

## Biologically Effective Grazing Management Reduces the Detrimental Effects from Drought Conditions on Grasslands

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Healthy grassland ecosystems with fully functional biological and ecological processes are effected less from the negative impacts of drought conditions than moderate and low health status grassland ecosystems functioning at below potential levels. Biogeochemical processes of grassland ecosystems can be enhanced and biological requirements of grass plants can be met when partial defoliation by grazing occurs during phenological growth between the three and a half new leaf stage and the flowering (anthesis) stage activating compensatory physiological processes in remaining leaf and shoot tissue, stimulating vegetative reproduction from axillary buds, and stimulating rhizosphere organism activity that increases available mineral nitrogen (Manske 2007). Implementation of biologically effective grazing management during nondrought growing seasons improves the health status of grassland ecosystems (Manske 2001) and increases the resistance to detrimental effects from drought conditions.

Periods with rainfall shortage are normal weather conditions for the Northern Plains. Growing seasons with drought conditions occur during 15.3% of the years, or about 2 drought seasons every 13 years. Moderate drought conditions, that have growing season precipitation at less than 75% and greater than 50% of the long-term mean, occur during 11.9% of the years, or about 1 moderate drought in 8 years. Severe drought conditions, that have growing season precipitation at less than 50% of the long-term mean similar to the water deficiencies received in 1919, 1934, 1936, and 1988, occur during 3.4% of the years, or about 1 severe drought in 29 years. Nondrought conditions are an abnormal phenomenon and occur during only 5.9% of the growing seasons, or about 1 season without water deficiency in 17 years (Manske 2010a).

The average 6 month perennial plant growing season, mid April to mid October, has water deficiency or drought conditions during 2 of those months, 32.7%. The frequency of water deficiency occurrence is not distributed evenly across the growing season months. Water deficiency frequency has been 16.9% in April, 13.6% in May, 10.2% in

June, 38.1% in July, 52.5% in August, 50.0% in September, and 46.6% in October (Manske 2010a).

Drought conditions reoccur at irregular intervals and can create serious forage deficiency problems for livestock producers. The precipitation shortage during drought conditions is generally assumed to be the sole cause for the reduction in herbage production and for the accompanying calamities. Because rainfall can not be increased on demand, it is commonly presumed that nothing can be done ahead of a drought to mitigate the detrimental impacts and it is consequently concluded that there is no other recourse than to improvise high-cost, makeshift, emergency schemes to get through the climatic hard times. Despite these common assumptions, by implementation of drought mitigating management practices, drought conditions do not have to be reoccurring disasters.

Low rainfall is the most obvious detrimental factor occurring during a drought, however, there are additional factors involved that intensify the severity of the problems that develop during drought conditions. Along with low precipitation, high evapotranspiration rates and antagonistic effects from the previous years' traditional grazing management practices that reduce grass plant size and density, decrease soil organism activity, deteriorate soil structure, and reduce ecosystem health status negatively affect the quantity of herbage produced during drought conditions. The detrimental effects caused by these additional factors can be diminished by implementing biologically effective grazing management strategies that increase grass plant size and density, stimulate rhizosphere organism activity, improve soil structure, and increase ecosystem health status.

The shortage of rainfall should not be given all of the blame for all the problems that materialize during drought conditions. If reduced rainfall was the only factor causing reduced herbage production, the percent reduction in herbage below normal herbage production would be the same as the percent reduction in precipitation. Herbage production on grasslands managed with traditional grazing

management practices is usually reduced by about double the percent reduction in precipitation. During the growing season of 2002, southcentral North Dakota received precipitation at 21% to 26% below normal. Most of the informed estimations in the reductions of herbage production were around 50% to 60% below normal (Manske 2002a, b).

The cause for the quantity of reduction in herbage production greater than the reduction in precipitation is primarily the reduction in available mineral nitrogen resulting from the detrimental effects of previous management practices. Traditional management practices, like seasonlong, deferred, and repeat seasonal grazing, are antagonistic to the processes that convert organic nitrogen into inorganic (mineral) nitrogen. A minimum rate of mineralization that supplies 100 pounds of mineral nitrogen per acre is required to sustain herbage production at biological potential levels on rangelands (Wight and Black 1972).

