregion boundaries take on a greater degree of cartographic complexity versus the relatively smooth boundaries of provinces. Geologic condition and physiography are the primary basis for recognizing sections, with the assumption that those factors provide the major control over ecosystems. Subsections represent a further refinement of sections and include patterns in potential vegetation, soil, and hydrography. Classifications at smaller scales can be based on disturbance regimes, hydrologic function, local landform pattern, soil, and basic land capability at each appropriate scale. These geographic boundaries are local in nature and serve as guidance for conducting the USFS Terrestrial Ecological Unit Inventory (Winthers et al., 2005).

Environmental Protection Agency Ecoregions. The ecoregion geography (Table 1) and hierarchy developed out of a

Table 2. Relationship between landscape type criteria and soil survey classifications, ecological site correlative unit, NRCS Land Resource Hierarchy, and the USFS National Hierarchical Framework of Ecological Units (Modified after Caudle et al., 2013).

	NRCS			USFS
Landscape type criteria	Soil unit/soil resource inventory order	Ecological site correlation	Land resource hierarchy	National hierarchical framework of ecological units
Regional climate, geology, geomorphology, soil great groups and subgroups,	fifth Order General soils or soil great groups	Land Resource Unit (LRU)	Major Land Resource Area (1:7,500,000-1:1,000,000) and Land Resource Unit (1:250,000-1:60,000)	Subregion: Section (1:3,500,000) and Subsection (1:250,000)
Climate, geology, geomorphology, soil great groups and subgroups, potential vegetation series and subseries	fourth Order Phases of soil families or soil subgroups	General Ecological Sites (GES)	General Soil Map (1:63,360 -1:250,000)	Land-type association (1:60,000– 1:250,000)
Potential natural vegetation, soils, local climate, geomorphology, surficial geology, and hydrology. Based on integrated field plot sample	Third Order Phases of soil series or soil families	Correlated with soil series and differences in species composition of the reference community phase. Mapped as soil series, soil associations, or soil complexes.	Detailed soil map mostly of soil series, soil associations, or soil complexes. (1:20,000 -1:63,360)	Land type (1:24,000– 1:60,000) One (i.e., soil consociation) or more ecological types (i.e., soil association or soil complexes)
Potential natural vegetation, soils, local climate, geomorphology, surficial geology, and hydrology. Based on integrated filed plot sample	second Order Soil series, soil series phase	Correlated with soil series, soil series phase, and reference community phase. Mapped as single soil series, some soil associations.	Detailed soil map mostly single soil series, soil series phase, some soil associations (1:12,000–1:31,680)	Land-type phase (< 1:24,000) One (i.e., soil consociation); sometimes more than 1 ecological type (i.e., soil association or soil complexes)
N/A	first Order Soil series phase	Correlated with soil series phase and reference community phase. Mapped as single soil series phase.	Detailed soil map, mostly single soil series phase map units (1:1,200–1:12,000)	N/A

spatial framework initially used by the Environmental Protection Agency (EPA) for assessing and regulating surface water quality (Omernik, 1987, 1995), the purpose of which evolved into facilitating ecosystem management and environmental understanding (Omernik and Griffith, 2014). The ecoregion framework origins are different from the USFS, as Omernik's strategy has been described as qualitative and driven by expert judgment and analysis (Loveland and Merchant, 2004). This approach establishes an ecoregion based on an enduring feature or features that establish the essence of each ecoregion, and unlike the USFS approach, ecoregions sometimes use land use in defining ecoregion boundaries (Omernik, 2004). This weight of evidence approach considers that the consequences of any one of these phenomena can contrast from one region to another regardless of the scale or level in the hierarchy.

The largest Ecoregions (Level I) are delineated based on the coarse scale domains that "are easily distinguished" from each other (Commission for Environmental Cooperation, 1997; Omernik, 2004), while the next two levels (II and III) attempt to capture the variability within the broad Level I Ecoregions. Even though all tiers of the hierarchy are delineated based on the weight of evidence and the human perception of each division, Level III and Level IV are generally divided based on each area's soils, physiography, potential natural vegetation, and land-use characteristics. Level IV Ecoregion mapping involved numerous federal agencies, state agencies, non-governmental organizations, and academic institutions in the creation, involving an order of magnitude more time and effort than the initial Level III Ecoregion mapping (Omernik and Griffith, 2014).

Natural Resources Conservation Service Land Resource Areas. The NRCS Land Resource Areas (Table 1, Fig. 1) were designed to be a resource for conservation and environmental management (USDA-SCS, 1981). Resource areas historically emphasized agricultural regions containing problem areas in soil conservation and the land use concerns that emerged during, and subsequently following, the dustbowl of the 1930s. Thus, land use and soil properties were always a component of the LRH and its predecessors. Also, because the NRCS was the agency charged with mapping and classifying soil resources of the USA, its resource hierarchy (and subsequent updates) were driven based on advances in classification of soils in the Soil Taxonomic System (Soil Survey Staff, 1960).

