Using Ecological Site Information to Improve Landscape Management for Ecosystem Services

By Joel R. Brown and Kris M. Havstad

On the Ground

- Ecological sites and their component state-and-transition models are valuable tools for predicting the effects of climatic and management changes on a variety of ecosystem services.
- Site-specific information must be able to be both refined to finer scales to account for spatiotemporal variability within a mapped site and expanded to include interactions with other sites in the landscape to identify priorities and account for integrative disturbances and ecosystem services such as wildlife habitat, hydrology, fire, insect outbreak and invasive species.
- Ecological site groups, spatially contiguous and behaviorally similar, are an important level in the land hierarchy to organize and interpret information.

Keywords: soil survey, natural resource management, Major Land Resource Areas (MLRA).

Rangelands 38(6):318–321

doi: 10.1016/j.rala.2016.10.011

People, and their societies, have a complicated relationship with land. The unofficial patron saint of ecologists, Aldo Leopold, in "The Sand County Almanac," traced the modern human relationship with land from a purely economic to an ecologically based approach, culminating in his "Land Ethic."[1] In this ground-breaking and influential essay, Leopold proposed that "a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it." The main idea embodied in this essay was that good land management was an individual and community responsibility that transcended pure economics. While Leopold focused primarily on the cooperative nature of the human relationship to land, a secondary, but just as important, part of the essay was that "The land ethic simply enlarges the boundaries of the community to include soils, waters, plants and animals, or collectively, the land."

Whether explicitly stated or not, "The Land Ethic" has become the basis for most modern conservation efforts, both through the ideas of *sustainability* as an individual and collective ethical commitment, but also in the inclusion of diversity in products and processes that go beyond commodities.[2] It has provided a foundation for the ideas of ecosystem services by expanding the benefits of nature to human communities.[3] By going beyond the traditional provisioning (food, fuel, fiber) services to also include regulating (control of climate and disease), supporting (nutrient cycles, pollination), and cultural (aesthetics, re-creation, spiritual) services, the modern ecosystem services approach is both a way to incentivize more sustainable management and to communicate to humans their connection to the natural world.[4] While a reasonable argument could be made that Leopold did not have the "commodification of nature" in mind, there is no doubt about the connections.

One clear benefit of an ecosystem services approach to land management is the realization that there are no nonworking lands. Everything is managed to achieve some sort of societal benefit. Even "wildlands" have guidance for management (Wilderness Act of 1964). In most cases, the luxury of managing land for a single commodity output is not available. Even the most intensively farmed croplands have to be managed to ensure some level of sustainable yield. At the other end of the spectrum, completely protected lands require some kind of extensive management and are frequently surrounded by lands managed at different degrees of intensity (e.g., the Greater Yellowstone Ecosystem).

Thus, the ecosystem services model has expanded to include virtually all types of land and land management. The idea that all land is, to some degree, working land and requires at least strategic management is pretty easy for practicing rangeland managers to accept; the expansion to products and processes beyond immediately marketable commodities is more difficult. Making those connections more tangible and transparent is what Ecological Sites are for. In this issue, multiple papers (*see Salley et al., Karl and Talbot, Bestelmeyer et al., this issue*) address the framework for connecting ecological process and pattern, while others (the case studies) provide interpretations of those patterns and processes to address emerging conservation issues. The purpose of this paper is to explicitly define the necessary requirements of a system that provides those tangible and transparent connections so that scientists, managers, policymakers, and an interested public can see specifically how landscapes can be managed to achieve a range of objectives. The fact that there is frequently an overwhelming lack of agreement on what those services should be is not considered in this paper, but there are techniques and proven applications for making those decisions as well.[5]

For ecosystem services to provide an incentive for land managers to adopt improved practices, there has to be some motivation. For the purposes of this discussion, we will rule out regulations and legal pressure as incentives. In the voluntary realm, if the ecosystem service has a well-developed market (i.e., beef, wool, fuel), relationships between land manager actions and price are relatively reliable. While government conservation programs track payments and activities closely, there is a decided lack of standardized methodology for determining the relationship between landowner actions and the resulting non-commodity ecosystem services.

In this paper, we propose that ecological sites and their supporting information can be the basis for developing more quantitative and transparent relationships between incentives, whether public or private, land owners actions, ecological processes, and, ultimately, ecosystem services. This is not a new issue. DeGroot et al.[6] provides a comprehensive list of 23 different ecosystem services, but also points out that a standardized methodology to account for these benefits, assess tradeoffs, and provide a basis for markets is lacking. Recent critiques of ecosystem service markets are evidence that more specificity in definitions and rules, as well as in project level applications, could be improved, especially in terms of improving links to land management and science.[7]

A Systematic Approach to Ecological Sites for Ecosystem Services

We believe that there are three principles that a systematic approach to ecological site information should follow to ensure transparency, accuracy, and consistency.

