Classifying Northern New England Landscapes for Improved Conservation

Authors: Johanson, Jamin K., Butler, Nicholas R., and Bickford, Carl I.

Source: Rangelands, 38(6) : 357-364

Published By: Society for Range Management

URL: https://doi.org/10.1016/j.rala.2016.10.007

Case Study

Classifying Northern New England Landscapes for Improved Conservation

By Jamin K. Johanson, Nicholas R. Butler, and Carl I. Bickford

On the Ground

- Ecological land classification enables improved conservation by linking land types to vegetation, ecosystem services, disturbance regimes, and conservation practices.
- Defining landscape-scale ecological site groups allows for the development of generalized state-and-transition models for summarizing the major ecological dynamics and associated conservation practices within a region.
- We defined nine ecological site groups for northern New England (MLRA 143) by identifying the fewest number of ecological classes as possible while retaining maximum utility of state-and-transition models for each class.
- Ecological site groups provide scalability of ecological site information and simplify the development of ecological concepts and the application of appropriate conservation practices.

Keywords: ecological site, state-and-transition model, ecosystem services plant community, ecological classifications.

Rangelands 38(6):357–364

doi: 10.1016/j.rala.2016.10.007

Northern New England is famous for its vibrant fall foliage. Each year thousands travel north along scenic byways and backroads to enjoy the beauty of rugged mountains and low hills draped in gold, crimson, and amber hues (Fig. 1). Beneath this alluring tapestry of vegetation lies an intricate network of landforms and soils that govern the distribution of water, nutrients, and energy that support the region's vibrant and diverse ecosystems. In addition to natural beauty, the ecosystems of northern New England provide various wood products, wildlife habitat, clean air and water, and other services valued by society.

The Northern New England Landscape

Conservation of the northern New England landscape requires knowledge about the dynamics of its ecosystems and the services they provide. Although many plant communities have been described for the area, very limited information exists relating plant communities to soil and topographic properties. Ecological classifications that relate plants to soil and topographic properties are useful for understanding where plant communities and ecosystem services occur over space (due to environmental gradients) and how they change over time (due to changes in disturbance and management regimes).

As part of its mission to provide resources that enable conservation, the USDA-Natural Resource Conservation Service is engaged in a nationwide effort to capture, organize, and share knowledge about ecosystems using the Ecological Land Resource Hierarchy as a framework. Within this framework, northern New England is classified as Major Land Resource Area (MLRA) 143 and occurs within the Northeastern Forage and Forest Region at the highest level of the hierarchy. This paper describes a conceptual subdivision of MLRA 143 into nine ecological site groups (ESG), which represent a newly proposed level in the hierarchy between MLRAs and Ecological Sites (*see Salley et al., this issue*). The ESG concepts described here are based on soil and landform properties, which produce distinctive functional groups of plants that respond similarly to management and disturbance. The primary reasons for developing ESGs are 1) to describe, in the simplest way possible, meaningful relationships between plant functional groups and the landforms and soils on which they occur; and 2) to use information about these relationships as a basis for effective conservation of ecosystem services.

MLRA 143 consists of the northernmost mountains and hills of the eastern United States, including the Adirondacks in New York, the Greens in Vermont, the Berkshire Range in Massachusetts, the Whites in New Hampshire, and most of northern and eastern Maine (Fig. 2). The area is sparsely populated, with less than 5% developed for agriculture, residential, and urban development. About 90% of the area is forested, most of which is actively managed for timber. Elevations range from nearly sea level to over 1,500 m on the

Figure 1. Northern Maine in autumn, overlooking Sebec Lake, Borestone Mountain (center left), and Grapevine Ridge (center right).

highest peaks, and tree line ranges between 1,100 and 1,400 m. The majority of MLRA 143 averages 815 to 1,145 mm of annual precipitation and has a 5 to 6 month growing season with frigid winter temperatures. However, the higher elevations may receive up to double the annual precipitation of the lower elevations and have a 3 to 4 month growing season with extremely cold winters.[1]