Historical products that influenced the Land Resource Areas have their roots in national classifications of soil properties, land use, and conservation potential. The predecessor of resource areas can be linked to Norton's "Problem Areas in Soil Conservation" (Norton, 1937; Soil Conservation Service, 1950), whose geography and concepts lacked hierarchical relationships of the current LRH. The upper tiers of the LRH: LRR, MLRA, and LRU were designed in practice as aggregations of the lower scaled resource area (Austin, 1965). Because local and state conservation offices typically controlled the mapping of resources and soil information, details of the development and subsequent changes to resource areas are difficult to obtain. Also, the current MLRA supporting text (USDA-NRCS, 2006) is simply extracted information describing the MLRA contents instead of the MLRA being defined by the biotic and abiotic properties.

Smaller scale soil resources are considered a part of the LRH, fitting into the hierarchy based on their cartographic standards or specific order of survey. For example, the State Soil Geographic database (STATSGO2) represents a broad-based inventory of soil map units aggregated from the smaller Soil Survey Geographic database (SSURGO). The LRH scales down to the point or soil pedon scale, showing a level of spatial explicitness not inherent with the other landscape classifications.

ATTEMPTS TO CROSSWALK

Historically, federal agencies with management directives within common geographic areas have worked independently when developing their own land resource classifications. Understandably, activities and priorities of each agency helped guide their respective landscape hierarchies. Many of these differences emerged due to predilections associated with each agency's directives. For example, the NRCS's LRH was driven by conservation and management strategies for cropland, rangeland, and soil survey, while the USFS hierarchy was driven as a tool to map and classify vegetation classes across federal land administered by the USFS. These differences have been mirrored in the spatial frameworks resource managers use in the planning, implementation, and assessment of their work. Even though several management agencies may undertake similar programmatic responsibilities in the complementary settings (e.g., inventorying, monitoring, assessment, modeling, policy) each agency has typically operated within their own directive boundaries that limit the kinds of information collected, analyzed, and shared (McMahon et al., 2001).

In the 1990s, geographers tried to harmonize their products so that they were based on ecology rather than political or administrative division (U.S. General Accounting Office, 1994). Due to similar cartographic standards, relationships between the scales within each landscape classification can be made based on scales of each hierarchical level (Table 1). However, direct associations between the three landscape classifications is challenging because not only were they created with different priorities and programs in mind, but were also theoretically constructed differently: Ecoregions based on the weight of evidence (human expertise), Resource Areas based on bottom up (aggregation), and Ecological Units based on a top-down and bottom-up hybridization (aggregation and subdivision).

McMahon et al. (2001) summarized the collaborative steps taken by an interagency technical team to create common ecological regions among many of the federal agencies. The collaboration was in part necessary to address shortcomings in the individual frameworks, particularly when an agency's framework limited interagency communication or program coordination. Omernik (2004) presented many reasons for disagreements between the landscape classifications, which, in addition to the reasons previously discussed, include disagreement in the mutual definition of the ecosystem as well as the reluctance to change.

One collaboration that arose between the NRCS, BLM, and USFS was the interagency agreement for developing a standardized ES handbook for rangelands. Interagency cooperation reinforced the need to reconcile the regional landscape classifications of the USFS and NRCS to stratify ecological site concepts. Caudle et al. (2013) suggest that a unified spatial hierarchy would help in the establishment of ES geographic extent, and progress was made to place ES concepts into both landscape hierarchies (Table 2). Cross walking the respective agency spatial hierarchy systems is indeed necessary for ES classification and correlation; however, strengthening concepts of the NRCS LRH is also a crucial step, especially since MLRA is directly tied to other programmatic directives of the NRCS.

A TOP-DOWN RESOURCE HIERARCHY

NRCS Land Resource Areas (LRU, MLRA, LRR) are historically based on the aggregations of soil associations, specifically the grouping of general soil patterns based on taxonomic classification (Austin, 1965). However, the application of the LRH is directed toward the management and conservation of natural resources. This distinction is important because prioritizing management and conservation occurs at scales larger than the individual soil map unit or field (e.g., at the national, regional, or state level). Furthermore, because the resilience and sustainability of ecosystem and environmental resources contrast regionally, programs cannot make effective management decisions without understanding regional differences and without using a geographic framework distinguishing resources at multiple scales or levels of detail (Omernik, 2004).

