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Understanding Vegetation Succession with State and Transition Models

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Introduction

Effective natural resource management involves balancing benefits derived from utilizing the environment against potential environmental degradation. Rangeland managers need to not only recognize change in plant communities, but also need to identify possible causes of vegetation trends. Vegetation evaluation procedures must be able to measure and interpret both reversible and nonreversible vegetation dynamics. Both patterns occur, and neither pattern alone represents the entire spectrum of vegetation dynamics on all rangelands (Briske et al. 2005).

To gain understanding of these vegetation dynamics, we often model ecological successional behavior. Vegetation successional models have been around for over a hundred years. More recently, State and Transition Models (STMs) have received a great deal of attention since the introduction of the concept to range management in 1989 (Westoby 1989; Bestelmeyer et al. 2003). STMs provide a framework to catalog multiple plant communities and vegetation transitions that are commonly observed in arid and semi-arid ecosystems (Archer and Stokes 2000). STMs explicitly define various vegetation states, transitions, and thresholds that may occur on an ecological site in response to natural and management events (Pyke et al. 2002).

Vegetation Successional Models

Vegetation succession is an orderly process of ecological development involving changes in vegetation species and structure over time. In 1916, Frederic Clements described and formalized a linear vegetation successional theory (Figure 1) that begins in a seral community and ends in a singular climax community. Clementsian successional theory has been used for decades. However, the traditional Clementsian theory that results in a linear, singular climax vegetation community does not accurately describe vegetation changes in semiarid rangelands (SRM Task Group 1998). The theory assumes that once disturbance is removed from the landscape, the plant community will progress back to the climax community. Returning to the climax plant community is not always possible in semiarid environments due to prolonged drought periods, conditions where topsoil has been removed, or invasive species have established in place of native species.

Since then, there have been many other conceptual designs or expansions of ecological succession models including: Dyksterhuis (1949), Egler (1954), Drury and Nisbet (1973), Picket (1976), Connell and Slatyer (1977), Nobel and Slatyer (1980), Pickett et al. (1987). In 1989, a new fundamental conceptual design of STM was proposed to describe vegetation dynamics. The STM framework provides multiple paths through which vegetation communities can change.

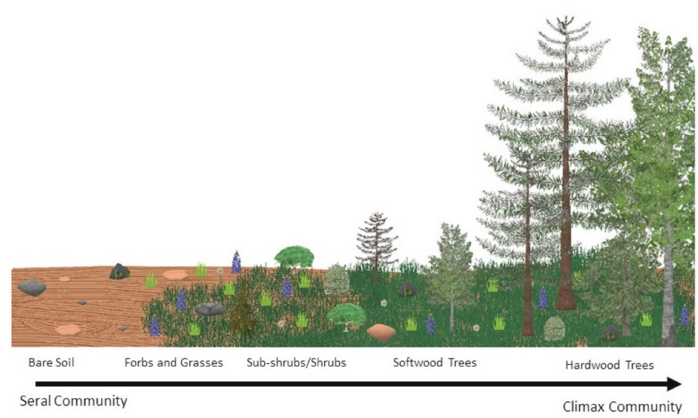

Figure 1. Clementsian Model of Succession is a linear model beginning with a seral plant community and ending in a singular climax plant community

What is a State and Transition Model?

State and Transition Models are conceptual theories about how plant communities change over time. STMs describe vegetation dynamics along multiple paths with descriptions that include various vegetation states, transitions, and thresholds that may occur on a site in response to natural influences and rangeland management decisions (Pyke et al. 2002). They identify patterns and mechanisms of ecosystem response to natural and human-caused disturbances to provide interpretive guidance (Briske et al. 2005). Their major advantage is they illustrate how vegetation communities shift along multiple paths rather than the single-path model described in the Clementsian successional model (Figure 2).

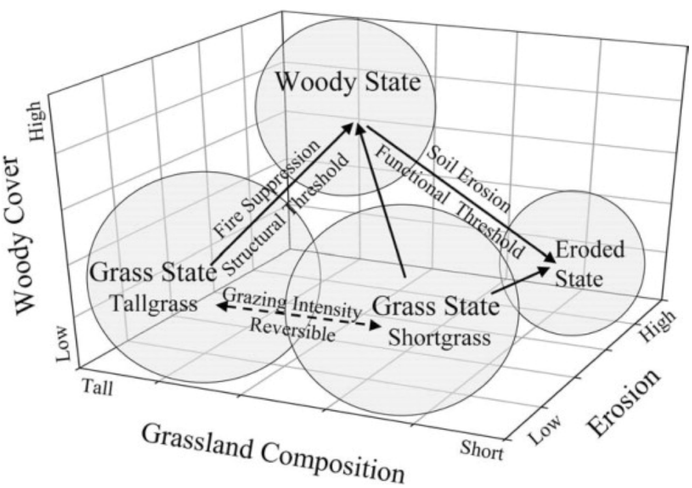

Figure 2. Conceptual Framework of State and Transition Models. STMs have multiple pathways leading to various vegetation states, transitions, and thresholds that may be supported by a particular ecological site. (Briske, et. al., 2005)