The characteristic landforms and soils of northern New England were derived from the massive continental ice sheet that engulfed the region during North America's most recent glaciation. Mighty glaciers, embedded with sediment and rock fragments, scoured bedrock and compacted mineral beds in a steady march south and east toward the Atlantic Ocean. The softer sedimentary rocks were pulverized into fine silts and clays under the immense weight of ice 1 to 2 km thick, while the more resistant igneous and metamorphic rocks were sculpted into steep mountains and hills or plucked and dragged along the base of the glacier. With a warming climate the ice retreated northward, depositing a thin layer of unsorted glacial till sediment atop the newly exposed bedrock and compacted mineral beds. Deeper mounds of unsorted till formed small hills known as kames, moraines, and drumlins. Enormous chunks of ice detached as the glacier retreated, melting slowly in place and forming many kettle lakes and basins where water and fine sediments collect. Raging torrents of glacial meltwater dissected much of the barren landscape, entraining coarse and fine sediments, carving river valleys, and leaving well-sorted deposits of mostly sand and gravel along the watercourse. By 10,000 years ago the ice sheet had fully receded from MLRA 143. Silty floodplains developed along perennial rivers, many of which occupy the same channels that once gushed with sediment-rich glacial meltwater. Over time, wet basins accumulated fine sediment; some dried out, and still others became acidified by organic matter inputs from colonizing vegetation.[2]

Understanding landscape setting provides a critical foundation for interpreting patterns and developing useful ESG concepts.[3] These landscape patterns are not only intuitive to most people, they are also strongly correlated to important soil and hydrologic features governing plant distribution, disturbance regimes, and ecological processes. By linking landscape units to vegetation, we set the stage for insightful ecological interpretations at a landscape scale.

Ecological Site Groups

Our guiding principle for developing ESGs was to minimize the number of groups while maximizing the utility of state-and-transition models (STMs) developed for each group. STMs are box and arrow diagrams depicting the ecological dynamics of an ecological class.[4] The boxes represent ecological states that typically occur within an ecological class, and the arrows represent transitions from one state to another over time. States are defined both by species composition and the ecological processes and management that perpetuate the state's characteristics. Arrows define disturbances and/or management practices that significantly alter ecological processes and vegetation, resulting in a persistent change from one state to another.[5] An STM diagram is accompanied by narratives, tables, and photos that describe the boxes and arrows in more detail for guiding management actions. Because STMs describe temporal changes in vegetation and ecological processes within an ecological class, they are ideal for comparing tradeoffs in ecosystem services among competing management alternatives.[6]

