

Grasslands or Shrubland?

Tipping the Balance



Figure 1. Top: Desert grasslands on the Santa Rita Experimental Range in southeastern Arizona in 1904. Woody plants such as mesquite were present, but largely confined to arroyos. Bottom: The same landscape photographed in 1997. Mesquite shrublands currently dominate uplands. (Photo station 333 from SRER digital archives: <http://ag.arizona.edu/SRER/>).

Introduction

Grasslands and savannas (grasslands with scattered shrubs or trees) constitute about 50% of the Earth's land surface. Characterized by low and highly variable rainfall, these ecosystems account for about one-third of plant production on land, contain about one-third of the world's human population and support the majority of the world's livestock production. Their extensive airsheds and watersheds provide habitat for game and non-game wildlife and a myriad of ecosystem goods and services important to rapidly growing settlements and cities that may be geographically distant. Grasslands and savannas thus have considerable, multi-dimensional conservation value.

A striking change in grasslands worldwide in recent decades has been the proliferation of trees and shrubs (Figure 1). In Arizona, the abundance of native woody plants such as mesquite (see Featured Plant, this issue), creosote bush [(see Featured Plant in *B&B* vol. 2 (2008)], juniper [see Featured Plant in *B&B* vol. 2, Issue 3 (2008)], oaks and ponderosa pine have increased within their historic geographic ranges. Non-native woody plants such as salt cedar and Russian olive have also spread. Increased woody plant abundance represents a fundamental alteration of habitat and the food webs linking plants, herbivores, carnivores and decomposer organisms.

Why has woody plant abundance increased on rangelands?

Causes of woody plant encroachment are actively debated. Traditional explanations center around intensified livestock grazing, changes in climate and fire regimes, and declines (natural and human-induced) in the abundance of browsing animals (Figure 2). Increases in nitrogen deposition and atmospheric carbon dioxide concentration since the Industrial Revolution may also have played a role.

All of these have likely interacted to varying degrees in various locations. Hence, it is difficult to rank their importance (Text Box 1). As you travel across Arizona and New Mexico, you may notice that woody plant encroachment has occurred on one side of a fence or road but not

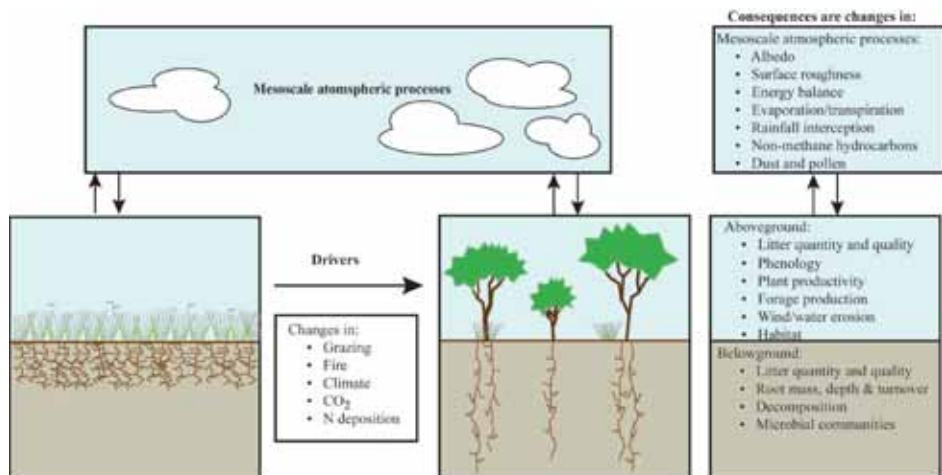


Figure 2. Drivers of woody plant encroachment (see Text Box 1) and the potential consequences of ecosystem function and land surface-atmosphere interactions.

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the other. These nearby areas often have similar soils and topography and have experienced similar climate, carbon dioxide enrichment and nitrogen deposition. Marked contrasts in vegetation over such a short distance suggest that explanations are likely to be local factors. For instance, differences in livestock grazing, brush management, and fire history.

What's the big deal?

When woody plants replace grasses, fundamental changes occur in ecosystem function – how plants process water, energy and nutrients (Figure 2). These changes often reduce forage production and alter grass composition. Shrub proliferation can also affect livestock safety and health, as woody plants provide cover for predators and habitat for insect and arthropod pests. Gathering and moving livestock can also be more difficult with increased woody plant height and density. Increases in shrub cover might reduce stream flow and groundwater recharge, though broad generalizations regarding shrub effects on water yield should be viewed with caution. It also represents fundamental changes in habitat for grassland-adapted birds, reptiles, rodents and large mammals. Increases in shrub abundance also affects soil bacteria and fungi critical in the decomposition process. Though not well understood, shrub proliferation has the potential to influence local weather and atmospheric chemistry (greenhouse gas concentrations and ozone production) by altering albedo (the reflection of incoming sunlight), cloud formation (via changes in evaporation/transpiration, soil temperature and dust production), carbon sequestration and plant/soil emissions of carbon dioxide, nitrous oxide, methane and non-methane hydrocarbons.