Parts of the State and Transition Model

State and Transition Models are specific to the ecological site, including the Major Land Resource Area (MLRA) and Common Resource Area (CRA). A CRA is a geographical area that shares common resource concerns. Natural resource data such as soils, climate, human impacts, etc., are used to determine the boundaries of a CRA. CRAs are subdivisions of the larger MLRAs (NRCS 2018a). Figure 3 illustrates an example of a State and Transition Model for the Southeastern Arizona Basin and Range MLRA 41 and the Chihuahuan – Sonoran Semidesert Grasslands CRA 3 with a 12-16″ Precipitation Zone (PZ) Loamy Upland ecological site (orange). For more information on ecological sites, see Understanding Ecological Sites (Arizona Cooperative Extension Publication az1766).

Each ecological site may have multiple explicitly defined vegetation states. The various plant community types possible on an ecological site correspond to the various states (blue). Natural disturbance events or management actions can push these stable vegetation states to a threshold (green). When the disturbance or management action crosses a threshold, the vegetation community resides in a state of transition (solid or dashed arrows). Specific disturbances or management actions that push these transitions are listed in the key highlighted in purple.

Continuous and reversible vegetation dynamics prevail within stable vegetation states, whereas discontinuous

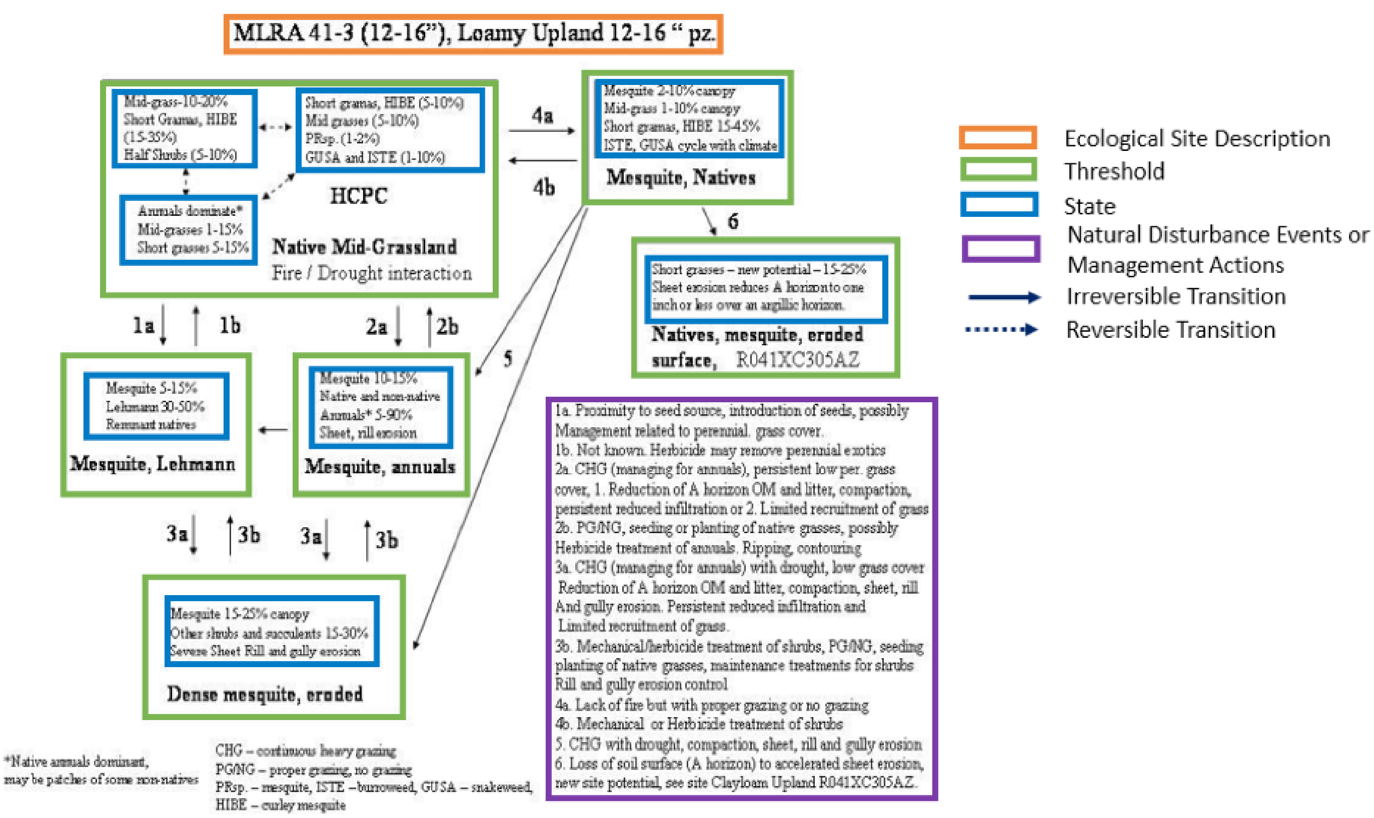

Figure 3. Parts of the State and Transition Model. (Adapted from USDA. ESIS, 2018)

and nonreversible dynamics occur when thresholds are surpassed and one stable state replaces another. Both patterns of vegetation dynamics have important implications for rangeland ecology and management (Briske et al. 2003). Examples of both patterns of vegetation dynamics can be seen in Figure 3. Continuous and reversible dynamics occur in the Native Mid-Grassland state where three communities may exist in the same state but may change compositionally depending on fire or drought interactions. An example of a nonreversible change would be moving from Mesquite, Native state to the Dense Mesquite, Eroded state (Transition 5). Because of the severely eroded state of the site and loss of topsoil, native grasses are prevented from reestablishing.

Where can I find State and Transition Models?

State and Transition Models can be found in Ecological Site Descriptions. Ecological Site Descriptions can be found at the USDA-NRCS Ecological Site Information System (ESIS): https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.

Applying State and Transition Models

The most effective application of STMs is to assess the relative benefits and potential risks of various management decisions and ecological conditions on subsequent vegetation dynamics (Bestelmeyer et al. 2003). STMs provide information for the appropriate management actions required to keep a plant community in its current state, or move from one community to another.