Account for Everything, Including Interactions

A consistent hurdle in the development of a framework that will increase the use of ecosystem services to broaden incentives for management action is the inability to integrate across scales. While some land units (and landowners) may opt to manage for a particular ecosystem service (say, water quality), others within the same watershed or basin may focus their management efforts on production of commodity grains. The grain producers, depending upon where their land is located within the watershed, may or may not have influence on water quality. These complex, spatially explicit relationships require baseline information and models that can integrate across multiple spatial scales to insure cost-effective policy implementation.[8] In this special issue of *Rangelands*, the case study by Spiegal et al. similarly identifies critical landscape components (ecological site groups) that should be the focus of management for an endangered species, but also acknowledges the important context of surrounding sites. The selection of critical sites for either water quality or habitat management is impossible without knowledge of the interactions among sites and how the ecological process(es) of interest integrate those sites. Incomplete or inconsistent information about ecological sites within a landscape makes it difficult to predict across scales, and more importantly, to convince, through various incentives, land managers of their role in managing landscapes for ecosystem service goals.

Ecological sites (especially in the United States), as a derivative of the modern soil survey approach, have suffered from the tendency of mappers to view landscapes as collections of polygons. This approach has led to an overemphasis on what makes soils/sites different and how can they be distinguished, described, and archived in a defensible manner. The outcome has been the overemphasis on some sites, based on areal extent, productivity or accessibility, and an underemphasis on interactions among sites. The map-making approach has also led to a fixation on differentiating the polygons, both spatially and in terms of describing their inherent properties (*see Karl and Talbot, this issue*). These point and polygon scale rules for differentiating pieces of land have made the bookkeeping and programmatic parts of conservation easier, but treating the landscape as a collection of non-interacting polygons has not contributed greatly to more stable, diverse, and productive landscapes.[9]

Provide Compatible, Consistent Information, Including Tradeoffs

The father of modern soil conservation, Hugh Hammond Bennett, founded an entire movement based on some key social and ecological principles. His central belief, "use every acre within its capability and treat it according to its needs," provided the basis for a variety of soil and land classification schemes, as well as a conservation philosophy.[i] Our expanding expectations of what ecosystem services we require from land, as well as our evolving understanding of ecosystem function, has moved us away from a precise definition of "best use" of Bennett's early 20th century to a more modern, multidimensional approach to both what we expect from working lands and how we treat them.[10]

The idea of multiple potential stable states, multiple unidirectional pathways, and multiple ecosystem services has had a profound effect on all land management, but especially rangelands. Managing land without intensive inputs requires a much more refined and nuanced understanding of ecological processes, especially how extensive management practices and ecological processes can interact over relatively minor changes

[i] Read more about Hugh Bennett at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nc/newsroom/features/?cid=nrcs142p2_046733.

in space and time. More input-intensive land management (tillage, seeding, fertilization) generally has a predictable impact, at least within a broad range of conditions. On the other hand, applying the same practice can have vastly different outcomes over very short spans of space (*see Bestelmeyer et al., this issue*), primarily reflecting differences in soil properties that are smaller in scale than even the most precise commonly available maps. Temporally, applying the same practice can also have substantially different effects, depending on the initial conditions (ecological state). Stringham and others (*see Stringham et al., this issue*) present state-and-transition models in which response to fire can vary depending on the ecological state at the time of burning. In many cases, these slight variations can result in a differential rate of response, but it is not uncommon that the right practice at the wrong place or time can be disastrous.

Comparing such differential responses further complicates an already complicated exercise. Selecting site(s) within a landscape for application of specific management practices requires both site-specific information and the context of how that site interacts with others around it (item 1). Those types of comparisons can only be made if there is a standardized database of information (comparing sites) and a hierarchical context (interactions) with similar information. Williams and others (*see Williams et al., this issue*) provide an excellent example of how a tool for comparing site scale hydrology with management can be integrated into a larger landscape scale assessment of which sites should be treated to achieve different landscape scale goals, using the same currency (water).

Information Must Be Accessible, Transparent, and Organized

It goes without saying that any kind of information needs to be accessible, especially if there is a substantial public investment in gathering and interpreting, and a public interest in using it to improve people's lives. Unfortunately, making information useful is a lot more difficult than just making it easy to download (*see Karl and Talbot, this issue*). In fact, too much information or too easy access can be just as inhibiting to people who need the information as too little. The key is to have information easily available on demand, while simultaneously creating the demand.

