

Managing Drought Resistance into Grasslands

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The percent reduction in herbage production during drought conditions on grasslands managed with traditional grazing management practices, like repeated seasonal, seasonlong, and deferred grazing, is greater than the percent reduction in precipitation (Manske 2002a, b). The shortage of rainfall is the most obvious detrimental factor occurring during a drought, however, it is not the only factor contributing to the reduction in herbage biomass production. The other primary factors responsible for this enhanced loss of herbage production are reductions in available mineral nitrogen and degradation of ecosystem health status.

Reductions in mineral nitrogen limit herbage production more often than water in temperate grasslands (Tilman 1990). Grasslands in the Northern Plains are not low in nitrogen. Grassland soils contain about 3 to 8 tons of organic nitrogen per acre. Plants, however, can not use organic nitrogen. The organic nitrogen must be converted into inorganic (mineral) nitrogen to be usable by plants. Soil microorganisms in the rhizosphere zone around perennial grass roots convert organic nitrogen into inorganic nitrogen. This process is symbiotic and mutually beneficial for both the plants and the rhizosphere organisms. Plants fix carbon and capture energy from the sun during photosynthesis. Organisms in the rhizosphere are low in carbon and receive a portion of the carbon fixed by the plants. Grassland plants are low in inorganic nitrogen which is a waste product from rhizosphere organism metabolism. Plants trade carbon to rhizosphere organisms for nitrogen and rhizosphere organisms trade nitrogen to plants for carbon (Manske 2007).

The quantity of organic nitrogen converted into inorganic nitrogen by rhizosphere organisms is dependent on the quantity of carbon released into the rhizosphere by plants. The quantity of carbon released by the plants is dependent on the type of grazing management practices used and the amount of leaf material removed by grazing at different plant phenological growth stages. Traditional grazing management practices that are not based on the biological requirements and the phenological growth stages of plants restrict the quantity of carbon released into the rhizosphere causing a reduction in

rhizosphere organism volume and activity, resulting in a reduction in the quantity of available inorganic nitrogen. The quantity of available inorganic nitrogen gradually decreases each year. After several years of management with traditional grazing practices that are antagonistic to biogeochemical processes, the accumulated reduction in available inorganic nitrogen results in a substantial reduction in herbage biomass production; generally around 25% to 50% of the grasslands' potential herbage biomass production during average growing seasons (Manske 2007).

Wight and Black (1979) conducted a fertilization on native rangeland plot study at the ARS Research Center, Sidney, MT from 1967 to 1976 and determined the precipitation use efficiency (pounds of herbage produced per inch of precipitation received) for unfertilized treatments deficient in available mineral nitrogen and fertilized treatments not deficient in available mineral nitrogen. The pounds of herbage produced per inch of precipitation were greater on rangeland ecosystems with adequate mineral nitrogen available compared to rangeland ecosystems that had insufficient quantities of available mineral nitrogen. During the eight study years with normal precipitation, the ambient deficiency in available mineral nitrogen on rangeland ecosystems caused the weight of herbage production per inch of precipitation to be reduced an average of 45.4% below the herbage produced per inch of precipitation on rangeland ecosystems without mineral nitrogen deficiencies.

The traditional grazing management practices of 6.0-month seasonlong (6.0-M SL) and 4.5-month seasonlong (4.5-M SL) caused decreases of 51.2% and 33.7% in rhizosphere volume after 20 years of treatment, respectively (figure 1) (Manske 2008b). A traditional deferred (DEF) grazing practice caused a 70.6% decrease in available mineral nitrogen after 35 years of treatment (figure 1) (Manske 2008b). During growing seasons with drought conditions, both inorganic nitrogen and soil water are greatly diminished in grasslands managed with traditional grazing practices and together low nitrogen and low water cause most of the reductions

in herbage production and the resulting reductions in stocking rate.

The biologically effective twice-over rotation grazing management strategy (TOR) that is based on partial defoliation at beneficial phenological growth stages and on meeting the biological requirements of grass plants enhanced the biogeochemical processes in grassland ecosystems and caused a 67.7% increase in available inorganic nitrogen after six years of treatment and caused a 122.7% increase in rhizosphere volume after 20 years of treatment (figure 1) (Manske 2008b).

Biologically effective grazing management improves the biogeochemical processes in grassland ecosystems and activates the defoliation resistance mechanisms in grass plants. The increased rhizosphere organism volume and activity increases the quantity of available mineral nitrogen resulting in increases in herbage biomass production and beef weight production per acre. The increased ectomycorrhizal fungi in the rhizosphere improves the structure of the soil by increasing the quantity and depth of aggregation which increases the quantity of water infiltration and increases the water holding capacity of the soil. The increased plant density and increased litter cover shade the soil, lowering the soil temperature and decreasing the rate of soil water loss through evaporation (Manske 2007). Biologically effective grazing management improves the health status of grassland ecosystems (Manske 2001) and increases the drought resistance of grasslands.