The Way Forward?

Conservation of existing grasslands and savannas will require progressive management that ensures that grass production is maintained and that prescribed fire can be used regularly. In areas where woody plants have already taken over, grassland restoration may require the implementation of integrated brush management systems strategically employing chemical and mechanical treatments in conjunction with prescribed fire.

Suggested Readings

Archer, S. 1994. Woody plant encroachment into southwestern grasslands and savannas: rates, patterns and proximate causes, pp.13-68. In "Ecological implications of livestock herbivory in the West" (M. Vavra, W. Laycock, R. Pieper, eds.). Society for Range Management, Denver, CO.

McClaran, M. P. 2003. A century of vegetation change on the Santa Rita Experimental Range, pp. 16-33. In "Santa Rita Experimental Range: 100 years (1903 to 2003) of accomplishments and contributions." Proc. RMRS-P-30, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT, Tucson, AZ. See also: <http://ag.arizona.edu/SRER/proceedings.html>.

Van Auken, O. W. 2000. Shrub invasions of North American semiarid grasslands. *Annual Review of Ecology & Systematics* 31:197-215.

CAUSES OF WOODY PLANT ENCROACHMENT

Causes for the increased abundance of woody plants in drylands are actively debated. There is no single-factor explanation for this widespread phenomenon. Most likely, it reflects drivers that vary locally or regionally, or from the interaction of more than one driver. Changes in a given driver may be necessary to tip the balance between woody and herbaceous vegetation, but may not be sufficient unless co-occurring with changes in other drivers. Potential causes for increases in wood plant (WP) abundance in rangelands include changes in:

CLIMATE – Changes in the amount and seasonality of precipitation (PPT) can affect the balance between grasses and WPs. Increases in total PPT can enhance WP size and density; decreases in PPT can promote shifts from mesophytic grasses to xerophytic shrubs. Shifts from summer to winter PPT regimes can favor woody plants. PPT effects at local scales are strongly mediated by soil texture and depth: WPs are favored on relatively deep, well-drained soils; and grasses on shallow, clayey/loamy soils.

GRAZING – Utilization of grasses by herbivores reduces their leaf and root biomass making them more susceptible to other environmental stresses. Repeated heavy grazing by large numbers and high concentrations of livestock without adequate rest and plant recovery, and utilization of grass seeds by granivores (rodents, ants) can cause shifts in herbaceous species composition to assemblages less effective at competitively excluding woody plant seedlings. Herbivores and granivores may also be effective agents of WP seed dispersal in certain cases. Changes in soil properties and microclimate accompanying over-grazing may create conditions more favorable for WP establishment and less favorable for grass establishment.

BROWSING – Preferential utilization of WPs by browsing animals (e.g., goats) may keep shrubs and trees from establishing or from reaching large sizes or high densities. WPs kept low in stature by browsers will be more susceptible to fire. Reductions in the abundance of browsers may remove a major constraint to WP dominance on sites that are otherwise climatically and edaphically suitable. Widespread eradication of prairie dogs in the early 1900s may have created opportunities for woody plant encroachment in areas where these colonial rodents occurred.

FIRE REGIMES – Grasslands and savannas are typically characterized by high fine fuel loads and hence frequent fire that would either prevent woody plants from establishing or prevent fire-tolerant WPs from gaining dominance. Past heavy grazing reduced fine fuel abundance, and likely reduced the frequency and intensity of fires that historically kept WPs suppressed.

INCREASES IN ATMOSPHERIC CO₂ – There is some evidence that increases in atmospheric CO₂ concentrations since the industrial revolution may have favored WPs that have the C₃ photosynthetic pathway over grasses with the C₄ photosynthetic pathway. However, WPs have numerous other adaptations that allow them to compensate for and overcome disadvantages that may be related to their photosynthetic pathway. Furthermore, the differential response of photosynthetic pathways to CO₂ fertilization cannot explain increases in WP abundance in temperate regions where both grasses and shrubs possess the C₃ photosynthetic pathway.

NITROGEN DEPOSITION – A correlation between levels of N deposition and the extent of forest expansion into grasslands has been shown for the northern Great Plains of North America.