A Prototype Application of State and Transition Simulation Modelling in Support of Grassland Management

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Introduction

The Great Plains grasslands of North America provide a multitude of ecosystem services including clean water, forage, habitat, recreation, and pollination of native and agricultural plants. A general lack of quantitative information regarding the effects of varied management strategies on these spatially heterogeneous landscapes complicates our understanding of the processes within them. Given the paucity of studies in the western Great Plains, it is difficult to quantify the interaction of environmental (e.g. drought) influences and managerial strategies, such as grazing intensity and seasonality or fire frequency and behavior. This presents unique challenges to managers seeking to understand, explain, and justify desired management strategies.

In response to this need, we have developed a decision support system based on ecological models for predicting the impact of climate on fuelbed properties on Great Plains grasslands. The system is comprised of two distinct tools which act in concert to produce state-of-the-art ecosystem modelling capabilities. First, the Rangeland Vegetation Simulator (RVS), deterministically estimates growth, succession, and fuels and second, the State-and-Transition Simulation Model (ST-SIM) enables stochastic modelling of ecological processes such as plant community development and response to climate.

This new decision support system (DSS) enables managers to determine the most appropriate strategies for reducing fuel loads and fostering ecological resiliency. The DSS represents a multiyear international effort, and this document describes a prototype application on the Great Plains estimating ecosystem response by focusing on two important elements including: 1) estimating future fuelbed properties and 2) quantifying feedbacks between fire cycle, climate and species assemblages and structure.

Materials and Methods

Here we demonstrate the application of the decision support system by applying it to the Loamy Plains Ecological Site on the central Great Plains in north central Colorado. The Loamy Plains Ecological Site was chosen to prototype this system and identify uses and limitations of its application on the Great Plains. The climate within this region is characterized by a mean average annual precipitation of 305 – 406 mm, with the amount received in any given year varying widely, from less than 200 mm to more than 500 mm. The region also experiences average winds of 9 mph annually, with peak winds in the spring. Average growing season length is 142 days, with the frost-free period extending from mid-May to late-September. Mean monthly minimum temperatures vary from -11.0 °C (Dec) to 13.0 °C (July), and mean maximum monthly temperatures vary from 7.3 °C (Jan) to 34.4 °C (July).

The dominant plant species on this Ecological Site (in terms of their basal area and contribution to ANPP) are two C_4 shortgrasses *(Bouteloua gracilis*, *Bouteloua dactyloides*). Other less abundant but important plant species include C_3 perennial graminoids (*Pascopyrum smithii, Hesperostipa comata*, *Elymus elymoides*, and *Carex* spp.), a C_3 annual grass (*Vulpia octoflora*), C_4 bunchgrasses (*Aristida longiseta,* *Sporobolus cryptandrus, Bouteloua curtipendula*), plains pricklypear cactus (*Opuntia polyacantha*), and subshrubs (*Gutierrezia sarothrae, Eriogonum effusum, Artemisia frigida*) (Lauenroth and Burke 2008).

Management actions evaluated using the decision support system included a gradient of grazing intensities from low, moderate and high for the region equivalent to 0.08, 0.10, and 0.15 Animal Unit Months (AUM's) per ha per year. These management schemes were tested across a simulation period of 15 years (2000 to 2014). During each year, community response in terms of annual production, vegetation cover and height, composition and fuelbed properties were quantified. Annual production, standing crop, and vegetation were validated against data collected on vegetation structure on the Loamy Plains Ecological Site by the Agricultural Research Service in Cheyenne Wyoming.

Results and Discussion

The calibrated model closely matched observations of annual production (Fig. 1) and emulated the temporal variation in climate observed during the study period (Figure 1). The heavy grazing scenario increased the area of a sodgrass state dominated by *Bouteloua dactyloides* by about 30% while simultaneously decreasing annual production by approximately 18%. In addition, the heavy grazing scenario reduced overall fuel loadings by about 40%, thereby commensurately decreasing potential flame length and spread rate. In contrast, the moderate and light grazing scenarios did not increase the abundance of the sodgrass state but did enable steadily increasing coverage by cool season (C_3) graminoids.

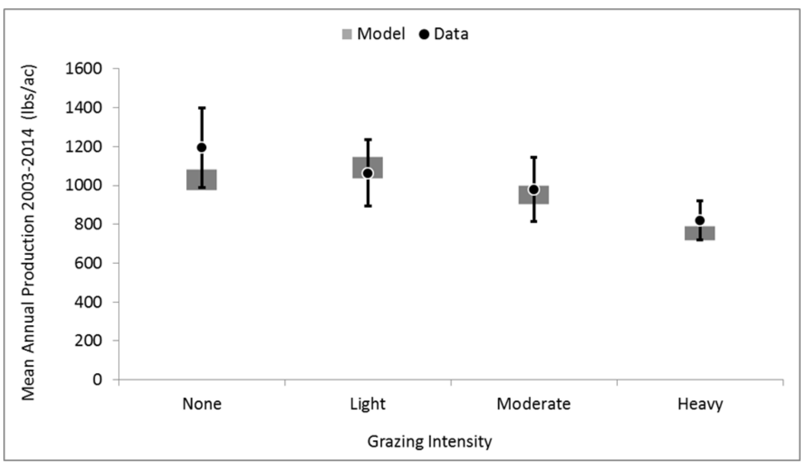

Figure 1. Predicted and observed annual production for the Loamy Plains Ecological Site across four grazing scenarios.

Conclusions and Implications

The RVS/ST-SIM decision support system prototyped on the Loamy Plains Ecological Site indicates significant potential to improve management outcomes. The grazing strategies examined provide a range of outcomes influencing annual production, fuelbed properties and species assemblages. Results demonstrate the inherent resiliency of this shortgrass steppe to moderate levels of herbivory. Application of this combined model to quantify likely management outcomes will become increasingly important in the future for species conservation as demands for sustainable goods and services continue to increase and feedbacks on natural systems become more complicated. Future research will involve adding multiple management strategies simultaneously (e.g. wildfire, off-road vehicle use, increased competition from non-native feral horses and burros). Our goal is to produce recommendations for future management strategies which will increase the probability achieving desired landscape conditions.

References

Lauenroth, W.K., Burke, I.C., 2008. Ecology of the Shortgrass Steppe: A Long Term Perspective. Oxford University Press, New York City, NY.