Drought resistance in grasslands is directly related to the ecosystem health status and depends on the effectiveness of the grazing management to meet the biological requirements of grass plants, to enhance the ecosystems biogeochemical processes, to cause improvements in soil aggregation, water infiltration, water holding capacity, vegetative reproduction, plant density, litter cover, rhizosphere volume and microorganism activity, and to increase the quantity of available mineral nitrogen converted from soil organic nitrogen.

The antagonistic effects of traditional grazing management practices on the living and nonliving (abiotic) ecosystem components degrade ecosystem health status and decrease drought resistance over time in grasslands by causing deterioration of soil characteristics, reduction of plant physiological mechanisms, decrease of rhizosphere volume and activity, suppression of ecosystem biogeochemical processes, and reduction of the

quantity of available mineral nitrogen. The level of ecosystem health status and drought resistance determines the severity of the reduction in herbage biomass production and the reduction in stocking rate during drought conditions, and determines the length of time needed for ecosystem recovery following a drought.

Grasslands with low health status managed by heavy stocking or by starting dates too early and/or ending dates too late with traditional grazing practices, like repeated seasonal, 6.0-month seasonlong, and deferred grazing, require 2 years of recovery with reduced stocking rates for moderate drought conditions and 4 years of recovery with greatly reduced stocking rates for severe drought conditions (Whitman et al. 1943; Manske 1989, 1990).

Grasslands with moderate health status managed with moderately stocked traditional grazing practices, like 4.5-month seasonlong, require 1 year of recovery with reduced stocking rates for moderate drought conditions and 2 years of recovery with reduced stocking rates for severe drought conditions (Manske 1989, 1990).

Grasslands with high health status managed with biologically effective twice-over rotation grazing strategies have sufficient resistance to moderate drought conditions that reduction in stocking rate is not necessary during 1 season of moderate drought, however, if 2 growing seasons with moderate drought conditions occur successively, stocking rates need to be reduced during the second season. High health status grasslands require less than 1 growing season with no reduction in stocking rates to recover from moderate drought conditions and require 1 year with reduced stocking rates to recover from severe drought conditions (Manske 1989, 1990).

Periods with rainfall shortage are normal weather conditions for the Northern Plains. Average 6 month perennial plant growing seasons, mid April to mid October, have water deficiency or drought conditions during 32.8% of the period, amounting to 2 months per growing season, and occur during 78.5% of the years. Growing seasons with drought conditions that receive less than 75% of the long-term mean precipitation occur during 15.5% of the years. Moderate drought conditions, that have growing season precipitation at less than 75% and greater than 50% of the long-term mean, occur during 12.1% of the years. Severe drought conditions, that have

growing season precipitation at less than 50% of the long-term mean, occur during 3.5% of the years. Nondrought conditions are actually the abnormal phenomenon and occur during only 6.0% of the growing seasons (table 1) (Manske 2008a).

During a hypothetical 48 year career in agriculture (table 1), a beef producer in the Northern Plains experiences 3 growing seasons with no drought conditions, 37 growing seasons each with an average of 2 months with water deficiencies, 6 growing seasons with moderate drought conditions that have precipitation at less than 75% but greater than 50% of the long-term mean, and 2 growing seasons with severe drought conditions that have precipitation at less than 50% of the long-term mean.

Grasslands with low health status and low drought resistance have a total of 28 years during a 48 year career (58.3%) with reduced herbage production and reduced stocking rates; 8 years caused by drought conditions and 20 years caused by recovery from drought conditions; and have 20 years (41.7%) in which the grasslands are properly stocked at full capacity (table 1).

