Data support for a state-and-transition model: what have we learned?.

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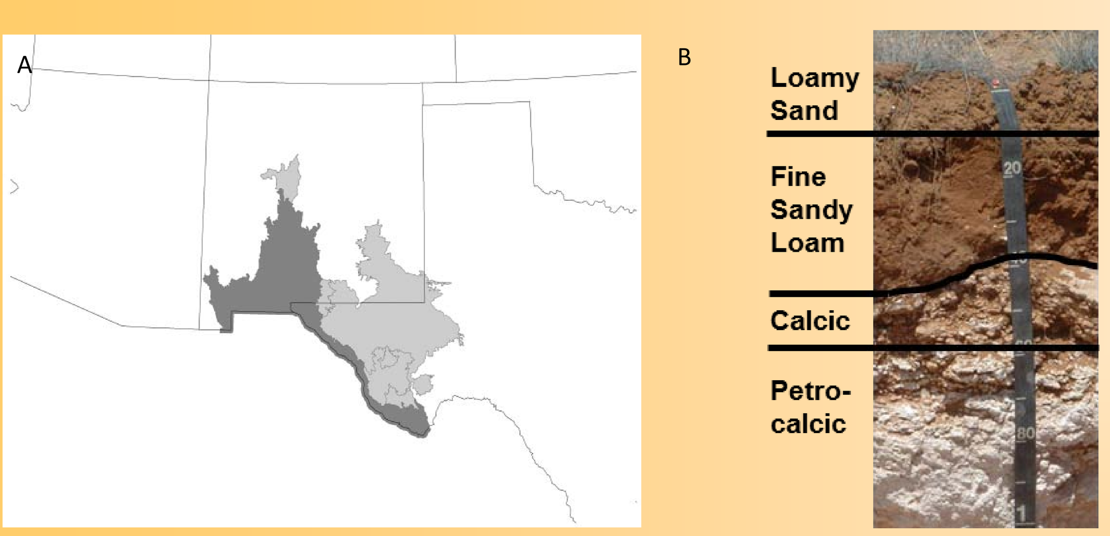
Introduction

State-and-transition models (STMs) are used to describe the possible vegetation dynamics for an ecological site. Vegetation dynamics include succession and disturbance-caused shifts among plant communities as well as state changes that are unlikely to be reversed within several decades, if reversal is possible at all. STMs integrate several information sources into a STM diagram and narratives, which are housed within an Ecological Site Description (ESD) document by the USDA Natural Resources Conservation Service (http://esis.sc.egov.usda.gov). Information sources can include local and expert knowledge, historical reconstructions, plant-soil inventory data, and short- and long-term experiments. Because new information can be discovered, and existing information can yield novel interpretations, STMs are viewed as dynamic and subject to change. To provide an example of how novel data and interpretations can change the structure of a STM, we compare a STM developed in 2001 with a version revised 10 years later.

Background on the state-and-transition model

The STM pertains to the Sandy ecological site of Major Land Resource Area (MLRA) 42.2 (Southern Desertic Basins, Plains, and Mountains, 8-10" precipitation zone) of the northern Chihuahuan Desert in New Mexico and Texas, USA. MLRA 42.2 currently includes thermic and hyperthermic soils across its extent. These different soil temperature regimes appear to support different potential vegetation. Consequently, the STM applies to only a portion of MLRA 42.2 and most information derives from New Mexico and extreme west Texas.

The soil components correlated to the Sandy ecological site are generally fine- to coarse-loamy Argids and Calcids, typically including a non-gravelly loamy fine sand to medium sandy loam surface horizon overlaying horizons of finer texture, typically sandy loam to sandy clay loam, and a calcic horizon whitened by calcium carbonate. A petrocalcic horizon (caliche) is often present at depths greater than 50 cm (20"). Similar ecological sites include Shallow Sandy (petrocalcic horizon is < 50 cm), Loamy (surface textures fine sandy loam to clay loam), and Deep Sand (no clear pedogenic horizons below A).