One issue that arises when environmental classification systems are based on aggregation is called the "aggregation problem" (Wu, 2004). In general, there is a certain amount of information that is lost when macroscale data is substituted for the microscale data. When presented with the grouped level data, information about the individual level data is not only interpreted differently, but there is no information about the interactions between the individuals. Aggregation approaches fail to embrace holistic ecosystem concepts necessary to understand the basic interrelationships between biotic and abiotic patterns. Simply stated, it is difficult to predict higher levels from only knowing the lower levels. This approach has long been a tradition of soil scientists when mapping soil patterns (Omernik, 2004). For example, soil mappers extract accurate soil maps (from sampling only a tiny fraction of the soil) by visualizing landscapes in a holistic sense (Hudson 1992). With this approach, the soil scientist has to develop an understanding of the basic interrelationships between the soil and patterns of geology, vegetation, hydrology, and land use. Mapping of regional and national resource areas are analogous except that the object is to define regions where there are similarities in the mosaics of all ecosystems and their components (Omernik, 2004).

Systems built on aggregation are applied when coarse-scaled events are not well understood. Because of this, the LRH served the needs of the NRCS as soil resources were continually being inventoried and mapped. However, with much of the continuous USA possessing completed soil surveys, a link should now be established between continental or regional macroclimate processes to the down-scaled landscape phenomenon. Furthermore, landscape classification is considered a deductive process because subsystems can only be understood within the context of the whole (Bailey, 2004), and classifications from below cannot determine ecological units of significance (Rowe, 1997) or be appropriately correlated with other maps because they were derived independently with no whole system in mind (Omernik, 2004).

LAND RESOURCE UNITS

Often intermediate scales, such as the LRU, tend to be poorly defined conceptually when linking fine scale processes with the larger scale phenomenon. This is because factors controlling these intermediate scales transition between the controls of macroclimate at continental scales and modifying effects of the earth's surface at the local scales (Bailey, 2014). Classification of LRUs was left up to state conservationists without standardized criteria and oversite (USDA-NRCS, 2007), and the concepts and geography of this scale often lacked consistency with conflicting concepts where resource areas cross state boundaries. This gap in a functional land resource hierarchy has led to further confusion leading to the creation of Common Resource Areas (CRA). Common Resource Areas were developed to coordinate specific conservation program implementation where resource concerns, problems, or treatment needs are similar (USDA-NRCS, 2007). Our belief is that CRAs are interchangeable with MLRA and LRU concepts depending on scope and scale of the CRA planning unit, however, more work is needed to strengthen landscape interpretations for development of LRU concepts.

If the LRU is indeed a spatially discrete unit on the landscape (as MLRAs are considered), then they have to be delineated based on regionalization principles of subdivision, not through aggregation. Delineating spatially explicit geography of LRUs (and eventually ecological sites) is important due to the ability to overlay MLRA, LRU, and ES concepts into a Geographic Information System (GIS) alongside important spatial phenomenon. This should be a common goal of policymakers and land resource managers allowing MLRA and LRU concepts to be used for stratification of scientifically defensible products, such as ES concepts, resource inventories, and soil survey updates.

GENERAL ECOLOGICAL SITES

In part because of inconsistently defined LRUs, the scale of ES concepts has sometimes been stretched to include larger areas of the landscape. For this reason, we are proposing General Ecological Sites (GES) to represent groupings of ecological sites (Fig. 1, Table 3). The concept of GESs are important for two reasons: first, it allows spatial scaling links between ecological scales of the LRH to scales of general soil maps and the USFS

Table 3. The scales and definitions of resource areas and ecological components of the NRCS Land Resource Hierarchy at approximate map scale.†

Resource area	Map scale	Definition
Land Resource Region (LRR)	1:7,500,000	General physical geographic areas approximating broad agricultural market regions identified by regional macro-climates.
Major Land Resource Area (MLRA)	1:3,500,000	Areas with comparable biotic potentials or limitations, identified as geographic areas with similar physiography, geology, climate, water resources, soils, biological resources, and land use.
Land Resource Units (LRU)	1:1,000,000	Class or areas based on difference in sub-regional climate variation, soils, geomorphology, or topography within Major Land Resource Areas and may or may not be spatially explicit.
General Ecological Sites/Soil Geomorphic System	1:250,000-60,000	Areas of similar geology and linked geomorphic/biotic processes controlling landscape evolution.
Ecological Site	1:24,000-12:000	Classes of land with similar potential vegetation, soil, geomorphology, topographic position, and microclimate
Ecological State/plant community	1:12,000-1:5,000	Areas of similar plant species composition and dynamic soil properties occurring over time.
Patch	1:1	Discrete unit of homogeneous vegetation and soil pedon properties

†After from USDA-NRCS (2007) and Bestelmeyer et al. (2011).

Land-type Associations (Table 2), and second, an intermediate scale in the hierarchy between LRU and ES concepts will serve as a course filter for organizing landscapes on the mid-scale influences of local weather, disturbance regimes, productivity and resiliency, and hydrologic patterns and function. General Ecological Sites are different from the site clusters proposed by Woodmansee (1990) which were intended to integrate ES concepts to their landscape position. At the management scale, site clusters are still valuable as they include catenary concepts showing that sites are linked by their exchange of matter, capturing the variability at the pasture level.