State and Transition Models serve three primary functions. First, STMs contrast the properties of reference and alternative states (Scheffer and Carpenter 2003). Second, STMs describe the mechanisms by which transition among states occur (Westoby et al. 1989). In doing so, the models identify particular patterns that indicate the management risk of transitioning to an alternative state (Bestelmeyer et al. 2003). Third, STMs describe the point at which changes in soil or plant communities cross an ecological threshold that requires energy intensive measures to reverse (e.g., herbicide treatments, planting and seeding of native grasses, ripping and contouring, etc.).

Using Photo 1 and Photo 2 as an example, the two photos are at the same site captured in 1988 and 2010 respectively. The site is located on Ecological Site 41-3, 12-16" PZ Loamy Upland (Figure 3). From the photos one can conclude the site has transitioned from a blue grama (*Bouteloua gracilis*) dominated site to a Lehmann lovegrass (*Eragrostis lehmanniana*) dominated site. Figure 3 shows that the site has crossed the threshold from the Historic Climax Plant Community (HCPC), defined as "the plant community that was best adapted to the unique combination of factors associated with the ecological site. It was in a natural dynamic equilibrium with the historic biotic, abiotic, climatic factors on its ecological site in North America at the time of European immigration and settlement," (NRCS 2018b). This has been replaced with the Mesquite, Lehmann alternative stable state. Natural disturbance, introduction of exotic species, or management actions that transition a vegetation community from one state to another are described (purple).

Photo 1. Loamy Upland 41-3, 12-16" PZ dominated by a blue grama vegetation community (Upper TB Site, 1988).

Photo 2. Loamy Upland 41-3, 12-16" PZ dominated by a Lehmann lovegrass vegetation community (Upper TB Site, 2010).

Transition 1a describes the process as thus: "Proximity to seed source, introduction of seeds, possibly management related to perennial grass cover." Transition 1b describes the management actions needed if the goal is to return to the HCPC. Unfortunately, the management action is unknown, noting that herbicide treatments may remove perennial exotics. This is another example of a non-reversible dynamic. In this case, it may be advisable to manage to maintain the Lehmann lovegrass dominated site properly to discourage it from crossing another threshold and transitioning to the more degraded dense mesquite, eroded stable state.

Summary

Rangeland managers need to be able to recognize where plant communities exist in an ecological successional continuum. It is equally important for rangeland managers to be able to predict the relative benefits and potential risks for natural disturbances and management actions. State and Transition Models identify the patterns and mechanisms of disturbance that drive ecological change, and can help managers set realistic goals and objectives to drive ecological succession.

Resources

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