National Assessment and Critiques of State-and-Transition Models: The Baby with the Bathwater

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On the Ground

- Ecological site descriptions and state-and-transition models are national-level tools for organizing and delivering information about landscape dynamics and management.
- Recent papers criticized state-and-transition models because they overemphasize grazing, are inconsistently presented, and do not address climate change.
- I argue that the analysis of Twidwell et al. does not support an overemphasis on grazing, that inconsistent presentation is a necessary consequence of early model development efforts and immature science concepts, and that climate change effects should not be addressed in site-level models without evidence.
- Improving these important tools requires fair critique, but also the strong commitment of scientists and funders.

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Ecological site descriptions (ESDs) have been characterized as the world's largest land management framework.[1] They comprise a database and document collection used throughout the United States to provide management guidance in rangelands and, increasingly, in forests, wetlands, and croplands. ESDs are specific to fine-grained (1:12,000) land classes called *ecological sites* that differ in soil, landscape position, or climate, and therefore in potential plant communities. Different ecological sites call for differences in the details of management actions such as stocking rates, restoration seed mixes, and strategies for managing woody plants.

The focus of ESDs is on vegetation and soils as primary elements governing ecosystem services including forage for livestock, erosion control, and wildlife habitat. A core part of ESDs is the state-and-transition model (STM) that describes how vegetation responds to management and natural processes. STMs replace older "range succession" models that represented vegetation change as reversible linear trajectories driven by grazing and weather. The STM format encourages inclusion of a broader array of drivers, interactions among drivers, and multiple possible trajectories, reflecting recent advances in ecological science.

ESDs and STMs have become central tools for rangeland evaluation in the United States, primarily used by the USDA Natural Resources Conservation Service (NRCS), the Bureau of Land Management, and the US Forest Service. ESDs are used for activities including the evaluation of rangeland health, decision support for the selection of conservation or restoration practices, communication with land managers, and stratification and interpretation of monitoring data. Thousands of ESDs (9,341 as of 2014) in varying stages of completion have been created, spanning the United States.

Twidwell et al.[1,2] offered a severe critique of ESDs. The critique was based on an evaluation of 340 STMs to quantify and compare among ESDs the particular kinds of states (e.g., herbaceous or herbaceous shrub mix), types of transition between alternative states (e.g., woody plant encroachment, shifts in composition of herbaceous species), and drivers of transition or restoration (e.g., grazing, fire, brush management). Several of their conclusions are ultimately constructive, but others are incorrect or overstated. My primary concern is that their critique leaves the impression that, collectively, ESDs provide poor or even damaging guidance to land managers. Based on the critique, ESDs may appear to some readers to be a poor investment and not be worth the involvement of scientists or potential funders. ESDs have much to improve on, no doubt, but they offer unprecedented advantages for organizing and delivering information about landscape dynamics and management.

I will be transparent about my potential biases. I have worked with STMs and ecological sites since 2000. I have worked closely with ESD developers. Like others, I am frequently frustrated by how ESD development has progressed. Yet I continue to believe in the value of ESDs, for reasons described here.

This article will focus first on what I regard as misinterpretations about the ESDs analyzed by Twidwell et al. and misunderstanding of the function and evolution of ESDs. I also point to disagreements and research shortfalls within the broader science community that are merely reflected in ESDs, rather than being specific to ESDs. I then describe, and amplify from the Twidwell et al. critique, what I feel would improve the rigor and utility of ESDs.

The Critique

Grazing Is Overemphasized

Twidwell et al.'s primary critique centers on an apparent inconsistency. They found that grazing is featured as a driver in a larger number (268) of STMs than is fire (235) or brush management (208). Yet woody plant encroachment (239 STMs) is the most common transition process, followed by woody plant reduction (223), and shifts in herbaceous species (163). Twidwell et al. consider these patterns to reflect a "grazing-woody plant fallacy" in which "grazing is listed as the number one driver of both degradation and restoration when woody plant encroachment and reduction characterize the two dominant state changes in ESD[s]." They go on to state that "Decades of scientific research suggest grazing management does little to prevent the conversion of grass-dominated ecosystems to woody-dominated ecosystems upon the onset of woody plant encroachment." Twidwell et al. also point out that, in one ecological site that the authors are familiar with, "long-term increases in woody plants are observed … irrespective of grazing pressure" and that "Grazing-induced reduction of fine fuels is one of many pathways that influence fire intensity and its effects."

The assertion that a "grazing-woody plant fallacy" is responsible for flawed STMs is not supported by their analysis. First, in their reference to Archer et al. (2011) that grazing management does little to prevent woody encroachment after its onset, they overlook another statement in the same review: "However, grazing management influences on [woody plant] encroachment are indirectly important in terms of how they affect the amount and continuity of fine fuels available for wildfire or prescribed burning." Even if this is not true in Great Plains sites known to Twidwell et al., grazing management can be an important part of managing woody plant encroachment in other systems.[3] By electing to examine only transitions to and from the reference state (see p. 7[1]), the evaluation emphasized the initial triggers of woody plant encroachment in which grazing management can be especially important.[4,5] Grazing management is similarly an important part of grassland recovery following woody plant removal and "Brush management conducted in isolation of grazing management is therefore treating symptoms rather than addressing the root causes of the problem."[6]

In fact, multicausality in transitions was apparently common in the narratives; there were 340 models analyzed yet there were 1,328 records of "drivers," yielding an average of about four drivers per model (Table 2[1]). Because grazing is ubiquitous in rangelands and interacts with other drivers, it is not surprising that it is a commonly discussed feature in STMs. For example, grazing management is important for both managing and adapting to woody plant encroachment.[6] For herbaceous community shifts (163) and reseeded rangelands (133), attention to grazing management is critical.[7,8] Grazing management is also important in managing erosion rates.[3,9] The fact that grazing is included as an important driver in rangelands experiencing different kinds of transition is not evidence that grazing is overemphasized.

Second, it is important to recognize that existing ESDs had been developed by NRCS to interact with stakeholders that have primary interests in grazing uses. ESDs implicitly consider humans and their actions as part of ecological systems, known now as social-ecological systems.[10] Especially since 2011, interagency teams are in the process of expanding ESDs to encompass new stakeholders (e.g., national parks) and broader interests (wildlife populations). Accommodation of multiple ecosystem services and new land uses will take time and must

Figure 1. A word cloud representing the frequency of 55 informative terms used in transition narratives cataloged in the Ecological Site Information System (as of 2014). Each term is sized according to its total number of occurrences (e.g., grazing = 1,828, fire = 1,290, native = 730, bare = 204). Narratives contained a total of 95,538 words (3,291 unique terms) after punctuation, numbers, and standard English stop words were removed. In all, 1,001 ecological site descriptions and 3,304 transition narratives were analyzed. Terms deemed to have little informative value (e.g., plant. can, state, increase) were removed from the data set before creating the word cloud.