Wight and Black (1972) found that precipitation use efficiency (pounds of herbage production per inch of precipitation received) of rangeland grasses improved when soil mineral nitrogen was available at quantities greater than 100 lbs/ac. The inhibitory deficiencies of mineral nitrogen on rangelands that had less than 100 lbs/ac of available soil mineral nitrogen caused the weight of herbage production per inch of precipitation received to be reduced an average of 49.6% below the weight of herbage produced per inch of precipitation on the rangeland ecosystems that had greater than 100 lbs/ac of mineral nitrogen and did not have mineral nitrogen deficiencies (Wight and Black 1979). The quantity of herbage biomass production on rangeland ecosystems that have greater than 100 lbs/ac soil mineral nitrogen will be about double the quantity of herbage biomass production on rangeland ecosystems that have less than 100 lbs/ac soil mineral nitrogen, even during periods of water deficiency.

Manske (2010b, 2010c) found evidence that two defoliation resistance mechanisms had threshold requirements for activation at 100 lbs/ac of mineral nitrogen. Partial defoliation of grass tillers at phenological growth stages between the three and a half new leaf stage and the flower (anthesis) stage activated the compensatory physiological processes within grass plants that enabled partially defoliated grass tillers to rapidly and completely replace the leaf material removed by grazing, and activated the asexual processes of vegetative reproduction that produced secondary tillers from axillary buds in

rangeland ecosystems that had soil mineral nitrogen available at quantities greater than 100 lbs/ac, however, the same defoliation treatments did not activate the defoliation resistance mechanisms of grass plants in rangeland ecosystems that had soil mineral nitrogen available at quantities less than 100 lbs/ac. Inhibitory mineral nitrogen deficiencies exist in rangeland ecosystems that have soil mineral nitrogen available at less than 100 lbs/ac and mineral nitrogen deficiencies do not occur in rangeland ecosystems that have soil mineral nitrogen available at 100 lbs/ac or greater.

The quantity of mineral nitrogen available on rangeland ecosystems managed by traditional grazing practices was found to be; 31.2 lbs/ac on deferred grazing, 62.0 lbs/ac on 6.0-m seasonlong, and 76.7 lbs/ac on 4.5-m seasonlong (figure 1).

Reductions in mineral nitrogen limit herbage production more often than water in temperate grasslands (Tilman 1990). Traditionally managed grasslands have below normal available mineral nitrogen and reduced herbage production even during nondrought growing seasons. Both low mineral nitrogen and low soil water are major factors that cause reductions in herbage production during drought conditions.

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 mineral nitrogen to be usable by plants. Soil microorganisms in the rhizosphere zone around perennial grass roots convert organic nitrogen into mineral 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 mineral 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 mineral 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 suppress 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 mineral nitrogen. The quantity of available mineral nitrogen gradually decreases each year. After several years of management with traditional grazing practices, the accumulated reduction in rhizosphere volume and in available mineral nitrogen results in a substantial reduction in herbage biomass production at about 50% to 75% of the grasslands' potential herbage biomass production (Manske 2007). The traditional grazing management practices of 6.0-month seasonlong and 4.5-month seasonlong caused decreases of 78.1% and 70.2% in rhizosphere volume after 20 years of treatment, respectively (figure 1) (Manske 2008). During growing seasons with drought conditions, both mineral nitrogen and soil water are greatly diminished in grasslands managed with traditional grazing practices and are the two major causes for reductions in herbage production and the resulting reductions in stocking rate.

The biologically effective twice-over rotation grazing management strategy 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 131.8% increase in available mineral nitrogen after six years of treatment and caused a 235.8% increase in rhizosphere volume after 20 years of treatment greater than that on 4.5-month seasonlong (figure 1) (Manske 2008). Biologically effective grazing management improves the health status of grassland ecosystems increasing the ecosystems resistance to drought conditions. The increased rhizosphere organism volume and activity increases the quantity of available mineral nitrogen. 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). During growing seasons with drought conditions, the mineral nitrogen and soil water are not reduced as severely and the quantity of herbage biomass production is not reduced as greatly on grasslands managed with the twice-over rotation strategy as those on grasslands managed with traditional grazing practices.