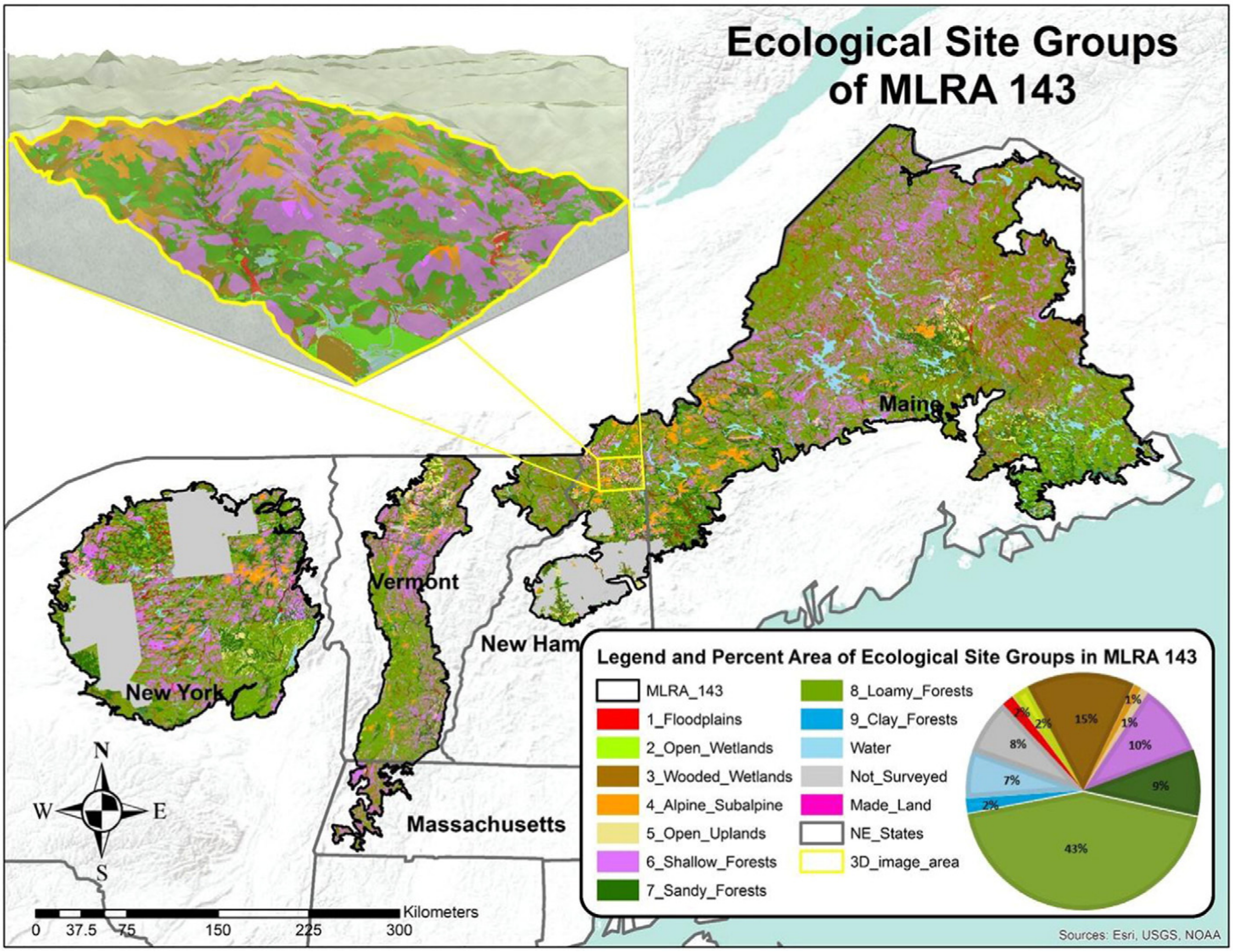

Figure 2. Map of nine ecological site groups in MLRA 143 (Northeastern Mountains Area). Pie chart shows approximate percentage of area for each group.

The nine ESGs in MLRA 143 were conceived by 1) identifying landforms with similar soil and hydrologic properties, which 2) support similar functional groups of vegetation, and 3) exhibit similar drivers of ecological processes. Existing plant community classes and data from ongoing Natural Resource Conservation Service field investigations helped verify likely functional groups of vegetation for each ESG.[7–10] Ranges in important landform and soil features were obtained by assigning an ESG to each major soil component in the US soil survey geographic database in MLRA 143 (select features summarized in Table 1). The approximate spatial distribution of ESGs throughout MLRA 143 (Fig. 2) was produced with these same soil component-ESG correlations. The order of the nine ESGs provides a sequential key for identifying the appropriate ESG for any piece of land, starting with group one and working sequentially by process of elimination.

The first three ESGs, Floodplains, Open Wetlands, and Wooded Wetlands, occur on the wettest landscape positions. Floodplains include landforms adjacent to major rivers and streams subject to flooding, erosion, and deposition processes. Open Wetlands lack sufficient nutrients and/or oxygen in the soil to support significant tree cover, whereas Wooded Wetlands support greater than 40% tree cover. The next three ESGs, Alpine/Subalpine, Open Uplands, and Shallow Forests occur on the most exposed landscape positions. Alpine/Subalpine includes high elevation areas, near or above tree-line. Open Uplands are mostly small, exposed areas with little or no soil, resulting in limited tree establishment despite being below tree-line. Shallow Forests have less than 50 cm of soil over bedrock. The final three ESGs, Sandy Forests, Loamy Forests, and Clay Forests, occur in intermediate landscape positions, being neither the wettest nor the most exposed. Sandy Forests consist of very deep, coarse mineral deposits—such as eskers, deltas, and outwash plains—formed by high-energy glacial meltwater. Loamy Forests are the most extensive ESG in MLRA 143, occurring primarily in unsorted glacial till deposits, but also in various other settings