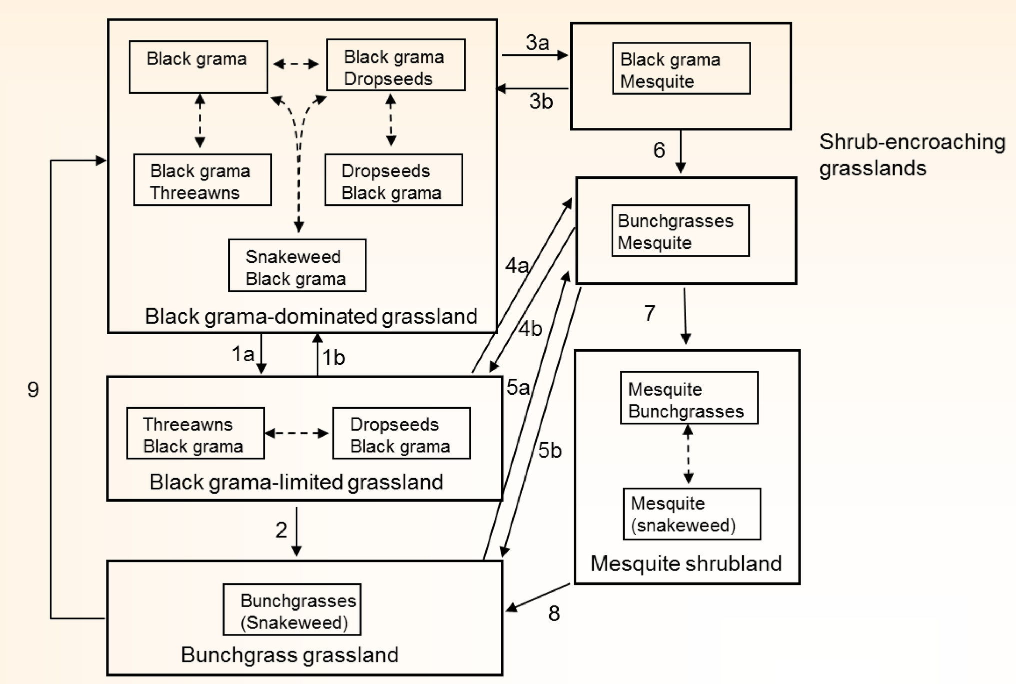
A) The location of the 8-10" precipitation zone (dark grey) within MLRA 42 (all greys combined) defining the extent over which the Sandy site is found and B) A typical Sandy soil profile.

The characteristic, reference plant community of the Sandy site features a high dominance of black grama (*Bouteloua eriopoda*; BOER) with bunchgrasses as subordinates, including dropseeds (Sporobolus spp.) and threeawns (Aristida spp.; together referred to as "other PG"). Alternative states feature a loss of black grama and increasing dominance of honey mesquite (*Prosopis glandulosa*; PRGL) and snakeweed (*Gutierrezia sarothrae*).

Although not formally designated as such, the Sandy ecological site can be regarded as a benchmark ecological site for MLRA 42.2 due to the large amount of research pertaining to this site. The Sandy site is the second most extensive ecological site in MLRA 42.2 in New Mexico.

The 2001 state-and-transition model

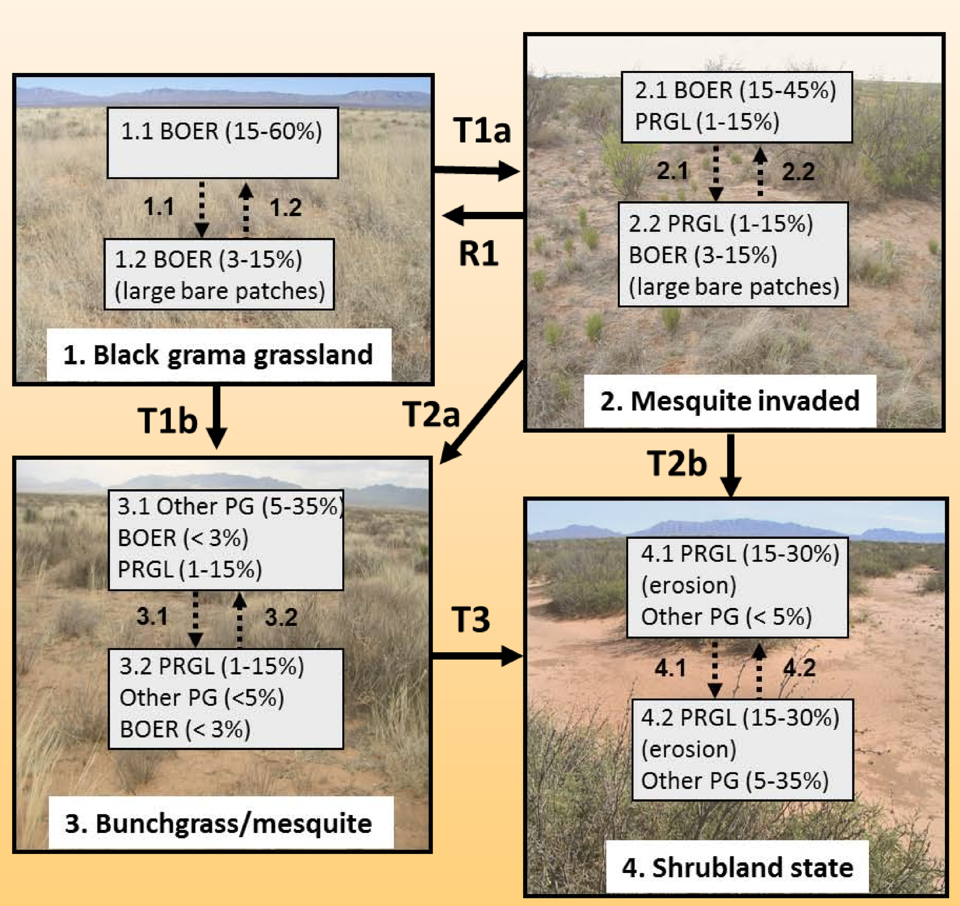
This model was produced using existing literature, low intensity traverses (Bestelmeyer et al., 2009), and local knowledge obtained from current and retired range specialists of the USDA Natural Resources Conservation Service and Bureau of Land Management and scientists from the Jornada Experimental Range and New Mexico State University. This model remains associated with the currently available ESD. The model features 12 plant community phases and six states. Plant community phases were defined by species dominance and states by key plant functional groups and processes. Note that longer narratives are associated with each model, but not shown here (e.g., Briske et al., 2008).