The quantities of soil water and mineral nitrogen available for grassland plants affect the quantity of herbage biomass production and the stocking rates during growing seasons with drought conditions and affect the length of time needed for recovery after droughts. Recovery of grasslands managed with heavily stocked traditional grazing practices following the severe drought conditions of 1936, that had growing season precipitation at less than 50% of the long-term mean (Manske 2010a), required 4 years with greatly reduced stocking rates (Whitman et al. 1943). Grasslands managed with moderately stocked traditional seasonlong grazing practices required 2 years with reduced stocking rates to recover; and grasslands managed with the biologically effective twice-over rotation grazing strategy required 1 year with only slightly reduced stocking rates to recover following the severe drought conditions of 1988 (Manske 1989, 1990), that had growing season precipitation at less than 50% of the long-term mean (Manske 2010a). Recovery following growing seasons with moderate drought conditions, that have below normal precipitation at greater than 50% but less than 100% of the long-term mean and with perennial grasses under water stress for 2.5 to 3.5 months, required 1 year with reduced stocking rates for grasslands managed with moderately stocked traditional seasonlong grazing practices, and required less than 1 growing season with no reductions in stocking rates for grasslands managed with the twice-over rotation grazing strategy (Manske, data on file).

Healthy grasslands managed with biologically effective grazing practices have lower reductions in herbage biomass production during droughts and require less recovery time after droughts than moderately healthy grasslands managed with moderately stocked traditional grazing practices, which in turn, have lower reductions in herbage biomass production during droughts and require less recovery time after droughts than grasslands possessing low health status managed with heavily stocked traditional grazing practices (table 1) (Whitman et al. 1943; Manske 1989, 1990).

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. The degree of

reductive impacts on grassland herbage production and stocking rates encountered during drought conditions depends on the level of effectiveness that the previous grazing management has benefited the grass plant biological requirements and the ecosystems biogeochemical processes. The number of years with reduced herbage production and reduced stocking rates resulting from drought conditions and recovery from drought conditions as affected by the managed health status of grassland ecosystems are shown in table 1.

Grasslands with low health status (available mineral nitrogen at less than 50 lbs/ac) managed by heavy stocking or by starting dates too early and/or ending dates too late with traditional grazing practices have reduced herbage production and reduced stocking rates during 6 growing seasons with moderate drought conditions and 2 growing seasons with severe drought conditions. Low health status grasslands 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 resulting in a total of 28 years (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. Low health status grasslands are properly stocked at full capacity for 20 years (41.7%) (table 1).

Grasslands with moderate health status (available mineral nitrogen between 50 and 75 lbs/ac) managed with moderately stocked traditional grazing practices have reduced herbage production and reduced stocking rates during 6 growing seasons with moderate drought conditions and 2 growing seasons with severe drought conditions. Moderate health status grasslands 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 resulting in a total of 18 years (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. Moderate health status grasslands are properly stocked at full capacity for 30 years (62.5%) (table 1).