Table 1. Summary of select topo-edaphic features for ESGs in MLRA 143

ESG	Hydric soils?	Drainage classes	Particle size classes (and related terms)	Landforms	Other
1. Floodplains	Yes No	Very poorly, Poorly, Somewhat poorly, Moderately well, Well, *Excessively	Fine-silty, Coarse-silty, Fine-loamy, Loamy, Coarse-loamy (over sandy) Sandy, Sandy-skeletal	Floodplains, stream banks and terraces, natural levees, backswamps, etc.	All land subject to alluvial processes, particularly river flooding
2. Open Wetlands	Yes *No	Very poorly, Poorly, *Somewhat poorly	Mostly Peat and Muck, sometimes over minerals of any particle size class	Marshes, bogs, fens, depressions, beaches, etc.	Waterlogged soils lacking sufficient oxygen or nutrients for tree persistence
3. Wooded Wetlands	Yes *No	Very poorly, Poorly, *Somewhat poorly	Mostly Peat and Muck, often over minerals of any particle size class	Depressions on uplands, swamps, plains and terraces on outwash, lakebeds, till, etc.	Wet soils with sufficient oxygen and nutrients for tree persistence
4. Alpine/ Subalpine	No	Somewhat poorly, Moderately well, Well, Somewhat excessively, Excessively	Loamy, Coarse-loamy, Loamy-skeletal, Medial, Sandy, Sandy-skeletal, *Thixotropic	Ridges and slopes of mountains	High elevations with a cryic soil temperature regime, not including wetlands
5. Open Uplands	No	Well, Somewhat excessively, Excessively	Fragmental, N/A for Rock Outcrop and other miscellaneous lands	Ledges, ridges, cliffs, rock outcrop, balds, blow-out land, etc.	Exposed sites lacking sufficient water or nutrients for tree persistence
6. Shallow Forests	No	Well, Excessively, Somewhat excessively	Loamy, Loamy-skeletal, N/A for Organic Duff	Ridges and slopes of hills, drumlins, and mountains	Upland forests with less than 50 cm of soil over bedrock
7. Sandy Forests	No	Moderately well, Well, Somewhat excessively, Excessively	Sandy, Sandy-skeletal	Eskers, kames, deltas, outwash plains, terraces, moraines, hills, etc.	Includes blueberry barrens, which, without regular fire, revert to conifer forests
8. Loamy Forests	No	Moderately well, Well, Somewhat excessively, *Somewhat poorly	Coarse-silty, Fine-loamy, Loamy, Loamy-skeletal, Coarse-loamy, Split-family	Till plains, hill slopes and ridges, drumlins, moraines, lake plains and terraces, etc.	Some split-family particle size classes likely grade into the sandy group
9. Clay Forests	No	Somewhat poorly, Moderately well, *Well	Very fine, Fine, Fine-silty, Coarse-silty over clayey	Lake beds, lake plains	

* **Indicates soil properties that can occur in a group when associated with other soils that fit the core concept of that group**.

where soils are loamy. Clay Forests formed in dry lakebeds and lake plains and therefore have fine clay soils with very few rock fragments.

ESGs are connected in predictable ways that help to conceptualize how landforms and soils affect the distribution of energy, nutrients and water across the landscape. For instance, the Alpine/Subalpine, Open Uplands, and Shallow Forests tend to shed water, which carries nutrients downslope into the Sandy, Loamy, and Clay Forests, which tend to be the most productive timber sites. Eventually, large amounts of water flow into the Floodplains, Open Wetlands, and Wooded Wetlands in the lowest landscape positions.

State-and-Transition Models

Linking ecological classes to conservation practices requires the development of an STM for each ESG. STMs provide the framework for organizing knowledge about temporal dynamics within an ESG. Table 2 summarizes the most common ecological states and drivers of state change in each ESG, generalized for simplicity.

Overall, the ESGs in MLRA 143 are very resistant to disturbance and highly resilient following disturbance compared to other MLRAs. The wet, cold climate extends fire return intervals well beyond a thousand years, though spruce-fir and pine forests may burn somewhat more frequently.[11] Windthrow is a common disturbance that occurs naturally on all forested ESGs, resulting in small patches where trees are uprooted by wind, or rarely as large patches when entire stands or landscapes are pummeled by microbursts or hurricane-force winds.[12] Species composition may change significantly following disturbance; however, invasive species are not documented as exerting sufficient dominance in MLRA 143 to constitute a state change. Of all the naturally occurring disturbances, tree mortality from insects and disease has arguably the greatest impact on these otherwise highly resistant ecosystems. For example, spruce budworm kill, which historically affected small patches of mature forest, are amplified by timber production and pest management activities that promote extensive tracts of even-aged forest, resulting in entre landscapes of standing dead spruce and fir. Alternatively, forest stand management practices that limit the patch size of even-aged forest stands help alleviate the impacts of spruce-budworm.[13] The threat posed by native and invasive insects and disease will likely be affected by management practices in a similar way.