Accessibility of natural resource information requires thorough analysis of decision-making and decision-makers. In addition to the wide variety of natural resources, land managers have different objectives, different personal resources, and different backgrounds.[11] While the natural resource management profession has been relatively active in acknowledging and accepting this diversity as part of the profession, we have not made much progress in how our decision support tools can be adapted to improve decision-making across this diverse set of users. Contrary to how many resource technicians and scientists view the world, natural resource information may be relatively easy to organize compared to trying to account for how users prefer to access and use information.[12]

Part of the accessibility challenge involves transparency—that is, can users see where the information came from, how it was organized, and how it was interpreted. One of the major failings of the range condition model was the reliance on "climax" conditions, at a very high level of specificity, as a point of departure for measuring current conditions and determining management responses. In many cases, the climax plant community was a compilation of extant plant communities, based on a limited number of experts' opinions. In others, it was no more than a historical reconstruction. In either case, the lack of supporting documentation about what it was and why that particular very specific mix of plant species was chosen to represent a highly variable group of soil and climatic properties, greatly diminished the value of the concept as a communication tool.

In the current version of ecological site descriptions, a similar problem can greatly limit user confidence and utility. Even if "reference community" conditions are quantified for the reference state in the state-and-transition model, and provide a basis for the calculation of departure (similarity index), the false precision of a specific plant composition list and the lack of consistent relationships among ecological states in the form of transitions undermines the credibility, both in real-world field applications and in conceptual analysis.[13] Ecological site groups that rely on logic for grouping soil behaviors, published literature for general ecological state-specific soil and vegetation relationships as indicators, and experimental and modeling results to guide practice selection to achieve objectives are much more defensible (*see Bestelmeyer et al, this issue*).

In defining the relationship between ecosystem dynamics as described in site-specific state-and-transition models and the provision of ecosystem services at the landscape scale, a collection of accurate ecological site groups with generalized state-and-transition models, supported by decision models for up and down-scaling, is much more likely to provide a basis for effective decision-making and credible delivery to public and private sector markets than an incomplete list of sites, overly precise plant species lists, and inconsistent state-and-transition models.

Finally, organizing the vast array of information, most of which is relevant only within specific spatiotemporal situations, is no small challenge. Fortunately, there are well-developed tools for defining and refining information delivery as a precursor to introducing the user to the decision process. Once a user has definitively defined the location of interest, many of the options for land management will naturally fall away (Fig. 1). Similarly, an accurate assessment of ecological state will exclude many management options, while bringing others to the fore. As an example, think of a shrub-dominated site in South Texas with a land manager who desires to return to an open-savannah grassland.[14] Realistically, there are not a lot of options for achieving that transition, especially in a management (decadal) timeframe. The initial management actions implemented in the first 5 to 7 years are very limited, and follow-up activities then are contingent on the relative success of the initial practices.

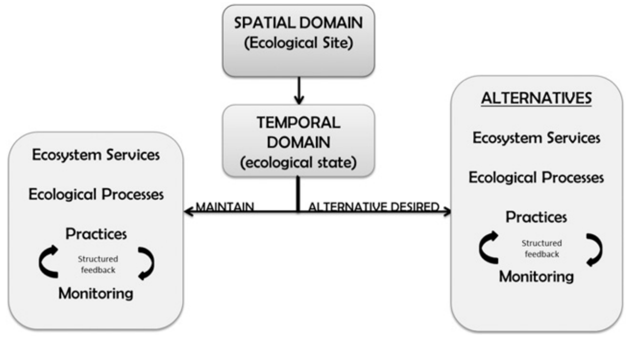

Figure 1. A conceptual flow model for making and implementing conservation decisions using ecological site and state-and-transition model information. The user first determines the spatial domain (ecological site) to assess the range of potential ecological processes and plant communities possible for the site. The existing plant community then is determined to identify the range of management options available. The user can then decide to maintain the existing conditions (ecological processes, ecosystem services), implement appropriate management practices, and monitor to determine if the practices are working to achieve objectives. Alternatively, the user can opt for another potential state and access information about timeframe, cost: benefits, and likelihood of success.

While the land manager needs a lot of information about how to get out of the shrub-dominated state, the most relevant information is how long it will take and what the initial steps are. Ultimately, the most relevant information may be what kind of ecosystem services are provided by an ecological site/state combination that is not responsive to management inputs or the time available for a specific landowner.

This approach to decision-making is by no means an attempt to constrain access to information. Rather, it is more an effort to integrate logic, expert knowledge, and (incomplete) supporting data into a more structured approach to decision-making. Not every user is going to have a degree in rangeland ecology, but they just want to know what they can do to avoid the negative effects of climate change and some idea of the most important thing to do first (now), when should the second step be implemented, and so on. While a precise roadmap may be more satisfying to the resource professional, a thoughtful discussion of what is possible and how to start may be more helpful to the land manager.

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