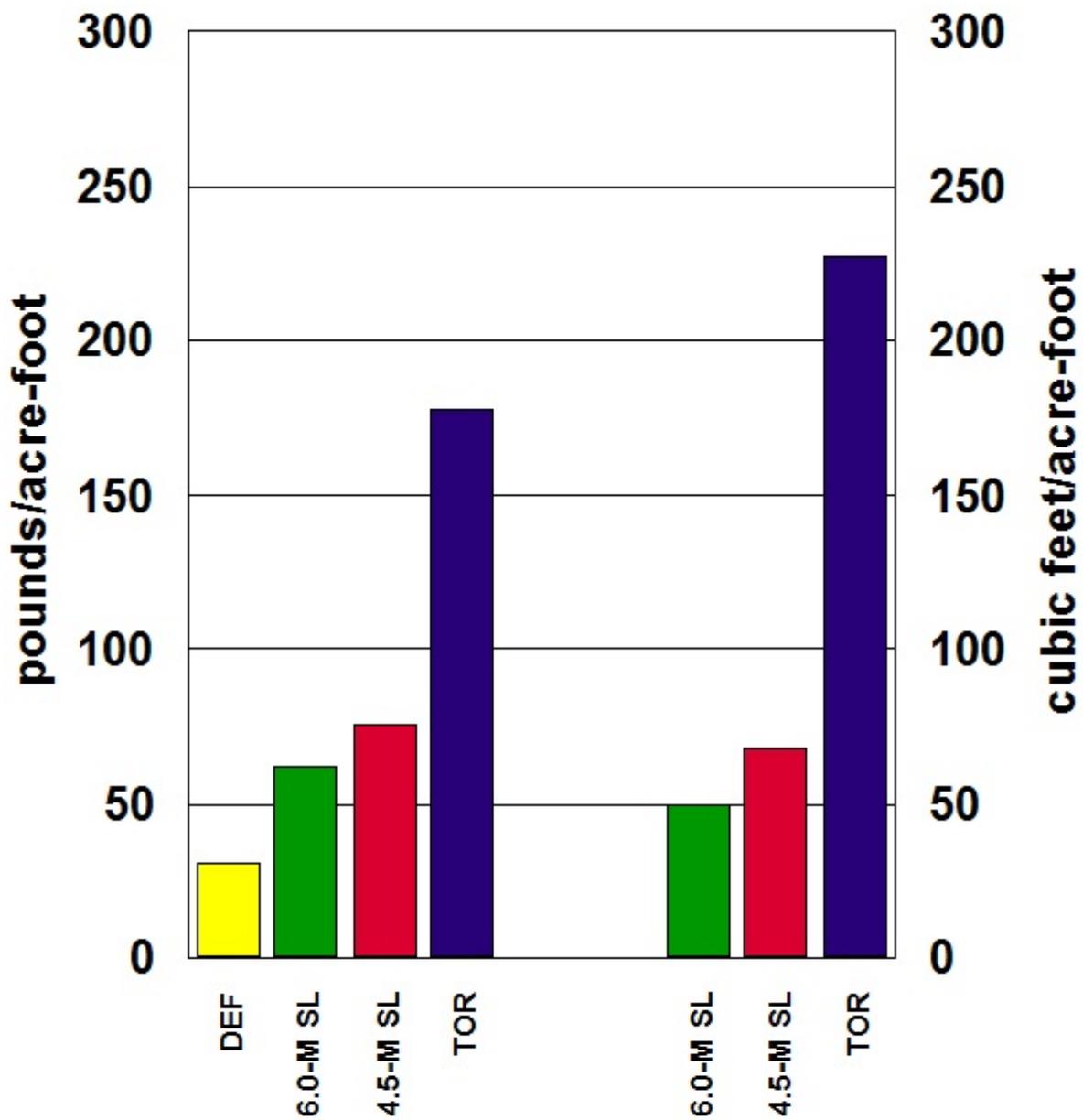
Grasslands with high health status (available mineral nitrogen greater than 100 lbs/ac) managed with biologically effective twice-over rotation grazing strategies have some reduction in herbage production, but the stocking rate is not reduced, during 6 growing seasons with moderate drought conditions; and high health status grasslands have reduced herbage

production and reduced stocking rates during 2 growing seasons with severe drought conditions. High health status grasslands 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 resulting in a total of 4 years (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. High health status grasslands are properly stocked at full capacity for 44 years (91.7%) (table 1).

With a frequency of drought conditions occurring during an average of 15.3% of the years in the Northern Plains, it is necessary to reduce stocking rates during 58.3% of the years (28) on grasslands at low health status, 37.5% of the years (18) on grasslands at moderate health status, and 8.3% of the years (4) on grasslands at high health status. The number of years during a beef producers career that grasslands have reduced herbage production and reduced stocking rates resulting from drought conditions and recovery from drought conditions is related to the managed health status of the ecosystem. Biologically effective grazing management based on meeting the biological requirements of grass plants and on enhancing the biogeochemical processes of ecosystems improves the health status of the grassland and reduces the negative impacts from drought conditions.

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**Mineral nitrogen (pounds/acre-foot) and rhizosphere volume (cubic feet/acre-foot) for grazing management 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.

Ecosystem Health Status		Healthy Grasslands	Moderately Healthy Grasslands	Low Health Grasslands
Available Soil Mineral Nitrogen		>100 lbs/ac	50-75 lbs/ac	<50 lbs/ac
Ag Career	yrs	48	48	48
No Drought	(5.9%) yrs	3	3	3
Drought for 2 mo/yr	(78.8%) yrs	37	37	37
Moderate Drought Growing Seasons	(11.9%) yrs	6	6	6
Recovery Time	yrs	0	6	12
Severe Drought 1936-1988 levels	(3.4%) 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 2010a.

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

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