Hydrologic changes resulting from dams, roads, and other structures impeding water movement primarily impact Floodplains, Open Wetlands, and Wooded Wetlands. Changes in flooding frequency and intensity, along with bank armoring practices, alter the hydrologic regime, which historically governed ecological dynamics on Floodplains. An increase or decrease in water table impacts Open Wetlands and Wooded Wetlands, most commonly as ponding depth and duration change both upslope and downslope of road grades or other structures. Although less than 3% of MLRA 143 is cultivated,[1] similar landscapes to the north across the Canadian border are mostly cleared and cultivated, indicating potential for increased cultivation in the area. Timber production is the primary land use in northern New England, and many of the observable ecological states have resulted from forest stand management designed to maximize harvest efficiency. By contrast, a hemlock-dominated state may be the unintended consequence of selectively harvesting more valuable timber species, leaving hemlock to dominate in areas where it may not have done so historically.

Figure 3 shows how the knowledge of ecological states and drivers of transitions contained in Table 2 can be depicted visually in a STM, using Sandy Forests as an example. Our modeling approach differs from common STM depictions of less-resilient systems, which tend to rely on reversibility and threshold concepts to define states and depict transitions.[14] Instead, we define states as compositionally-distinct, persistent plant communities with significantly different interpretations for managing ecosystem services (*see Brown et al., this issue*).

The Sandy Forests STM consists of four forested states, which may transition between one another by selective harvesting and/or target species establishment. The pine forest state, for example, can be achieved by selectively removing other tree species, cutting and dragging seed-laden mature pine across the site on a good mast year, and/or planting pine saplings. However, care should be taken to minimize contiguous areas of young pine without overstory canopy, as these are susceptible to weevil damage. The resulting pine stand can be pruned and otherwise managed for high-value timber production, as well as upland wildlife habitat. The pine forest state can also result when intensively managed cleared land reverts to forest under natural or managed succession, as can the hardwood forest and spruce-fir forest states. The hemlock state, however, cannot supplant intensively managed cleared land because hemlock requires shaded conditions for establishment. Additional ecosystem services can be identified and described for each state in the model, and should be developed by local experts[15] for each ESG.

Ecological Classes for Conservation Decision-Making

The addition of the ESG landscape level between MLRA and Ecological Sites in the land classification hierarchy provides an intuitive, landscape-scale summary of the ecology and management of northern New England ecosystems. ESGs divide the landscape into intuitive soil-landform groups, and STMs link each group to the ecosystem services, processes, and management practices associated with various ecological states and transitions. The development of tables and narratives describing alternative conservation practices for each state will be the key to maximizing the utility of ESG classifications and associated STMs. This represents a large workload that will require new and creative ways of organizing ecological information, as well as collaboration among various stakeholder groups.[16] However, when

Table 2. Summary of the most common disturbances driving state transitions and the most common ecological states (both generalized for simplicity) for ESGs in MLRA 143

	1. Floodplains	2. Open Wetlands	3. Wooded Wetlands	4. Alpine/ Subalpine	5. Open Uplands	6. Shallow Forests	7. Sandy Forests	8. Loamy Forests	9. Clay Forests
Common disturbances driving state transitions									
Hydrologic regime change	X	X	X						
Soil erosion, deposition	X				X				
Cultivation	X		*			*	X	X	*
Windthrow	X		X	X		X	X	X	X
Timber harvest	*		*	*		X	X	X	X
Insects, disease			X	*		X	X	X	X
Fire				*	*	*	*	*	*
Invasive plant Dominance									
Common, generalized ecological states									
Shrubs and herbs	*	X		X	X		X		
Wetter (ponded)	*	X	X						
Drained, regulated flow	X	*	*						
Hay or pasture	X		*			*	X	X	*
Crop/agronomic system	X					*	*	X	*
Hardwood forests	X					*		X	X
Mixed conifer forest			X			X	X	X	X
Hardwood/ conifer mix			*			X	*	X	X
Spruce-fir forest			X	X		X	X	X	X
Pine forest						X	X	X	X
Hemlock forest						X	X	X	X

* Not likely in many areas, but can occur when specific land features allow it (i.e., context dependent).