1a. Grazing in drought periods, moderate soil degradation. **1b.** Restoration of soil fertility (if climate not involved)
2. Black grama extinction due to heavy grazing in drought, severe soil degradation.
3a. Introduction of mesquite seeds, reduced grass competition, lack of fire. **3b**.Shrub removal, restoration of fuel loads and fire.
4a, **5a**. Mesquite invasion. **4b**, **5b**. Shrub removal, restoration of fuel loads and fire.
6. Black grama extinction due to mesquite competition and grazing.
7. Heavy grazing and grass loss, inter-shrub erosion, soil fertility loss, high soil temperatures, small mammal herbivory.
8. Dune destruction, mesquite removal, soil stabilization, nutrient addition, seeding during wet periods.
9. Reseeding, replanting with restoration of soil fertility.

The 2011 state-and-transition model

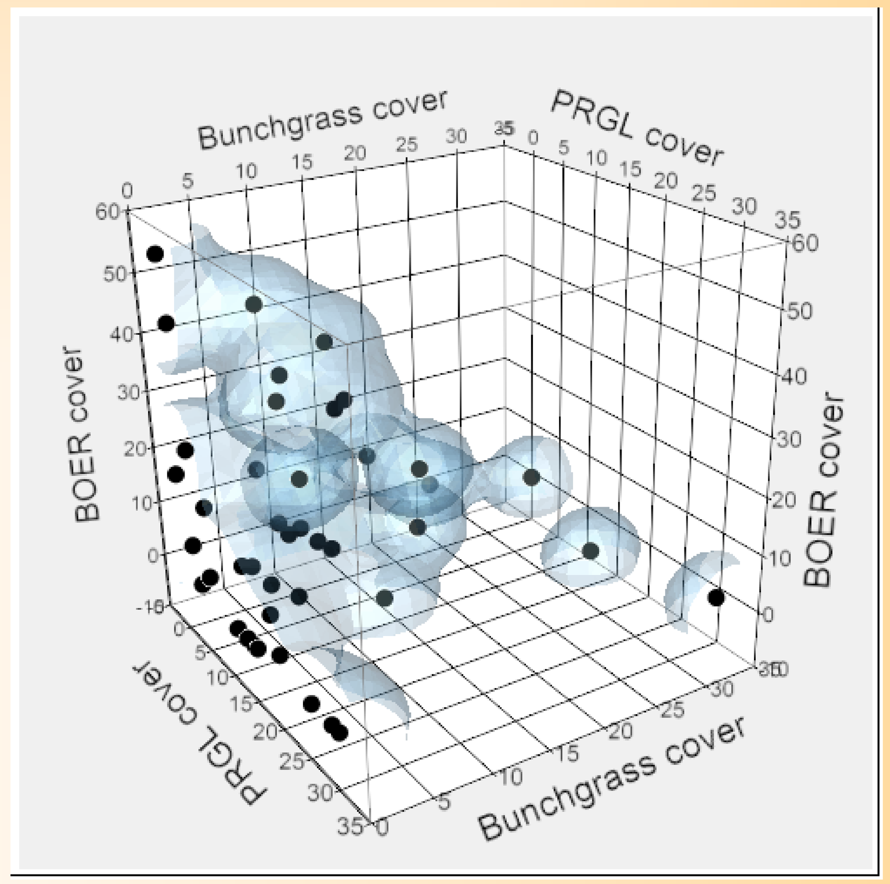
This model is consistent with a large body of medium and high intensity data collected throughout the region, newly available historical reconstructions, and new experimental data. Plant community phases now include quantitative guidelines (foliar cover) rather simple dominance rules. Eight communities and four states are now recognized.