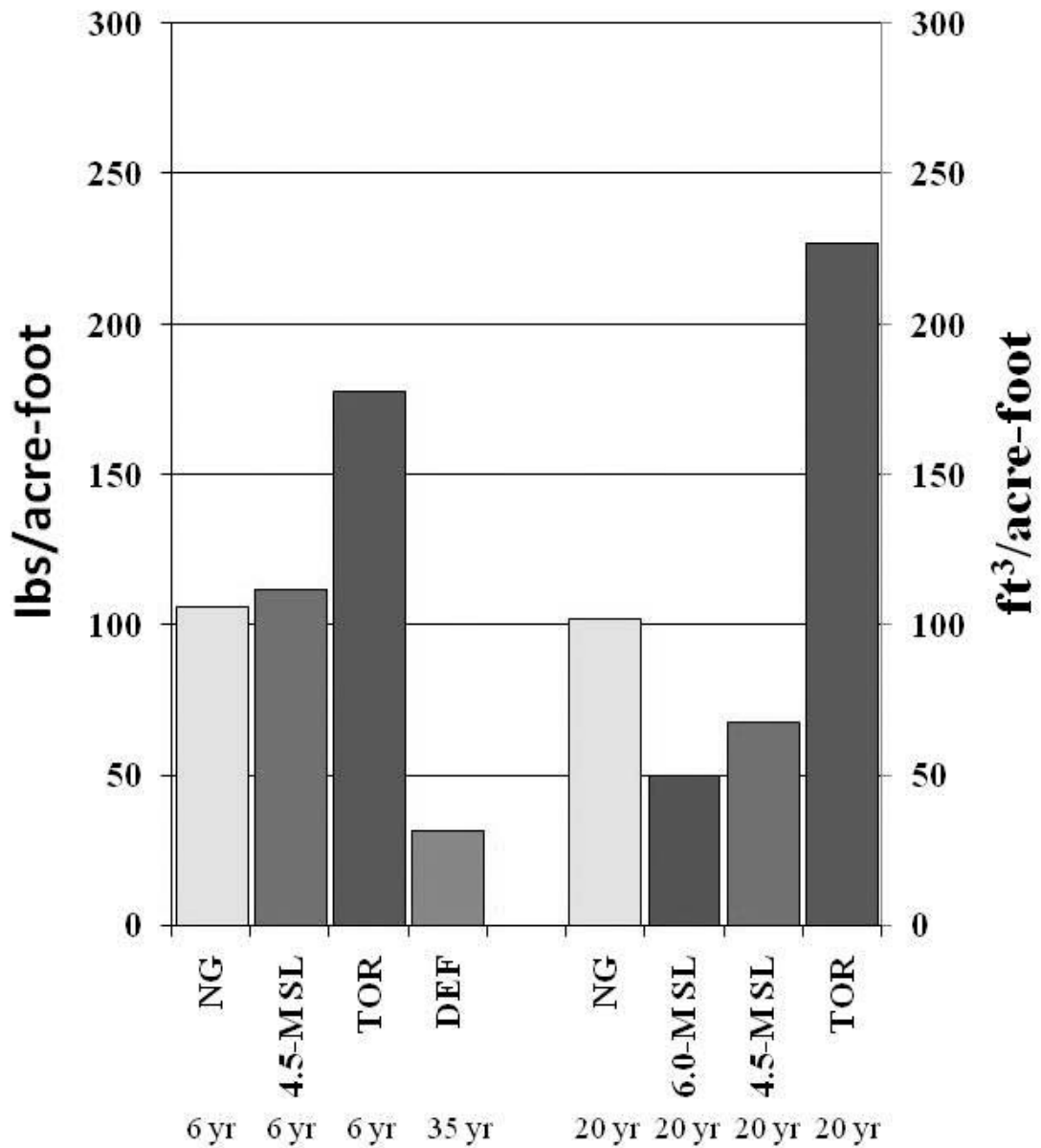
Grasslands with moderate health status and moderate drought resistance have a total of 18 years during a 48 year career (37.5%) with reduced herbage production and reduced stocking rates; 8 years caused by drought conditions and 10 years caused by recovery from drought conditions; and have 30 years (62.5%) in which the grasslands are properly stocked at full capacity (table 1).

Grasslands with high health status and high drought resistance have a total of 4 years during a 48 year career (8.3%) with reduced herbage production and reduced stocking rates; 2 years caused by drought conditions and 2 years caused by recovery from drought conditions; and have 44 years (91.7%) in which the grasslands are properly stocked at full capacity (table 1).

The shortage of rainfall is not the only factor that causes reductions in herbage production and reductions in stocking rate during drought conditions. Deteriorated soil characteristics, reduced plant physiological mechanisms, decreased rhizosphere volume and activity, suppressed ecosystem biogeochemical processes, and reduced available mineral nitrogen on grasslands with low or moderate health status are the additional negative factors that intensify the severity of the problems that develop during drought conditions. These living and nonliving (abiotic) ecosystem components can be improved with biologically effective grazing management and changed into beneficial factors that diminish the detrimental effects from drought conditions on grasslands with high health status. Implementation of twice-over rotation grazing management can improve the drought resistance in grasslands.

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Mineral nitrogen (lbs/ac-ft) and rhizosphere volume (ft³/ac-ft) for 6, 20, and 35 years of grazing treatments.

Table 1. Effects from drought conditions and length of recovery time on the number of years with reduced stocking rates on grasslands with different managed health status.

			Healthy Grasslands	Moderately Healthy Grasslands	Low Health Grasslands
Ag Career		yrs	48	48	48
No Drought	(6.0%)	yrs	3	3	3
Drought for 2 mo/yr	(78.5%)	yrs	37	37	37
Moderate Drought Growing Seasons	(12.1%)	yrs	6	6	6
Recovery Time		yrs	0	6	12
Severe Drought 1936-1988 levels	(3.5%)	yrs	2	2	2
Recovery Time		yrs	2	4	8
Reduced Stocking for Droughts		yrs	2	8	8
Reduced Stocking for Recovery Time		yrs	2	10	20
Total Time with Reduced Stocking		yrs	4	18	28
Fully Stocked		yrs	44	30	20

Drought frequency data from Manske 2008a.

Recovery time data from Whitman et al. 1943 and Manske 1989, 1990.

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