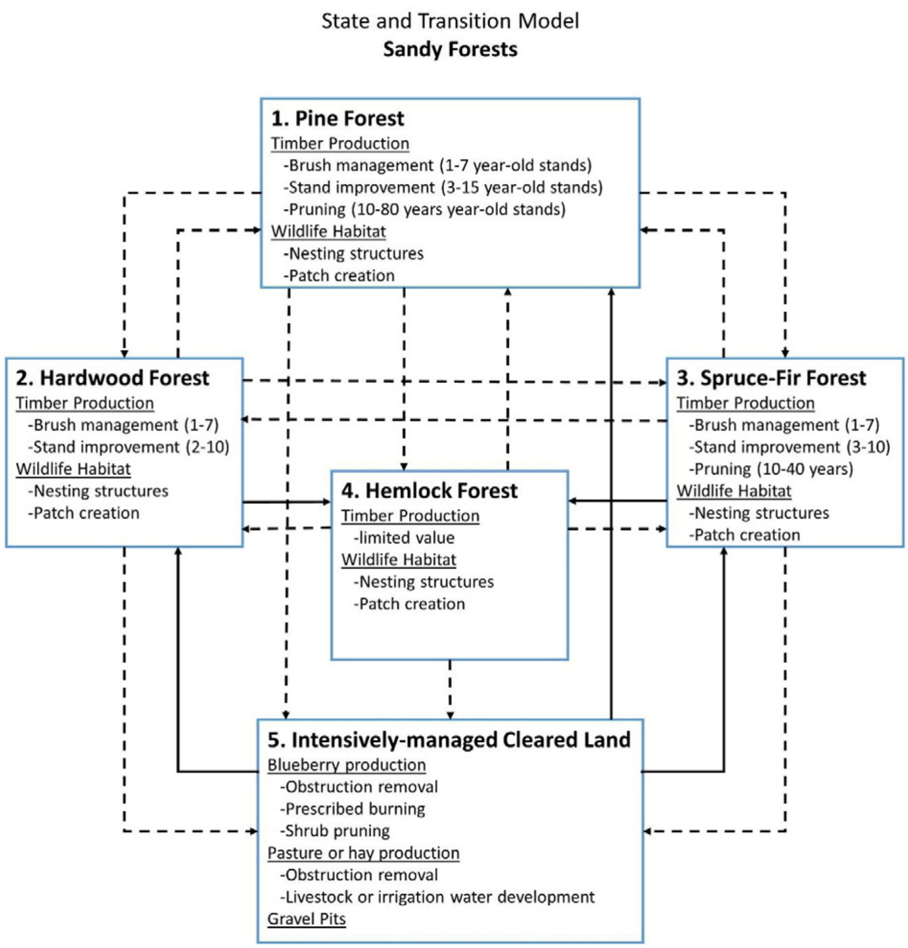

Figure 3. State-and-transition model for the Sandy Forests group. Boxes represent states, with example production and habitat practices listed for each (age of stands for each practice in parentheses). Dashed lines indicate transitions that may require active management, typically involving expensive, deliberate practices. Solid lines indicate transitions that may occur in the absence of active, deliberate management.

compared to current efforts to develop STMs at the ecological site scale—which has several times as many classes—the workload of developing useful STMs at the ESG scale is significantly more manageable.

Ecological sites and ESGs are complementary concepts. For some users, important site-scale variability in soil–plant relationships may require more detailed information about floristics, wildlife use, conservation practices, and other considerations than that which is available at the ESG scale presented here. As an example from MLRA 143, the US Fish and Wildlife Service is using ecological site concepts to guide conservation practices with the express purpose of matching plant communities to soil properties in order to approximate historical reference conditions, maximize species diversity, and preserve important site-scale ecosystem features and processes. Ecological sites are expected to have states, transition drivers, and conservation practices that are similar to the ESG to which they belong. Therefore ESGs are expected to aid in the development of ecological site descriptions for MLRA 143, which currently has none available for use.