ECOLOGICAL SITES

The ES concept stratifies landscapes based on their biotic and abiotic environmental factors. As with other scales in the resource hierarchy, multiple components can define an ES including climate, soils, landforms, hydrology, vegetation, and natural disturbance regimes (Table 3). Ecological sites are used in conservation management to provide a standardized classification of landscape conditions and provide information for developing and executing land management plans.

Due to the reporting nature of ESs within current NRCS protocols, the area of the ES is directly related to the size of the soil map unit, as ESs are directly correlated to components (rather than soil series). Ecological sites can be represented spatially by linking soil map unit components from the SSURGO with ES classification from the nonspatial tables (Steele et al., 2012). If a soil map unit has a uniquely correlated ES, then the ES is the same size as the soil map unit; however, because soil map unit components frequently describe soil complexes or soil associations, components translate into multiple ESs per soil map unit polygon (Forbis et al., 2007). Because information in the ES database is not spatially referenced with readily available geospatially accessible information, the geographic extent of ESs requires additional levels of interpretation (Twidwell et al., 2013). While attempts are being made to reconcile ES concepts into a spatially explicit framework, having a functional land resource hierarchy with properly nested scales and concepts will aid in the development of ES concepts.

SMALLER SCALES

Incorporating ES concepts into the LRH introduces a temporal component not apparent with a resource hierarchy based only on soil resources. Ecological sites concepts are based on both vegetation and soil as primary elements that govern ecosystem services, and a core part of the ES description is the state-and-transition model describing how vegetation responds to management and natural processes (Bestelmeyer et al., 2009). The ecological "state" is a single community phase, or suite of community phases, that interacts with the environment to produce a characteristic plant species composition, functional and structural group, and soil functions within the range of variability determined by the natural disturbance regime (USDA-NRCS, 2007). Ecological states are indeed a lower level in the resource hierarchy (Table 3); however, because the state is often a product of management decisions and natural processes, precise contrast between the spatial scales of the state and site concepts will be challenging (Steele et al., 2012).

The LRH terminates at the discrete vegetation patch and the soil pedon (Fig. 1, Table 3), giving the NRCS resource hierarchy a spatially explicit nature not inherent in other landscape classifications. This link to the vegetation patch is crucial because implementation of conservation programs and management decisions are based on specific points on the ground. Furthermore, implementation and monitoring of conservation practices require an explicit statement of the point scale of soil-vegetation relationships (Karl et al., 2012). The vegetation patch provides the opportunity to monitor effects of specific management practices and provides a feedback to reassess the properties and processes of higher scales within the LRH.

CONCLUSION

In this paper we have outlined the historical developments of landscape classifications and characterized those developed by the U.S. federal agencies charged with management of natural resources. We have placed ES in the LRH. We propose a new concept, GES, to associate ESs into like groups and to correspond with USFS land-type associations; however, the hierarchical relationships between MLRA, LRU, GES, and ES concepts must be tested and strengthened across resource area scales. Finally, we propose that resource area geography should be defined based on principles of subdivision instead of aggregation.

Because the mission of NRCS is to provide conservation planning resources to individual farmers and landowners, the LRH has typically lacked a robust scientific organization. For that reason we have provided the background of classification systems and contrasted the LRH with other systems used by the federal agencies. Historically, academic research supported soil survey efforts regarding landscape classification, soil function, and mapping techniques; however, those collaborations have decreased since the soil survey went into production mode. The current push to develop ES concepts has highlighted a need to refocus research on the ecological principles of landscape classification and for the NRCS to develop stronger standards and concepts for each level of its resource hierarchy.

Strong standards and definitions are severely needed for MLRA and LRU concepts and geography. Without a standard means of delineating and classifying resource areas, communication within NRCS and among other federal agencies is hampered. Without a national policy, MLRAs, LRUs, and ESs become less scientifically defensible and inconsistent in addressing same or similar resource management issues. To have successful conservation programs and practices, resources areas have to be tied to spatially explicit delineations of the landscape. Considerable monetary and personnel resources are currently being directed toward MLRAs, yet based on the current framework we can't quantifiably separate individual MLRAs.

As stated by Rowe and Sheard (1981) and Bailey (1983), classification maps are products of hypotheses that must be tested and improved. Furthermore, Omernik and Griffith (2014) argued that the framework of landscape classification should be judged based on its usefulness. We feel that for the ES concept to be successful and useful, it has to be nested within the LRH and LRAs have to be restructured based on classification principles of subdivision. By structuring resource areas based on sound scientific principles we will be able to more appropriately describe landscapes for the provisioning and regulating of ecosystem services and the development of conservation plans for natural resources.

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