T1a. Mesquite establishment facilitated by seed transport by cattle, bare patches > 50 cm, and relatively wet springs
R1. Shrub removal via herbicide or fire followed by black grama recovery to > 15%
T1b, T2a. Black grama is reduced below ca. 3% cover by heavy grazing in drought
T2b, T3. At perennial grass cover < 5%, wind and storm events, trigger deep, spreading soil erosion

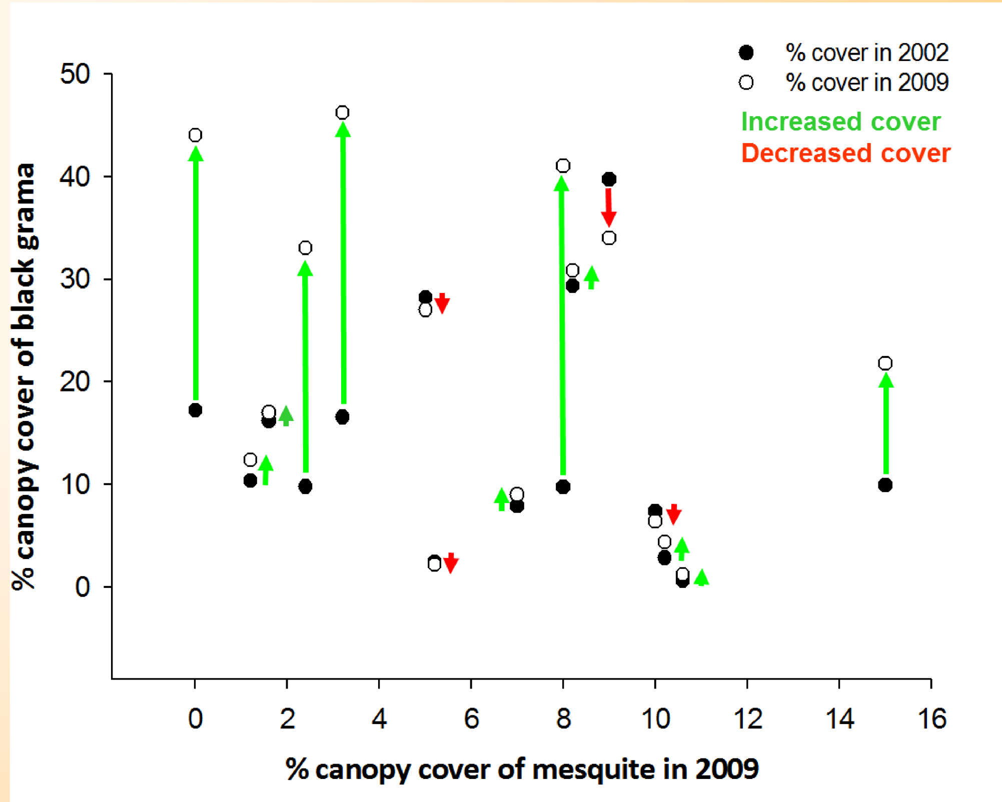
Major changes in the models and supporting logic and evidence

Inventory data suggest fewer states and new community phases



Historical data suggest that mesquite was not present or very sparse in black grama grassland. Current inventory data from Sandy sites (line-point intercept) indicate that black grama coexists with mesquite up to ca. 15% cover (mesquite invaded state). When black grama is lost and bunchgrasses are dominant, their cover varies widely across a range of mesquite cover values (1-15%; bunchgrass/mesquite state). Above ca. 15% mesquite cover, black grama is absent, but bunchgrass cover can attain high values during unusual sequences of high summer rainfall (shrubland state). High levels of soil redistribution are typically observed in the shrubland state, but this process does not necessarily limit bunchgrass recruitment.

Black grama loss is not reversible but black grama is resilient to low cover values



Line-point intercept monitoring data encompassing a drought (2002-2003) and wet period (2007-2009) indicate that:

- Black grama recovery is possible even when mesquite cover is high.
- Black grama recovery is limited when its cover is < 3%, providing a useful criterion for defining thresholds.
- Black grama has not been observed to recover where it has been extirpated.
- Bunchgrass populations can collapse rapidly during drought (not shown), even when cover is high.

Summary

Initial models generated from local ecological knowledge and literature provided a basis for testing of models using inventory, monitoring, and historical data (Knapp et al., 2011). These data revealed that 1) the vegetation dynamics in the Sandy site can be expressed in a more simple form; 2) black grama can be more resilient than some have thought, but its loss is irreversible and has important consequences for ecosystem services; and 3) grasses and shrubs appear to coexist across a broad range of cover values (including low cover of both grasses and shrubs), suggesting that a focus on sustaining grass populations may be as or more important than a focus on shrub populations. STMs can undergo significant changes in structure and become more detailed and useful with relatively minor investments. Such investments would be especially worthwhile for benchmark ecological sites in each MLRA.

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