The need for reliable ecological knowledge reflects increasing demands for the sustainable conservation of ecosystem services as diverse as food and fiber production, recreation, wildlife habitat, aesthetic value, water quality, air quality, and so on. The addition of ESGs to the land classification hierarchy improves the scalability of ecological knowledge transfer for improved communication, monitoring, assessment, and management of ecosystem services.

Acknowledgments

Special thanks to Brandon Bestelmeyer and Joel Brown for reviewing the article for clear language and content.

References

1. United States Department of Agriculture, and Natural Resources Conservation Service. 2006. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. US Department of Agriculture Handbook 293. Washington, DC, USA. pp. 473-475.
2. Barton, A.M., A.S. White, and C.V. Cogbill. 2012. The changing nature of the Maine woods. University of New Hampshire Press: Lebanon, New Hampshire, USA. pp. 24-40.
3. Monger, H.C., and B.T. Bestelmeyer. 2006. The soil-geomorphic template and biotic change in arid and semi-arid ecosystems. *J Arid Environ* 65:07-218.

4. Bestelmeyer, B.T., J.R. Brown, K.M. Havstad, R. Alexander, G. Chavez, and J.E. Herrick. 2003. Development and use of state-and-transition models for rangelands. *J Range Manag* 56:114-126.
5. Stringham, T.K., W.C. Krueger, and P.L. Shaver. 2003. State and transition modeling: an ecological process approach. *J Range Manag* 56:106-113.
6. Herrick, J.E., B.T. Bestelmeyer, S. Archer, A.J. Tugel, and J.R. Brown. 2006. An integrated framework for science-based arid land management. *J Arid Environ* 65:319-335.
7. Gawler, S.C., and A. Cutko. 2010. Natural landscapes of Maine: a guide to natural communities and ecosystems. Maine Natural Areas Program, Maine Department of Conservation: Augusta, Maine. pp. 64-77.
8. Thompson, E.H., and E.R. Sorenson. 2000. Wetland, woodland, wildland. Vermont Department of Fish and Wildlife and The Nature Conservancy. University Press of New England: Hanover, New Hampshire. pp 1-386.
9. Sperduto, D.D., and B. Kimball. 2011. The nature of New Hampshire. University Press of New England: Lebanon, NH. pp 1-307.
10. Edinger, G.J., D.J. Evans, S. Gebauer, T.G. Howard, D.M. Hunt, A.M. Olivero, editors, Ecological communities of New York State. Second Edition. A revised and expanded edition of Carol Reschke's Ecological Communities of New York State. New York Natural Heritage Program, New York State Department of Environmental Conservation, Albany, New York. 160. [Available at: http://www.dec.ny.gov/animals/97703.html. Accessed 22 November 2016].
11. United States Department of Agriculture, and Forest Service. Fire Effects Information System. Available at: http://www.fs.fed.us/database/feis/fire_regime_table/PNVG_fire_regime_table.html#Northeast. Accessed 1 September 2016.
12. Lorimer, C.G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. *Ecology* 58:139-148.
13. Hennigar, C.R., J.S. Wilson, D.A. MacLean, and R.G. Wagner. 2011. Applying a spruce budworm decision support system to Maine: projecting spruce-fir volume impacts under alternative management and outbreak scenarios. *J For* 109:332-342.
14. Bestelmeyer, B.T. 2006. Threshold concepts and their use in rangeland management and restoration: the good, the bad, and the insidious. *Restor Ecol* 14:325-329.
15. Knapp, C.N., M. Fernandez-Gimenez, E. Kachergis, and A. Rudeen. 2011. Using participatory workshops to integrate state-and-transition models created with local knowledge and ecological data. *Rangel Ecol Manag* 64:158-170.
16. Johanson, J., and M. Fernandez-Gimenez. 2015. Developers of ecological site description find benefits in diverse collaborations. *Rangelands* 37:14-19.

Authors are Ecological Site Specialist (Johanson, jamin.johanson@me.usda.gov); Soil Scientist (Butler); and Soil Scientist (Bickford), Natural Resources Conservation Service, Dover-Foxcroft, Maine, 04426, USA.